Delft3D Wave, Sediment and Bed dynamics

Functional Specifications

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1 Introduction

Deltares has developed a unique, fully integrated modelling framework for a multi-disciplinary approach and 3D computations for coastal, river, lake and estuarine areas. It can carry out numerical modelling of flows, sediment transport, waves, water quality, morphological developments and ecology. It has been designed for experts and non-experts alike. The Delft3D framework is composed of several modules, grouped around a mutual interface, while being capable to interact with one another.

Delft3D can switch between the 2D vertically averaged and 3D mode simply by changing the number of layers. This feature enables to set up and investigate the model behaviour in 2D mode before going into full 3D simulations.

1.1 Areas of application

Delft3D can be applied, but is not limited, to the following areas of applications:

- ◇ flows due to tide, wind, density gradients and wave induced currents;
- ◇ propagation of directionally spreaded short waves over uneven bathymetries, including wave-current interaction;
- ◇ advection and dispersion of effluents;
- ◇ online morphodynamic computations (local scour, short time and length scales);
- ◇ sediment transport of cohesive and non-cohesive sediment;
- ◇ water quality phenomena including ecological modelling, the prediction of heavy metal concentrations, interaction with organic and inorganic suspended sediment, interaction between the water and bottom phase (such as sediment oxygen demand), algae blooms;
- ◇ particle tracking, including oil spill and dredging plume modelling;
- ◇ initial and/or dynamic (time varying) 2D-morphological changes, including the effects of waves on sediment stirring and bed-load transport.

1.2 Delft3D framework overview

Delft3D is composed of a number of modules (see Figure 1.1), each addressing a specific domain of interest, such as flow, near-field and far-field water quality, wave generation and propagation, morphology and sediment transport, together with pre-processing and post-processing modules. All modules are dynamically interfaced to exchange data and results where process formulations require. In the following chapters these modules are described in more detail.

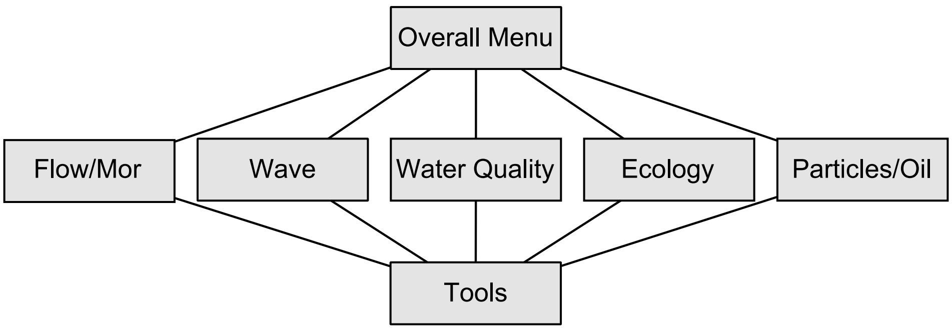

Figure 1.1: *System architecture of Delft3D*

All features are embedded in Graphical User Interface suitable for Linux or the MS Windows. An application (model) can be completely defined, inspected and analysed through a menu-driven, user-friendly, graphical interface.

The basic processes covered by each of the modules are:

Delft3D-FLOW and MOR 2D and 3D hydrodynamic, salinity, temperature, transport and online sediment transport and morphology
Delft3D-WAVE short wave propagation (using SWAN)
D-Water Quality general water quality
Delft3D-SED cohesive and non-cohesive sediment transport
Delft3D-ECO complex eutrophication and ecological modelling
D-WAQ PART particle tracking, oil spill modelling

1.3 Utilities

The following utility programs are available for pre-processing and post-processing:

RGFGRID: for generating orthogonal curvilinear grids, in Cartesian or spherical co-ordinates
QUICKIN: for preparing and manipulating grid oriented data, such as bathymetry, initial conditions for water levels, salinity, constituents and other parameters
Delft3D-TRIANA: for performing off-line tidal analysis of time-series generated by Delft3D-FLOW
Delft3D-TIDE: for performing tidal analysis on time series of measured water levels or velocities
GPP: for visualisation and animation of simulation results
Delft3D-QUICKPLOT: for visualisation and animation of simulation results
GISVIEW: ArcGIS extension to export GIS-coverages to Delft3D format and to read, visualise and process results from Delft3D (ArcGIS is not included)
Delft3D-MATLAB: user interface and Matlab functions to read Delft3D files and to visualise or process results in Matlab environment (Matlab is not included)
D-WAQ DIDO: interactive grid aggregation editor for coupling FLOW with WAQ models

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2 Hydrodynamic module

The hydrodynamic module, Delft3D-FLOW, is a multi-dimensional hydrodynamic simulation program that calculates non-steady flow and transport phenomena resulting from tidal and meteorological forcing on a curvilinear, boundary-fitted grid. In 3D simulations, the hydrodynamic module applies the so-called sigma co-ordinate transformation in the vertical, which results in a smooth representation of the bottom topography. It also results in a high computing efficiency because of the constant number of vertical layers over the whole computational domain.

