Deltares

Enabling Delta Life

User Manual
Delft3D-Geological Tool
Version 1.1

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1 Introduction

1.1 Motivation

In the oil and gas industry geologists assess the stratigraphic architecture of fluvio-deltaic sedimentary packages in the subsurface to study the geological properties in and around (potential) oil reservoirs. These assessments are often based on a combination of local measurements (e.g. remote sensing, well data, dynamic production data) and geological analogues from elsewhere. Often the availability of local measurement data is limited, which hampers the accuracy of the assessments. Numerical process-based morphological modelling packages like Delft3D can partly compensate for the lack of geological data by producing synthetic (numerical) analogues for river delta geo-bodies in the subsurface (Figure 1.1). In this way, these numerical models help to quantify and limit the geological uncertainties around geological properties in hydrocarbons reservoirs. Furthermore, they have the advantage that they can simulate the heterogeneity and continuity of geo-bodies in space and time (4D) and allow for total control of boundary conditions, thereby enabling geologists to test hypotheses and perform sensitivity analysis for different parameters.

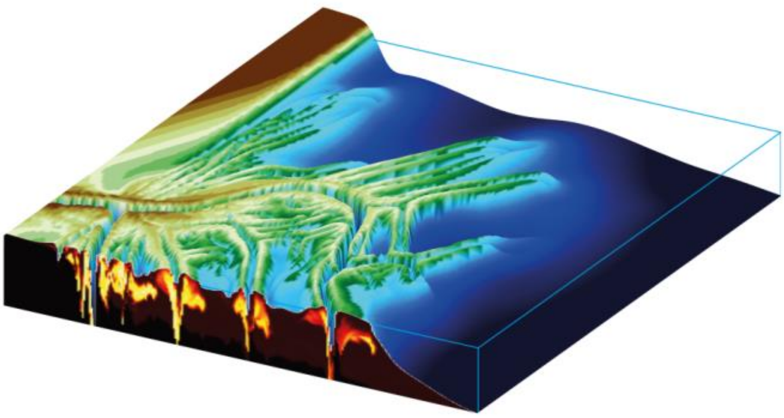


Figure 1.1 Example of a synthetic numerical analogue of a river delta generated with Delft3D

Despite the potential added value of Delft3D for the oil and gas industry, its use in practice is hampered by both the complexity of the software and its terminology for model input and output that is not aimed at geologists but hydraulic engineers. Delft3D-Geological Tool (GT) is developed with the aim to overcome these obstacles in order to better align with the workflow of geologists.

1.2 Delft3D-GT concept and components

The Delft3D-GT is a web based modelling system to run, process, store and access Delft3D simulations for geological purposes. As such it facilitates the set-up of geometrically simple process-based forward models through an easily accessible Graphical User Interface (GUI) for non-modelling experts (e.g. assets teams). The input and output of Delft3D-GT are tailored to geological use. To align with the workflow of geologists Delft3D-GT includes a component to convert and export its output for use in geo-statistical packages later on. Different users from different companies can access and use the application at the same time. The database of Delft3D-GT allows users to share their runs[1] within their own company or in public, so that users can make use of the same knowledge base without having to re-run the (computationally expensive) numerical simulations over and over again. In this way the application caters for data mining.

Delft3D-GT consists of the following components:
1 Web based Graphical User Interface (GUI) for the setup and inspection of model simulations
2 Central database for simulation control, user management, storage and version control
3 Computational (cloud) cluster to queue, run and process the model simulations

This user manual focuses on user guidance for the GUI (component 1). The other components are described in a separate Technical Reference document (Deltares, 2017a).

1.3 Areas of application

Delft3D-GT is primarily developed for geologists with the following in mind:
- Focus on the generation of synthetic numerical analogues of river dominated deltas. Furthermore, Delft3D-GT supports the effects of tide, waves and base level change on the delta development. In principle, both the Delft3D engine and the Delft3D-GT architecture allow for a wider range of applications. However, processes like consolidation, submarine turbidites, meandering rivers and vegetation and peat formation are not yet supported by Delft3D-GT.
- Allowing non-modelling experts to set up and analyse these numerical models. Therefore, the GUI is primarily aimed at these non-modelling experts by making use of simplified model setups, a limited number of user editable parameters, constrained parameter ranges and output tailored to geological users.
- A wider range of input and output parameters is available for expert users. However, in order to get access to the full range of parameters, expert users need to run Delft3D outside the Delft3D-GT environment.

The software architecture is setup such that the functionality of Delft3D-GT can also be useful beyond geological applications:
- The web-based GUI allows for worldwide, platform independent access to the tool as well as easy setup, inspection and analysis of (multiple) models (which are the basic steps in practically any type of model application).
- The database allows for sharing simulations between professionals from different companies working on the same type of model. This way it can stimulate sharing of knowledge, peer reviewing of models and analysis scripts, version control and, hence, making efficient use of resources.
- The cloud simulation environment allows for (efficient) parallel processing of multiple computationally intensive simulations without making heavy demands on the in-company IT infrastructure. It is foreseen that in the future Delft3D-GT will also support running simulations in a local environment, for users that prefer to run simulations locally instead of in the cloud.
- The above functionalities offer potential for use of the software in many types of other applications of surface (e.g. riverine, deltaic, coastal and offshore environments on

[1] *A run or simulation is defined as a set of unique model settings both in terms of parameters and model version.*

different time-scales) and subsurface modelling (e.g. groundwater, aquifer recharge and geothermal energy).

1.4 Reader's guide

Chapter 2 (Getting started) provides an overview of the Delft3D-GT GUI and its main components. This chapter helps the user to getting started with Delft3D-GT. Chapter 3 describes all the GUI features of Delft3D-GT with a guide on how to use them in practice. Finally, Chapter 4 provides a number of hands-on tutorials to help the user getting acquainted with the Delft3D-GT GUI by means of some simple problems.

If this is your first time to start working with Delft3D-GT we suggest you to read and practice the getting started and tutorial chapters of this user manual.

2 Getting started

2.1 Overview of Delft3D-GT

Delft3D-GT version 1.0 consists of (1) a web-based Graphical User Interface (GUI), (2) central database and (3) cloud-based computational cluster as schematically depicted in Figure 2.1. Through the GUI the user can create, control, inspect and export Delft3D simulations for geological applications. Behind the screens the runs that are created in the GUI are stored in a central database and put under version control. This web-based database is the central hub in Delft3D-GT that controls the Delft3D simulations (e.g. create, start, stop, process, delete), user management and storage of run information (e.g. input, output and meta-information). For simulation performance and data storage reasons the actual simulations are executed on a cloud-based cluster. This cluster controls the queuing, execution and processing of the Delft3D simulations. The remainder of this user manual focuses on the GUI.

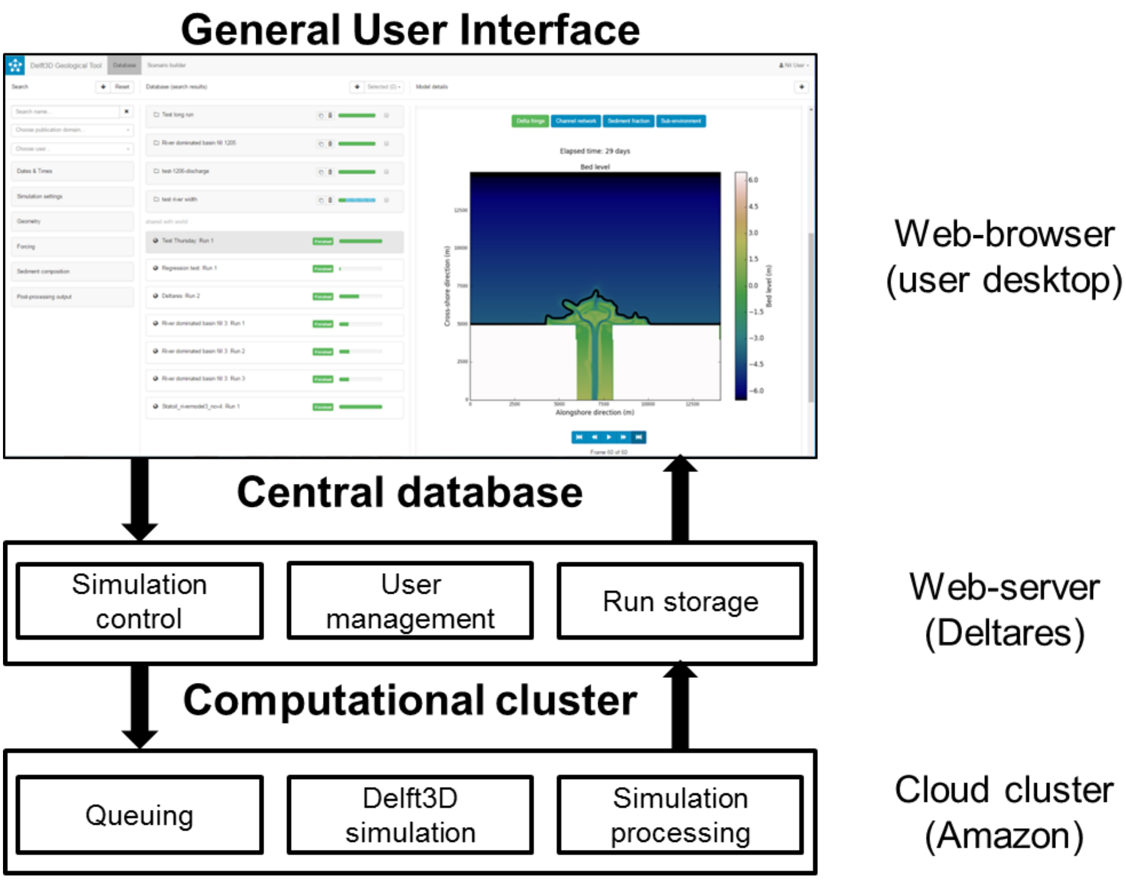


Figure 2.1 Schematic overview of Delft3D-GT version 1.0 and its components

2.2 Runs/simulations vs scenarios in Delft3D-GT

Delft3D-GT makes use of the terms runs/simulations and scenarios. A run or simulation is defined as a set of unique model settings both in terms of input parameters and model version. A scenario is defined as a set of runs/simulations that are largely the same, except for one or more of parameters that is/are systematically varied (schematically indicated in Figure 2.2). In this way a scenario can be used to quickly generate a set of runs and perform a systematic sensitivity analysis. A scenario can consist of one or multiple runs, depending whether or not input is varied. Furthermore, one run can be part of multiple scenarios. When a run is part of multiple scenarios, Delft3D-GT automatically re-uses the runs that are already available in the database to avoid duplication and save computational time. This is schematically presented in Figure 2.2, where run 1 in scenario 1 and run 2 in scenario 2 are identical. In this case, the run that is generated first is used for both scenarios.

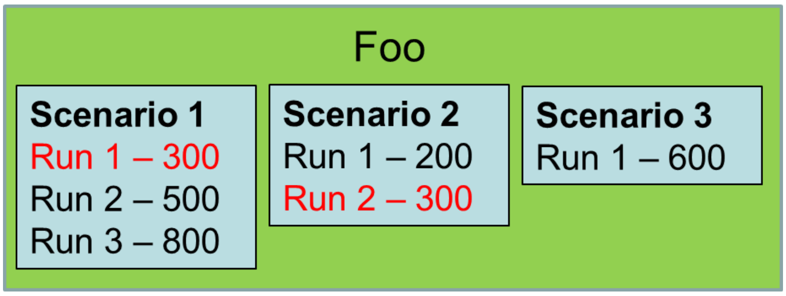


Figure 2.2 Schematic visualization of scenarios and runs. In this simplified example the user Foo generated 3 scenarios consisting of 3, 2 and 1 run(s) respectively. In this example only one input parameter could be changed. The values behind the runs indicate the parameter setting for each run. Note that run 1 of scenario 1 and run 2 of scenario 2 are identical.

2.3 Starting Delft3D-GT

To start Delft3D-GT:

1. Open a web-browser and surf to http://delft3dgt.openearth.eu (Figure 2.3). NB: please note that Delft3D-GT is mainly designed for the Google Chrome, Mozilla Firefox and Safari web-browsers. On other web-browsers Delft3D-GT may not function optimally.
2. Login with your user credentials (Figure 2.4)

After a successful login, the Delft3D-GT GUI opens at your own user page. The main components of the GUI are described in more detail in Section 2.4.

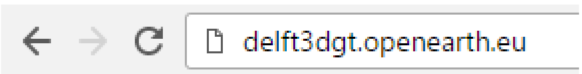


Figure 2.3 Surfing to Delft3D-GT in the web-browser

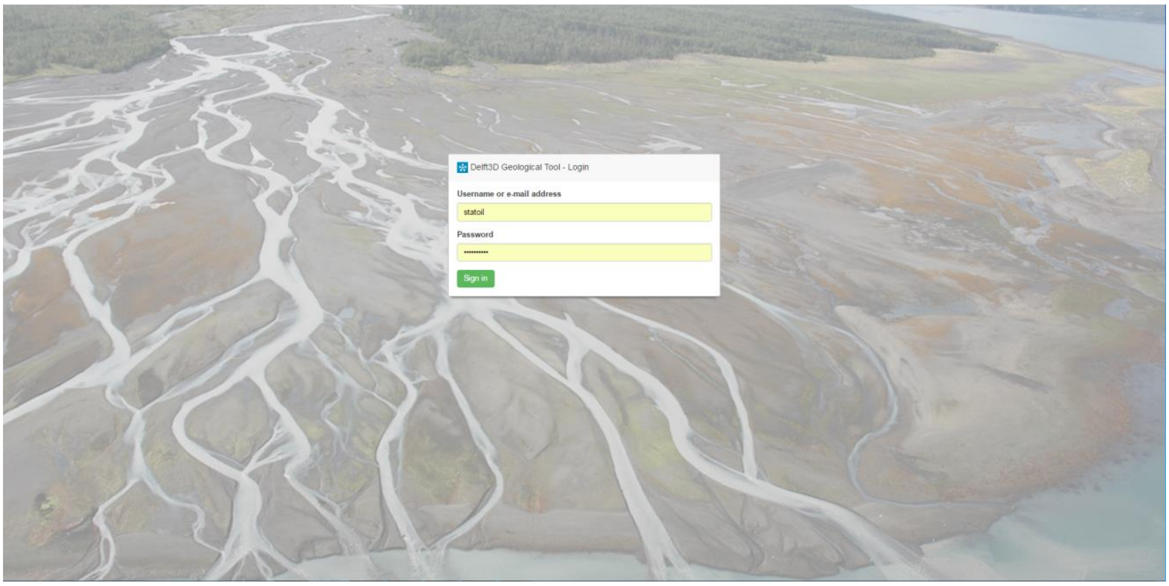


Figure 2.4 The Delft3D-GT login screen

2.4 Delft3D-GT GUI components

The Delft3D-GT GUI has two main components that are accessible via the menu bar (Figure 2.5): (1) the database with a search facility, an overview of available scenarios/runs in the database and run details and (2) the scenario builder for the creation of new scenarios/runs. The subsequent sections provide an overview of the main features of the database (Section 2.4.1) and scenario builder (Section 2.4.2). A detailed description of all GUI functionality is provided in Chapter 3.

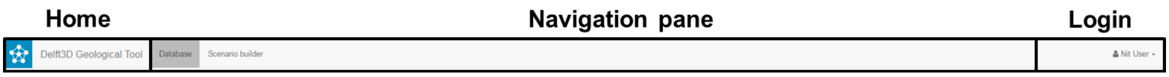


Figure 2.5 The Delft3D-GT menu bar with the 'Home' button, navigation pane and login menu

2.4.1 Database

After a successful login procedure, the user is directed to the Delft3D-GT database (Figure 2.6). This is the central feature of the Delft3D-GT GUI. It has three main components: (1) a search facility, (2) an overview of the (filtered) available scenarios/runs and their status and (3) the run details in terms of meta-information, input and output.

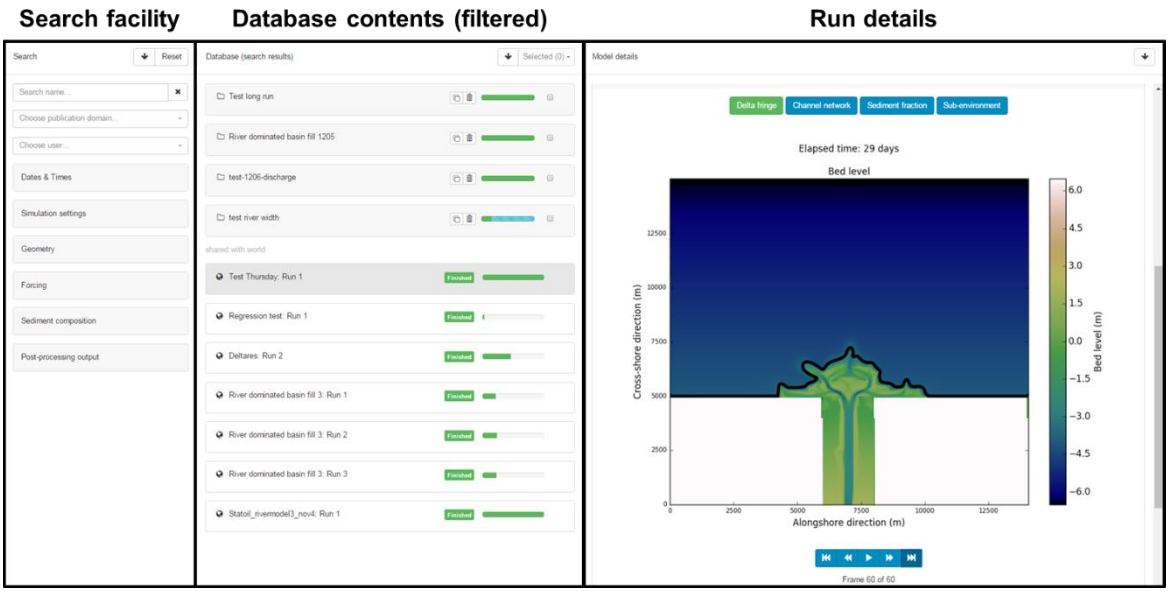


Figure 2.6 Overview of the Delft3D-GT database displaying the search facility, the (filtered) database contents and run details

By default the database view displays all the scenarios and runs that are available to the user. This includes (1) *private* runs that are only accessible for the user him/herself, (2) runs *shared in company* that are only accessible for the users within the same company and (3) runs *shared in public* that are accessible to all Delft3D-GT users. The search facility (Figure 2.7 left) allows the user to filter the results based on its meta-information (such as run name, owner, user domain or creation date), input (e.g. parameter settings) and/or output (e.g. geological parameters). In this way the search facility allows the users to quickly navigate through the database.

The central panel of the database view shows the contents of the database to the user (Figure 2.7 right). The contents of the database display the (filtered) scenarios and runs as well as their status (e.g. waiting for user, in progress, finished). The runs in the database are categorized based on the user domain in which they are shared (e.g. private, company or world).

By selecting a run from the database contents the user can inspect the run details (Figure 2.8). The run details provide the user with all relevant information in terms of meta-data, input and output. The run details also contain controls with which the user can control the simulation, share the results and/or download the outcomes for further use.

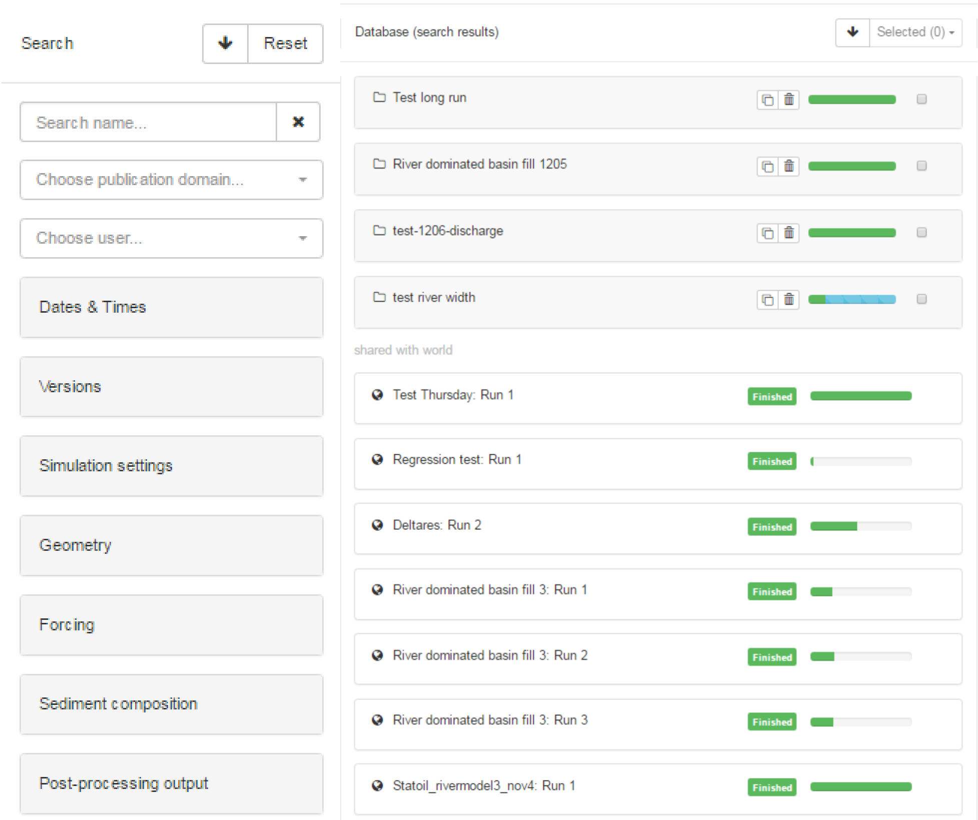


Figure 2.7 Overview of the search facility and its filters (left panel) and the database contents (right panel) of the Delft3D-GT database.

2.4.2 Scenario builder

The scenario builder (Figure 2.9) allows the user to create new scenarios based on a standard template. The user can edit parameters related to geometry forcing, sediment composition and simulations settings in order to generate (multiple) runs. Currently, the user can only select the template “River dominated delta” for the creation of scenarios. However, it is foreseen that more templates will be made available in the future. In order to make optimal use of the database, the database is checked before the creation of runs. If existing runs with exactly the same settings are available in the database (and accessible to the user), Delft3D-GT will not create new runs but make use of the existing ones in order to save computational time.

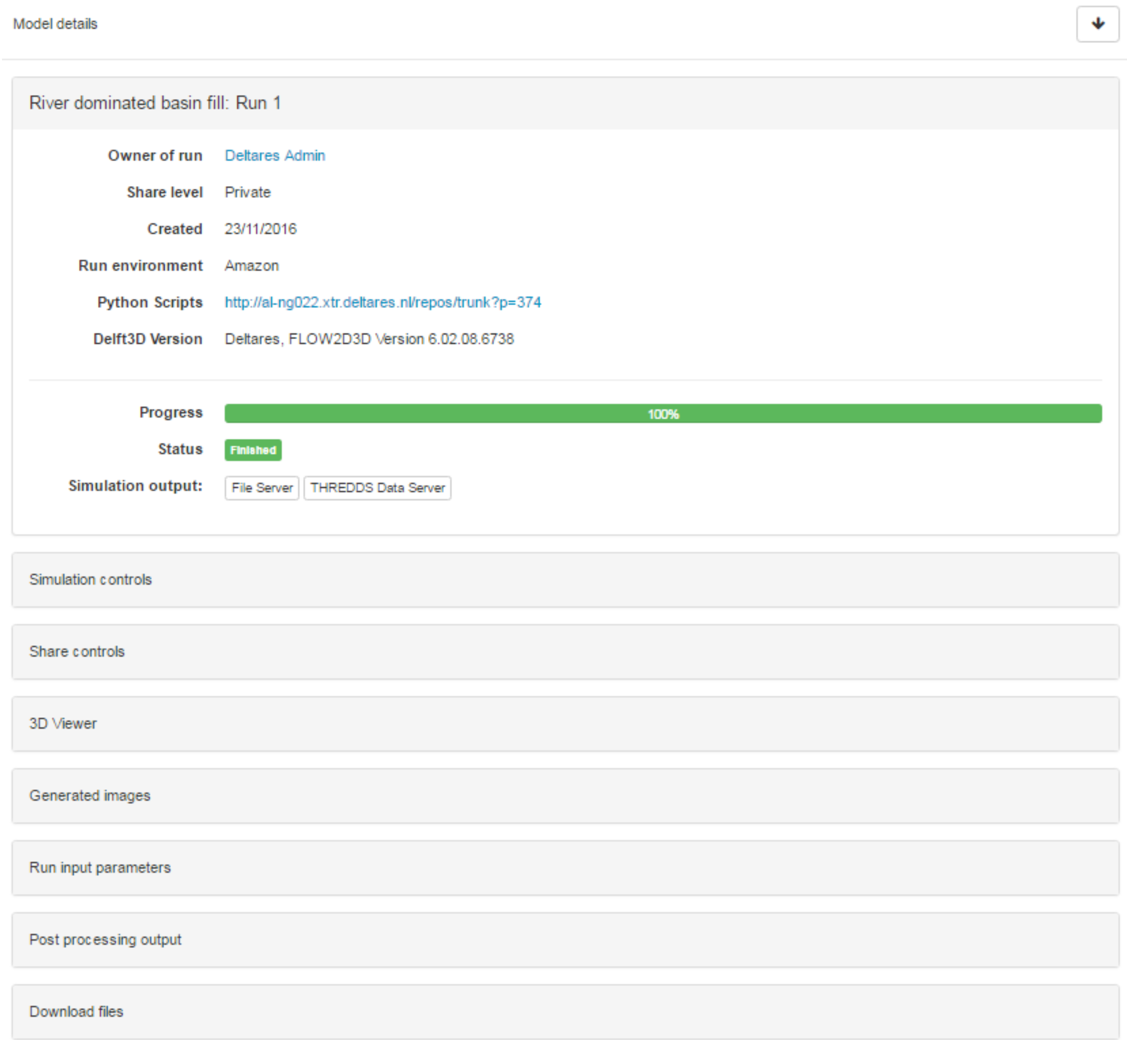


Figure 2.8 Overview of the run details with the meta-information, simulation controls, share controls, 3D viewer, generated images, run input parameters, post-processing output and download options

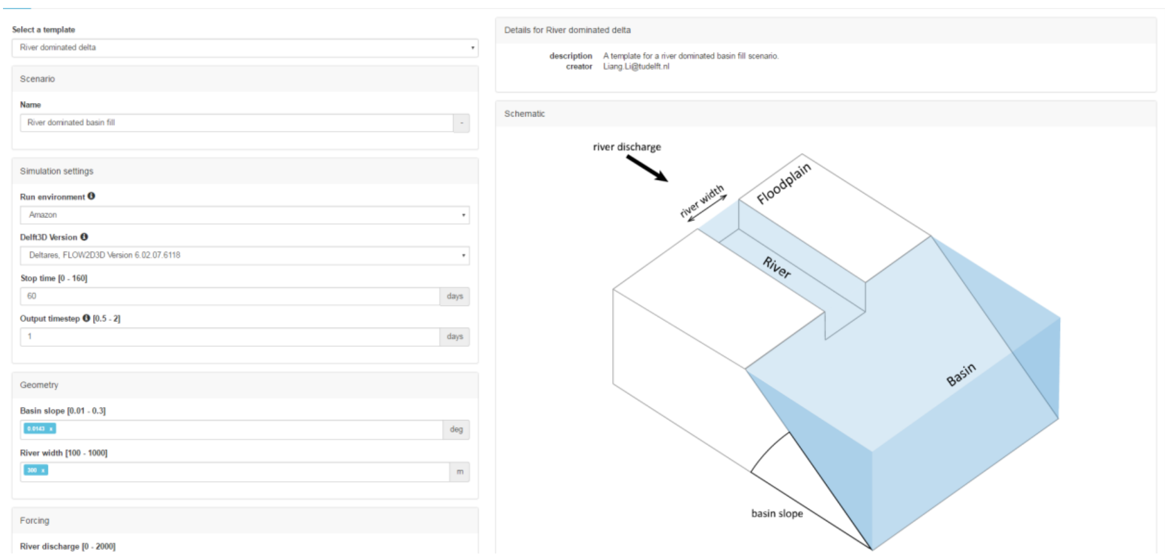


Figure 2.9 Overview of the scenario builder

2.5 Typical workflows in Delft3D-GT

Delft3D-GT facilitates 3 typical workflows (Figure 2.10):

1. Create a scenario from scratch:
   This workflow is particularly useful to test a specific hypothesis by means of a scenario (being either one or a set of runs). The user (1) creates the scenario with the scenario builder, (2) starts the simulations in the database, (3) inspects the progress in the database overview and results in the run details, (4) optionally shares the results runs with others and/or (5) downloads/exports the results for further analysis.
2. Create a scenario from an existing one (cloning):
   This workflow is particularly useful to build further upon an existing scenario for further analysis. The workflow is similar to workflow 1, but has a different starting point. The user (1) finds the scenario of interest in the database, (2) clones the scenario to make sure that exactly the same settings are taken as a starting point and (3) edits the parameters that need further investigation. The other steps are the same as workflow 1.
3. Analysing existing runs in the database without creating new ones:
   This workflow makes optimal use of the database. The user only performs analysis on existing runs without creating new ones and, therefore, saves computational time. The user (1) finds the runs of interest in the database, (2) inspect their results in Delft3D-GT and (3) selects the results to be downloaded for further analysis.

