MIKE 1D

What is included in MIKE 1D 2021?

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MIKE 1D
What is included in MIKE 1D 2020?

1 General Information

The purpose of this document is to outline the capabilities of the MIKE 1D engine and the changes compared to the older engines for MIKE URBAN/MOUSE and MIKE 11.

The document will also highlight some notes for using MIKE 1D for existing users of MIKE 11.

The MIKE 1D engine is used by MIKE 11, MIKE HYDRO and MIKE+.

1.1 Background

The MIKE 1D engine is the result of a re-engineering and merger process of the calculation capabilities of MIKE's collection system and river simulation packages (MIKE URBAN / MOUSE and MIKE 11) into one engine.

The vision with the MIKE 1D engine is to bring the existing functionality of the two engines into one engine in order to optimise performance and to utilise functionality from both domains. The new engine is parallelised and hence it is able to utilise multiple cores when available during the simulation. MIKE 1D will also contain new functionality across domains along with the existing functionality. Various improvements have been done throughout the re- engineering, which means that results will have the same dynamic behaviour, but will not exactly match the results from the older engines. For the main differences please refer to Chapter 2.

1.2 Release 2021 of MIKE 1D

Release 2021 is the seventh release of the MIKE 1D engine. The basic modules are fully implemented.

Release 2021 of the MIKE 1D engine includes:
- Hydro-Dynamics (HD) module
  - River/Pipe network
  - Boundaries
  - Cross sections
  - Structures

- Advection-Dispersion/Transport (AD/TRAP) module

- Sediment Transport for MIKE HYDRO River and MIKE+ Collection System

- MIKE ECO Lab (EL) module

- Rainfall Runoff (RR) module
  - NAM / RDI, including Auto-calibration in MIKE 11/MIKE HYDRO
  - Urban A / Time-Area (A)
  - Urban B / Kinematic wave (B)
  - UHM
  - Linear reservoir (C1 / C2) in MIKE+
  - SWQ in MIKE+

- Control module
    - Control structures
    - Real Time Control

- Long Term Simulation (LTS)

- Pipe Design

- Data Assimilation (DA)

- Couplings to other engines e.g. coupling to 2D overland flow

- SDK for interacting with engine while running, i.e. user written controls, user written structures, result data processing and much more.

The following options in the above modules are not included:
- SMAP runoff model in MIKE 11

- FEH runoff model in MIKE 11

- Bridges in MIKE 11: "Bridge Piers (D'Aubuisson)" and "Submerged Bridge".

The following modules are not included in the Release 2021:
- Flood Forecasting (FF)

- Heat balance: this is replaced by the use of MIKE ECO Lab

- Quasi Steady State

The basic HD computational scheme is the same in MIKE 1D and MIKE URBAN / MOUSE / MIKE 11, but many special cases and minor improvement have been added to the MIKE 1D engine. Techniques from the MIKE URBAN / MOUSE engine have been used in MIKE 11 contexts when appropriate and vice versa. Because of this, some simulations will give almost equal results in MIKE 1D and MIKE URBAN / MOUSE / MIKE 11, while others will give slight deviations from previously.

The AD/Transport scheme in MIKE 1D has been improved dramatically. Results will differ in MIKE 1D and MIKE URBAN / MOUSE / MIKE 11. However, the overall behaviour is similar, solving the same equations.

The Sediment Transport (ST) module has been included in MIKE HYDRO and MIKE+. The modelling concepts from MIKE 11/MIKE URBAN has changed and been improved. It supports modelling of cohesive (mud) and non-cohesive (sand) sediments simultaneously. The transport modelling supports both suspended load and bed load, where suspended load modelling is utilizing the new AD scheme for the transport.

The MIKE URBAN MOUSE WQ Process model has been replaced with MIKE ECO Lab.