2.1 Module description

The hydrodynamic module is based on the full Navier-Stokes equations with the shallow water approximation applied. The equations are solved with a highly accurate unconditionally stable solution procedure. The supported features are:

- ◇ two co-ordinate systems, i.e. Cartesian and spherical, in the horizontal directions
- ◇ two grid systems in the vertical direction; the boundary fitted sigma grid and the horizontal layer Z-grid
- ◇ domain decomposition both in the horizontal and vertical direction
- ◇ tide generating forces (only in combination with spherical grids);
- ◇ simulation of drying and flooding of inter-tidal flats (moving boundaries);
- ◇ density gradients due to a non-uniform temperature and salinity concentration distribution (density driven flows);
- ◇ for 2D horizontal large eddy simulations the horizontal exchange coefficients due to circulations on a sub-grid scale (Smagorinsky concept);
- ◇ turbulence model to account for the vertical turbulent viscosity and diffusivity based on the eddy viscosity concept;
- ◇ selection from four turbulence closure models: k-ε, k-L, algebraic and constant coefficient;
- ◇ shear stresses exerted by the turbulent flow on the bottom based on a Chézy, Manning or White-Colebrook formulation;
- ◇ enhancement of the bottom stresses due to waves;
- ◇ automatic conversion of the 2D bottom-stress coefficient into a 3D coefficient;
- ◇ wind stresses on the water surface modelled by a quadratic friction law;
- ◇ space varying wind and barometric pressure (specified on the flow grid or on a coarser meteo grid), including the hydrostatic pressure correction at open boundaries (optional);
- ◇ simulation of the thermal discharge, effluent discharge and the intake of cooling water at any location and any depth in the computational field (advection-diffusion module);
- ◇ the effect of the heat flux through the free surface;
- ◇ online analysis of model parameters in terms of Fourier amplitudes and phases enabling the generation of co-tidal maps;
- ◇ drogue tracks;
- ◇ advection-diffusion of substances with a first order decay rate;
- ◇ online simulation of the transport of sediment (silt or sand) including formulations for erosion and deposition and feedback to the flow by the baroclinic pressure term, the turbulence closure model and the bed changes;
- ◇ the influence of spiral motion in the flow (i.e. in river bends). This phenomenon is especially important when sedimentation and erosion studies are performed;
- ◇ modelling of obstacles like 2D spillways, weirs, 3D gates, porous plates and floating structures;
- ◇ wave-current interaction, taking into account the distribution over the vertical;
- ◇ many options for boundary conditions, such as water level, velocity, discharge and weakly reflective conditions;
- ◇ several options to define boundary conditions, such as time series, harmonic and astro-

nomical constituents;
- ◇ option for linear decay of conservative substances
- ◇ online visualisation of model parameters enabling the production of animations.

2.2 Applications areas

Delft3D-FLOW can be applied to the following application areas:

- ◇ salt intrusion in estuaries;
- ◇ fresh water river discharges in bays;
- ◇ thermal stratification in lakes and seas;
- ◇ cooling water intakes and waste water outlets;
- ◇ sediment transport including feedback on the flow;
- ◇ transport of dissolved material and pollutants;
- ◇ short-term sediment transport including feedback on the flow;
- ◇ storm surges, combined effect of tide and wind/typhoon;
- ◇ river flows, meandering and braided rivers;
- ◇ floodplains, with or without vegetation;
- ◇ reservoir siltation and degradation below dams;
- ◇ bottom vanes, spurs, groynes, bridges, weirs and levees.

2.3 Coupling with other modules

The results of the hydrodynamic module are used in all other modules of Delft3D. The results are dynamically exchanged between the modules through the use of a so-called communication file. Basic (conservative) water quality parameters like concentrations of dissolved material and pollutants, can be included in the computations. But, for more dedicated water quality simulations, the hydrodynamic module is coupled with the far-field water quality module (D-Water Quality) , the nutrient phytoplankton module (Delft3D-ECO) and the near-field particle tracking module (D-WAQ PART). A coupling with the sediment transport module (Delft3D-SED) is available to simulate cohesive and non-cohesive sediment transport processes, e.g. in the case of erosion and sedimentation studies. For wave-current interaction a dynamic coupling is provided with the wave module (Delft3D-WAVE) and for morphodynamic simulations the hydrodynamic module is integrated with the wave module and a sedimentation and erosion module into a morphodynamic module.

To simulate a model defined on a curvilinear grid system, an orthogonal grid must be provided. To generate such a grid the program RGFGRID is provided, though the grid can be generated by any grid generator program as long as the grid is delivered in the prescribed (ASCII) file format. The generation of a curvilinear grid is an important and somewhat complex task. Along with the main model parameters, the grid will ultimately determine the accuracy of the final model results.