Note that the above workflows are indicative for how to use Delft3D-GT and (small) variations on the above workflows are possible. The tutorials in Chapter 4 provide step-by-step guidance to the user for application of these workflows in practice.

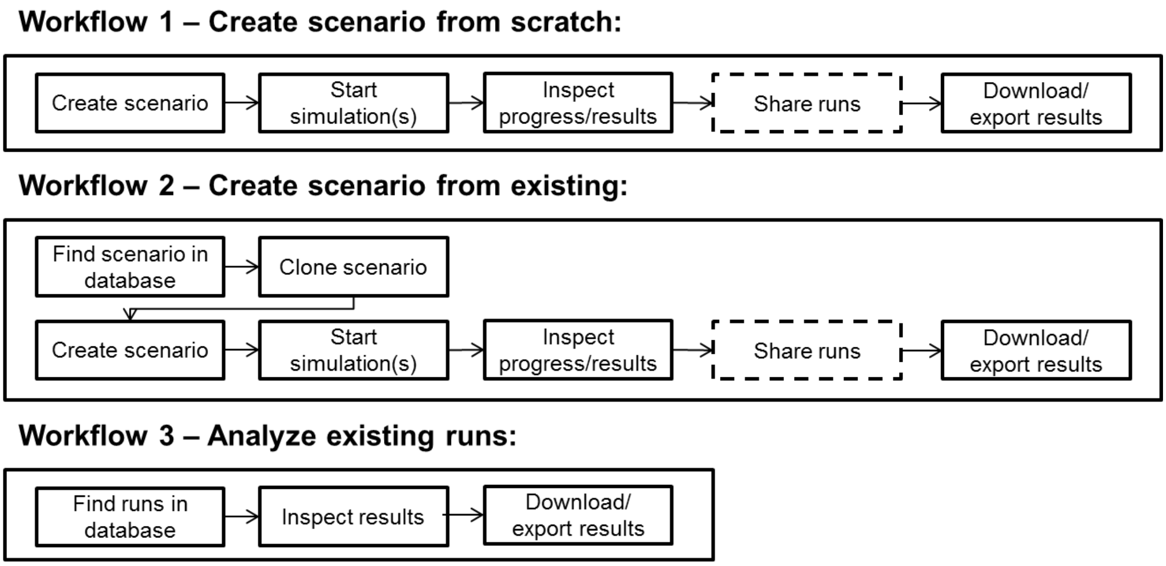


Figure 2.10 Typical workflows in Delft3D-GT

3 Graphical User Interface

3.1 Introduction

This chapter describes all features of the Delft3D-GT Graphical User Interface (GUI). Section 3.2 discusses all the input parameters and options for creating scenarios with the scenario builder. Section 3.3 describes the features and functionality of the database, including the search facility, the database contents and the run details.

3.2 Scenario builder

The purpose of the scenario builder is to set up all the input parameters for the creation of Delft3D-GT scenarios. The scenario builder is accessed by clicking on the item ‘Scenario builder’ in the menu bar of Delft3D-GT (Figure 3.1). An overview of the scenario builder is provided in Figure 3.2. The left-hand panel contains the (default) input parameters and settings that can be edited by the user. The right-hand panel shows (a) the meta-information of the selected template (see Section 3.2.1) and (b) a schematic visualization of the model geometry and forcing parameters. Note that the schematic overview is static and will not automatically update based on user input. The user editable parameters are categorized by means of template, name, simulation settings, geometry, forcing and sediment composition. The user can create scenarios (e.g. multiple runs) by providing multiple values in the categories geometry, forcing and sediment compositions (press ‘Enter’ after each value). The subsequent sections discuss the parameter categories in more detail.

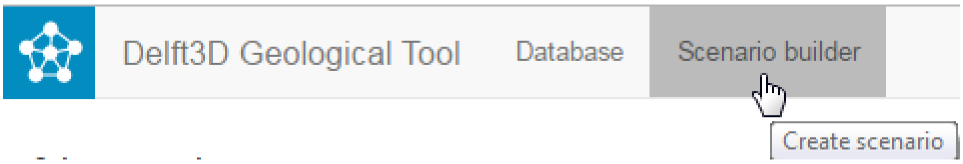


Figure 3.1 Select the scenario builder in the men bar of Delft3D-GT.

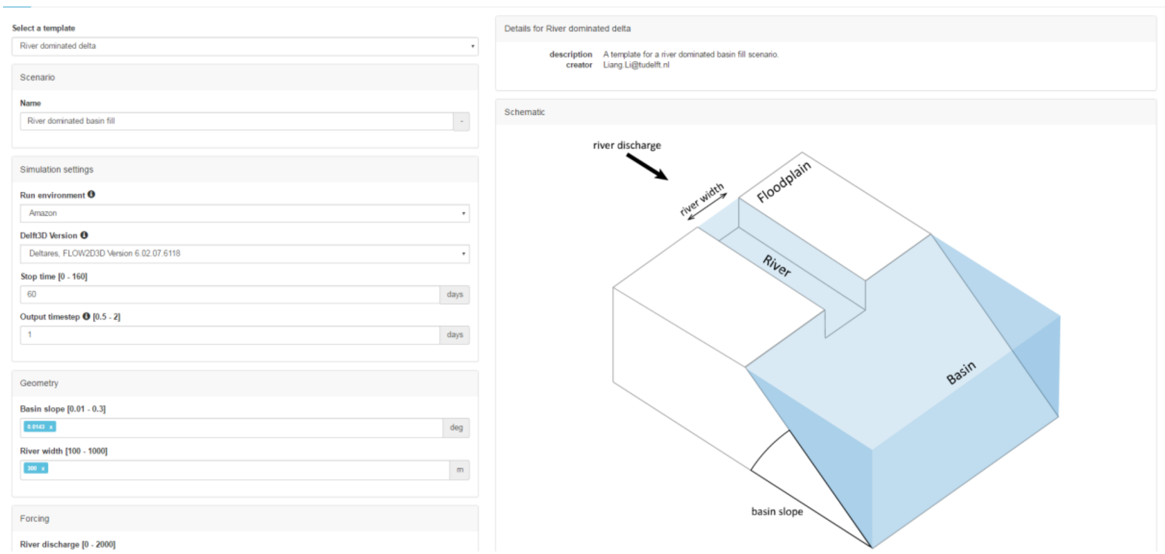


Figure 3.2 Overview of the scenario builder

3.2.1 Scenario template and name

Templates are pre-defined model set-ups. By clicking on the drop down menu below ‘Select a template’ the user can select a model template (Figure 3.3). At the moment only the river dominated delta template is available to the user. It is envisaged that more model templates will become available in the near future. The name of the scenario can be edited by clicking on text box below ‘Name’.

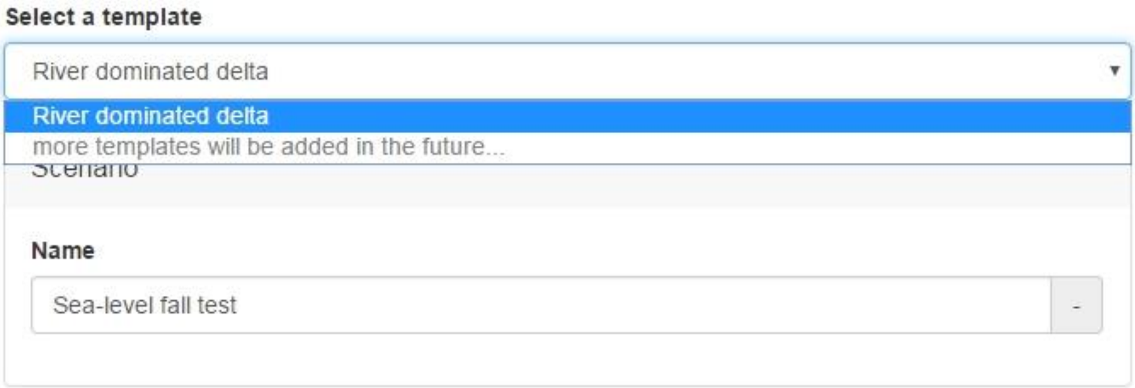


Figure 3.3 Scenario template and name in the left-hand panel of the scenario builder

3.2.2 Simulation settings

The simulation settings include the run environment of the simulations, the Delft3D version that is used for the simulation, the simulation duration and the output time-step of the simulation (Figure 3.4). Currently, the user has only one option for both the run environment (only on Amazon Web Service) and Delft3D version (FLOW2D3D Version 6.02.08.6738). It is foreseen that multiple options will become available in the near future. In the text box ‘Stop time’ the user can type in the simulation duration for the scenario ranging from 0 to 160 days. This is equivalent to 10s to 10,000s of years in geological time due to morphological upscaling. The morphological upscaling strongly depends on the selected wave condition and river discharge and their return periods in the area of interest. As a rule of thumb 1 day in Delft3D-GT (without waves) is equivalent to 7.5 years in reality. The text box ‘Output time step’ allows the user to set the interval at which output is stored and visualized ranging from 0.5 to 2 days. Please note that the simulations become more expensive in terms of computational time and required storage volume when the stop time is increased and/or the output time step is decreased.

NB: Please note that in case of long simulations (e.g. large stop time) and small output time steps the export functionality (Section 3.3.3.8) may not work properly because of memory limitations.

3.2.3 Geometry

The geometry parameters allow the user to make adjustments to the template geometry in terms of basin slope and river width (Figure 3.5). The ‘Basin slope’ refers to the bed slope of the sea basin. The user can vary this slope in the range from 0.01 to 0.3 degrees. The ‘River width’ refers to the initial width of the rectangular shaped river entering the sea basin. The user can vary the river width in the range from 100 to 1000 m. The initial river bed level is set to -4 m MSL and cannot be changed by the user.

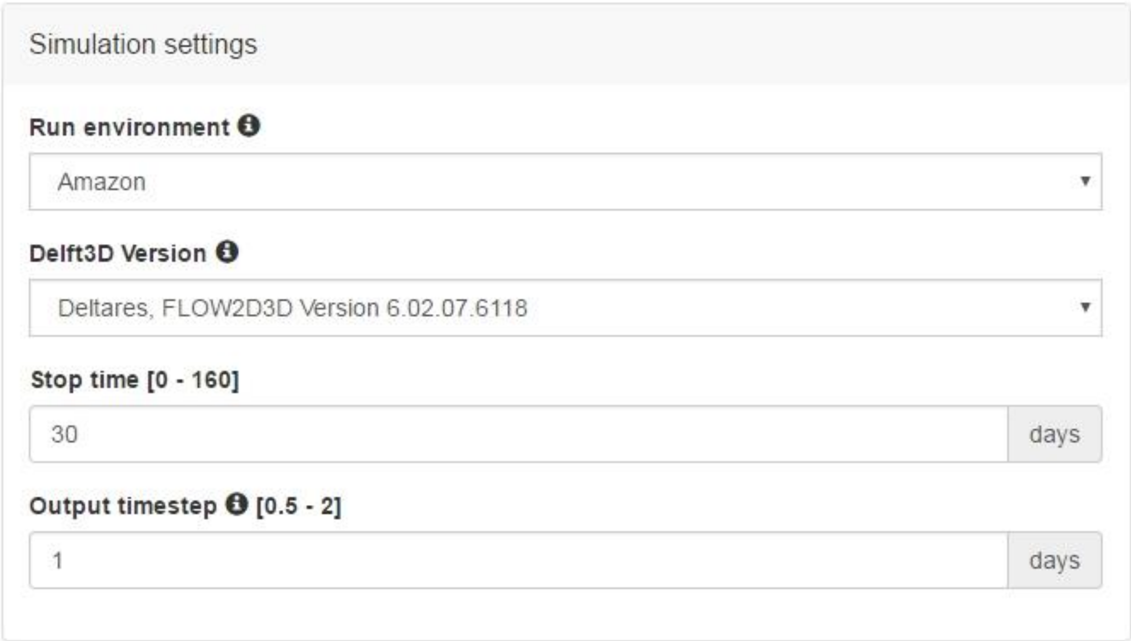


Figure 3.4 Simulation setting parameters in the scenario builder

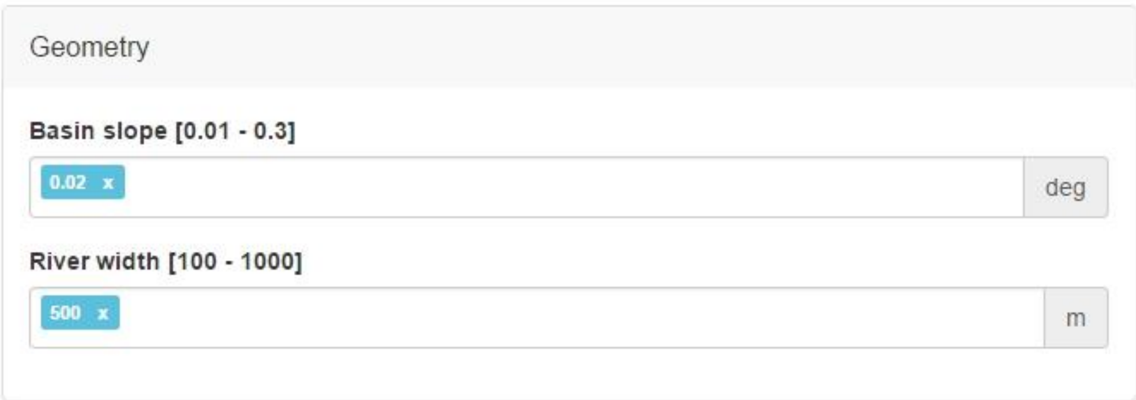


Figure 3.5 Geometry parameters in the scenario builder

3.2.4 Forcing

The forcing represents the external boundary conditions of the simulation (Figure 3.6). The river dominated delta template contains four forcing parameters: (1) river discharge (fluvial forcing), (2) tidal amplitude (harmonic tidal forcing), (3) wave height (wave forcing) and (4) base level change (sea-level forcing). Presently, forcing parameters remain constant throughout the simulation. In the future the user will also be able to import time series in order to create a time variable forcing.

The 'River discharge' refers to the upstream fluvial discharge in the range from 0 (no fluvial discharge) to 2000 m^3/s. The tidal amplitude is applied on the offshore model boundaries and can range from 0 (no tides) to 3 m (based on a single semi-diurnal M_2 tidal constituent with zero phase). For more information on tidal boundary conditions in Delft3D is referred to Section 4.5.6.1 of the Delft3D-FLOW user manual (Deltares, 2017b).

The wave height refers to the offshore significant wave height (H_s) on the model boundaries, which can range from 0 (no waves) to 2 m. The waves are coming in perpendicular to the initial coastline with a fixed peak wave period (T_p) of 4s (hence, the wave steepness increases for increasing H_s) and fixed directional spreading of cosine power 5. The wave boundary conditions are based on a JONSWAP spectrum (typical for a wind-sea state). Wind-driven wave generation within the model domain does not have to be accounted for given the relative small model domain. NB: note that the morphological acceleration factor that is used to speed up the geological simulations strongly depends on the wave energy: the higher the wave energy, the lower the morphological acceleration factor, the longer the simulation time. For more information on spectral wave models and boundary conditions is referred to Booij et al. (1999) and the SWAN documentation (Delft University of Technology, 2016).

The base level change refers to the changes in the base level (for example due to sea level rise or fall). The base level change is defined as a percentage of the basin depth and can range from -80 to +80%. The basin depth directly depends on the basin slope. For convenience the user can press “Toggle absolute value table for Base level change” (Figure 3.6) to inspect the absolute values. Positive values result in base level rise during the simulation, while negative values result in base level fall.

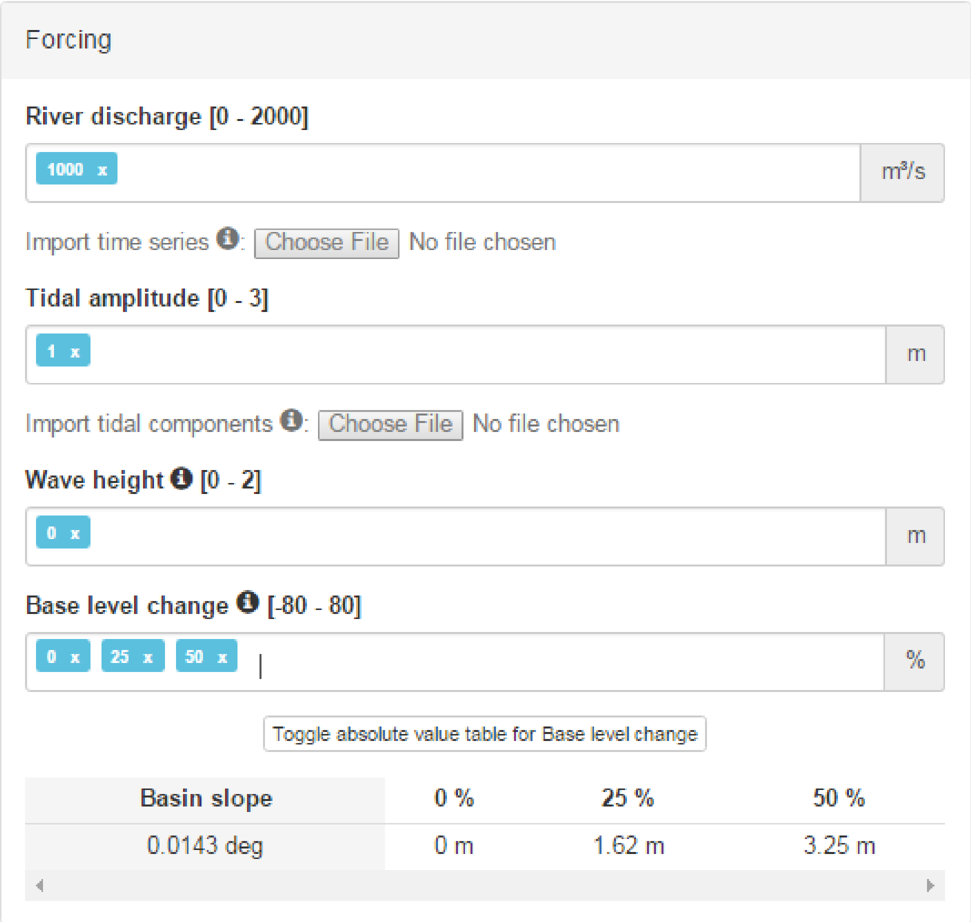


Figure 3.6 Forcing parameters in the scenario builder

3.2.5 Sediment composition

The sediment composition controls the distribution of sediment fractions in the bed substrate and water column. The user can select 5 different sediment compositions ranging from coarse sand to coarse silt by means of a drop down menu (Figure 3.7). Each sediment composition consists of 6 sediment fractions. More information on these sediment compositions can be found under the information button (Figure 3.8) which directs the users to a table with the details of the 6 sediment compositions (Figure 3.9). In the initial bed substrate the 6 sediment fractions are equally (e.g. the same sediment volume fraction) and homogeneously (e.g. over the model domain) distributed. It is foreseen that the user can also import a spatially variable sediment substrate field in the future. Equilibrium concentrations are prescribed at the model boundaries. Therefore, the concentration of each fraction depends on the transport capacity of the flow.

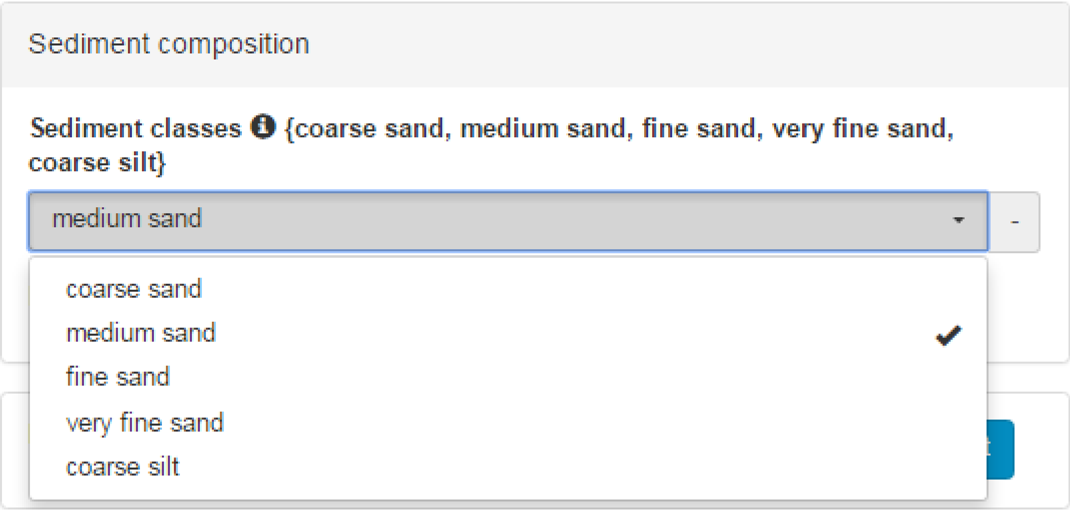


Figure 3.7 Sediment composition parameter in the scenario builder

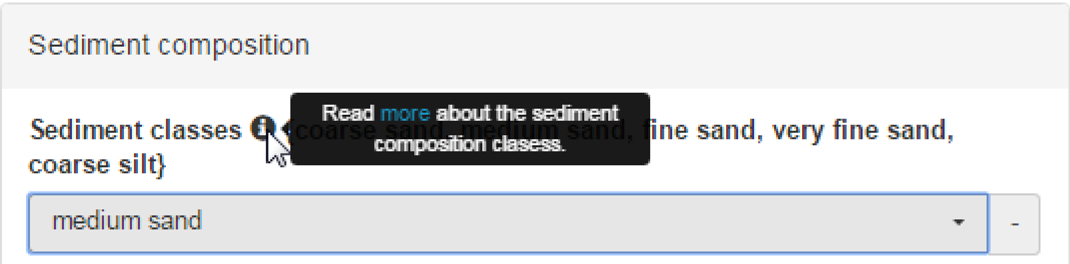


Figure 3.8 Information button for more details about the sediment composition classes. Please note that you may have to press the right mouse button to open this window in a new tab.

Sediment composition

Composition	Sand					Silt				Clay
	Very coarse	Coarse	Medium	Fine	Very fine	Coarse	Medium	Fine	Very fine	
Coarse-sand	✓	✓	✓	✓	✓	✓				
Medium-sand		✓	✓	✓	✓	✓	✓			
Fine-sand			✓	✓	✓	✓	✓	✓		
VeryFine-sand				✓	✓	✓	✓	✓	✓	
Coarse-silt					✓	✓	✓	✓	✓	✓

Notes:
1. D_{50} is determined based on Wentworth grain size chart.
2. Silt and clay are considered as cohesive sediment in Delft3D. The D_{50} for cohesive sediment is not directly implemented. Instead settling velocity and critical bed shear stress for erosion are defined based on the D_{50}.
3. 5 different sediment compositions are defined based on a selection of 6 sediment fractions. The number of fractions is optimized based on the computational efficiency and the accuracy to calculate the sediment distribution.

Figure 3.9 Sediment composition table with explanation

3.2.6 Submit a scenario

When the user has filled out all the parameter settings, the scenario can be submitted (e.g. created). To this end, the user can press the ‘Submit’ button at the lower end of the settings panel (Figure 3.10) and is redirected to the home page. Alternatively, the user can cancel the operation and is redirected to the home page. A scenario contains one or more runs. The number of runs in the scenario is shown at the left side of Figure 3.10 and is a function of the combination of specified input parameters.