The MIKE 1D engine is fully scriptable. It comes with an API for modifying the setup and interacting with the simulation engine during runtime. This feature replaces User Written Controls for MOUSE and User defined structures in MIKE 11, and allows for much wider interaction with the engine. The functionality is available through plugins and scripts. For details, visit

http://docs.mikepoweredbydhi.com/engine_libraries/mike1d/mike1d_api/

2   Changes

This chapter outlines the more significant changes in the MIKE 1D engine compared to the MIKE URBAN / MOUSE and MIKE 11 engines.

2.1   HD – Hydro Dynamics

General changes:
- Adaptive time stepping algorithm has been redesigned, and allows time steps to vary smoothly between a maximum and a minimum time step.

Changes compared to MIKE 11:
- Differences in bed level at river junctions (branch connection points) are now allowed and handled properly. A free outflow condition is applied on the "high" connecting river when the main river water level is below the free outflow condition.

- The Flood map functionality has been redesigned and improved. All markers are included in the process to provide better low flow bank maps. Memory consumption has been optimised.

- Lateral inflow in the form of global/distributed rain or distributed source is added at H grid points. For distributed inflows defined for a chainage interval, the exact chainage values are used to calculate the inflow, independent of the position of the grid points in the model.

Changes compared to MIKE URBAN / MOUSE:
- An improvement of the calculation of the Basin volume and geometry above ground level has been made.

- The Node extension (cover) functionality has been improved and unified such that manholes and basins are treated similarly.

- Improvement of transition between blocking and unblocking of water in a pipe with non-return valve.

- Improvements have been made for calculation of processed data for user defined cross sections.

- In natural channels, the resistance is now varied along the branch such that the manning number is interpolated at each grid point.

- The data type specified in dfs0-files is now used. If the data type is invalid, the engine will give an error. This is especially relevant for rainfall time series, with a rainfall depth item, usually in millimetre: The data type must be accumulated or step-accumulated; a data type of instantaneous will not be accepted.

- The soft start for boundary items is applied at the start of the validity interval.

- The initialization based on outlets flush-in will now not flush past a local maximum along a natural channel.

- When a pump operates outside the specified pump curve the curve is extended with the last value.

- The water level in an outlet node will now show the boundary conditions even if this is lower than the free outflow in the connecting pipe. The last water level grid point in

the pipe will still show the water level from a free outflow when this exceeds the given boundary condition. This has no effects on the results.

- With MIKE 1D, applying a valve regulation (only positive flow, or only negative flow) to culverts and weirs takes into account the branch's flow direction. For example, applying only a positive flow to a structure located on a branch with a negative 'Flow direction' will allow water to flow only in the direction of decreasing chainage values. This is the opposite of what the MIKE 11 Classic engine does. Therefore, before running a MIKE 11 simulation with MIKE 1D, it is necessary to change the flow direction for culverts and weirs, if any 'Valve' regulation is applied and if the branch is set to negative 'Flow direction'.

- The LTS module has been reengineered and improved. The job-list can be created directly from a RR run, and the RR and HD can be run in parallel. Identification of jobs have been improved, and output capabilities has also been improved.

2.2   AD – Advection-Dispersion / transport

General changes:
- The MIKE 1D AD/Transport module follows the grid point layout of the HD module: Alternating mass and transport grid points in the AD module matches the H and Q grid points of the HD module. Both MIKE 11 and MIKE URBAN/MOUSE has an AD "mass" grid point at both H and Q grid points from the HD module, and does interpolation and averaging to match between HD and AD calculations.

- The MIKE 1D AD/Transport scheme is for low Courant numbers using a tailored version of the accurate ULTIMATE-Quickest scheme, and for high Courant numbers using a less accurate but stable implicit up-winding method.
  - Basically oscillation free, i.e. no over- and under-shooting of values at sharp fronts.
  - Capable of handling all flow conditions.

Changes compared to MIKE URBAN / MOUSE:
- Additional volume introduced due to volume errors in the HD module is added in MIKE 1D with the concentration of the component, i.e. component concentrations are maintained, but component mass errors are introduced. MIKE URBAN/MOUSE adds additional volume with zero concentration, and thereby maintains the component mass, but not the component concentration.