To prepare the bottom topography or other grid-related data, such as a non-constant initial condition file, the program QUICKIN is provided. This program interpolates the scattered, digitised chart data to depth-values at the grid points in the model. Many powerful interactive processing options to further adjust the topography are supported, e.g. manual adjustment of the values at individual points, selection of the domain of influence, group adjustments, and smoothing. The output of this program (ASCII-file) can be imported into other Delft3D modules.

Analysis and interpretation of a hydrodynamic simulation in terms of tidal quantities can be performed by the program Delft3D-TRIANA. Delft3D-TRIANA performs off-line tidal analyses of time-series of either water levels and/or velocities. The results from these analyses can be subsequently compared with observation data supplied by you.

In case the open boundaries of a (detailed) Delft3D-FLOW model are located within the model domain of a coarser Delft3D-FLOW model, the coarse model can generate the boundary conditions of the detailed, nested model. The offline generation of boundary conditions is done by Delft3D-NESTHD.

3 Wave module

To simulate the evolution of random, short-crested wind-generated waves in coastal waters (which may include estuaries, tidal inlets, barrier islands with tidal flats, channels etc.) the wave module Delft3D-WAVE can be used. This wave module computes wave propagation, wave generation by wind, non-linear wave-wave interactions and dissipation, for a given bottom topography, wind field, water level and current field in waters of deep, intermediate and finite depth.

3.1 Module description

At present the wave model SWAN is available in the wave module of Delft3D. This is a third-generation wave model (Ris, 1997; Booij *et al.*, 1999). Where the previously available HISWA wave model was a second-generation wave model, (Holthuijsen *et al.*, 1989).

The SWAN model, which is an acronym for Simulating WAves Nearshore, is a spectral third-generation wave model (see e.g. Holthuijsen *et al.* (1993); Ris (1997). The SWAN model is the successor of the stationary second-generation HISWA model (Holthuijsen *et al.*, 1989) and has the great advantage, compared to HISWA, that the physics are explicitly represented with state-of-the-art formulations and that the model is unconditionally stable (fully implicit schemes). Moreover, the SWAN model can perform computations on a curvilinear grid (better coupling with the flow-module of Delft3D) and it can - for instance - generate output in terms of one- and two-dimensional wave spectra. In addition, the wave forces, as computed by SWAN on the basis of the gradient of the radiation stress tensor (instead of the dissipation rate as in HISWA), can be used as driving force to compute the wave-induced currents and set-up in the flow module.

The SWAN model is based on the discrete spectral action balance equation and is fully spectral (in all directions and frequencies). This latter implies that short-crested random wave fields propagating simultaneously from widely different directions can be accommodated. SWAN computes the evolution of random, short-crested waves in coastal regions with deep, intermediate and shallow water and ambient currents. The SWAN model accounts for (refractive) propagation - as the HISWA model - and represents the processes of wave generation by wind, dissipation due to white-capping, bottom friction and depth-induced wave breaking and non-linear wave-wave interactions (both quadruplets and triads) explicitly with state-of-the-art formulations. To avoid excessive computing time and to achieve a robust model in practical applications, fully implicit propagation schemes have been applied. It should be noted here, however, that although an efficient numerical technique has been implemented in SWAN the computing time for a typical wave computation may significantly be larger than that of the HISWA model. The SWAN model has successfully been validated and verified in laboratory and (complex) field cases (see e.g. Ris (1997); Ris *et al.* (1999)). It is noted that the SWAN model (as the HISWA model) does not account for diffraction effects.

The SWAN model has been developed at Delft University of Technology (the Netherlands) and where it is undergoing further enhancements. It is specified as the new standard for nearshore wave modelling and coastal protection studies Therefore, Deltares has integrated the SWAN model into Delft3D and is applying SWAN in its research and consultancy projects. The SWAN model has been released under public domain.

You can download the source code, documentation and installation guide lines from the SWAN-website: http://swan.ct.tudelft.nl. User support is provided by the Delft University of Technology. As agreed with the SWAN group Deltares can provide the SWAN version that is currently supported in Delft3D-WAVE. Upgrades must be downloaded from the SWAN website.

3.2 Application areas

The wave module can be used for harbour and offshore installation design and for coastal development and management related projects. It can also be used as a wave hindcast model. Typical areas for the application of the wave module lie in the range between 2 by 2 km to 50 by 50 km.

The wave module can optionally be coupled with the other modules of Delft3D. In this way an efficient and direct coupling is obtained between e.g. the flow module (wave driven currents) and the sediment transport module (stirring by wave breaking).

3.3 Coupling with other modules

The wave computations are carried out in Delft3D on a on a regular rectilinear grid or a curvilinear grid. The curvilinear grid can be the same as the grid used in the hydrodynamic module Delft3D-FLOW. The Delft3D system will automatically transfer all the relevant information to and from (2-way coupling) the hydrodynamic module Delft3D-FLOW, which simulates the flow on a curvilinear grid. The curvilinear grid can be generated with the grid generator RGFGRID
.