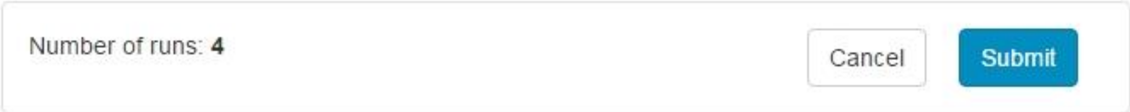


Figure 3.10 Number of runs to be created within a single scenario, and buttons to cancel or submit the scenario

3.3 Database

The Delft3D-GT database contains a search facility, the (filtered) contents of the database and the run details (Figure 3.11). The search facility (left panel) contains the filters to search for runs in the database. The database contents (central panel) display the available runs and scenarios and their status. The run details (right panel) show the details of a single selected run in terms of meta-information, input and output. These features are described in more detail in the subsequent sections.

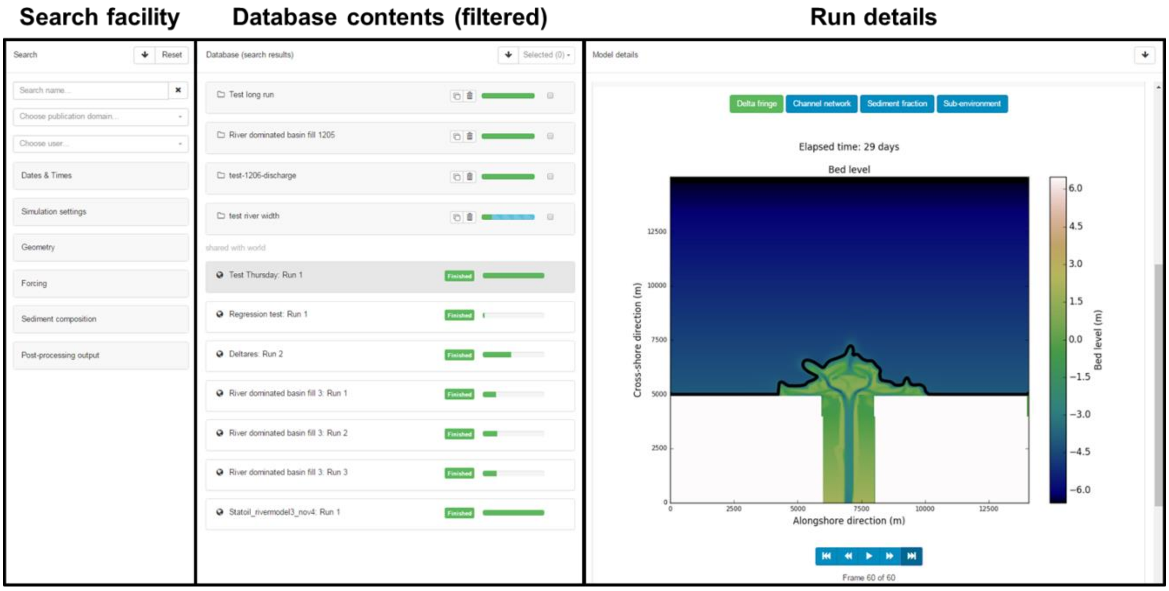


Figure 3.11 Overview of the Delft3D-GT database displaying the search facility, the (filtered) database contents and run details

3.3.1 Search facility (filters)

The search filters allow the user to search for specific runs in the database. The user can search on meta-information, simulation specifications, input and output. The panel is organized in different horizontal bars containing menus, which can be opened up by clicking on one of the bars. The bars can be opened up all together by clicking on the arrow on top of the panel (Figure 3.12). When this arrow points down, a click on it results in opening up the bars, while it results in collapsing of all bars, when it points to the top.

Figure 3.12 The arrow to collapse or open up all the search filters.

As a default, no filter is applied. This default can be restored by clicking on the icon ‘reset’ (Figure 3.12), which deactivates all filters. The use of each filter is explained below.

3.3.1.1 Meta-data filters

- ‘Name’ filters all the available runs based on their name. This filter can be deactivated by clicking on the cross on the right side of the filter icon (Figure 3.13)
- ‘Domain’ filters the database based on whether they are ‘private’ or shared with ‘company’ or with ‘public’ (Figure 3.13). Clicking on the icons ‘Select all’ and ‘Deselect all’ results in ticking and de-ticking of all the options, respectively.
- ‘User’ (Figure 3.13) filters the runs based on the user who created the runs (e.g. owner of the runs).
- ‘Date and times’ (Figure 3.13) filters the runs based on the date on which the run is created.

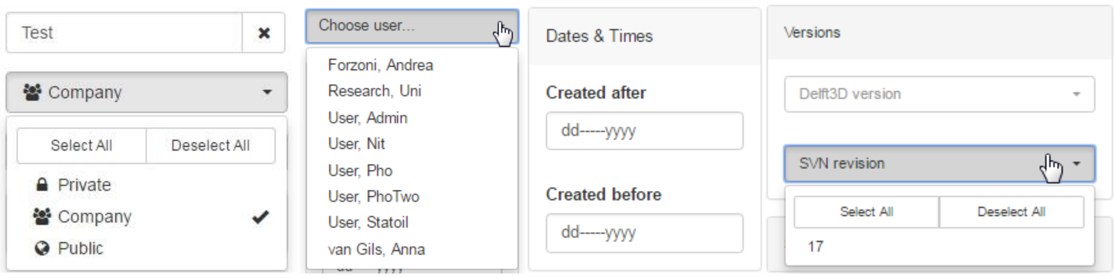


Figure 3.13 The name and domain (far left panel), user (central left panel), date & times (central right panel) and versions filters (far right panel).

3.3.1.2 Input filters

- ‘Simulation settings’ filters runs based on the simulation stop time and output time step using sliders to narrow the search range (Figure 3.14).
- ‘Geometry’ filters runs based on the basin slope and river width using sliders to narrow the search range (Figure 3.14).
- ‘Forcing’ filters runs based on river discharge, tidal amplitude, wave height and base level change using sliders to narrow the search range (Figure 3.14).
- ‘Sediment composition’ filters run based on the initial sediment composition by ticking one or more of classes in the drop down menu (Figure 3.14). Clicking on the icons ‘Select all’ and ‘Deselect all’ results in ticking and de-ticking of all the options, respectively.

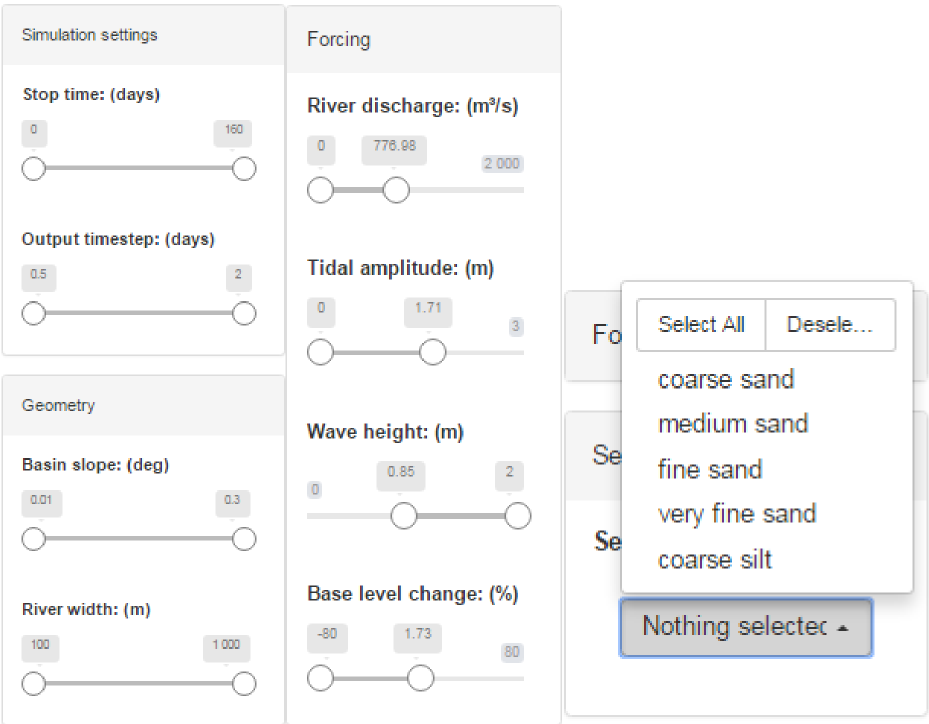


Figure 3.14 The simulations settings (left panel), forcing (central panel) and sediment composition filters (right panel)

3.3.1.3 Post-processing output filters

- Median sediment grain size (D_{50}) filter (Figure 3.15) for all sub-environments (e.g. prodelta, delta front and delta top)
- Median sediment grain size (D_{50}) of sand filter for all sub-environments
- Sorting parameter filter for all sub-environments

All filters can be (de-)activated by check boxes and narrowed down using sliders. For more information on the definitions of the characteristics of the sub-environments is referred to Section 5.3.

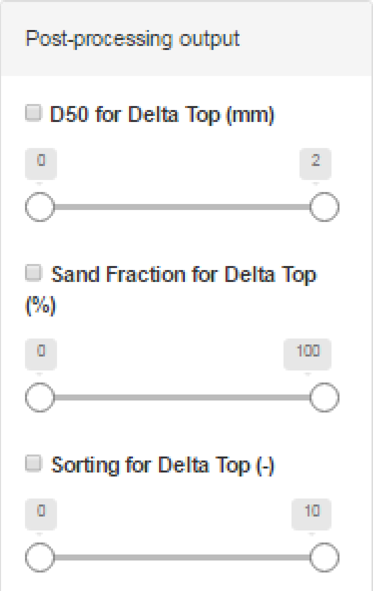


Figure 3.15 The output filters D50, sand fraction and sorting for each sub-environment (only shown for Delta Top)

3.3.2 Database contents

3.3.2.1 Scenario/run selection and actions

The central panel of the dashboard displays the runs available to the user in the database. The database is categorized in private runs, runs shared in company and runs shared with world. The user's private runs are grouped in scenarios (Figure 3.16). By selecting a scenario in the database the underlying runs become visible. By selecting a run the run details become visible in the right-hand panel (Section 3.3.3). The user can also select multiple runs and/or scenarios by checking the checkboxes behind at the right-hand side (Figure 3.16).

On the selected runs/scenarios the user can perform the following actions by means of the drop down box in the top-right (Figure 3.16):
- Start runs: to start runs after creation by means of the scenario builder (Section 3.2).
- Stop runs: to stop runs before completion. After the stopping the simulation the post-processing will be performed and the run will get the state "Finished" (see Section 3.3.2.3)
- Reset runs: to reset runs to their initial state (for restarting purposes). This will set the status of the run to "Idle: waiting for user input" (see Section 3.3.2.3). The existing simulation output and processing will be overwritten once the run is restarted.

- Delete runs: to delete runs. This means that all private run input and output are deleted from the database.

Note that the above actions can only be performed by the owner of the run. When one of the selected runs does not match the operation's criteria for being active (for example sharing a run that is not owned by the user or restarting a run that is already shared), the operation is disabled.

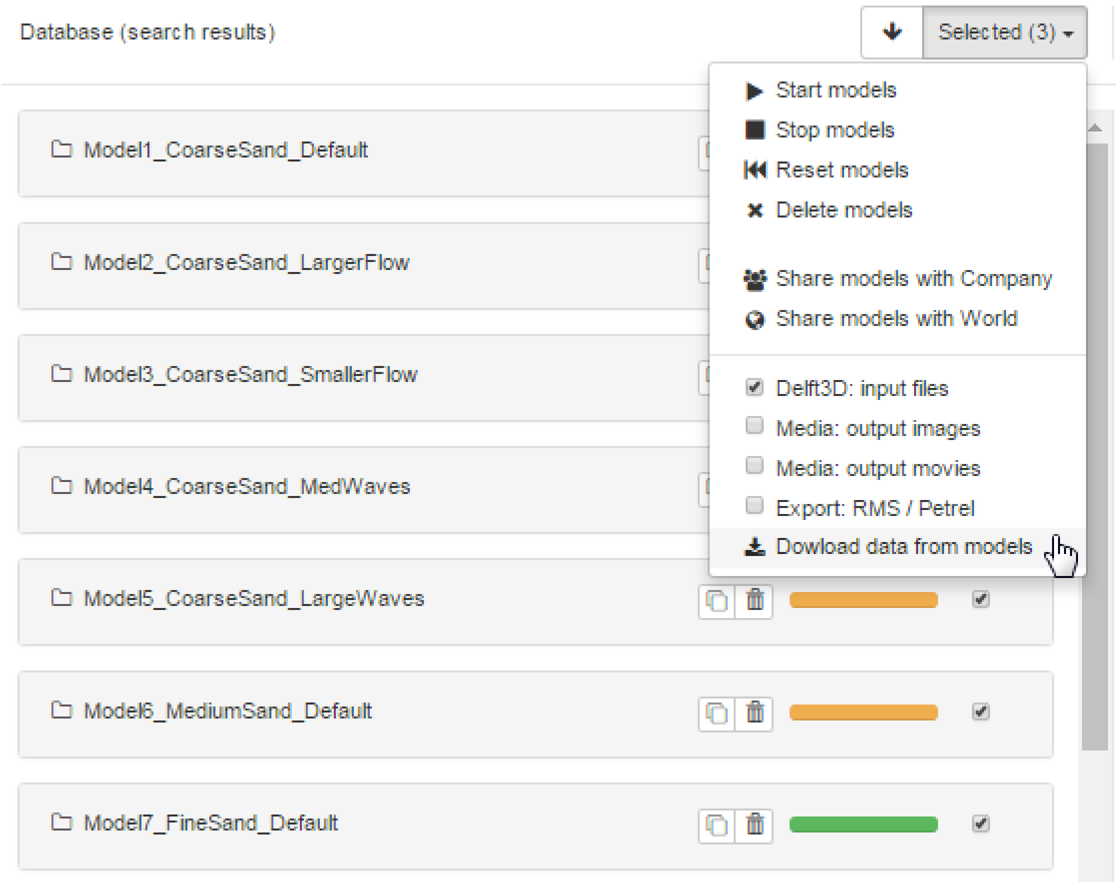


Figure 3.16 Selection of multiple runs by means of checkboxes and multi-run operations in terms of simulation controls, sharing controls and download options.

3.3.2.2 Scenario entry in database

A scenario entry in the database displays the name (in this example 'test river width') and progress of the scenario (Figure 3.17). The progress bar of the scenario is a summary of the states of the underlying runs with orange indicating "idle: waiting for user", blue indicating "in progress" and green indicating "finished". The length of each colour on the progress bar displays the fraction of the underlying runs having that state. Furthermore, the user can delete or clone scenarios using the buttons on the scenario entry (Figure 3.17). Deleting a scenario will permanently delete the scenario and underlying (private) runs from the database. Please note that shared runs that formed part of the deleted scenario will remain available in the database. Cloning a scenario allows the user to build further upon an existing scenario and redirects the user to the scenario builder with the inputs of the cloned scenario.

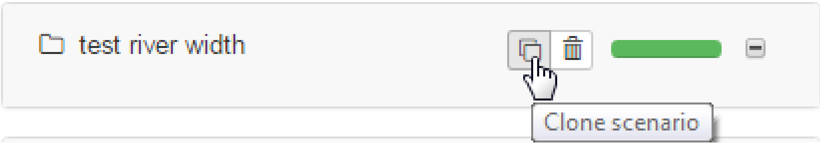


Figure 3.17 Delete or clone a scenario using the button on the scenario bar

3.3.2.3 Run entry in database

A run entry in the database displays the main information of each run (Figure 3.16): the sharing level (private, company, world), the name of the run and the progress bar. Similar to the scenario state, the state of each run is visualized. The user also gets information on the processing stage of each run. Table 3.1 provides an overview of the different run states, their colours and their meaning.

Table 3.1 Overview of all the run states, their respective colours in the progress bar and their meaning.

Status	**Explanation**
New	A new run has been created
Allocating pre-processing resources	Allocating resources on Amazon for pre-processing of Delft3D input files
Starting pre-processing	Start pre-processing of Delft3D input files
Running pre-processing	Running pre-processing of Delft3D input files
Finished pre-processing	Pre-processing of Delft3D input files is ready
Idle: waiting for user input	After pre-processing has finished, the user is requested to perform an action (start/stop/remove)
Queued	If not enough computing resources are available the run is queued and will start as soon as enough resources are available.
Allocating simulation resources	Allocating resources on Amazon for simulation
Starting simulation	Start Delft3D simulation
Running simulation	Running Delft3D simulation and processing (images)
Finishing simulation	Run processing (images) of the simulation for the last time
Finished simulation	Simulation finished
Stopping simulation	Stopping the simulation upon user command
Allocating post-processing resources	Allocating resources for post-processing after simulation has finished or it has been stopped.

Starting post-processing	Starting post-processing scripts
Running post-processing	Running post-processing scripts
Finished post-processing	Post-processing finished
Allocating export resources	Allocating resources on Amazon for export of Delft3D output to grdecl format
Starting export	Start running of export scripts
Running export	Creation of grdecl files for reservoir models
Finished export	Export finished
Allocating synchronization resources	Allocating resources on Amazon for synchronization of DelftD-GT database with the files on Amazon
Started synchronization	Starting synchronization
Running synchronization	Running synchronization
Finished synchronization	Synchronization of Delft3D-GT database completed
Starting container remove	Starting removal of containers on Amazon
Removing containers	Removing containers
Containers removed	All containers corresponding to the simulation are removed
Finished	Simulation and post-processing have finished. The run can now be shared and RMS/Petrel data can be exported.
Starting Abort	Start aborting the simulation in case something went wrong
Aborting	Aborting the simulation
Finished Abort	Simulation aborted

3.3.3 Run details

The run details panel (Figure 3.18) contains the following information and controls of a run:
- Meta-information
- Simulation controls
- Sharing controls
- Run input parameters
- Generated images
- Post-processing output
- Download files

These features are described in the subsequent sections.

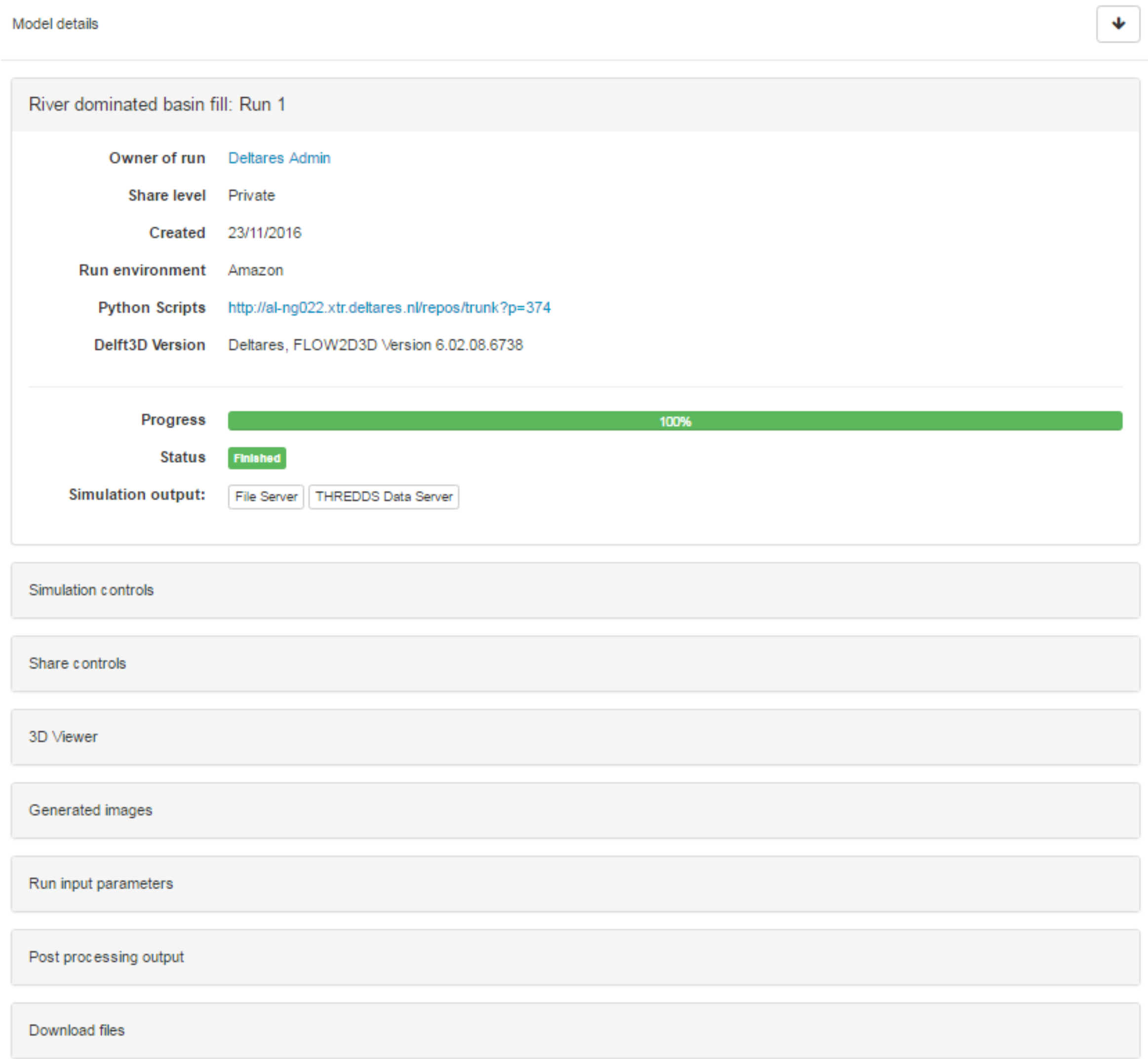


Figure 3.18 Overview of the run details with the meta-information, simulation controls, share controls, 3D viewer, generated images, run input parameters, post-processing output and download options.

3.3.3.1 Meta-information

The meta-information section (Figure 3.19) of the run details provides a summary of the following information:
- The owner of the run
- The user domain (or share level)
- The run creation date
- The run environment
- The version of the python scripting used for pre- and post-processing
- The Delft3D version
- The run progress bar (see Section 3.3.2.3)
- The run state (see Table 3.1)
- The simulation files on the file server (see below)
- The simulation output on the THREDDS server (see below)

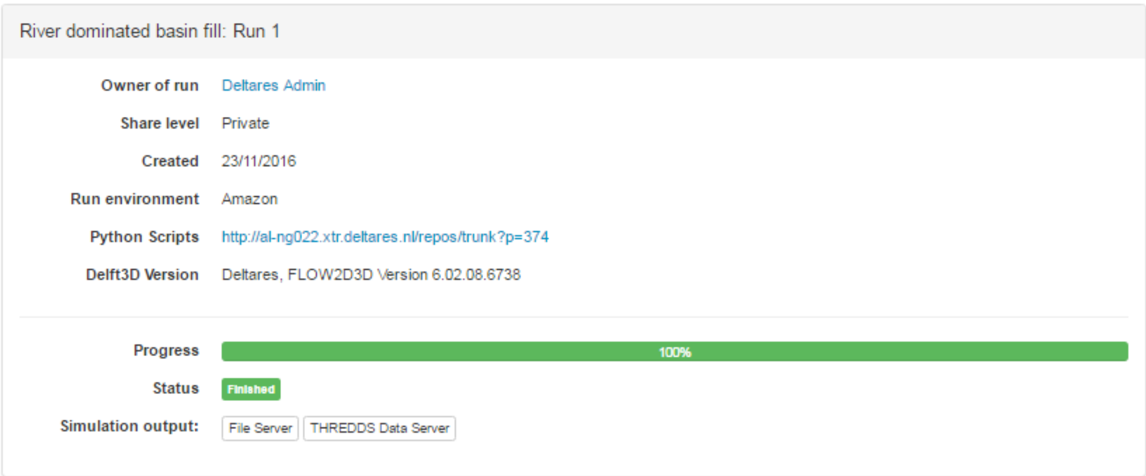


Figure 3.19 Run meta-information in run details panel

File server

By pressing the button the “File Server” the user can inspect all the input and output files of a run (Figure 3.20).The file server consists of the following folders:
- **Export:** containing the output of the run in *.grdecl-format, which can be imported in a reservoir model
- **Postprocess:** containing the post-processed geological output of the run in terms of sub-environment characteristics (both figures and data-file)
- **Preprocess:** containing an *.ini-file with the user input which the user entered in Delft3D-GT to create the run
- **Process:** containing the processed output of Delft3D-GT generated during the simulation in terms of delta fringe, channel network and sediment fraction (both figures and data-files)
- **Simulation:** containing all the input and output of the Delft3D simulation

The log files on the file server are mainly intended for developers for monitoring and bug fixing purposes.

Name	Last modified	Size
Parent Directory		-
export/	2016-12-08 14:55	-
postprocess/	2016-12-08 14:50	-
preprocess/	2016-12-08 14:55	-
process/	2016-12-08 13:35	-
simulation/	2016-12-08 14:55	-
docker_delft3d.log	2016-12-08 14:54	96K
docker_export.log	2016-12-08 14:54	1.8K
docker_postprocess.log	2016-12-08 14:54	1.5K
docker_preprocess.log	2016-12-08 14:54	779
docker_process.log	2016-12-08 14:54	46K

Figure 3.20 Contents of the file server with the user input (preprocess folder), simulation input (simulation folder), processed images (process folder), post-processing parameters (postprocess folder), export files (export folder) and log-files.

THREDDS server

By pressing the button the “THREDDS Server” the user can inspect the output of a run in more detail. The THREDDS server hosts the map (trim) and history (trim) output files of the Delft3D simulations in netcdf (*.nc) file format (Figure 3.21). The trim-file contains the spatial output of the entire Delft3D grid in time, whereas the trih-file only contains the time series of specific locations/cross-sections of the grid.

On the THREDDS server the user can access the netcdf files via OPeNDAP protocol (https://www.opendap.org/about). This protocol allows users to query/access (slices of) the output data via the internet without having to download the entire dataset. As the file size of the output files can become rather big, the OPeNDAP protocol helps both to improve the performance of Delft3D-GT (less data transfer) and to save storage space on the users own computer (no data storage).

By selecting the trim- or trih-file (Figure 3.21), the user is redirected to the THREDDS-server, where the file can be accessed through OPeNDAP protocol (Figure 3.22). By clicking the OPeNDAP link the user is redirected to the OPeNDAP dataset access form (Figure 3.23). Here, the user can inspect the contents of the netcdf file and select the data URL to access the data with Delft3D-QUICKPLOT (see Section 3.4) or for further processing by means of scripting (e.g. Python).

Figure 3.21 Contents of the THREDDS server with the trim- and trih-output of the Delft3D-GT simulation.