2.3   ST – Sediment Transport

The ST module has been re-engineered and implemented from scratch. It is only supported from within MIKE HYDRO River and MIKE+.

General changes:

- The MIKE 1D ST module follows the grid point layout of the HD module: Alternating mass and transport grid points in the ST module matches the H and Q grid points of the HD module.

- The MIKE 1D ST for cohesive sediments uses a special version of the AD/Transport scheme that handles the deposition and erosion.

- The MIKE 1D ST for non-cohesive sediments is truly split up in bed load and suspended load calculations. MIKE 11 models non-cohesive suspended load using a bed-load calculation approach.

- Cohesive and non-cohesive sediments can be mixed, and also works together with AD components and MIKE ECO Lab.

- MIKE 1D ST supports three types of bed layer layout: Fully alluvial mode (0-layer), active layer only mode, and active and passive layer mode. With the active and passive layer mode, it is possible to model fine sediments being trapped by heavier coarse sediments.

2.4   MIKE URBAN WQ Process Model

The MIKE URBAN WQ Process Model has been replaced with MIKE ECO Lab support. A MIKE ECO Lab template implementing the MIKE URBAN WQ Process Model is included with the installation. Parameters from the MIKE URBAN WQ Process Model must be transferred to the MIKE ECO Lab parameters.

2.5   RR – Rainfall Runoff

General changes:
- The additional result file from a NAM / RDI simulation includes the same information, but the naming has changed.

Changes compared to MIKE 11:
- Calibration plot time series in MIKE 11 are stored at every time step of the rainfall runoff simulation and values of the observed data is interpolated to the simulation times. The time series in MIKE 1D are stored at the times of the observed time series, and values of the simulation is interpolated to the observed times.

Changes compared to MIKE URBAN / MOUSE:
- Catchments are now considered independently of each other and can run with independent time steps. This may give slightly different results in situations where a catchment in previous versions was forced to run with a wet time step due to conditions in another catchment.

- It is now possible to include catchments in the Rainfall Runoff simulation that are not attached to the network. This is done by setting the connection type to "None" in the catchment connection dialogue. The catchment will be included in the Rainfall Runoff calculation, but the resulting hydrograph is not included in the network calculation.

- When modelling snow in RDI simulations, the snow storage will now be activated when the temperature is lower or equal to 0.

- Initial conditions for the first reservoir for overland and interflow are changed to correspond to the initial conditions for the second reservoirs in RDI simulations.

- The evaporation is now dependent on the snow depth in RDI simulations. Evaporation is neglected as long as the snow depth is greater than 0. In MIKE URBAN / MOUSE the evaporation was neglected when the temperature was below 0.

- Different types of catchments can be combined in a single simulation.

- RR can be run in parallel with HD, i.e. where runoff and catchment discharge are automatically transferred from the RR module to the HD module during the simulation. This works for HD (water), AD (pollutants) and ST (sediments).

2.6   Structures

The structure module has been improved-engineered. The set of structures is the same, but many improvements and stabilisations have been implemented for each structure individually. The basic behaviour is the same compared with MIKE URBAN / MOUSE and MIKE 11, but the many changes in the code may give deviations in the results, which in special cases can be significantly different. Please refer to MIKE 1D Reference Manual for further details.

3 Discontinued Features

During the re-implementation of the existing functionality some features have been discontinued. This has for example been done for functionality no longer being used due to other features having superior functionality.

3.1 HD

Not supported features compared to MIKE 11:
- Morphological Model and Flood Plain Resistance (HD parameters)

- Bed resistance toolbox: This functionality can be accessed through scripting.

3.2 RR

Not supported features compared to MIKE 11:
- DRiFT runoff model.

- RR Parameters as MDB file.

3.3 Structures

Not supported features compared to MIKE 11:
- Regulating structure – use control structure instead.

- User defined structure – similar functionality is available by use of the MIKE 1D API in plugins or scripts.