4 Morphodynamic module

The sediment transport module, integrates the effects of waves, currents, sediment transport on morphological development, related to sediment sizes ranging from silt to gravel. It is designed to simulate the morphodynamic behaviour of rivers, estuaries and coasts on time-scales of days to years.

The typical problems to be studied using the morphological module involve complex interactions between waves, currents, sediment transport and bathymetry. To allow such interactions, the individual modules within Delft3D all interact through a well-defined common interface.

The computational modules within Delft3D are identical to their stand-alone counterparts and each offer the full range of physical processes. In this way, Deltares combined experience of over thirty years in computer modelling is built into this system.

A morphological simulation in Delft3D is defined as a tree structure of processes and sub-processes down to elementary processes which contain calls to the computational modules. You are free to build up processes of increasing complexity, from a single call to the flow model to morphodynamic simulations spanning years, with varying boundary conditions. This module simulates the processes on a curvilinear grid system used in the hydrodynamic module, which allows a very efficient and accurate representation of complex areas.

4.1 Module description

Delft3D-MOR contains or is able to utilise the following components:

Wave

At present also the SWAN model is available in the wave module of Delft3D. The SWAN model is fully spectral (in all directions and frequencies) and computes the evolution of random, short-crested waves in coastal regions with shallow water and ambient currents. The SWAN model accounts for (refractive) propagation and represents the processes of wave generation by wind, dissipation due to white-capping, bottom friction and depth-induced wave breaking and non-linear wave-wave interactions (both quadruplets and triads) explicitly with state-of-the-art formulations. It is noted that the SWAN model does not account for diffraction effects.

Hydrodynamics

The hydrodynamic module (Delft3D-FLOW) used by Delft3D-MOR is based on the shallow water equations, including effects of tides, wind, density currents, waves, and turbulence models up to k-ε. The module includes a transport solver for salinity, temperature and conservative substances. The effects of salinity and temperature on the density and on the momentum balance are taken into account automatically.

The module uses a curvilinear grid in the horizontal plane. The vertical grid sizes are proportional to the local water depth.

For efficient morphological computations a one-layer, depth-averaged approach is used. The effects of spiral flow, i.e. in river bends, are computed by a secondary flow module which takes into account the advection of spiral flow intensity and the effect of the secondary flow on the primary current.

Wave effects in the model include radiation stress gradients associated with wave dissipation, wave-induced mass flux and enhanced bed shear stress, computed by a choice of formulations.

Sediment transport

The sediment transport module computes the bed-load and suspended-load sediment transport field over the curvilinear model grid, for a given period of time.

The bed-load transport is computed as a local function of wave and flow properties and the bed characteristics. The equilibrium suspended load is also computed as a local function of these parameters. The module then recognises two modes of transport: total transport (equilibrium) mode, or suspended load mode. In the first, the total transport is simply the addition of bed-load and equilibrium suspended-load transport. In the second mode, the entrainment, deposition, advection and diffusion of the suspended sediment is computed by a transport solver. Here, a quasi-3D approach is followed, where the vertical profiles of sediment concentration and velocity are given by shape functions.

The bed-load and equilibrium suspended-load transport can be modelled by a range of formulations, among which are Engelund-Hansen, Meyer-Peter-Muller, Bijker, Bailard and Van Rijn for sand, and a separate formulation for silt transport.

Effects of the bed slope on magnitude and direction of transport, and effects of non-erodible layers can be taken into account for all formulations.

Bottom change

The bottom update module contains several explicit schemes of Lax-Wendroff type for updating the bathymetry based on the sediment transport field. Options are available for fixed or automatic time-stepping, fixed (non-erodible) layers, various boundary conditions, and dredging.

4.2 Numerical aspects

All modules operate on the same rectangular or curvilinear, orthogonal grid. Fully implicit ADI schemes are applied in the hydrodynamic module for the momentum and continuity equations. The solver has robust drying and flooding procedures for both 2D and 3D cases. In the transport solver a Forrester filter can be applied which guarantees positive concentrations throughout.

The same transport solver is applied for suspended sediment computations.

The wave model HISWA operates on rectangular grids, and uses an implicit scheme in propagation direction, combined with a forward marching technique. The wave module takes care of all transformations and interpolations between these rectangular grids and the curvilinear flow and transport grid. The wave model SWAN can perform computations directly on a curvilinear grid.

The bottom update model uses an explicit scheme of Lax-Wendroff type. This leads to a Courant type stability criterion. However, cheap intermediate "continuity correction" steps keep the computational effort at a reasonable level.

4.3 Application areas

Delft3D-MOR is designed to simulate wave propagation, currents, sediment transport and morphological developments in coastal, river and estuarine areas.

Coastal areas including beaches, channels, sand bars, harbour moles, offshore breakwaters, groynes and other structures. The coastal areas may be intersected by tidal inlets or rivers; parts of it may be drying and flooding.

Rivers including bars, river bends (spiral flow effect), bifurcations, non-erodible layers, dredging operations and having arbitrary cross-sections (with overbank flow). Various structures may be represented. Special features for 2D river applications are presently being developed and validated, such as a bottom-vanes and graded-sediment.