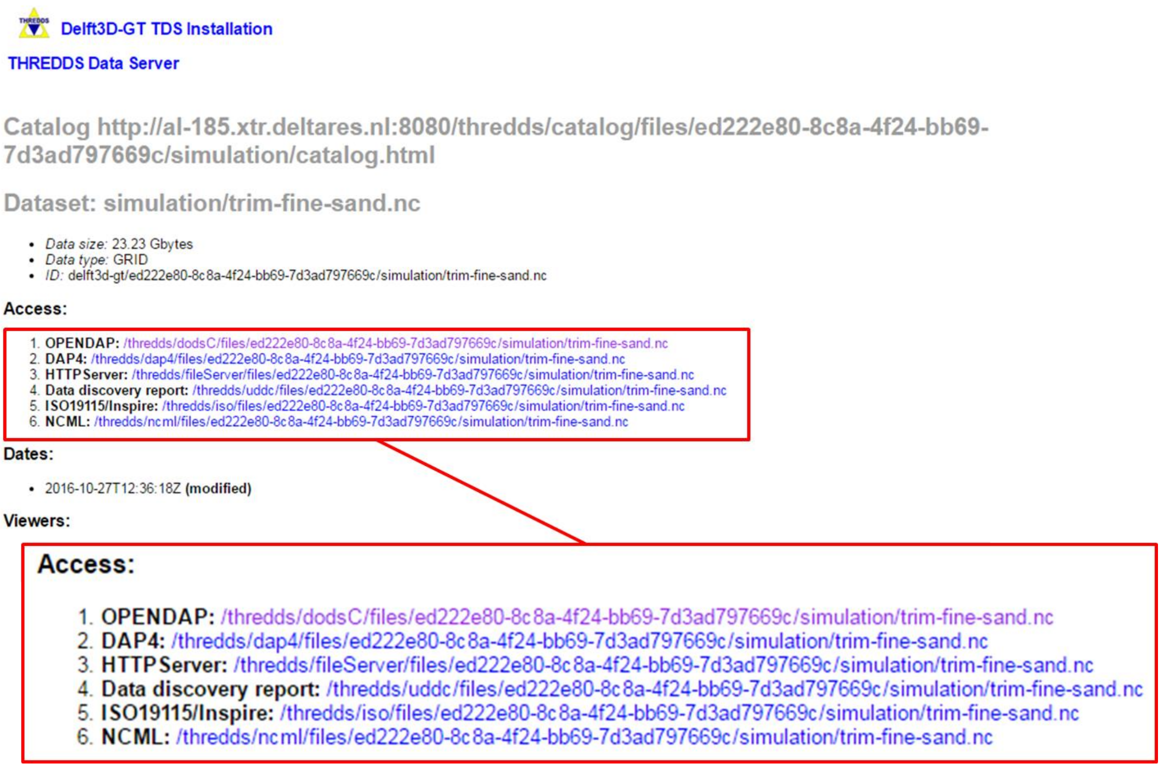


Figure 3.22 Link to access the data via OPeNDAP protocol

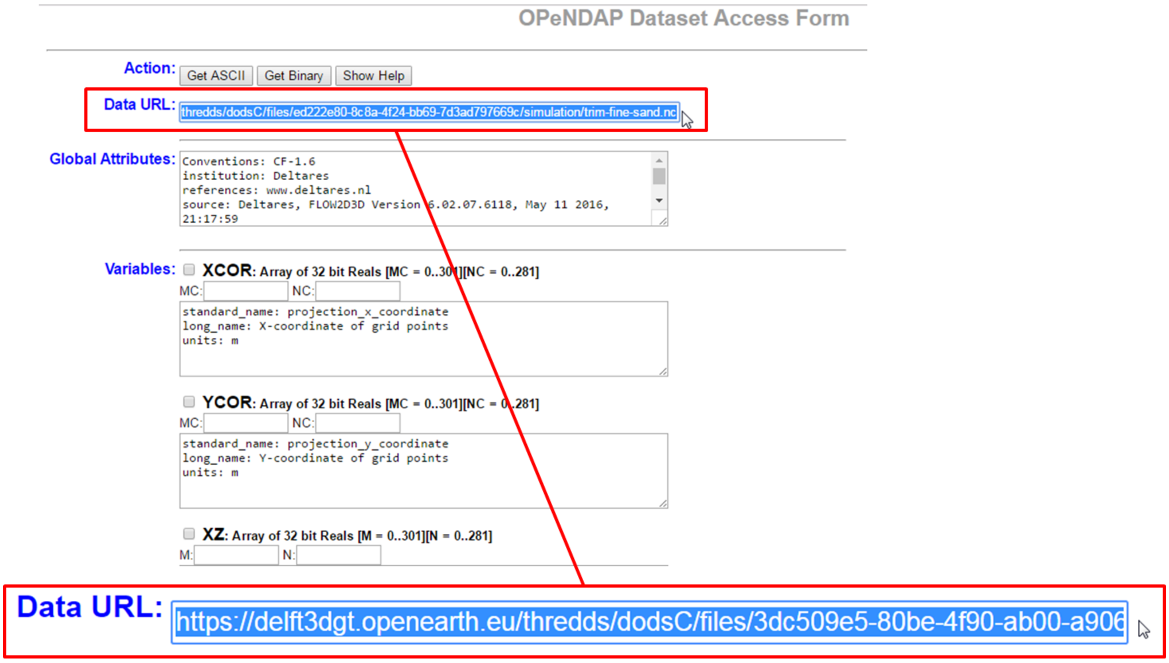


Figure 3.23 OPeNDAP Dataset Access Form with contents of the dataset and the data URL that can be used for visualization of the data in Delft3D-QUICKPLOT (part of the Delft3D suite) or further processing with custom scripting (e.g. in Python).

3.3.3.2 Simulation controls

The simulation controls section allows the user to start, stop, reset or delete a run (Figure 3.24), similar to the actions described in Section 3.3.2.1. Note that these actions can be performed only by the owner of the run as long as the run is in the private domain. Once the run is shared, the simulation controls are disabled.

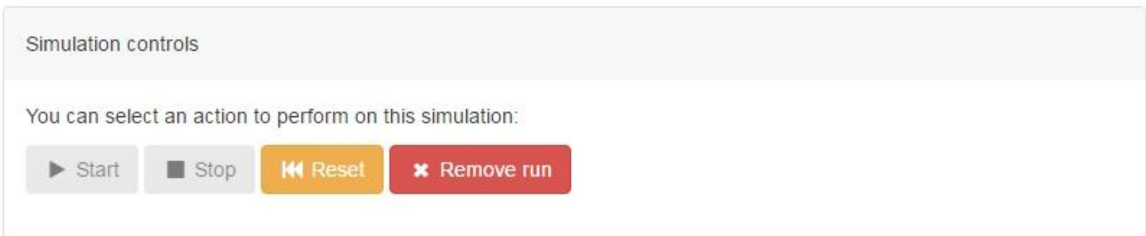


Figure 3.24 Simulation controls in the run details panel

3.3.3.3 Share controls

In the share controls section the user is able to share runs with other users. Only runs with the state “Finished” can be shared. The user can choose to share the run with ‘Company’ (only Delft3D-GT users within the same company get access) or ‘World’ (all Delft3D-GT users get access). After sharing the runs will become available in the selected category in the database view. Sharing can be performed only by the user who owns the run (Figure 3.25). NB: a sharing operation cannot be undone!

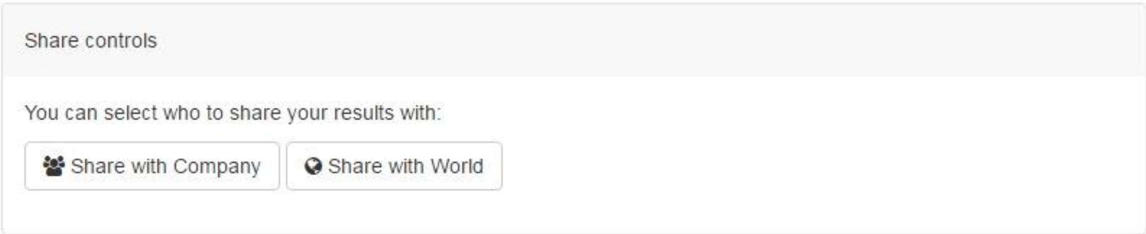


Figure 3.25 Sharing controls in the run details panel

3.3.3.4 3D viewer

For detailed inspection of the deltas generated with Delft3D-GT, the user can inspect the model results with a 3D viewer. Figure 3.26 provides an overview of the available functionality in the 3D viewer. Currently, only the sediment fraction property of the delta can be inspected. It is expected that in future version of Delft3D-GT more properties will be added to the 3D viewer.

In the subsequent paragraphs we will describe the following 3D viewer functionality in more detail:

- Zoom options
- View perspectives
- Time slider
- Slicing controls
- Color bar settings

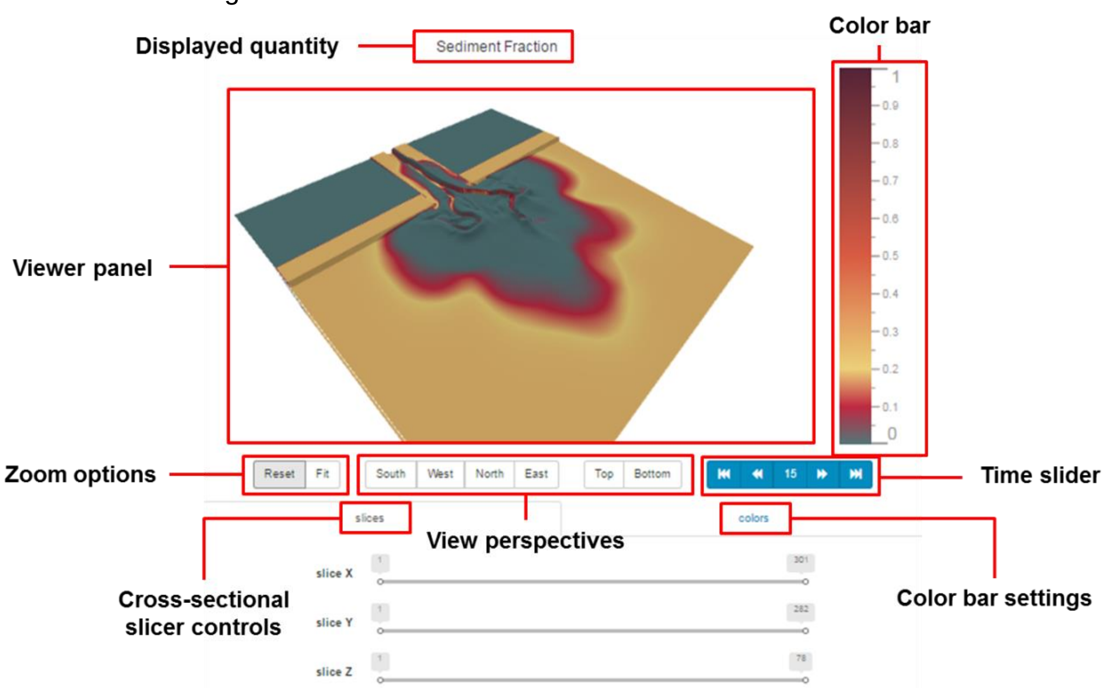


Figure 3.26 Overview of the 3D viewer components

Zoom options

The user has the following zoom options in the 3D viewer (for an example see Figure 3.27):

- Zoom in:
  - Move the mouse wheel upward
  - Or use CTRL + RMB (Right Mouse Button) + move the mouse cursor forward
- Zoom out:
  - Move the mouse wheel downward
  - Or use CTRL + RMB (Right Mouse Button) + move the mouse cursor backward
- Panning:
  - SHIFT + RMB + move the mouse cursor
- Rotating:
  - RMB + move the mouse cursor
- Reset: set the view back to its initial extent
- Fit: make the viewer fit the extent of the object that is displayed.

View perspectives

The user can select the following view perspectives to inspect the delta (for an example see Figure 3.28):

- South
- West
- North
- East
- Top
- Bottom

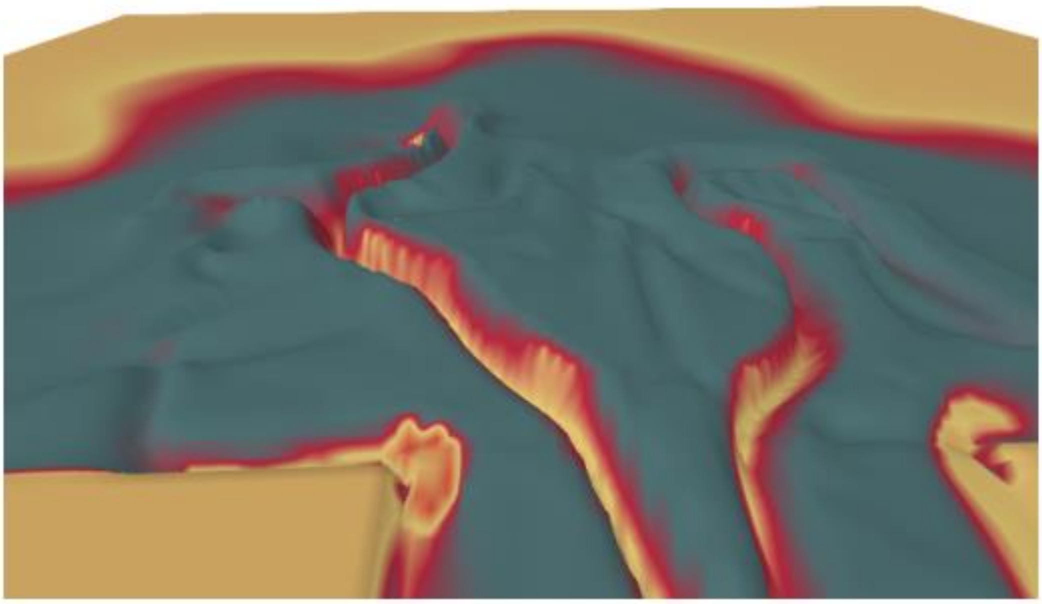


Figure 3.27 Example of controlling the 3D view using the zoom controls

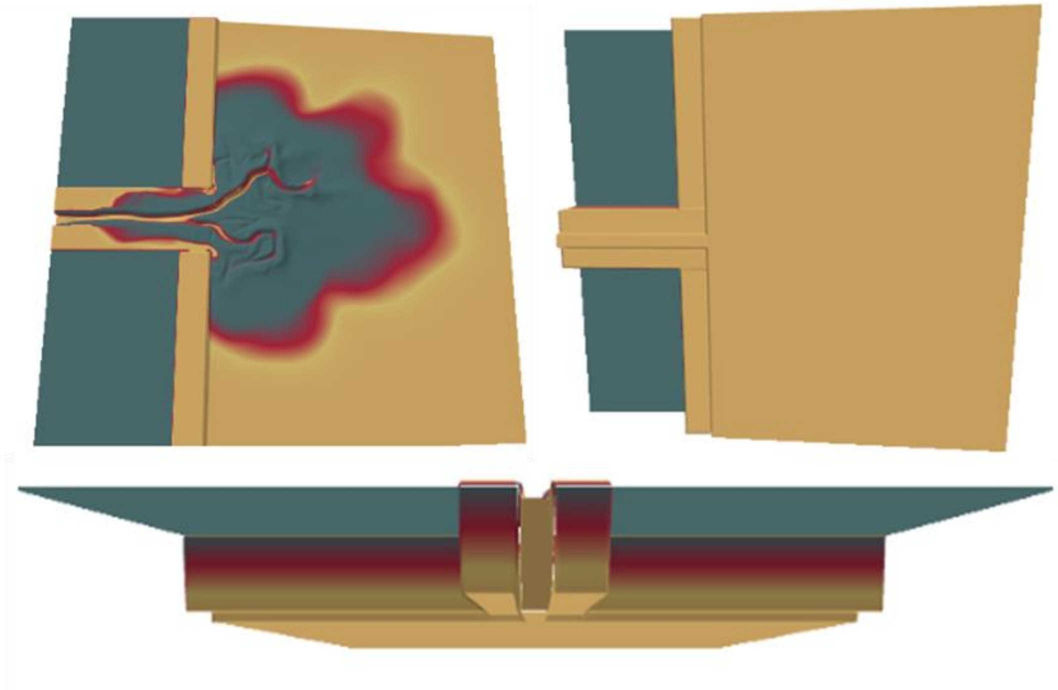


Figure 3.28 Different view perspectives on the delta (in this example top, bottom and East)

Time slider

With the time slider the user can step through the model output in time. From left to right the user has the following options:

- go to the first time step
- go to the previous time step
- play forward
- go to the next time step
- go to the last time step

Slicer controls

With the slicer controls the user has the option to slice through the 3D surface in x-, y- and z-direction for more detailed inspection. An example of such a slice is shown in Figure 3.29.

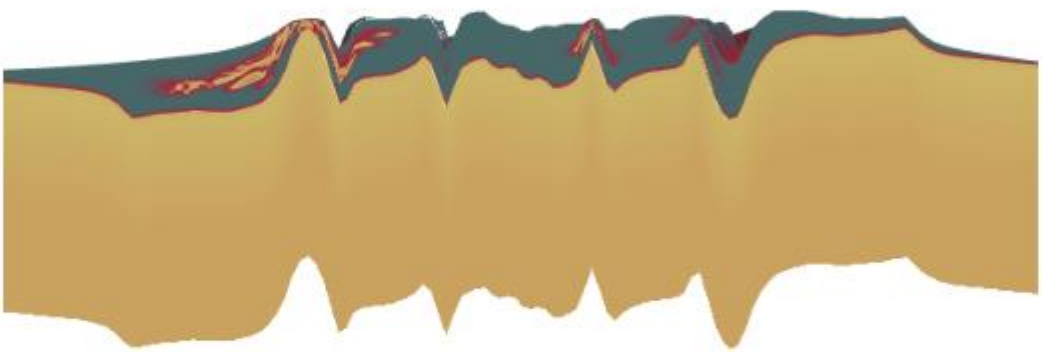


Figure 3.29 Example of a slice of a delta in x-direction.

Color bar options

The user has the option to change the color bar to his/her own preferences in the colors tab by adding, deleting and adjusting the colors corresponding to the numbers on the color bar (see Figure 3.30). An example result with an adjusted color bar is shown in Figure 3.31.

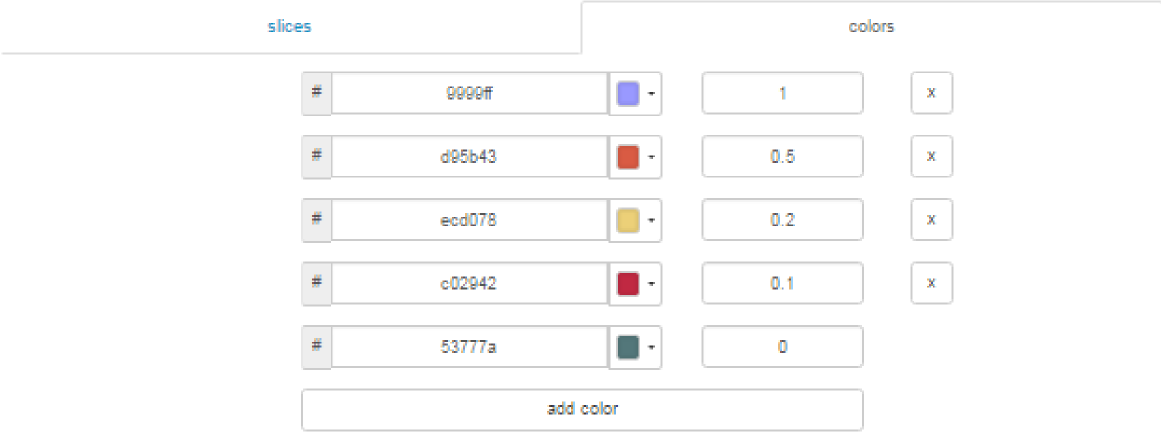


Figure 3.30 Controlling the color settings of the color bar in the colors tab.

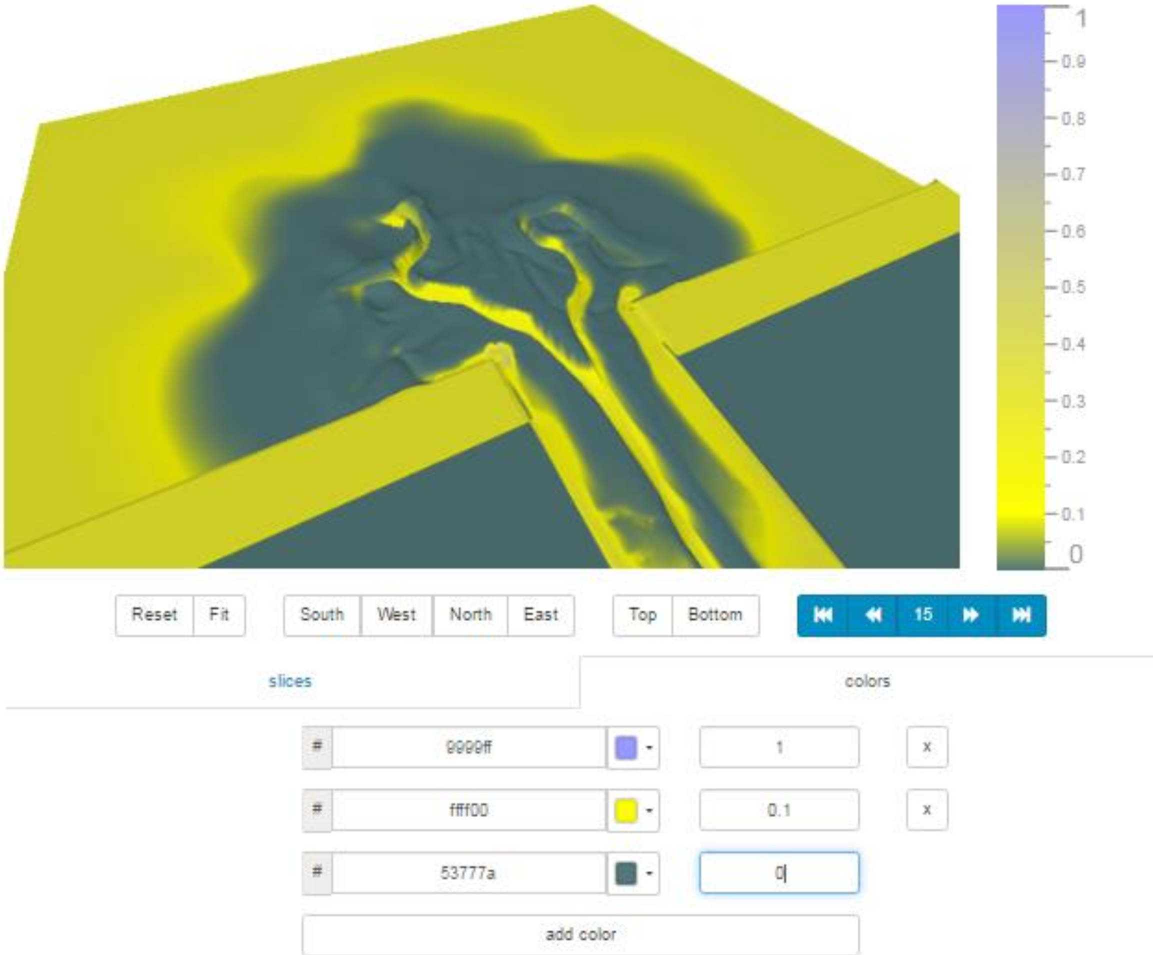


Figure 3.31 Example of a delta with an adjusted color bar.

3.3.3.5 Generated images

During and immediately after the simulation, the output is visually displayed in four sets of images, allowing the user to analyse simulation results. The four sets of images are generated by the model at a time step defined in the scenario builder (Section 3.2):

1. During the simulation: Map view of the delta fringe in time (Figure 3.32)
2. During the simulation: Map view of the channel network in time (Figure 3.33)
3. During the simulation: Cross-sectional view of the bed stratigraphy (sediment fractions) for a fixed cross-section on the central axis of the river (Figure 3.34)
4. After simulation: Map view of the erosion and sedimentation areas and delta sub-environments: pro-delta, delta-front and delta-top (Figure 3.35).

The controls below each set of figures enable the user to switch to different time frames (e.g. go to the first frame, go to the previous frame, play forward, go to the next frame and go to the last frame).