3.4 Control

Not supported features compared to MIKE URBAN / MOUSE:
- User Written Control (UWC) – similar functionality is available by use of the MIKE 1D API in plugins or scripts.

- Manual overwrite of control through the MOUSE Simulation Launcher

3.5 Miscellaneous

Not supported features compared to MIKE 11:
- Encroachment

- Stratification

- Ice

4 Note for MIKE URBAN Users

MIKE URBAN is no longer available as from Release 2021 and urban network modelling now takes place in MIKE+. MIKE+ supports only the MIKE 1D engine for 1D networks modelling.

MIKE+ 2021 can however be installed along with MIKE URBAN 2020 Update 1 on the same computer. The procedure for converting a MIKE URBAN model setup to MIKE+ should therefore be the following:
1. Install MIKE+ 2021 and MIKE URBAN 2020 Update 1
2. Run the MIKE URBAN simulations using the MIKE 1D engine
3. Apply changes to the model setup as necessary in order to fix the reported errors, if any
4. Start MIKE+ and create a new project
5. Import the MIKE URBAN project into MIKE+, using the predefined import routines.

The following includes some tips for existing MIKE URBAN users to transfer to the MIKE 1D engine.

4.1 Running MIKE 1D Engine in MIKE URBAN

On the simulation dialogue for MOUSE you will see an option for choosing between MOUSE and MIKE 1D. Changing the radio button to MIKE 1D the MIKE 1D engine will be launched when you press "Start simulation".