Estuarine areas including estuaries, tidal inlets and river deltas influenced by tidal currents, river discharges and density currents. Sediment can be non-cohesive (sandy) or cohesive (silt). The areas may include tidal flats, channels and man-made structures, e.g. docks, jetties and land reclamations.

5 Pre-processing and post-processing

In this chapter several pre-processing and post-processing programs available in Delft3D are described in some details. These programs concern visualisation, grid generation, manipulation of grid related data and data analysis and manipulation.

5.1 Visualisation

5.1.1 GPP

The general post-processor (GPP) module of Delft3D allows uniform access to all kinds of data files to select and visualise simulation results and measurement data. More specifically the program allows to:

- ◇ select the map and/or time histories you want to visualise;
- ◇ select the lay-out and composition of the plot figure to be produced;
- ◇ select the type of output medium, i.e. screen for inspection, plotter or printer for hard copy output.

The type of presentation depends on the character of the data set:

- ◇ vector plots for flow velocities, bottom shear stress and other vector quantities, with automatic or user-defined scaling of s-axis, y-axis and vector scale;
- ◇ time history plots, from a single run, from various runs in the same plot or simulation results in combination with measurement data. Depending on the data files, these can be typical hydrodynamic quantities, such as water levels, velocity magnitude and direction, but also water quality parameters like salinity, temperature and E.coli concentration. The scaling can be determined automatically or set by you;
- ◇ contour and isoline plots of scalar quantities like the depth, water levels or algae growth rates. Again you can choose automatic scaling or set the contour classes manually;
- ◇ vertical profiles for quantities defined on a three-dimensional grid;
- ◇ geometric plots of the grid itself, tidal flats, land boundaries;
- ◇ mass balances and limiting factors for displaying the details of water quality models.

Data sets can be plotted in any (sensible) combination, as long as there is a common coordinate system. Layouts may contain more than one viewport, allowing several independent plots on one page. It is noted that the overview above is by no means complete but it gives a general idea about the possibilities.

The program has been designed to be general enough to handle different kinds of underlying geometries and data files of widely varying formats.

The program is capable of producing high quality colour plots. It is also able to produce a plot file in various standard formats. At the same time a print-out of the results in ASCII format can be made, enabling the data to be imported in other post-processing programs.

For the use of ArcView and Matlab to visualise and further process Delft3D results, see Section 5.9.

5.1.2 QUICKPLOT

The post-processing program Delft3D-QUICKPLOT allows you to easily plot and animate data from most output files and some input files of Delft3D and several other software packages of WL | Delft Hydraulics (such as SOBEK and PHAROS). Furthermore, it supports some simple ASCII formats such that you can combine model output and measurement data in one plot, and it is possible to load bitmap data as a backdrop for your 1D or 2D plots.

Typical plots created using Delft3D-QUICKPLOT are 2DH or 2DV plots and time-series plots, although it also has basic support for 3D plots. Scalar results may be presented using contour lines, contour patches, grid cell based patches, interpolated continuous shades, coloured marker or value fields. Vector results may be presented as vectors, coloured vectors or normalised vectors or as scalar quantities by selecting a single component (e.g. x-component, y-component, magnitude, direction) of the vector.

Data sets can be linked to animate single or multiple data sets in a figure. Animation frames can be stored in various bitmap formats. Data sets can be exported to various in-house or 3rd party formats.

Delft3D-QUICKPLOT is a standalone program based on technology of The MathWorks Inc. It can be seamlessly integrated with the MATLAB environment via the Delft3D-MATLAB interface.