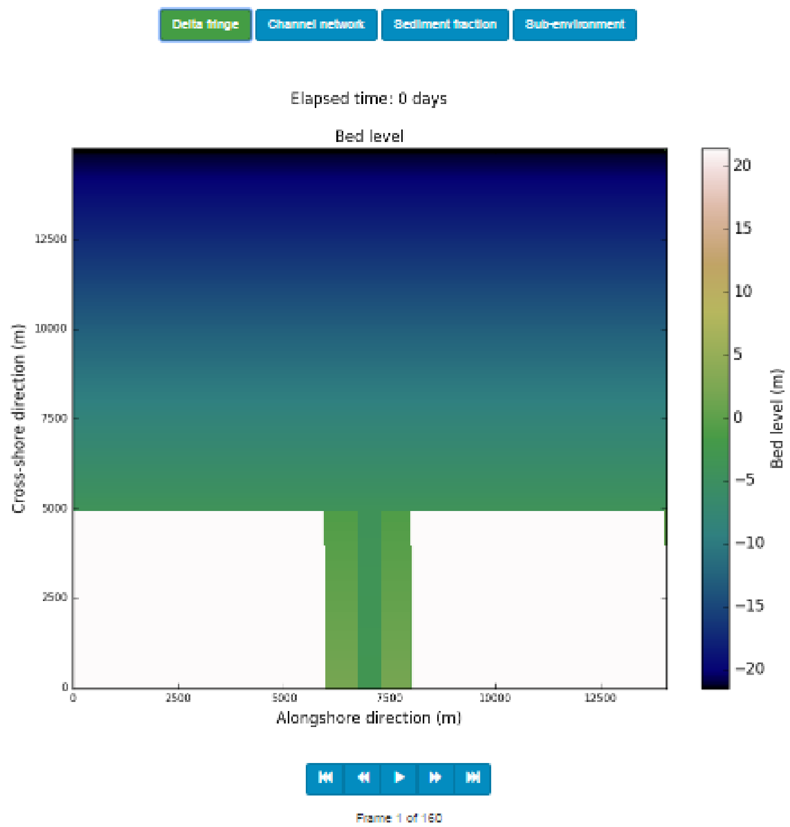


Figure 3.32 Example of Delta fringe output

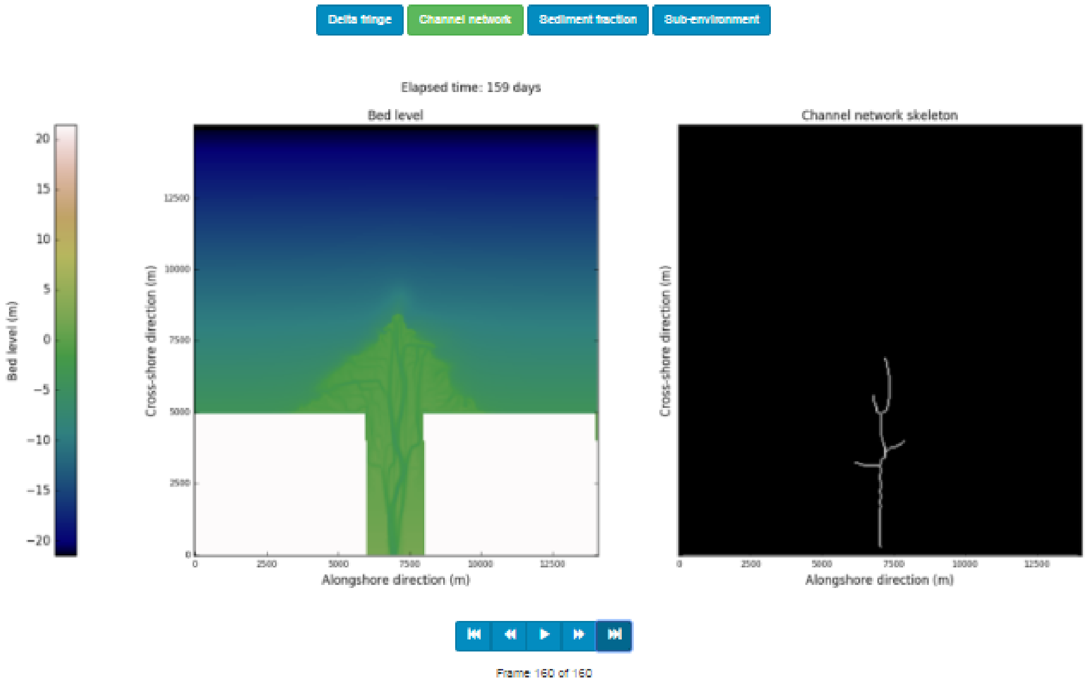


Figure 3.33 Example of channel networking output

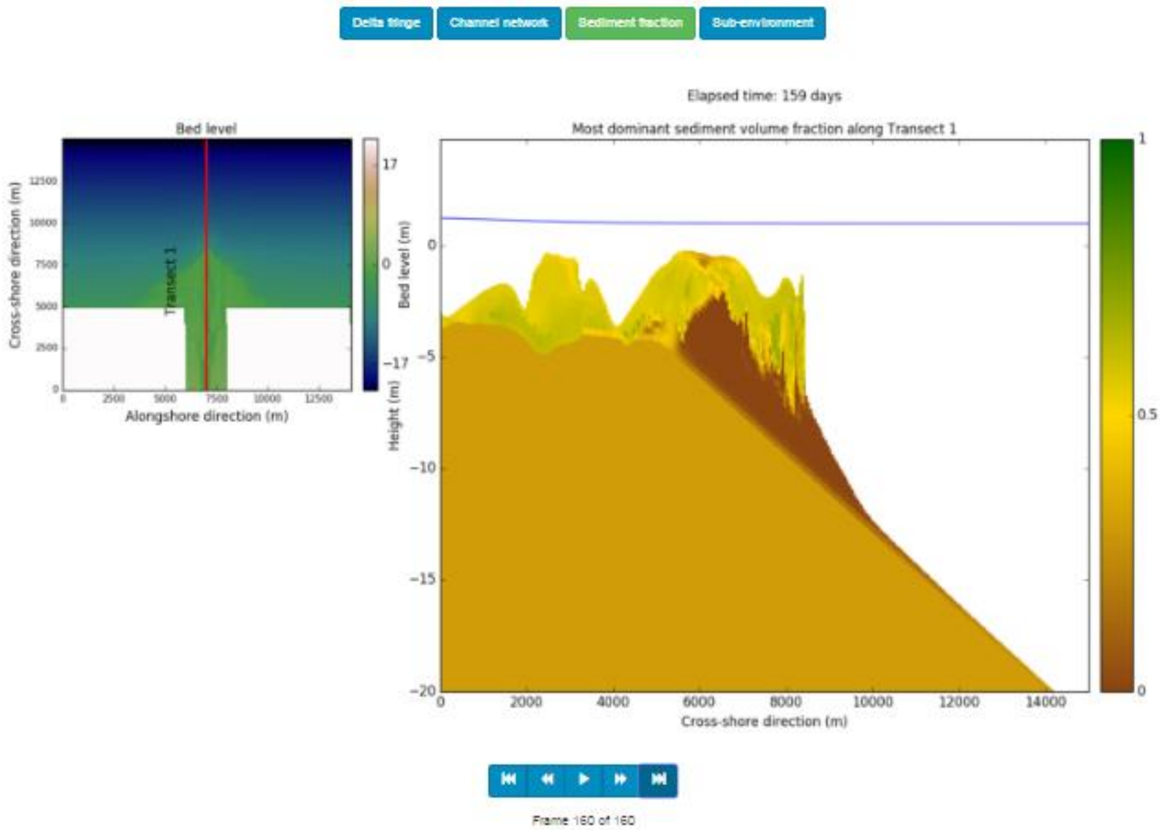


Figure 3.34 Example of sediment fraction output

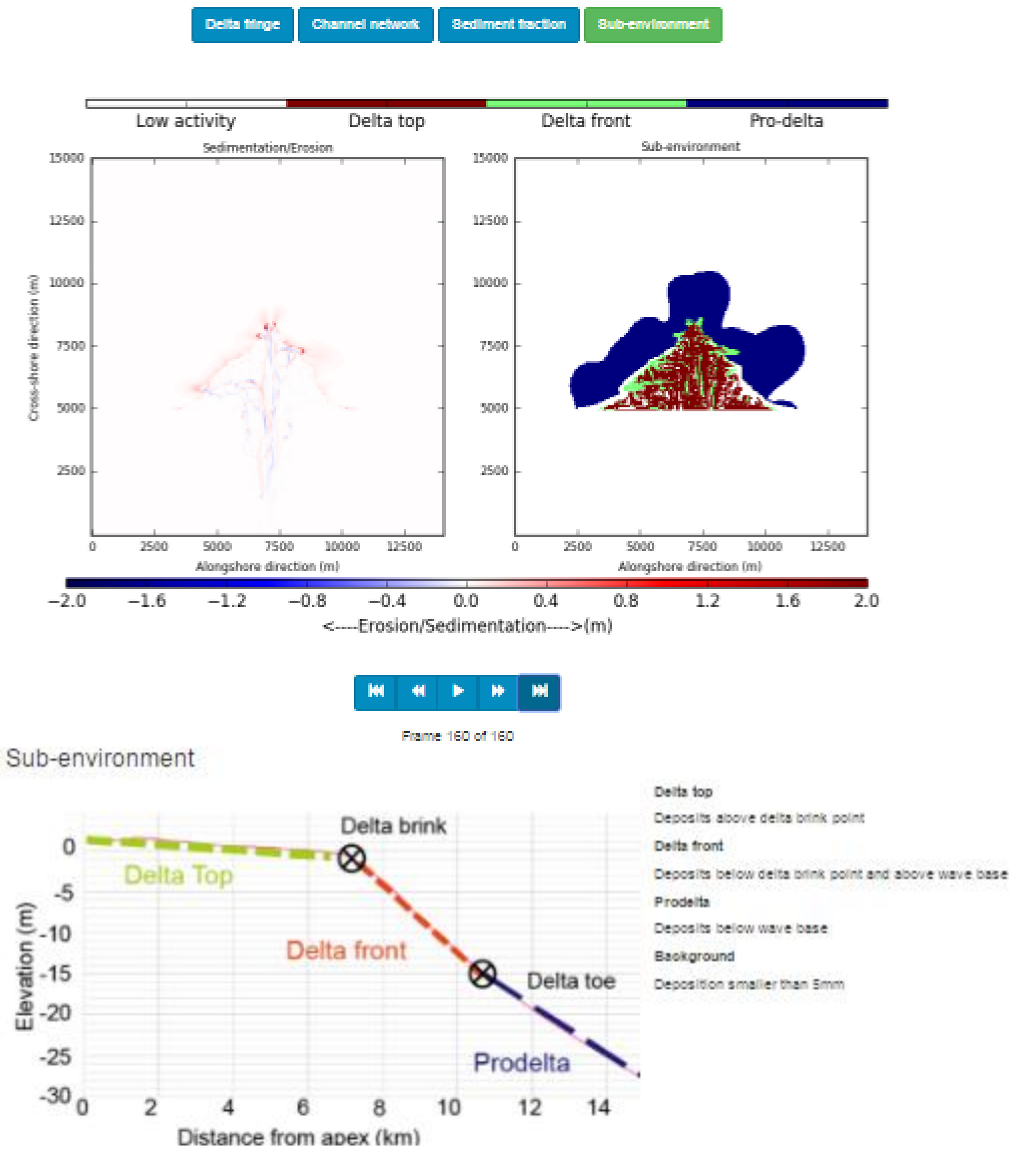


Figure 3.35 Example of sub-environment outputwith explanation of the definitions

3.3.3.6 Run input parameters

The table in the ‘Run input parameters’ section summarizes the parameter values used as input for the selected runs (Figure 3.36).

Run input parameters

Parameter	Value	Units
Base level change	0	%
Basin slope	0.1	deg
Sediment classes	fine-sand	
Output timestep	1	days
River discharge	1000	m³/s
River width	500	m
Stop time	160	days
Template	River dominated delta	
Tidal amplitude	1	m
Wave height	0	m

Figure 3.36 Overview of the run input used to run the simulation

3.3.3.7 Post processing output

The table in the post processing output section displays the values of the aggregated (geological) post- processing parameters (Figure 3.37). These parameters are the median grain size (D50) of all sediment fractions, the D50 of the sand fraction and the grain size sorting. All three parameters are calculated and displayed for each sub-environment.

Post processing output

Parameter	Value	Unit
D50 for Delta Top	0.606	mm
Sand Fraction for Delta Top	69.6	%
Sorting for Delta Top	-	-
D50 for Delta Front	0.465	mm
Sand Fraction for Delta Front	56.699999999999996	%
Sorting for Delta Front	-	-
D50 for Prodelta	1.17	mm
Sand Fraction for Prodelta	0.0709	%
Sorting for Prodelta	0.00396	-

Figure 3.37 Overview of the aggregated geological parameters of the simulation in terms of overall D50, sand fraction and sorting parameter for the prodelta, delta front and delta top sub-environments.

3.3.3.8 Download files

The ‘Download files’ section allows the user to download input files, generated output images and movies and export files for RMS/Petrel. The export files for RMS/Petrel can be downloaded only after the simulation has finished, whereas input files, images and movies can be downloaded already during the simulation.

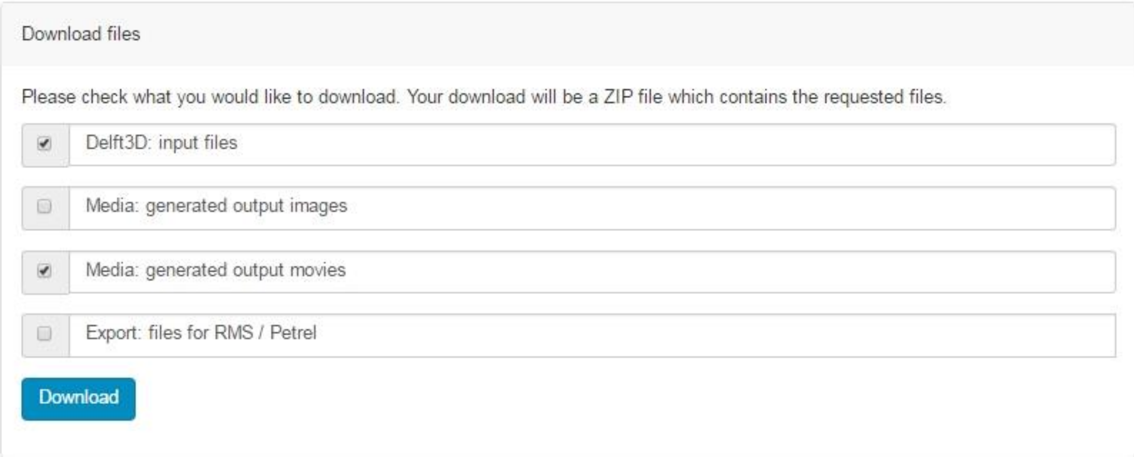


Figure 3.38 Over view of the download options in terms of (1) Delft3D input files, (2) generated output images, (3) generated output movies and (4) exported files in grdecl-format for use in geo-statistical packages.

3.4 Inspect Delft3D-GT results with Delft3D-QUICKPLOT

Delft3D-QUICKPLOT has been developed to be a user-friendly, flexible and robust tool for interactive data visualisation and animation of numerical model results produced by Delft3D modules. This user manual focuses on how to access and inspect Delft3D-GT model results from the THREDDS server (see Section 3.3.3.1) with QUICKPLOT. The details of QUICKPLOT are described in a separate user manual (Deltares, 2017c).

NB: please note that due to a bug in Matlab, reading OPeNDAP sources over https is currently not possible. As a workaround the user can replace the “https” string by “http”. This only works for 2015 Matlab releases.

To inspect Delft3D-GT output with QUICKPLOT, the following steps are required:
1. Copy the data url of the Delft3D-GT output on the THREDSS server (Figure 3.23)
2. Open QUICKPLOT and select “File” - “Open URL…” and enter/paste the data url of the GT model results (Figure 3.39)
3. Select the variable for plotting from the dropdown menu and set the clipping values for X=0 and Y=0 (Figure 3.40)
4. View the variable in using the “Quick view” button (Figure 3.41)

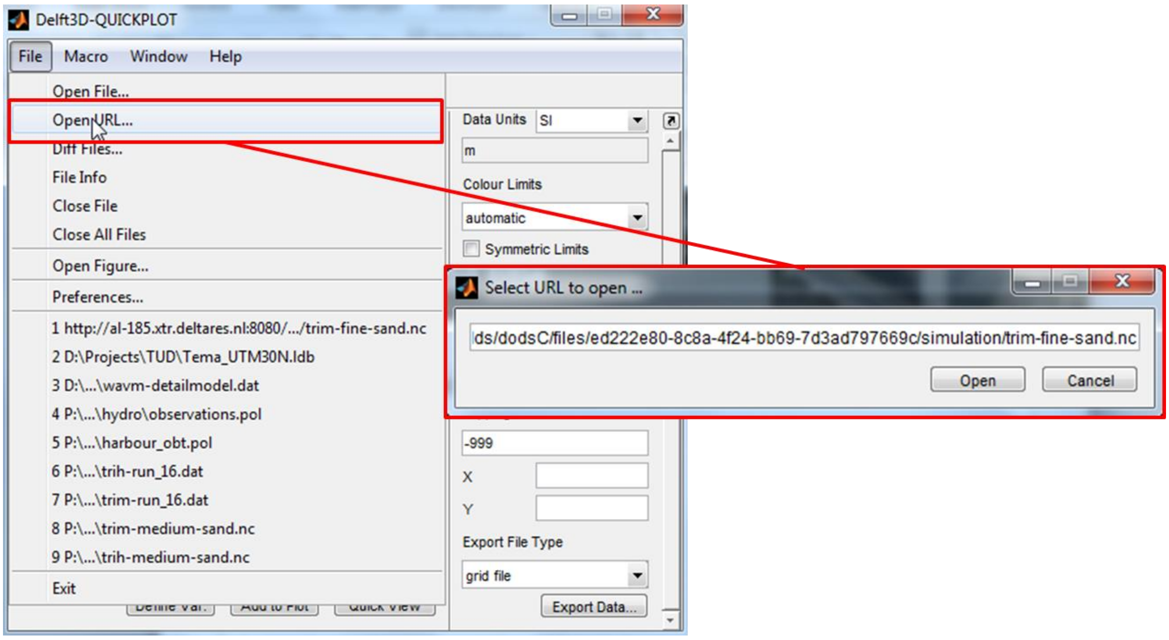


Figure 3.39 Open data URL via OPeNDAP protocol in QUICKPLOT

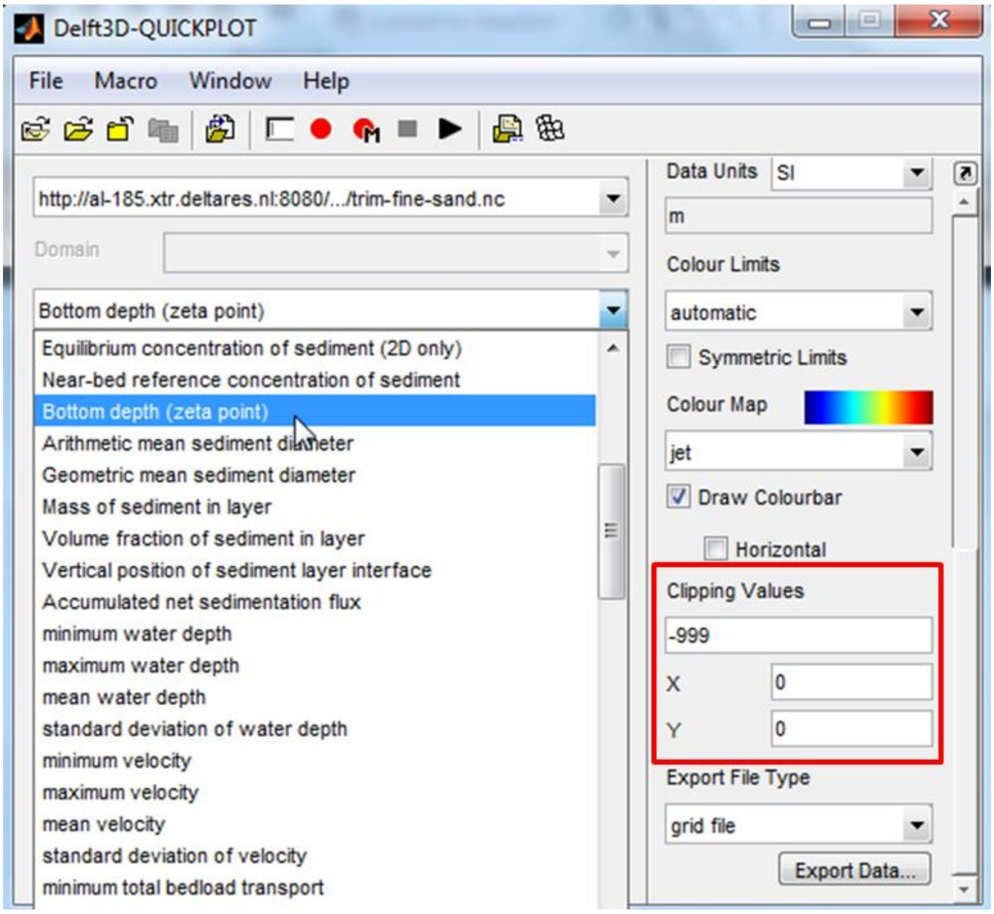


Figure 3.40 Select variable for plotting ("Bottom depth") and set clipping values for X=0 and Y=0.

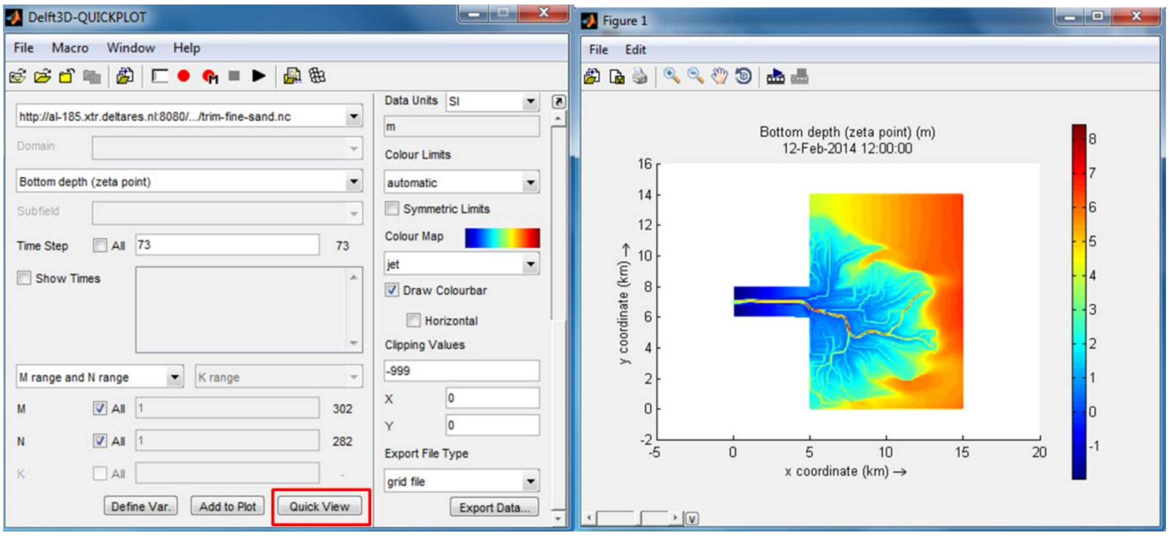


Figure 3.41 Quick view the bed morphology ("Bottom depth") in time.

3.5 Import Delft3D-GT results in reservoir models

The results of Delft3D-GT can be exported in GRDECL format for further analysis in reservoir models like ResInsight, RMS and Petrel. This section describes general aspects of the export file (Section 3.5.1) and provides an example of importing such a file in ResInsight (Section 3.5.2).

3.5.1 General aspects of the export file

The Delft3D-GT export file is a GRDECL file, which is an ASCII format for an ECLIPSE grid.

The grid description contains the following keywords:
- COORD: coordinate lines
- ZCORN: depth of grid point corners

Other properties associated with the ECLIPSE grid are:
- CHANNELS: a boolean array for channel identification with a 0 for False and 1 for True.
- SANDFRACTION: the ratio between sand volume and total sediment volume
- SUBENVIRONMENT: definition for depositional environment as depicted in Table 3.2.

Table 3.2 Defintions of sub-environments in grdecl format

Number	Sub-environment
0	Background
1	Delta top
2	Delta front
3	Prodelta

3.5.2 Import GRDECL file to ResInsight

A GRDECL file can be imported in most of the reservoir simulation software packages, such as ResInsight, RMS and Petrel. In this manual, ResInsight is used as an example for the importing a GRDECL file from Delft3D-GT. ResInsight is an open source, cross-platform 3D visualization package for curve plotting and post processing of ECLIPSE reservoir models and simulations.

The following steps can be taken in ResInsight:
1. Open ResInsight, and select ‘File’ > ‘Import’ > ‘Import Input Eclipse Case’ (Figure 3.42). NB: it might take several minutes for ResInsight to load the files.
2. Inspect the model results using the ResInsight viewer (Figure 3.43)
3. Control the visualization using the Project Tree and the Property Editor for switching views between different properties (Figure 3.44).
4. Make cross-sectional views of the modelling results (Figure 3.45).