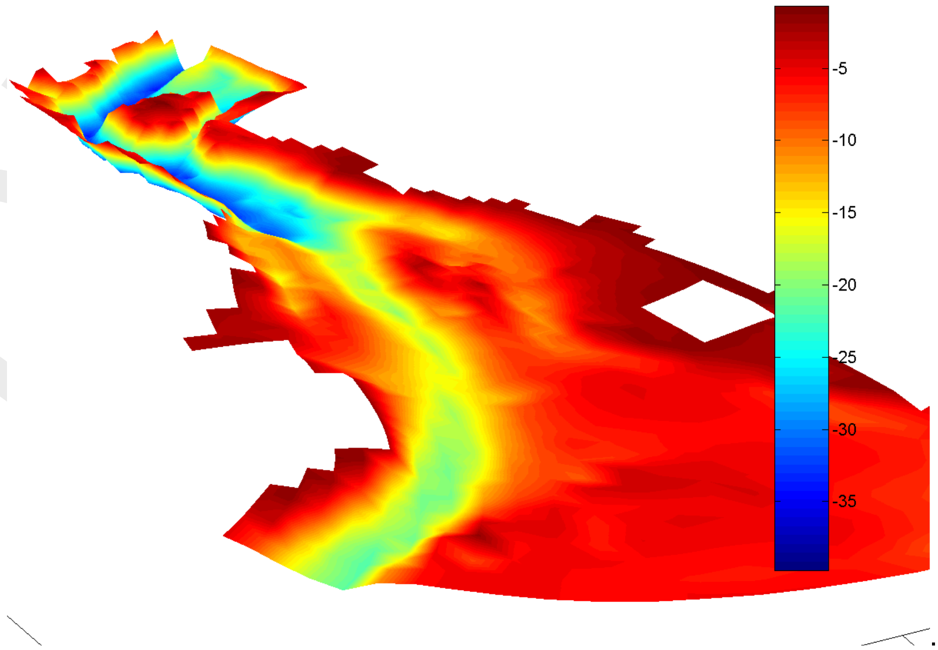

Figure 5.1: *Example QUICKPLOT figure: 3D view of bed level*

5.2 Grid generation

RGFGRID is a program to generate orthogonal, curvilinear grids of variable grid size, that are to be used in combination with each of the modules of the Delft3D suite. The grid-generator includes a graphical interface and an orthogonalisation module, providing easy control of the grid generation process.

RGFGRID supports the following features:

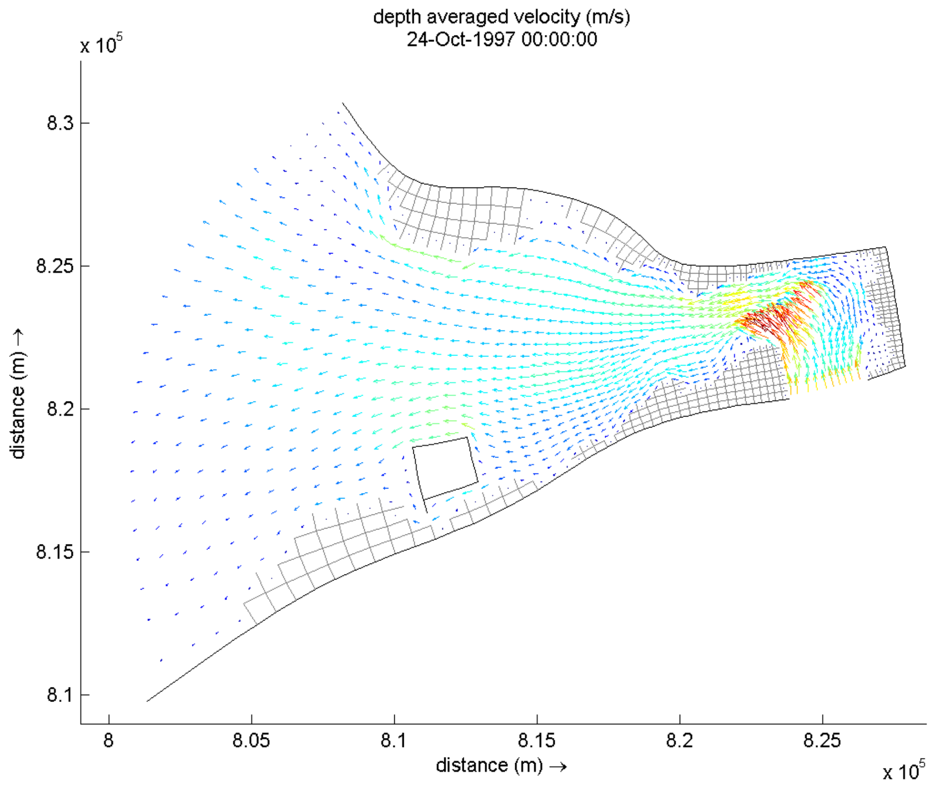

Figure 5.2: *Example QUICKPLOT figure: Depth-averaged velocity vectors and drying and flooding*

- ◇ graphical user interface;
- ◇ generation of grids in Cartesian or Spherical co-ordinate systems
- ◇ display of grid features as orthogonality, smoothness, aspect ration etc.;
- ◇ several user-functions have been implemented to provide easy control over the grid shape;
- ◇ keyboard and mouse driven events are supported;
- ◇ iterative way of working, each cycle providing more definition in the grid shape.
- ◇ generation of multi-domain interfaces.

5.3 Grid data manipulation

To create, visualise and modify grid based data, such as bathymetries, and other grid related data the program QUICKIN is provided. QUICKIN is used in combination with the modules of Delft3D.

QUICKIN supports the following features:

- ◇ graphical user interface;
- ◇ several interpolation options (averaging, triangulation, diffusion);
- ◇ suitable for different ratios of grid-density versus sample-density;
- ◇ various display possibilities: isolines, dots, perspective, etc.;
- ◇ implementation of various user-functions to provide easy control over the final bathymetry;
- ◇ sample data from different sources can be interpolated in sequence, thus, starting with the best quality data available, an optimal bathymetry can be created.
- ◇ Definition of dredge and dump sites with their characterristics.