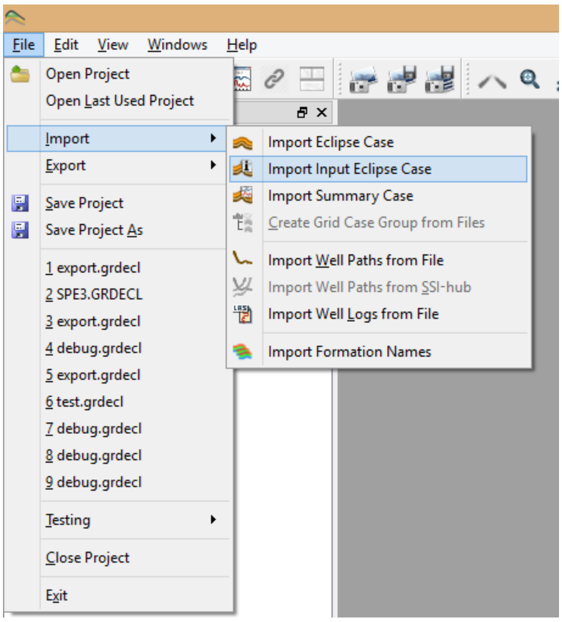


Figure 3.42 Import GREDCL file into ResInsight

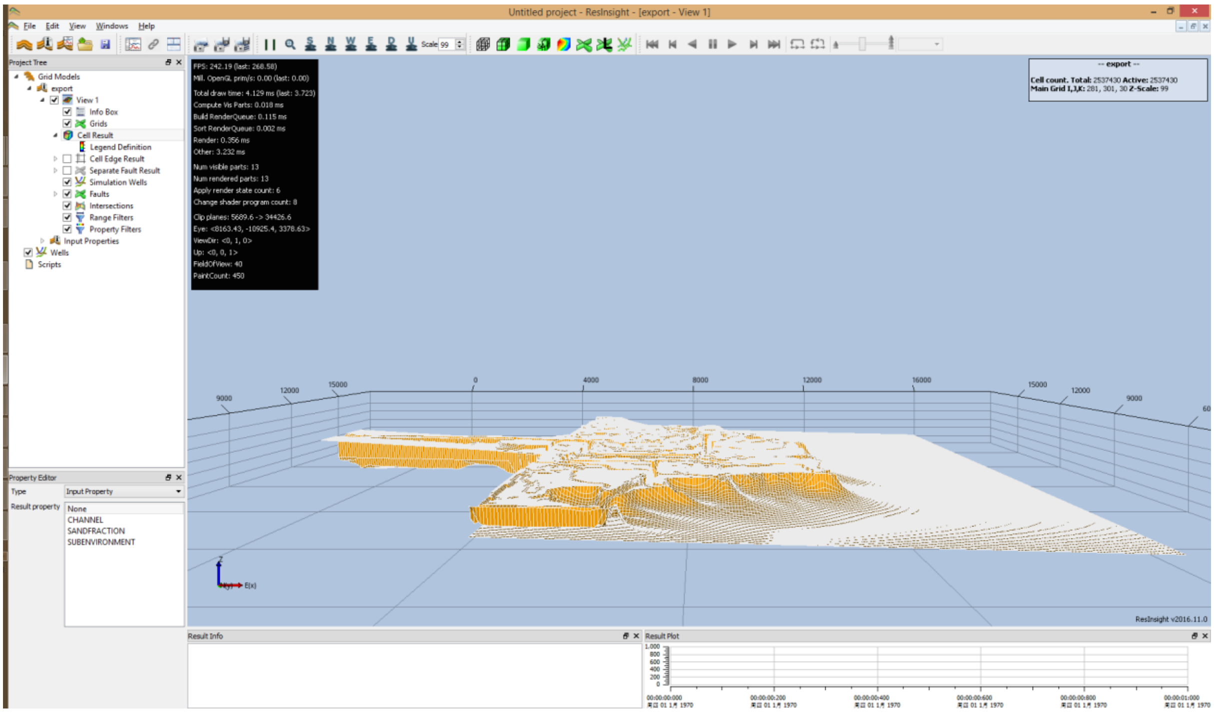


Figure 3.43 An example of the initial viewer for ResInsight

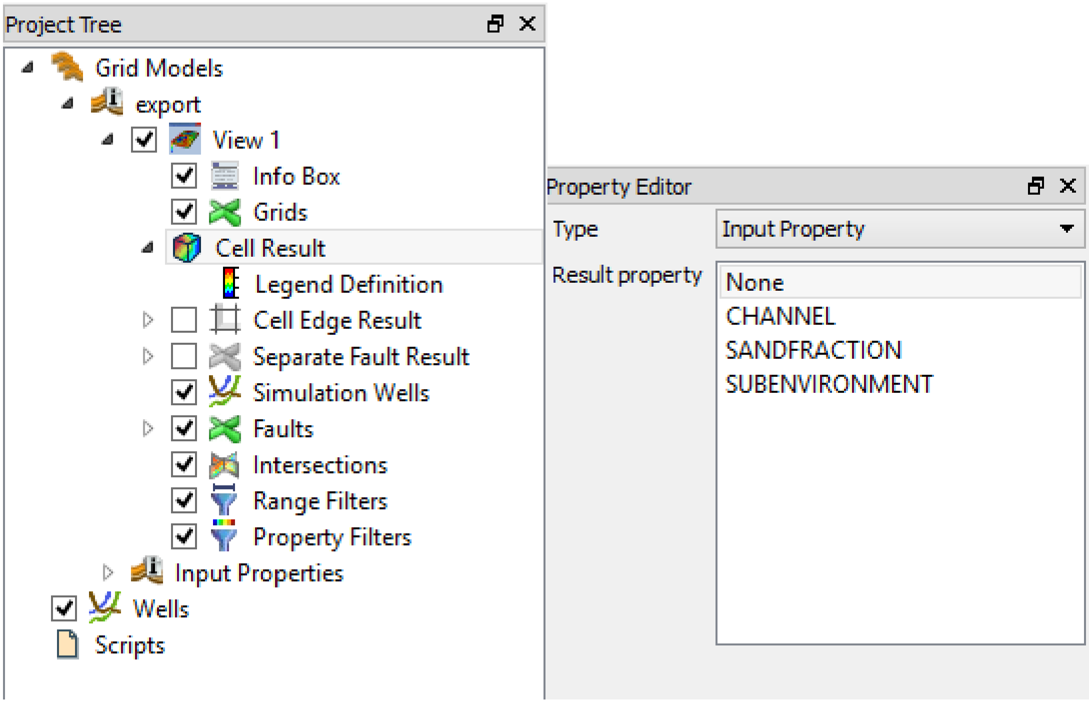


Figure 3.44 Project tree and property editor in ResInsight

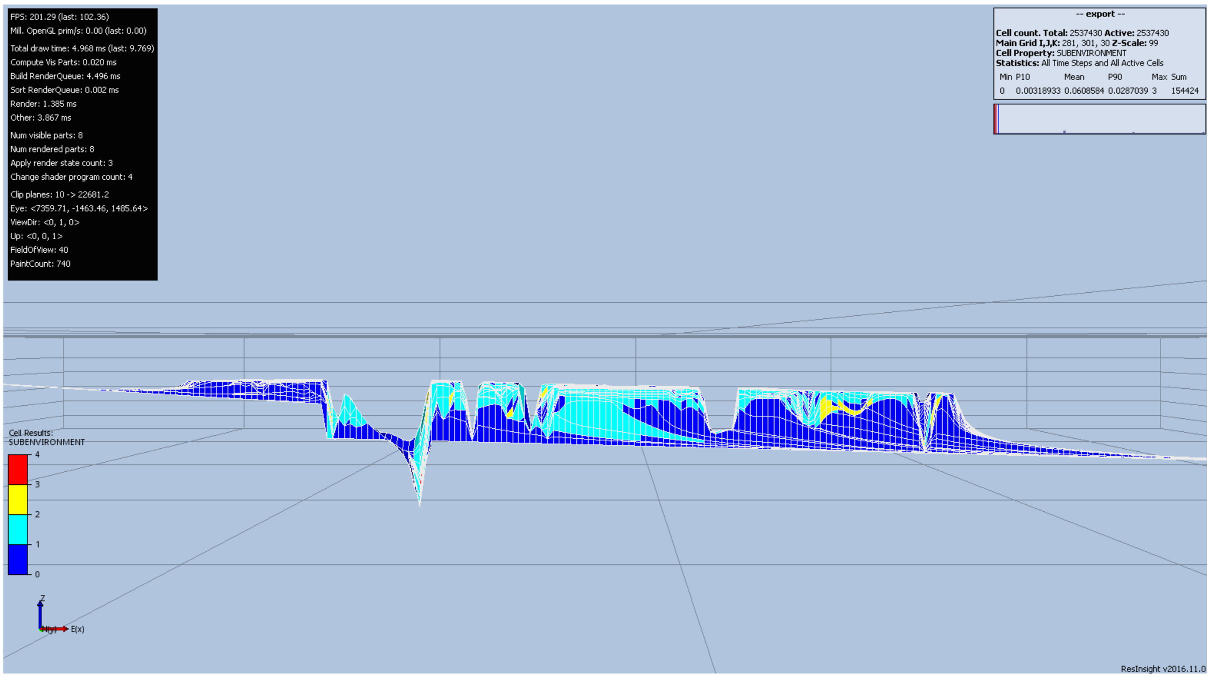


Figure 3.45 A cross-section view of sub environments in ResInsight. The colorbar: 0:background, 1:Delta top, 2: Delta front, 3: Prodelta.

4 Tutorial

In this chapter the user is guided though the practical application of the Delft3D-GT. The two tutorials focus on (A) the creation of runs/scenarios and the inspection of their progress and (B) the search for runs in the database, the inspection of their details, sharing and export.

4.1 Tutorial A: create, run and share Delft3D-GT simulations

This tutorial focuses on the creation of Delft3D-GT simulations to investigate the impact of different boundary conditions on the deltaic architecture. The scenario setup is aimed to investigate the impact of wave height on the delta stratigraphic architecture during base level fall. Following this tutorial the user will be able to create a scenario of three runs with different input parameters and follow their progress until simulations have finished. Consequently, the user will be able to share simulations in the database.

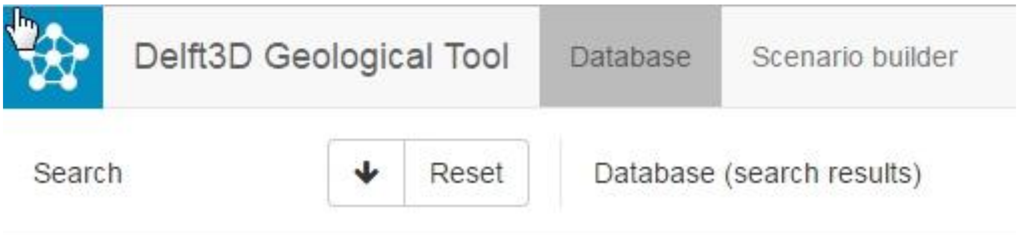


Figure 4.1 Upper part of the main page showing the icon to open the scenario builder

➢ Open the scenario builder by clicking on the scenario builder icon on the on the top of the main page (Figure 4.1)

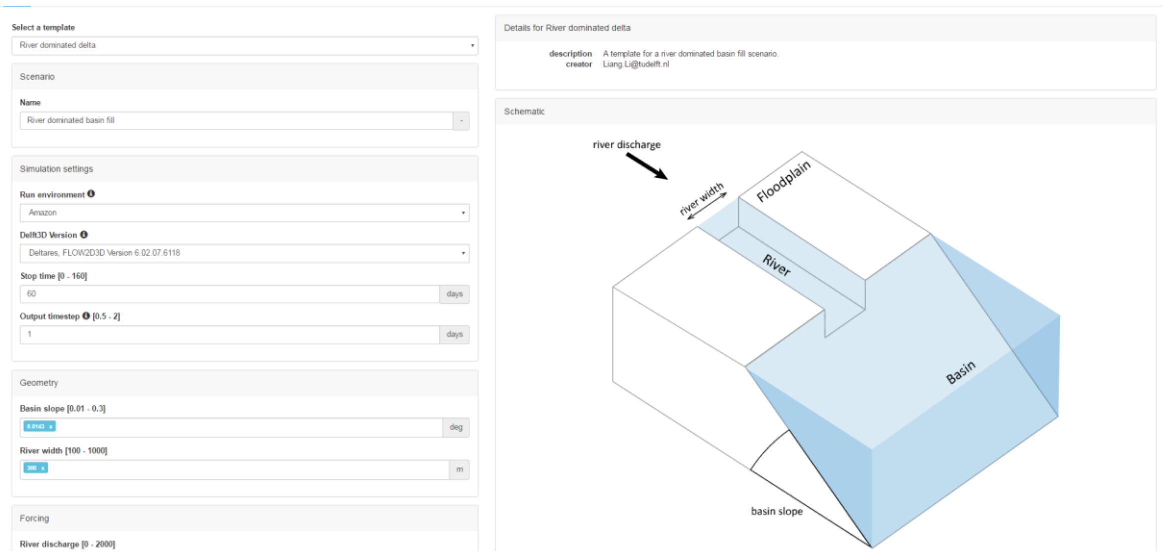


Figure 4.2 Overview of the scenario builder

The scenario builder page is open. The menu of input parameters for Delft3D scenarios is visualized on the left panel of the scenario builder (Figure 4.2). The right panel shows (a) the detail of the selected template (see templates) and (b) a schematic visualization of the initial morphology of the Delft3D realization and of the geometry and forcing parameters. When opening the scenario builder, a model template is already selected and default values are selected or specified for all simulation parameters. When multiple values are specified multiple runs will be created, within a single scenario, with the specified parameter values as input.

Figure 4.3 Templates and scenario name bars in the scenario builder

- In the template bar, click on the rectangle and select the ‘river dominated delta’ template (Figure 4.3).
- In the name bar, click on the rectangle and type in the name of the scenario ‘Tutorial geotool’ (Figure 4.3).
- In the simulation settings bar set the stop time to 30 days and the output time step to 1 day (Figure 4.4)

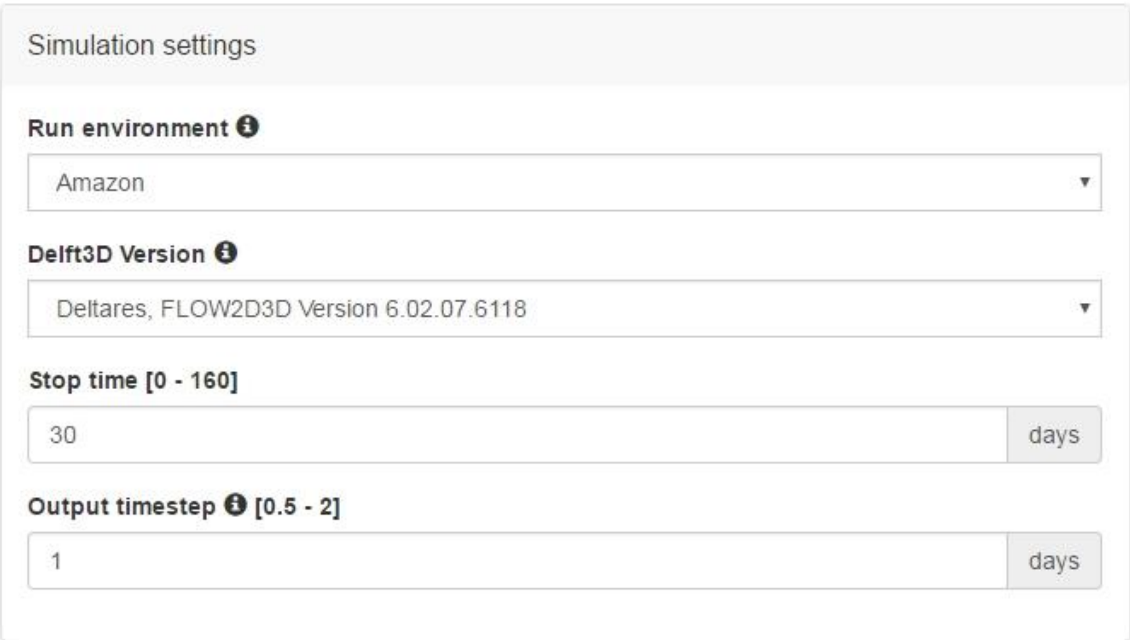


Figure 4.4 Simulation settings bar in the scenario builder

- In the geometry settings bar set the river width to 500 m and the basin slope to 0.02 degrees (Figure 4.5).

Figure 4.5 Geometry bar in the scenario builder

- ➢ In the forcing settings set the river discharge to 1000 m^3/s, tidal amplitude to 0.1 m, and base level change to -1 m. Type in three values for wave height: 0, 1 and 2 m (Figure 4.6).

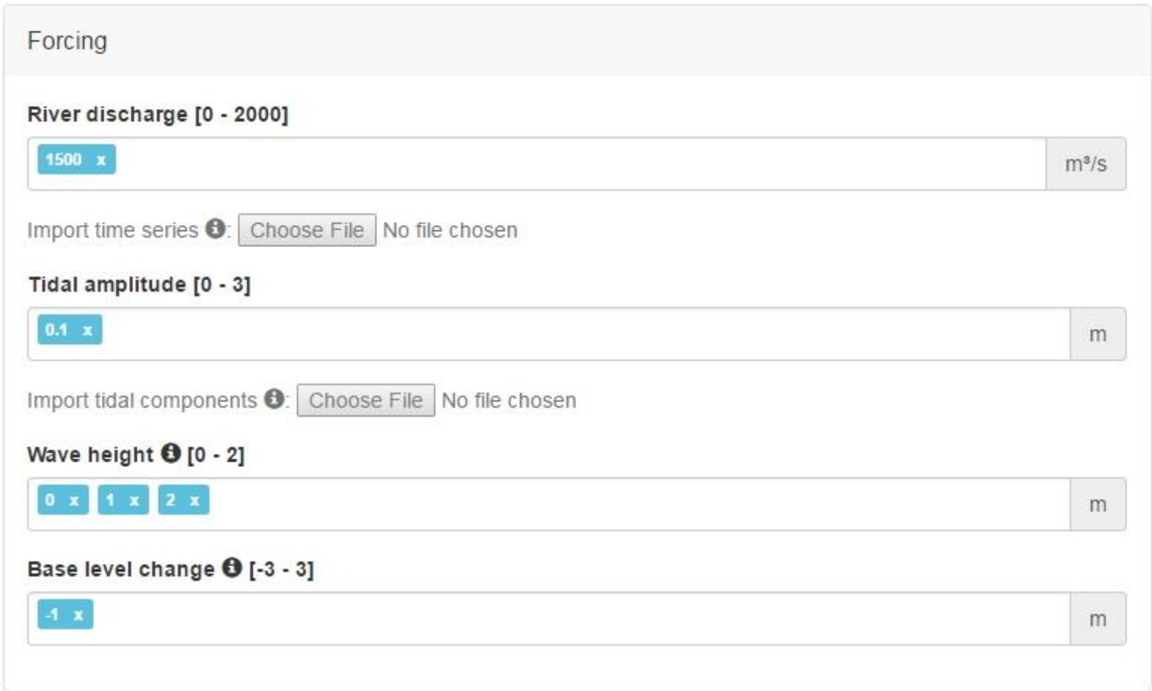


Figure 4.6 Forcing bar in the scenario builder

- ➢ In the sediment composition bar select the 'medium-sand' sediment class (Figure 4.7)
- ➢ Check that the number of runs in the scenario is three and then click on the icon 'submit' (Figure 4.7).

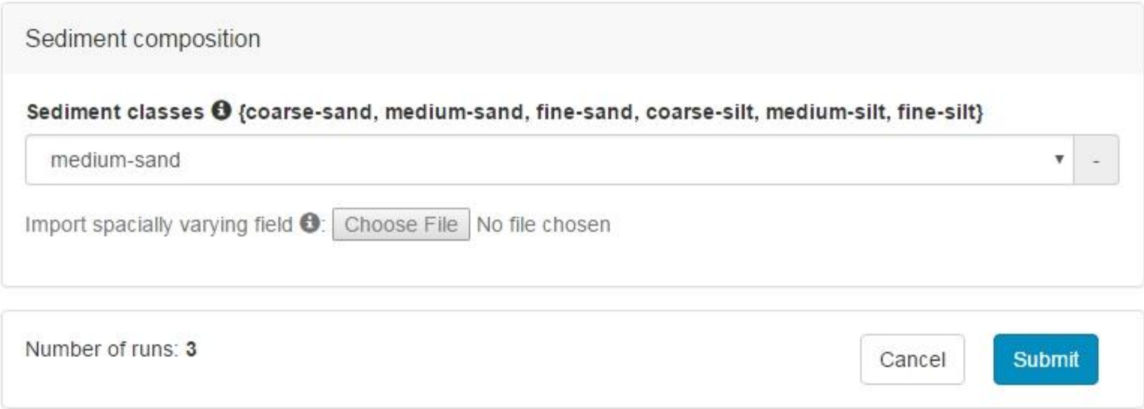


Figure 4.7 Sediment composition bar in the scenario builder

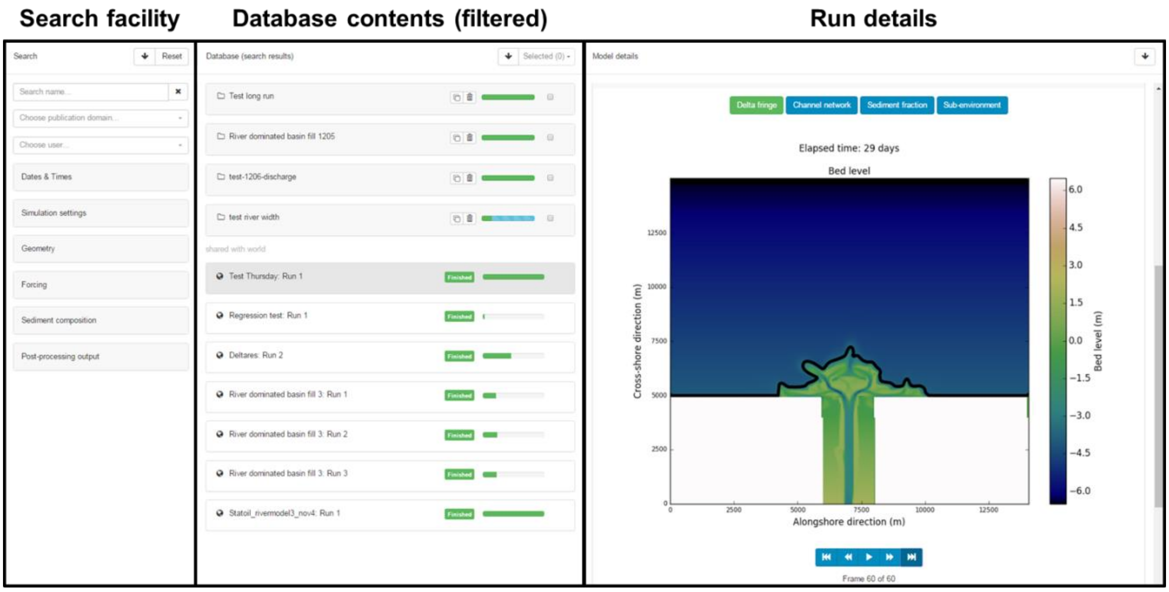


Figure 4.8 Overview of the Delft3D-GT database displaying the search facility, the (filtered) database contents and run details

After the scenario has been submitted, the user redirected to the main page of the Geotool Figure 4.8). Here the user can see three panels. The left panel (search) contains the filter to search for runs in the database. The central panel (database) displays the available runs and scenarios and their status. In the right panel (model details) the details of a single selected run are visualized. This panel also contains the simulation, sharing, and download controls.

➢ Scroll down the list of scenario in the database contents panel and look of the scenario that is created ‘Geotool tutorial’. As you click on the scenario bar the list of the three runs associated with your scenario appear (Figure 4.9).

Figure 4.9 Overview of the created runs within the Tutorial Geotool scenario in the database contents panel

The status of the runs you created is 'New' immediately after their creation. The status changes during pre-processing (see Table 3.1 for explanation). After a couple of minutes the status changes to 'Idle: waiting for user input' coloured in orange. At this point an action is required.

- ➢ Select all runs either by ticking the squares on the right side of each run bar or by ticking the square on the scenario bar (Figure 4.10). In the upper part of the database contents bar check that three runs are selected.
- ➢ Click on the icon 'Selected (3)'. A drop down menu appears with multiple options. Click on start models.

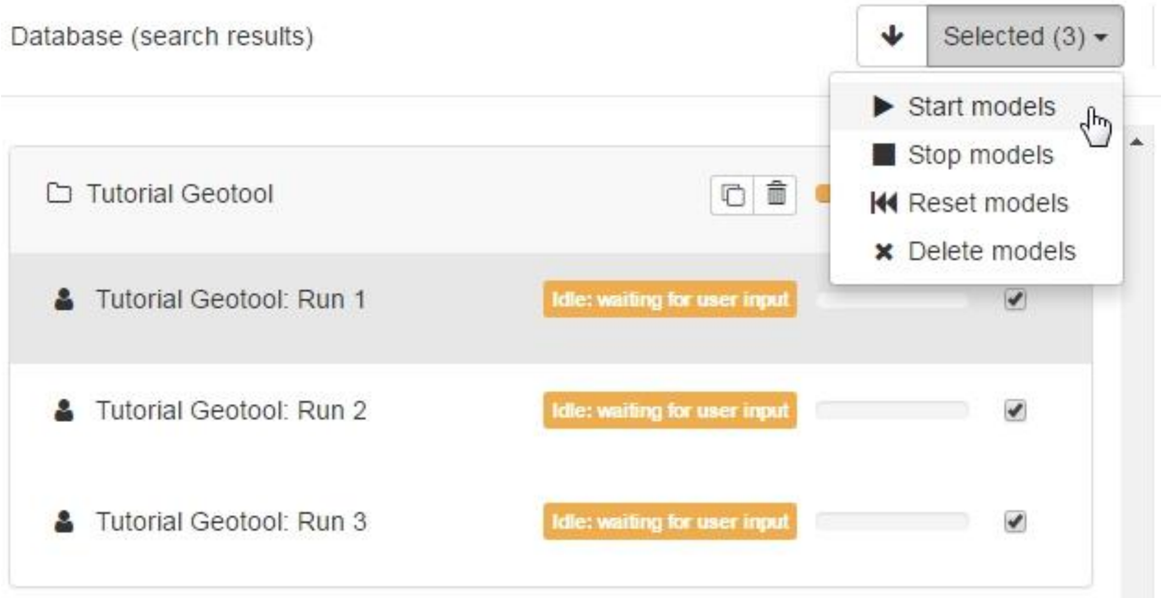


Figure 4.10 Overview of the created runs in the database contents panel. The status of the runs, shown in orange colour, indicates required action by the user. Four actions can be taken on the selected runs using the drop down menu at the top of the database contents panel

As soon as the models are started the status bar turns blue and the status follows a number of steps (see Table 3.1 for the explanation of the different statuses). The two most important statuses in this phase are 'Queued' and 'Running simulation'. If there is not enough computing capacity on the cloud computational facilities or on the server, then the run is queued. This means that the processing starts as soon as computing capacity is available. The status then changes to ‘Running simulation’. The progress of the simulation can be followed by checking the advance of the blue column in each run bar. The scenario bar is a combination of the statuses of the associated runs (Figure 4.11). After the run has finished its status turns green to ‘Finished’. In Figure 4.11 you can see that Run 1 and Run 2 have finished and Run 3 is still running.

- ➢ Select run 1 in the database content and inspect it in the right column (model details). Here you can see the details of the model, its progress, its status, and the link to access the input and output files ‘File server’ and ‘THREDDS server’ (Figure 4.12).

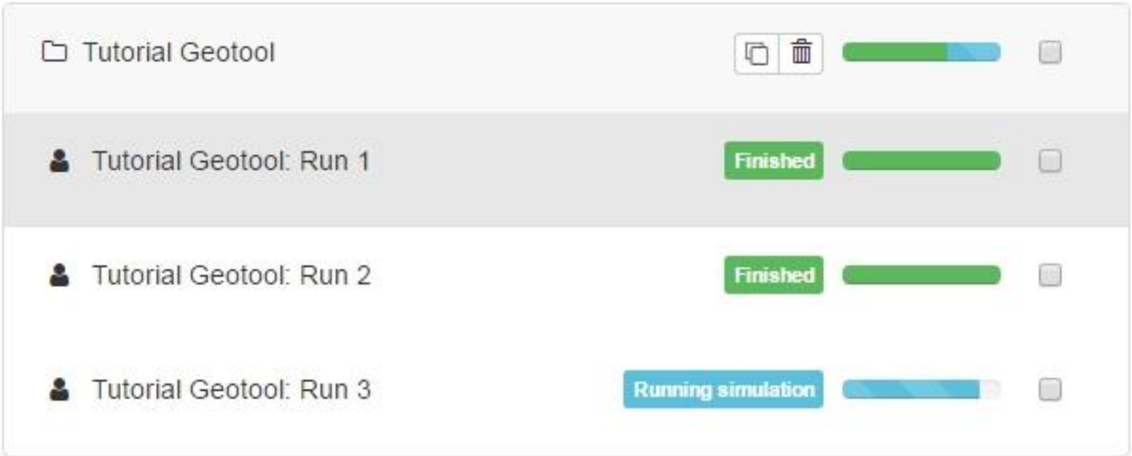


Figure 4.11 Overview of the finished ad running simulations in the database contents panel.