5.4 Grid aggregation

The program DIDO enables you to span coarser, irregularly shaped, grid segments for water quality modelling, starting from the fine grid of e.g. the grid used by the hydrodynamic model. For ecological modelling with large numbers of state variables, a coarser schematisation, following ecological and transport separation lines rather than grid lines, is often preferable. The fine grid of the hydrodynamic model serves as input, integer multiples of the input grid are used for the description of the coarse grid. The procedure is fully mass-conserving. Aggregation is only supported in a plane surface.

DIDO provides the following features:

◇ zoom in locally;
◇ separate a working area from the remainder of the schematisation;
◇ aggregate regularly (e.g. every 2 segments in the one and 3 in the other direction);
◇ aggregate irregularly (by rubber band lines comparable to the bulls hide);
◇ fine tune by point and click on single elements;
◇ select a subset of the hydrodynamic area for water quality modelling;
◇ display information of a selected segment;
◇ save intermediate results on the fly;
◇ resume unfinished work from saved files;
◇ save the final result for water quality simulation.

The final result of DIDO will be used as input to the coupling program between the hydrodynamic module Delft3D-FLOW and the water quality module D-Water Quality enabling the latter to run on a coarser grid using the fine grid hydrodynamic database. Water quality simulations are converted back to the fine grid in post-processing software. This gives spatial plots with the fine resolution (although aggregated areas will still show equal concentration values).

5.5 Tidal analysis and comparison with observations

Analysis and interpretation of a hydrodynamic simulation in terms of tidal amplitudes and phases can be performed by the program Delft3D-TRIANA. Delft3D-TRIANA performs offline tidal analyses on time-series of either water levels and/or velocities. Moreover, Delft3D-TRIANA compares the results from these analyses with observation data supplied by you. Amplitude ratios and phase differences as well as objective statistics are determined.

5.6 Tidal analysis and prediction

The program Delft3D-TIDE is used for the analysis of tidal recordings and the preparation of tidal predictions.

The main module TIDE/ANALYSIS performs tidal analysis on time-series of water levels or currents. A variety of features is included, such as:

◇ the coupling of closely positioned astronomical components;
◇ the simultaneous analysis of successive records of different instruments;
◇ the discrimination of sub-series to account for gaps in measurement recordings;
◇ the appreciation of linear trends and an accuracy analysis.

In a tidal analysis of a time-series of one year with a 10 minutes interval, 100 or more tidal constituents can be prescribed simultaneously. The constituents are selected from the internal database that contains 234 constituents that may be important at locations world-wide.

The module TIDE/FOURIER performs Fourier-analyses on any type of time-series. This feature can be used to investigate the series of residual levels or velocities which has been identified during the tidal analysis on remaining tidal components.

Using a set of tidal constants, such as computed in the analysis module, the TIDE/PREDICT module predicts water levels or tidal currents as a function of time.

The module TIDE/HILOW may provide the production of tide tables with the dates, times and heights of the High and Low Waters. Using a word-processor or desktop publishing software package, the basic tide tables can be processed further and combined with other relevant information like tidal stream data.

Whereas in the regular analysis part of the package you pre-define the constituents that will be considered, the program also features an option (TIDE/ASCON) to compute the astronomic arguments and node amplitude factors for all 234 internally defined constituents.

The package is accompanied with a comprehensive User Manual, exemplifying the use of the program and its scientific backgrounds. A number of examples is added in the form of input and data files.

5.7 Nesting of Delft3D-FLOW models

At the open boundaries of a Delft3D-FLOW model, boundary conditions are required for the vertical and/or horizontal tide and the substances if applicable. In case these open boundaries are located within a (coarser) overall Delft3D-FLOW model, then the overall model can be used to generate the boundary conditions for the detailed model. In this case we say the detailed model is nested within the overall model.

The procedure to generate nested boundary conditions consists of 3 steps:

1 Using the program Delft3D-NESTHD 1 a list of monitoring stations in the overall model, needed for the interpolation, will be generated. In addition to this, the program generates the nest administration, i.e. the link between the boundary support points in the detailed (or nested) model and the monitoring stations in the overall model.
2 Run the overall model with the list of monitoring stations generated by Delft3D-NESTHD 1.
3 The actual boundary conditions for the nested model are generated by Delft3D-NESTHD 2 using the history file of the overall model and the nest administration.

5.8 Nesting of D-Water Quality models

The transfer of data from an encompassing or 'overall' numerical model to an embedded or 'nested' numerical model is called nesting. In general the overall model has a coarse resolution of grid cells, whereas the nested model has a higher resolution. At the boundary locations of the nested model the results from the overall model are required as boundary conditions for the nested model. The boundary conditions can be water levels, currents, fluxes or discharges in case of hydrodynamic models, and water quality parameters in case of water quality models.

The procedure of nesting through concentrations between D-Water Quality (or D-WAQ PART) models is performed by the system D-WAQ NESTWQ. In this procedure two steps can be distinguished which are handled by separate subsystems:

1 D-WAQ NESTWQ 1, for the determination of nest segments and nest weights in the overall model. The concentrations at these segments are used by the next subsystem.