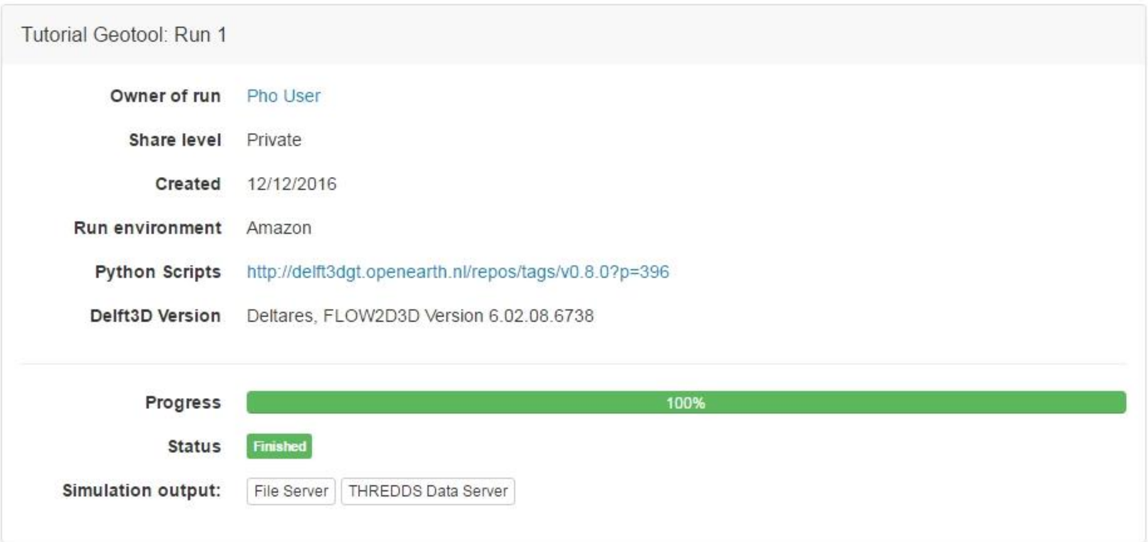


Figure 4.12 Simulation details of a selected run in the model details panel

- ➢ Inspect the ‘Generated images’ bar for Run 1. Figure 4.13 shows the water depth and the delta fringe for Run 1 in the last time frame.
- ➢ Scroll through the time frames using the commands below the image (back to first, backward, play, forward, forward to final) and inspect how the delta morphology changes.

- Click on the icons ‘Channel network’, ‘Sediment fraction’, and ‘Sub-environment’ to visualize the other generated images.
- Click again on the icon ‘Delta Fringe’, select the last time frame, and consequently select Run 2 in the database (central panel).
- Switch selection between Run 1 and Run 2 to compare the delta morphology without (Run 1) and with wave action (Run 2).
- Repeat the comparison for ‘Sediment fraction’ and ‘Sub-environment’.

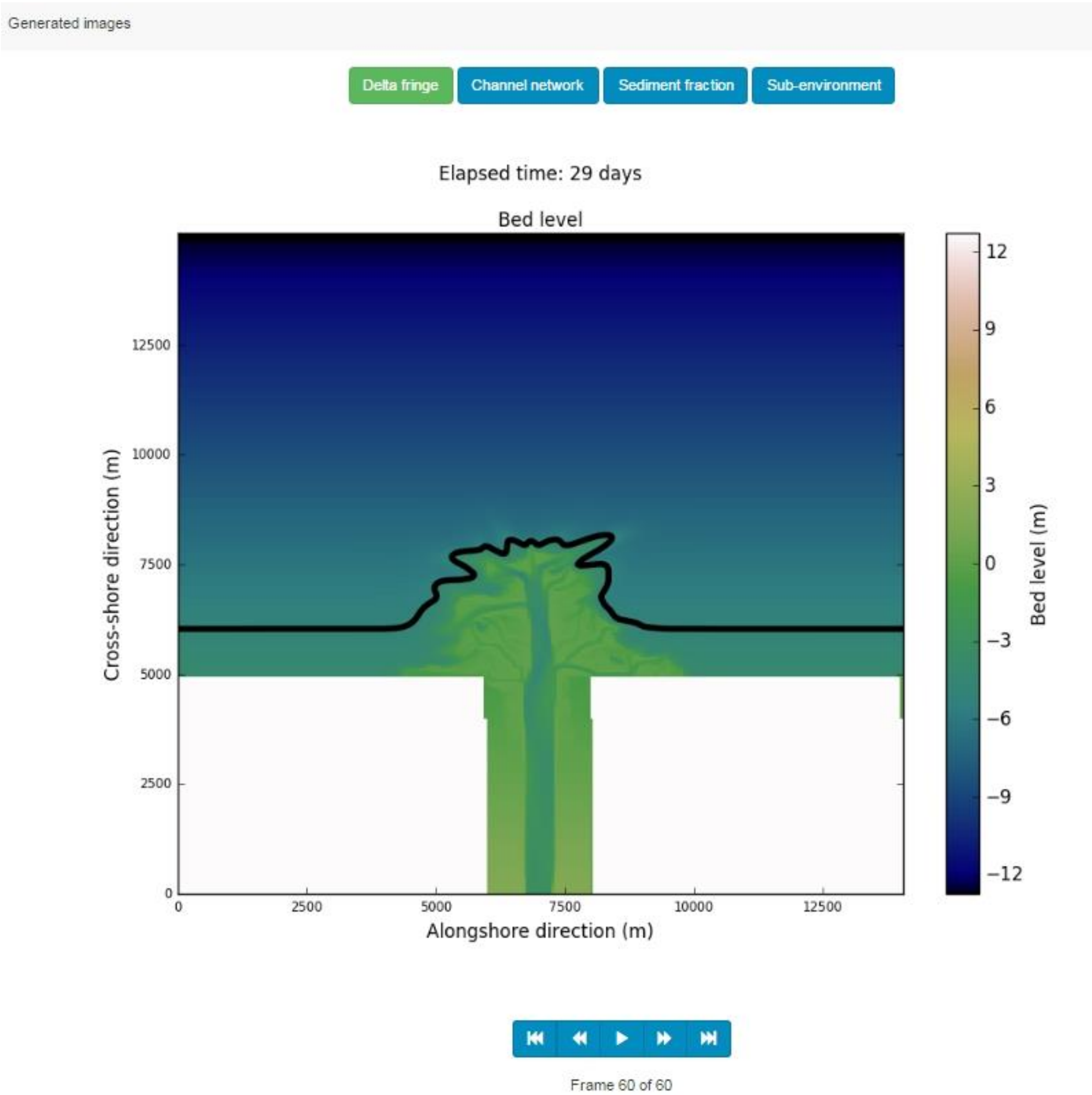


Figure 4.13 Delta fringe and water depth at tie frame 60 of a selected run in the generated images bar, in the model details panel.

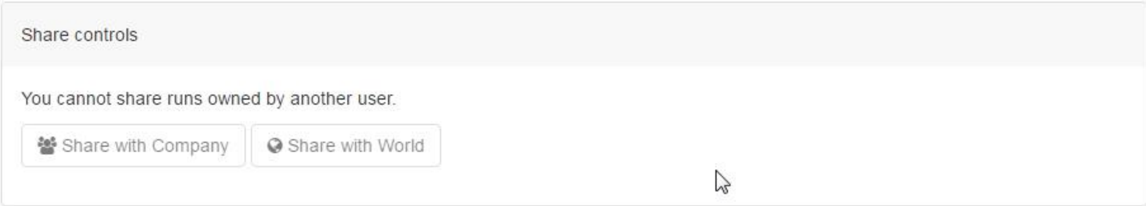


Figure 4.14 Share control bar in the model details panel with inactive icons 'share to company' and 'share with world'.

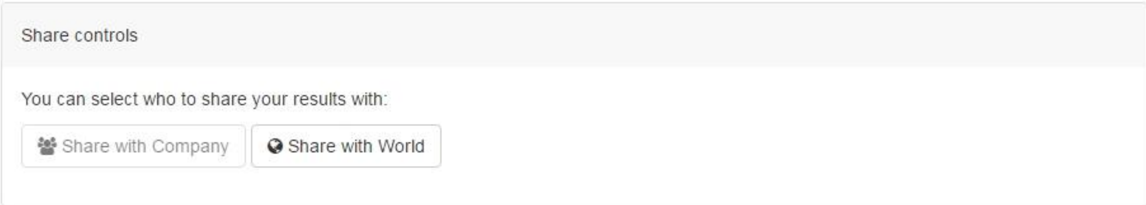


Figure 4.15 Share control bar in the model details panel with inactive icon 'share to company' and active icon 'share with world'.

After the simulations have finished, runs can be shared with other users in the database. In this example you want to share Run 2 with colleagues in your company in order to discuss and further analyse the results. You are happy with Run 1 and you want to share it with all Delft3D GeoTool users.

- ➢ Select Run 1 in the database and then open the Share controls in the right panel (Model details). Click on the icon 'Share with World'. After that both icons 'Share with Company' and 'Share with World' turn inactive.
- ➢ Select Run 2 in the database and then open the Share controls in the right panel (Model details). Click on the icon 'Share with Company'. After that both icon 'Share with Company' turns inactive. In a later stage you may still be able to share the run with all Delft3D-GT users.
- ➢ Inspect the database. You can see that two new bars have been created. Run 1 now appears in the section 'Shared with World', and Run 2 in the section 'Shared with Company'.

Now your colleagues are able to inspect and export Run 2 and all Delft3DGT users are able to inspect and export Run 1. The search, inspection, and exporting of runs in the database are dealt with in tutorial B.

4.2 Tutorial B: search, inspect, and export simulations in the database

This tutorial focuses on searching and exporting relevant scenarios from the database in order to further analyse the simulated data and use it for populating subsurface models. As an example, you will search and export simulations which can be used as numerical analogues for a specific kind of river delta, in this case sand-rich wave dominated deltas with a gentle slope. Following this tutorial you will be able to search for a set of scenarios in the database, inspect their details, and export them from the database.

Search in the database

- ➢ Examine the search facility on the left panel of the main page (Figure 4.16)
- ➢ Open the ‘Sharing level’ filter by clicking on it. Select ‘Company’ and ‘Public’ from the drop-down menu in order to search for runs shared by other users of the GeoTool (Figure 4.17)

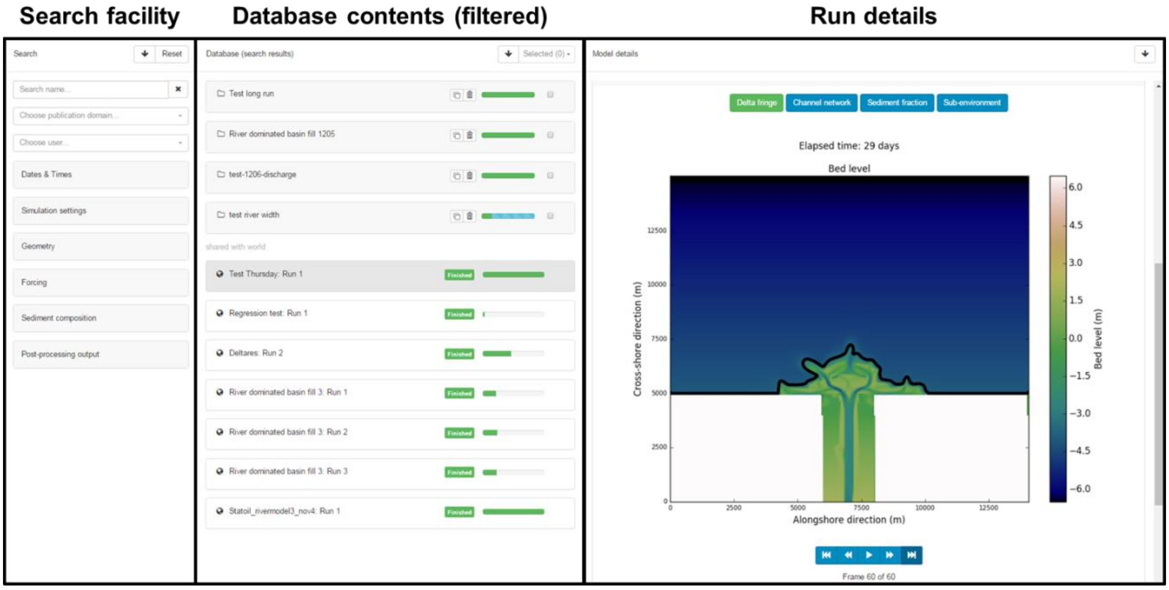


Figure 4.16 Overview of the Delft3D-GT database displaying the search facility, the (filtered) database contents and run details

Figure 4.17 Sharing level filter in the filter facility

- ➢ Click on the ‘Geometry’ filter. In order to select only the runs with a gentle basis slope you need to constrain the range of search by shifting the right white circle to the right until the desired maximum slope value (Figure 4.18).
- ➢ Click on the ‘Forcing’ filter. In order to select only the runs which are ‘wave-dominated deltas’ you need to constrain the input forcing parameters so to exclude runs with high tidal amplitude and low wave height. Shift the right white circle to the left in the

‘Tidal amplitude’ bar and shift the left white circle to the right in the ‘Wave height’ bar (Figure 4.18).

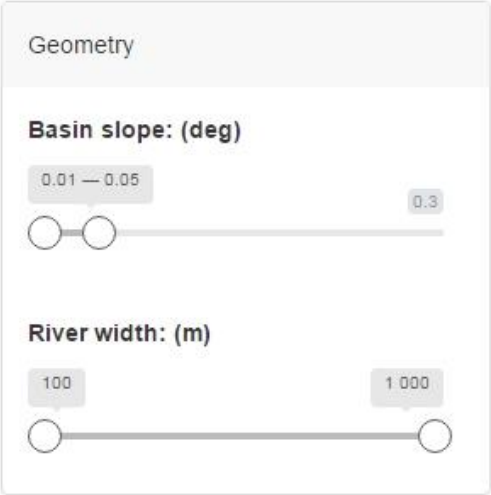


Figure 4.18 Geometry filter in the filter facility

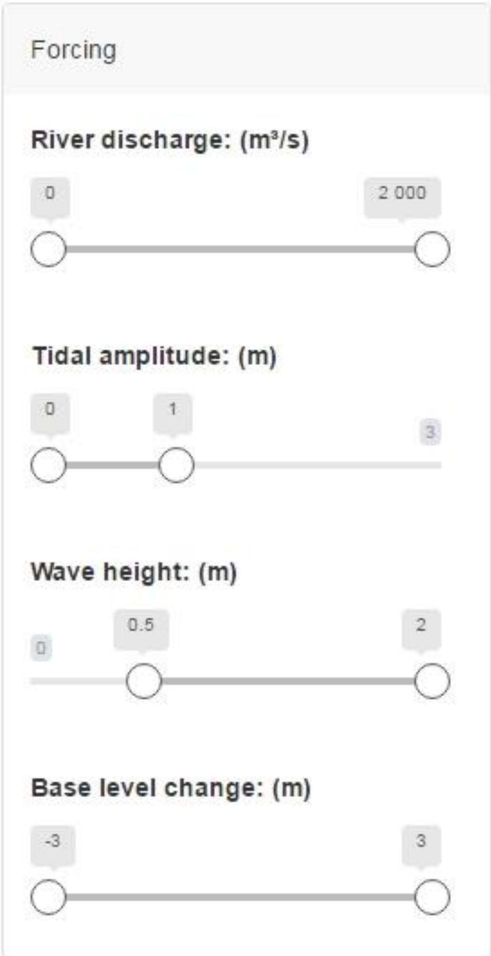


Figure 4.19 Forcing filter in the filter facility

- Finally, open the sediment composition filter and select only the sand sediment classes from the drop-down menu, in order to filter for only sand-rich river deltas (Figure 4.18)

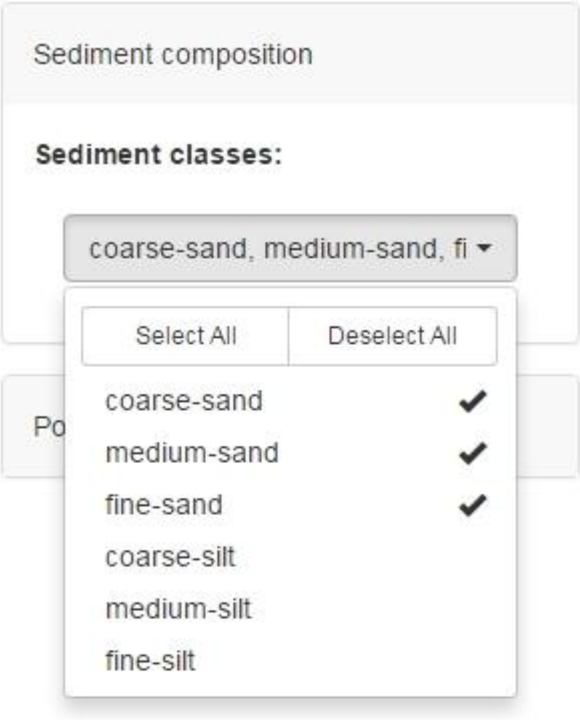


Figure 4.20 Sediment class filter in the filter facility

As you apply these filters, you will notice that in the central panel of the main page (database content) progressively fewer runs will be visible. Eventually, only the desired set of runs will be visible (Figure 4.21).

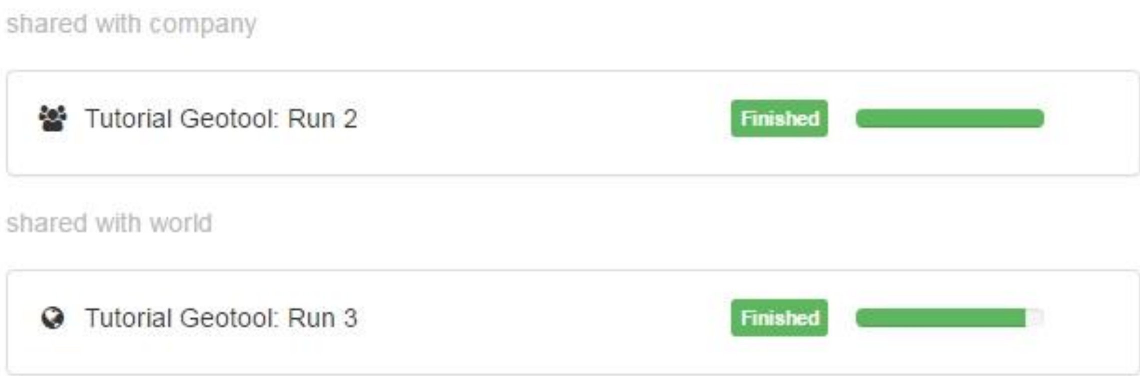


Figure 4.21 Available runs after filtering in the database contents panel

Inspect runs

- Look for two runs ' Tutorial Geotool: Run 2' and 'Tutorial Geotool: Run 3'. Run2 is shared with your company while Run3 is shared with the world. Select Run2 in the database contents panel.
- Examine the details of Run 2 in the right panel 'Model details' (Figure 4.21).
- Inspect the 'Generated images' bar for Run 2. Figure 4.23 shows the water depth and the delta fringe for Run 2 in the last time frame.
- Scroll through the time frames using the commands below the image (back to first, backward, play, forward, forward to final) and inspect how the delta morphology changes.
- Click on the icons 'Channel network', 'Sediment fraction', and 'Sub-environment' to visualize the other generated images.
- Click again on the icon 'Delta Fringe', select the last time frame, and consequently select Run 3 in the database (central panel).
- Switch selection between Run 3 and Run 2 to compare the delta morphology with different wave heights.
- Repeat the comparison for 'Sediment fraction' and 'Sub-environment'.

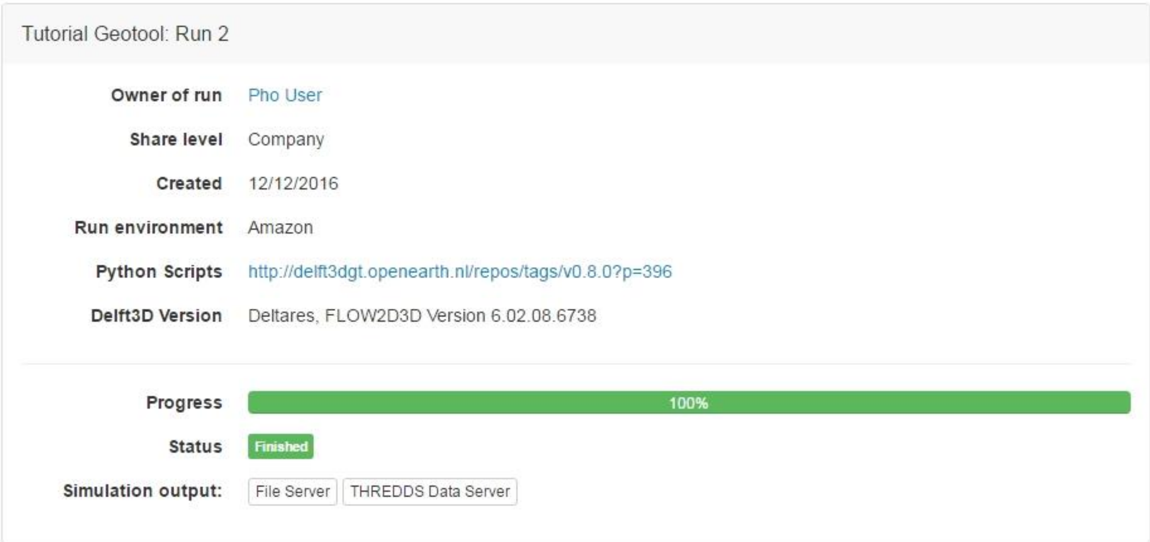


Figure 4.22 Run details in the model details panel

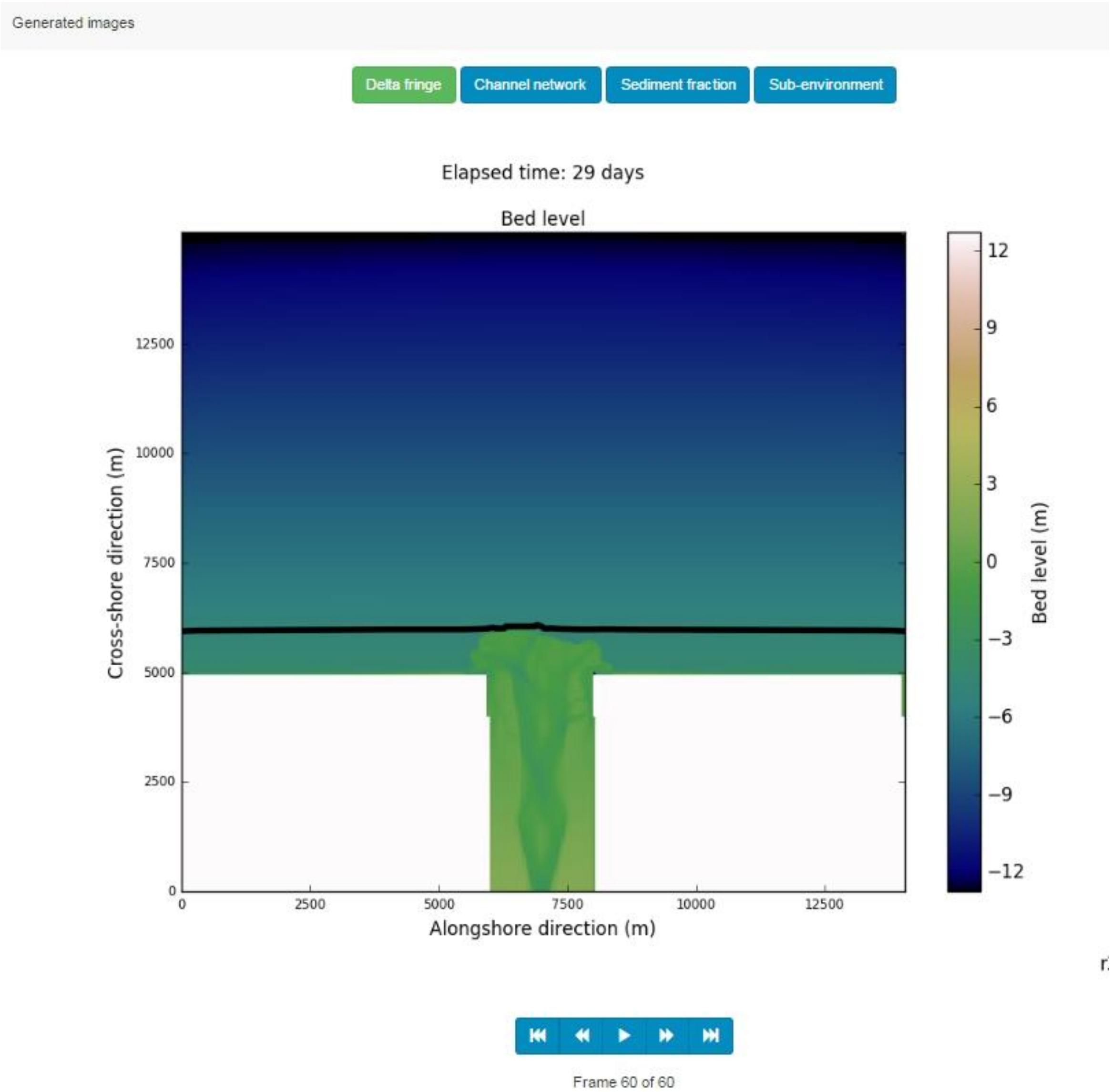


Figure 4.23 Delta fringe and water depth at time frame 60 in the generated images bar in the model details panel

Download data

You can also download the data of the runs for further analysis or population of a reservoir model. In this tutorial we will show you two ways: through the file server and though the download bar. A third option, the THREDDS server, is dealt with in Section 3.4.

- Select Run2 in the database contents.
- Open the Download files bar.

A menu with four options opens up: input files, generated output images, generated output movies, and export files for RMS/Petrel

- Tick on all four options and then click on the icon 'Download' (Figure 4.24) to download all the files.

Now all the files are stored on your computer and can be analysed and viewed. The export file for RMS/Petrel can be directly imported into RMS and Petrel.