2 D-WAQ NESTWQ 2, for the generation of boundary conditions for the boundary segments in the nested model from the results at the nest segments in the overall model.

5.9 Interfaces with other programs

It should be emphasised that even though these extensions can be quite useful as a supplement to the Delft3D tools, real benefits are gained mostly if you are familiar with both the Delft3D environment and the external environment.

5.9.1 Interface to GIS

While pre-processing and post-processing can be done quite adequately using the specific tools offered by Delft3D, recently a link have been established with ArcView. The link is intended as a supplement to the existing tools rather than a replacement. It adds the ability to view and manipulate model results and model input in a different environment.

The link to ArcView implies:

- ◇ exporting a GIS line coverage as land boundary outline and depth data as contained in ArcInfo/ArcView map layers to a format suitable for RGFGRID and QUICKIN;
- ◇ importing the model grid and the corresponding depth field as generated by RGFGRID and QUICKIN, so that they can be presented in a geographical context;
- ◇ importing the grid-based model results (scalar and vector quantities) with a user interface quite similar to that of GPP in the ArcView environment for presentation or further analysis

All data files are read directly by this ArcView extension and stored as shape files. There is no need to convert or process the model result files.

5.9.2 Interface to Matlab

In a similar way as with GIS it is possible to import the results produced with Delft3D directly into Matlab. This gives the opportunity to visualise or use the results for further analysis using the facilities offered by Matlab.

The Delft3D-MATLAB interface allows you to seamlessly integrate the simplicity of simulation data access by Delft3D-QUICKPLOT with the flexibility of the MATLAB environment developed by The MathWorks Inc. The combination of these two tools allows you to use the full power of MATLAB for analysing, processing and visualising the simulation results.

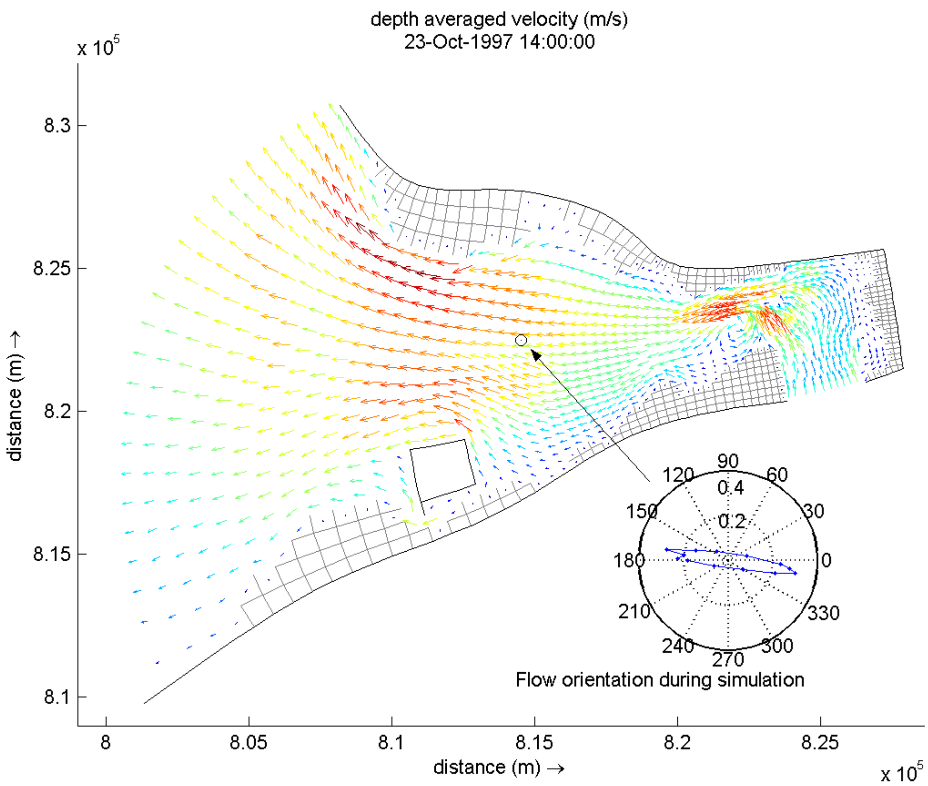

Figure 5.3: *Example QUICKPLOT figure: Depth-averaged velocity vectors and tidal ellips*

6 Hardware configuration

Delft3D and its accompanying programs is supported on the following platforms:

- ◇ Windows 32/64-bit platforms
- ◇ Linux Redhat 3.4

Configuration item	Minimal	Preferred
Processor	IA32, 1 GHz	IA32, 3 GHz or more
Internal memory	1024 MB	2 GB or more
Swap space	2.0 × internal memory	4.0 × internal memory
Hard disk	10 GB	80 GB or more
Monitor	17 inch colour	19 inch colour
Display	800 × 600 pixels 256 colours	1280 × 1024 pixels 16 million colours

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Deltares, 2016. “BIBTEX key with no entry, needed if no citations are made in the document.”

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