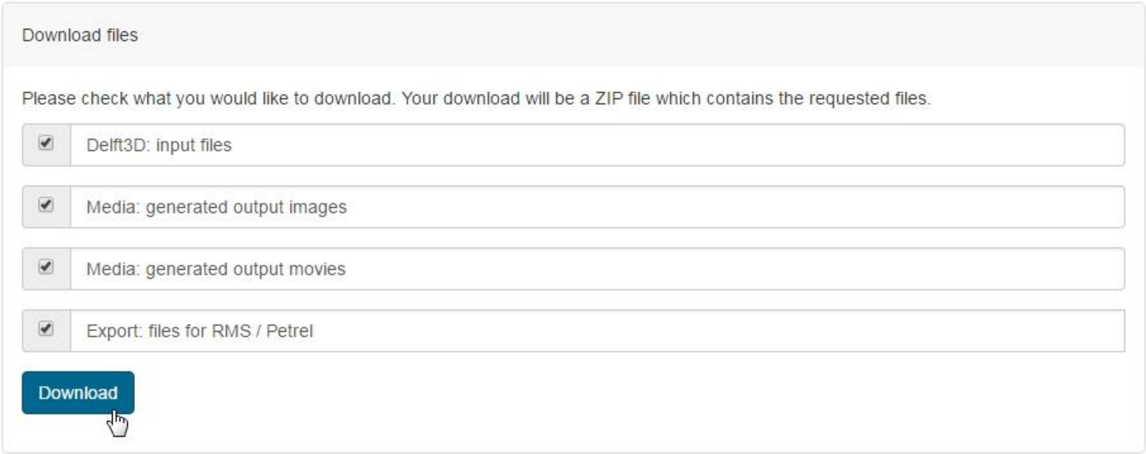


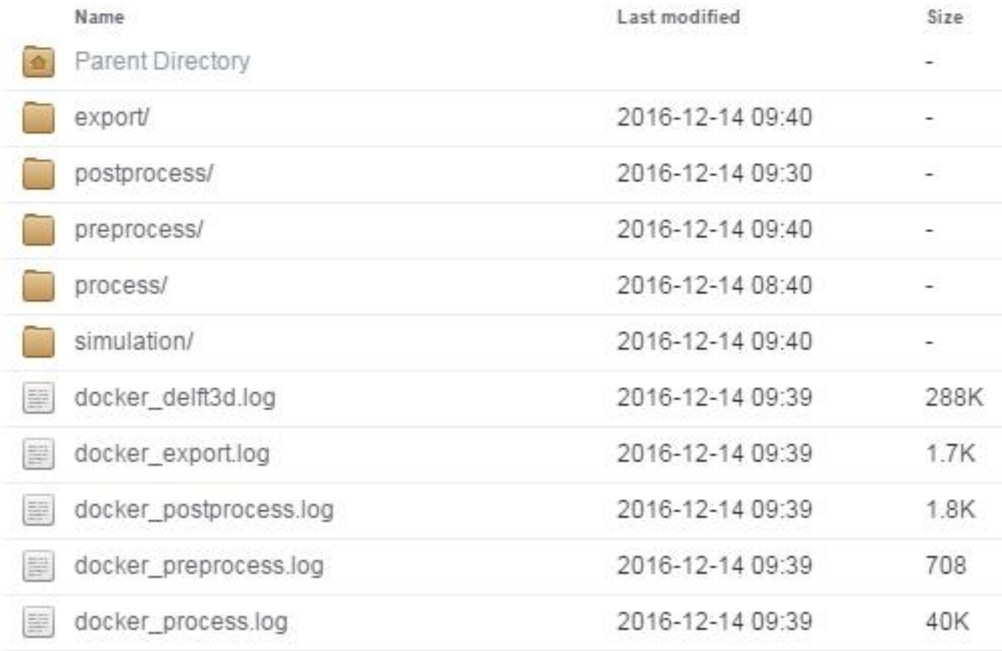
Figure 4.24 Download files bar in the model details panel

Alternatively to the export controls you can view and export data in the file server.

- Select Run2 in the database contents.
- Click on the icon' File server' in the 'model details' panel.

Here you can examine all the input and output files. These are grouped in folders (Figure 4.25).

- Open the 'Process' folder to inspect the generated images and movies. Click on one of the images to view it.
- Open the 'Postprocess' folder to inspect the generated post-processing images.
- Open the 'Simulation' folder to inspect the Delft3D input files.
- Look for the file 'trim-medium-sand.nc' and save this file on your computer. This is the Delft3D output files. Using the Delft3D visualizing tool QUICKPLOT you can directly visualize the output of the simulation. Alternatively, you can analyse and visualize the data using, for example, Python or Matlab.



Name	Last modified	Size
Parent Directory		-
export/	2016-12-14 09:40	-
postprocess/	2016-12-14 09:30	-
preprocess/	2016-12-14 09:40	-
process/	2016-12-14 08:40	-
simulation/	2016-12-14 09:40	-
docker_delft3d.log	2016-12-14 09:39	288K
docker_export.log	2016-12-14 09:39	1.7K
docker_postprocess.log	2016-12-14 09:39	1.8K
docker_preprocess.log	2016-12-14 09:39	708
docker_process.log	2016-12-14 09:39	40K

Figure 4.25 Overview of the file folders in the file server

5 Geological concepts in creation and analysis of simulations

5.1 Classification of deltas based on Delft3D-GT input

The present version of Delft3D-GT is aimed at the creation of river dominated deltas with sediment input profiles varying from the muddy “coarse silt” to the coarsest “coarse sand” sediment profile. The models however go beyond only the classical fluvial, tide, wave and grain size parameter variations (Orton and Reading 1993) and also allow the user to vary other parameters such as basin slope and base level change.

The suggested ranges of input parameters allow the user flexibility to create a wide variety of delta realisations, while still providing stable simulations. To provide a balance between flexibility and stability, we cannot guarantee that every combination of input parameters will be stable. E.g. a large discharge needed to mobilise coarse grained sediment may be too large to create a stable model for a fine grained sediment profile. Conversely, a small discharge which simulates a stable fine grained delta may not have enough energy to mobilise sediment in a coarser grained sediment profile.

To assist users, we have pre-populated the system with delta models which cover a large proportion of the input parameter space (see Figure 5.1 and Table 5.1). This provides users with a base from which to build up their own scenarios and investigate the wide range of delta simulations possible in Delft3D.

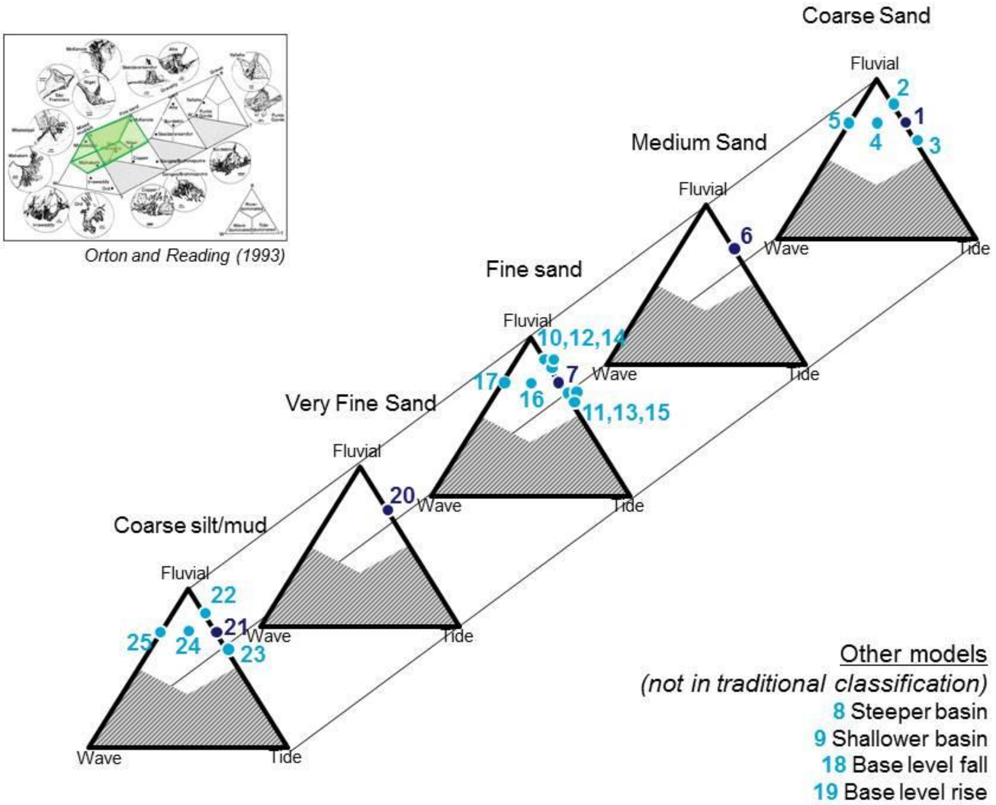


Figure 5.1 The location of the pre-populated models on a Orton and Reading (1993) style classification triangle. The model settings corresponding to the model numbers can be found in Table 5.1.

Table 5.1 Detailed parameter settings of the pre-populated models in Delft3D-GT. The colour-scale ranging from light-yellow to dark-brown indicates the sediment composition ranging from coarse to fine. The blue colours indicate the parameters that are systematically varied.

Nr	model name	sediment profile	basin slope (degrees)	channel width (m)	river discharge (m^3/s)	tide (m)	waves (m)	base level change (%)
1	CoarseSand_Default	coarse sand	0.1	500	1500	1	0	0
2	CoarseSand_LargerFlow	coarse sand	0.1	500	2000	1	0	0
3	CoarseSand_Smallerflow	coarse sand	0.1	500	1000	1	0	0
4	CoarseSand_MedWaves	coarse sand	0.1	500	1500	1	1	0
5	CoarseSand_LargeWaves	coarse sand	0.1	500	1500	1	2	0
6	MediumSand_Default	medium sand	0.1	500	1250	1	0	0
7	FineSand_Default	fine sand	0.1	500	1000	1	0	0
8	FineSand_SteepBasin	fine sand	0.3	500	1000	1	0	0
9	FineSand_ShallowBasin	fine sand	0.01	500	1000	1	0	0
10	FineSand_SmallerRiver	fine sand	0.1	100	1000	1	0	0
11	FineSand_LargerRiver	fine sand	0.1	1000	1000	1	0	0
12	FineSand_LargerFlow	fine sand	0.1	500	1500	1	0	0
13	FineSand_SmallerFlow	fine sand	0.1	500	500	1	0	0
14	FineSand_SmallerTide	fine sand	0.1	500	1000	0.5	0	0
15	FineSand_LargerTide	fine sand	0.1	500	1000	3	0	0
16	FineSand_MedWaves	fine sand	0.1	500	1000	1	1	0
17	FineSand_LargeWaves	fine sand	0.1	500	1000	1	2	0
18	FineSand_BaseFall	fine sand	0.1	500	1000	1	0	-5
19	FineSand_BaseRise	fine sand	0.1	500	1000	1	0	5
20	VeryFineSand_Default	very fine sand	0.1	500	750	1	0	0
21	CoarseSilt_Default	coarse silt	0.1	500	500	1	0	0
22	CoarseSilt_LargerFlow	coarse silt	0.1	500	1000	1	0	0
23	CoarseSilt_Smallerflow	coarse silt	0.1	500	100	1	0	0
24	CoarseSilt_MedWaves	coarse silt	0.1	500	500	1	1	0
25	CoarseSilt_LargeWaves	coarse silt	0.1	500	500	1	2	0

5.2 Interpretation during simulation

A delta is an evolving landform with morphology and stratigraphy changing over time. To account for the evolution of the depositional behaviour, analyses are performed per output time interval. Output files contain a record of the bathymetry and the hydrodynamic conditions prevailing at each output time interval. This provides insight into the morphology and stratigraphy as the delta evolves, as well as the processes controlling its evolution.

5.2.1 Channel network skeleton

The channel network skeleton constitutes a distributed sediment supply network across the delta top and delta front. In addition to acting as a sediment source, the active channels are also important erosive features responsible for reworking of sediment. The channel identification methodology is a generalised version of the method presented in van der Vegt et al. (2016). Thereafter a skeleton is extracted using the skimage processing library in python.

Delft3D-GT identifies the active channel network as locations with high sediment transport (bed load transport) values together with large flow velocity. We use a combination of maximum and minimum values to account for the influence of tidal and wave action on the hydrodynamics. These effects will amplify the maximum and minimum values distally, thus the maximum values best identify the channel network. Proximally, where tidal and wave processes have little or no impact on the hydrodynamics and the minimum values for flow velocity and sediment transport best identifies the channel network. Active channel network locations must have a water depth greater than 0.5m. Owing to the element size of 50m x 50m horizontally, a water depth of less than 0.5m would imply a width:depth ratio of more than 100. This value falls well outside of the definition of a channel, filtering out sheet flow at the current grid resolution (Gibling, 2006; Hajek and Wolinsky, 2012). The selection of critical cut-off values for sediment transport and flow velocity is based on visual inspection with different critical cut off values. Once the active channel network has been established, Delft3D-GT uses the skeletonize function from the skimage library to extract the channel skeleton.

The methodology is optimised for the best automated identification of channel network across the wide range of delta models possible in Delft3D-GT. Therefore, the active channel network will sometimes be over- or under-predicted. This is especially true for the finer grained models where the active channel network is significantly under-predicted (especially the distal part of the network) and coarse grained models where it over-predicts the network (sometimes including delta front or levee deposits too). In future versions the improvement of automated channel identification should be further explored.

5.2.2 Delta fringe

The delta fringe gives an approximation of the seaward limit of the delta plain, based on a contour line extracted from a water depth criterion. The landward limit of the delta plain is simply defined as the initial river mouth. While the active channel network of the delta will typically form part of the delta plain, channel topography which is deeper than this water depth cut-off value can interfere with the fringe identification. To remove the effect of channels the water depth of the active channel pixels is set to zero. A marching squares algorithm is applied to find constant valued contours in the water depth map. The solid black line (Figure 5.2) gives an example of the extracted seaward limit of the delta plain fringe.

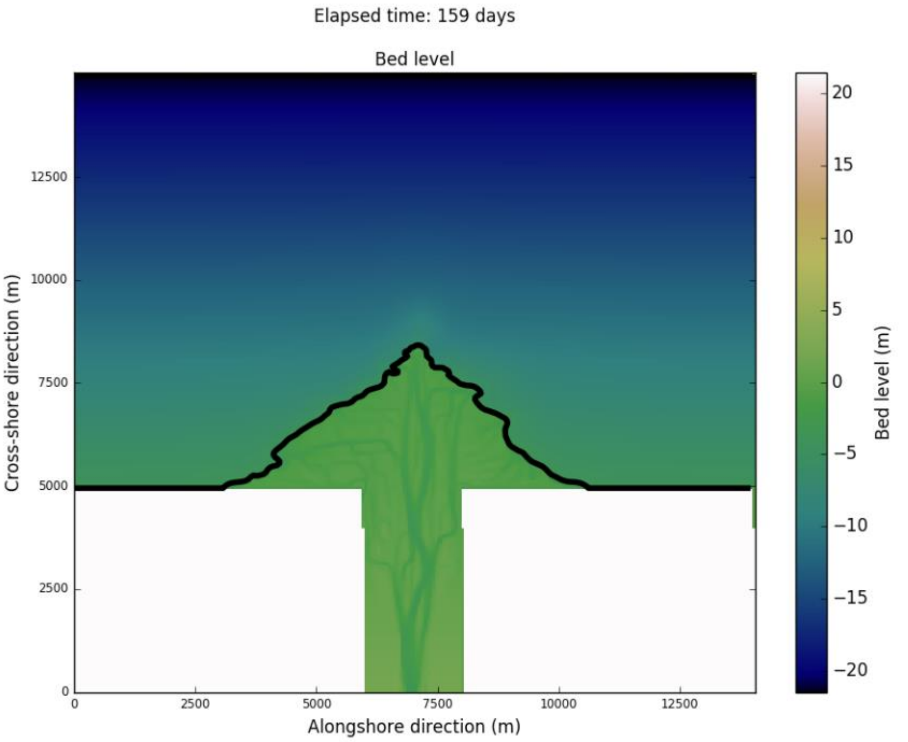


Figure 5.2 Identification of the seaward limit of the delta fringe based on a water depth criterion

5.2.3 Sediment fraction in cross-section

Each of the five sediment profiles which can be selected contains a bimodal distribution of 5 sediment classes (See Figure 5.1 and Table 5.1). A fine sand sediment profiles will supply sediment classes from medium sand down to coarse silt through fluvial input. Of these classes, the largest proportion of sediment will be from the fine sand class.

To allow the user to see how the delta develops during a simulation, we plot a cross-section through the delta, showing the proportion of the most prolific sediment class supplied to the basin. The class plotted matches the name of the sediment profile selected as input parameter. In the case of a fine sand delta, the cross-section will show the proportion of fine sand deposited at each element visualised in the cross-section (Figure 5.3). The remainder of each element is made up of a combination of coarser and finer sediment classes.

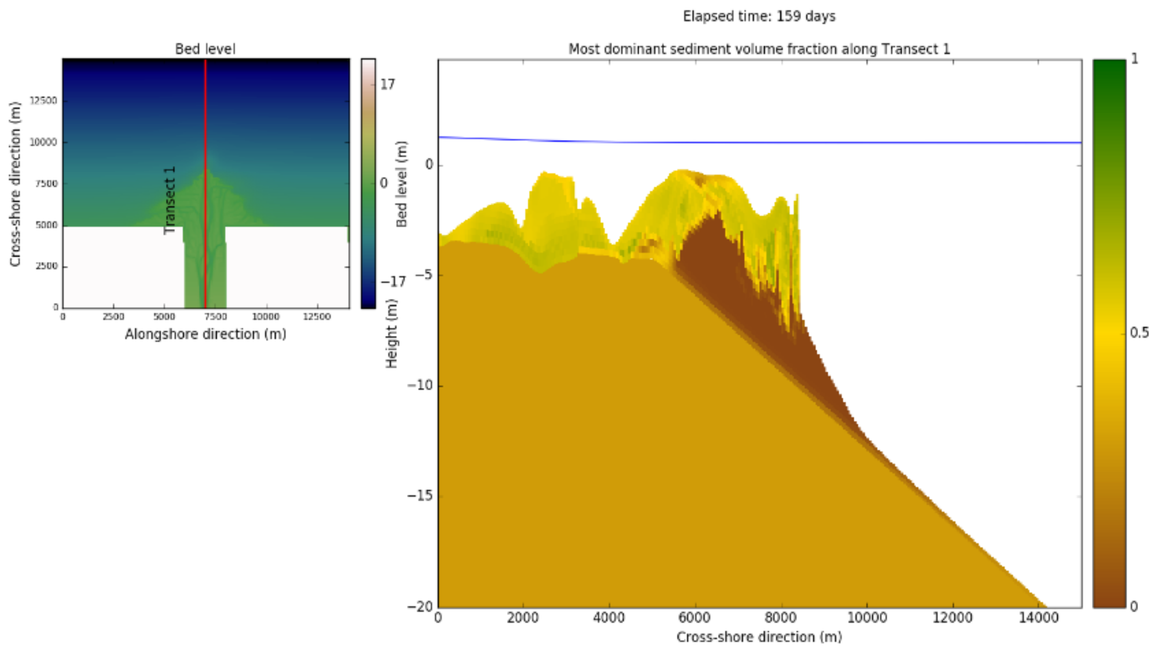


Figure 5.3 Cross section of sediment volume fraction for fine sand default model run.

5.3 Interpretation at the end of a simulation

5.3.1 Sub-environments classification

The deposited sediment is divided into three sub-environments namely delta top, delta front and prodelta. Deposition which does not fall within this classification is classified as “Low activity”.

Delta top

Delft3D simulates the transport of sediment by means of hydrodynamic processes. Therefore, the presence of water is a prerequisite for the transport and deposition of sediment. Since the fluvial input defined in the Delft3D-GT river dominated delta template is constant, the delta top is typically subaqueous, but with very shallow water depth. The boundary between delta top and delta front is defined as the brink point (see Figure 5.4). The brink point depth is obtained by radial averaging the bed level (for a detailed description see van der Vegt et. al. 2016).

Any deposition above the brink point is defined as delta top. In addition the active channel network and sediment later filling previously active channels are also included in the delta top.

Delta front

After the delta top deposits are defined, any remaining deposition which occurs lower than the brink point in water depths shallower than 10m and which contains at least 1% sand is defined as delta front deposits.

Pro delta

The remaining deposition deeper than 5m is defined as pro delta.

Low activity

The initial layer of sediment is defined as “low activity” if that location has never experienced more the 1.5 mm of bed level change throughout the simulation. Also any sediment which does not fit into the above classes is defined as “low activity”.

A number of limitations have been identified in this analysis method which can be addressed in future versions:

- A gap can form between the delta front and prodelta. This happens when the deposit is not sandy enough to be included as delta front and not deep enough to be classified as prodelta.
- The delta top can “contract” or “expand” between output time intervals. This happens when there are big changes in the delta brink point between output time intervals and can be related to large scale channel avulsion (for more information on this see van der Vegt et. al. 2016). It can be regarded as an artefact of the automated nature of these analyses.
- The delta front can appear within the delta top. This happens where small channel features which were not recognised as channels by the automated script are deeper than the brink point and therefore deposits in these features are classified as delta front. This is especially common in finer grained models where the channel network is often underestimated.
- The addition of waves creates a fragmented prodelta which shows elements of an interference pattern. This anomaly should be further investigated in future versions.

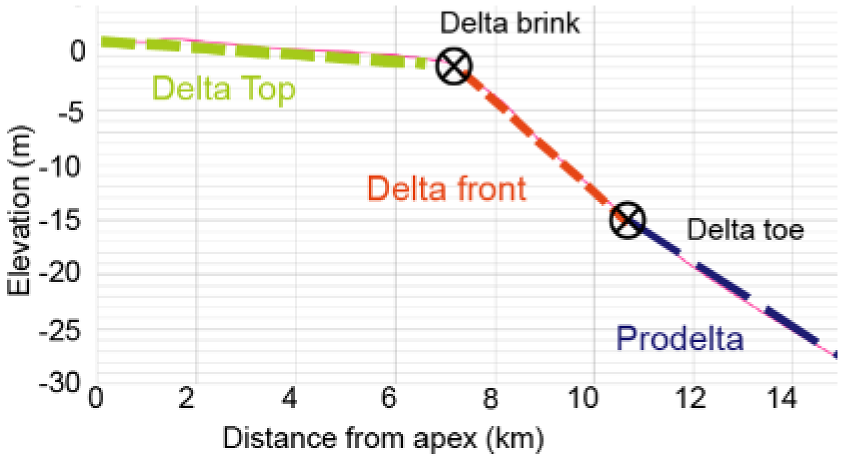


Figure 5.4 Definition of sub-environments

5.3.2 Sediment properties of sub-environments

Grain size distribution is widely used in classifying sediments and also is an important reservoir characteristic. We calculate 3 sediment properties: sand fraction, grain size percentile and sorting.

Sand fraction

The sand fraction is determined by taking the total volume fraction of the sediment classes defined as “sand” (grain sizes larger than silt). The volume fraction of each sediment fraction is direct output from Delft3D.

Grain size percentile

The volume fractions of the different grain size classes are used to transform to a continuous grain size distribution by using a so-called numerical sieve analysis. Figure 5.5 shows an example of how the sieve curve is derived from volume fraction data. First, a series of numerical sieve sizes is being prepared. The sieve size is equal to the boundary value for each aggregated size term based on the Udden-Wentworth scale. Since the grain size larger than pebble is not of our interests here, the maximum sieve size is set to be φ = -1. Overall, 10 sieves ranging from φ = -1 to 8 are established. The volume fraction data for a specific grain size is treated as the percentage retained sediments for the sieve which has the closest sieve size to the grain size. For example, a fraction data of 20% for grain size of 150μm is equivalent to retain percentage of 20% for the sieve of φ = -1. The cumulative percentage retained sediments is equal to the sum of the retained percentage in the previous sieves. The sieve curve is generated by simply assuming a linear relationship between sieve sizes. The curve is then used to calculate grain size percentiles (D_{50}, D_{84}, and etc.).

Sorting

The sorting parameter is derived based on Folk (1957), using the inclusive graphic standard deviation from the sieving curve.

The three sediment parameters described above are calculated for the sediment deposited in each horizontal element per time interval. Thereafter the mean of these values are obtained for each sub-environment. Note that these mean values are currently not accounting for the thickness of the deposit layers. Hence, when the initial layer is 50m thick with certain D_{50} and the deposit layer on top of that is only 1m thick with a different D_{50}, simply the mean of both D_{50}'s is taken irrespective the thickness of the layers. This analysis may give the user and initial idea of the grain sizes at each sub-environment, but the analyses are still a work in progress. More detailed grain size analyses will be included in future versions.

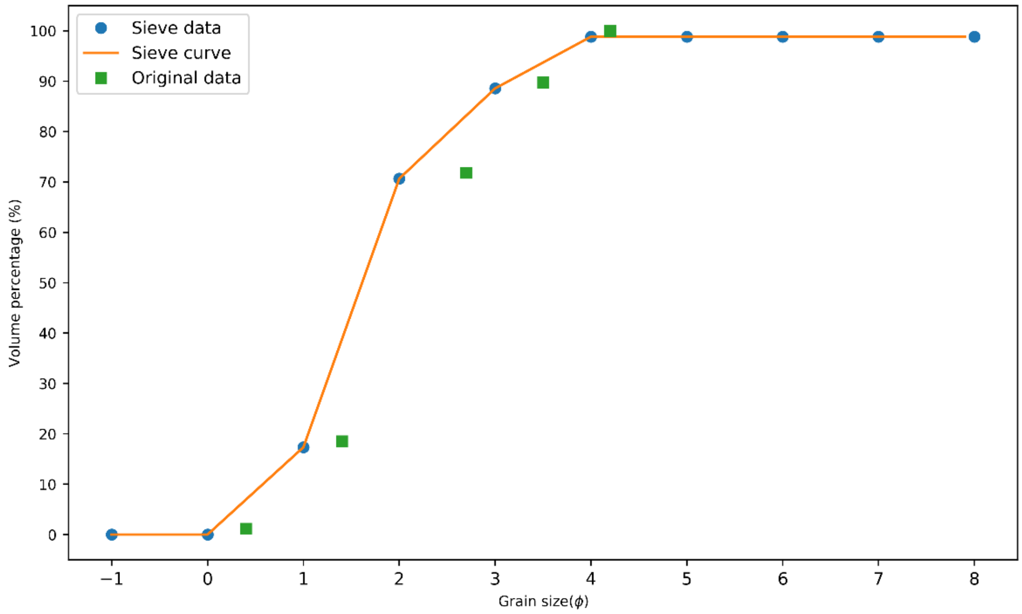


*Figure 5.5 An example of numerical sieve analysis to calculate sediment distribution from sediment volume fraction data. The grain size on x-axis is φ scale according to **(Wentworth, 1922)**. The original volume fraction data in cumulative percentage is: V(0.4) = 1%, V(1.4) =18%, V(2.7) = 72%, V(3.5) = 90%, V(4.2) = 100%.*

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