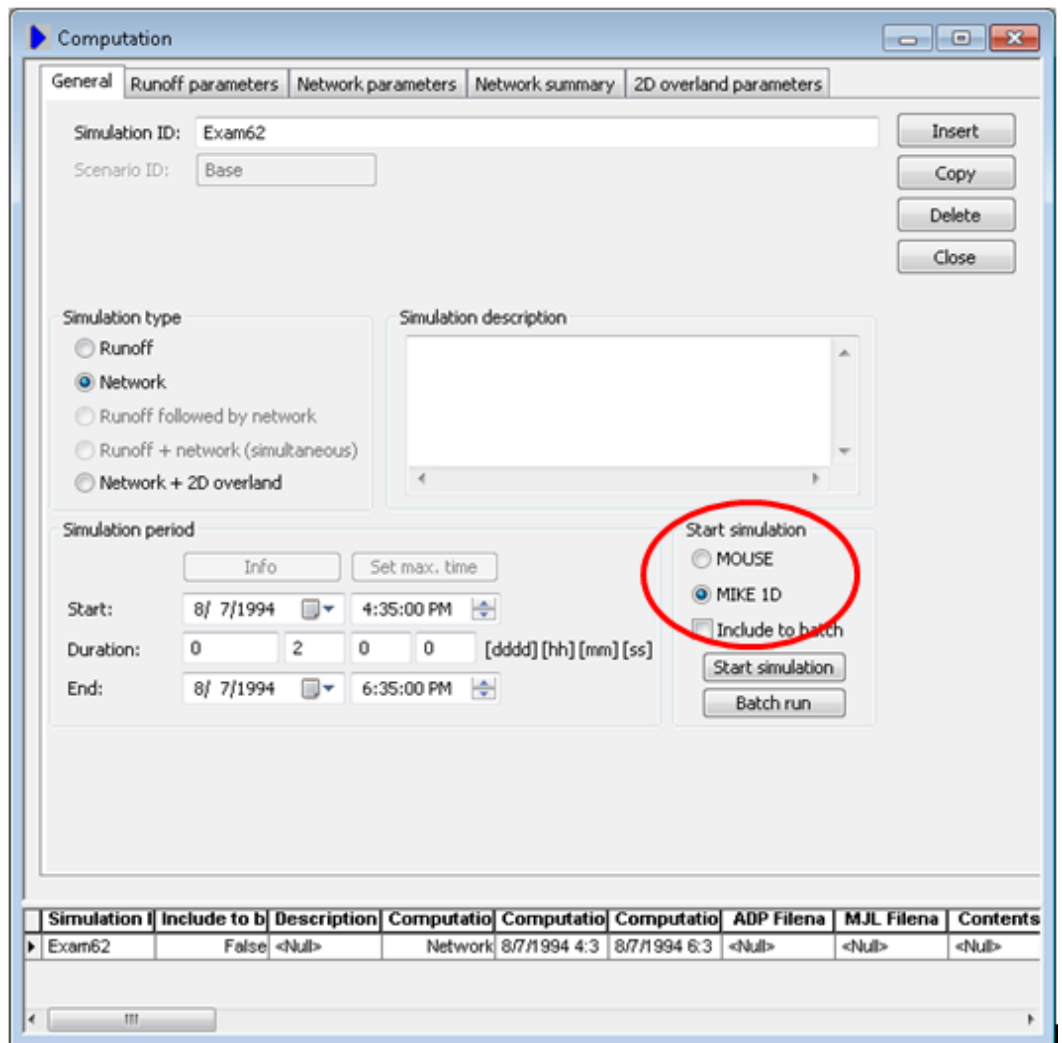
During the simulation a MIKE 1D Simulation Launcher is shown similar to the MOUSE Simulation Launcher. The MIKE 1D Simulation Launcher contains similar information, but looks slightly different (see figure below). The biggest difference is that the panel at the bottom of the launcher will show information, warnings and errors during the simulation. Warnings and errors are also written to a log-file.
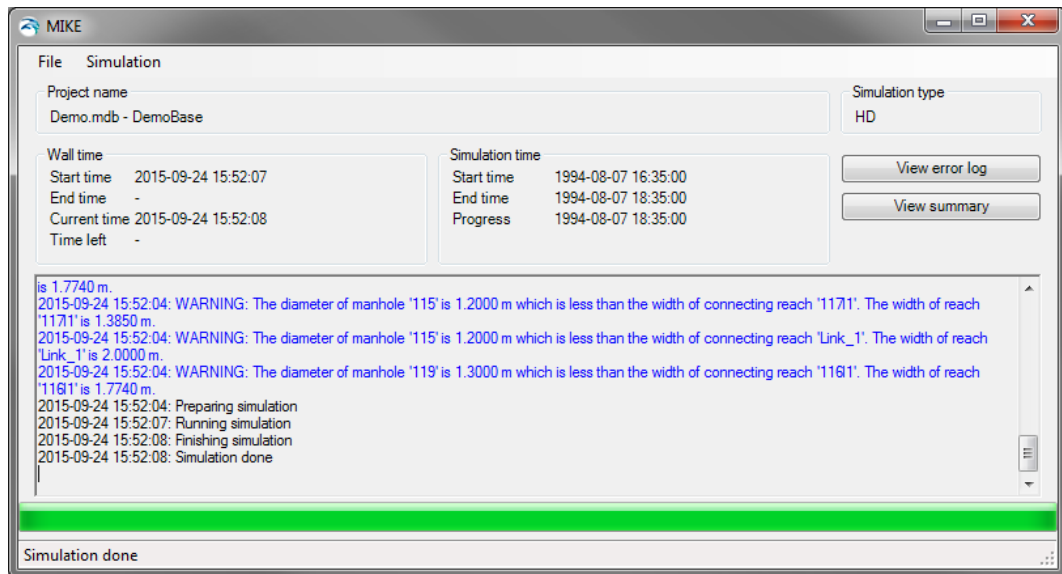
Under the menu "File | Load Simulation" or "File | Load Simulation from GDB folder" it is possible to load a database and rerun a simulation. If several simulation parameters exist in the selected database the latest run simulation will be re-run.

It should be noted that the simulation will run on the data *saved* in the database. This means that if the database is currently open in MIKE URBAN it will only reflect the current settings if you have exited edit mode or manually saved your data.

The MIKE 1D engine will use data directly from the MIKE URBAN database hence no MEX-file will be created during a MIKE 1D simulation.

4.2 MIKE 1D Result files and Results

If a warning or error occurs during initialisation or simulation, a log-file is created next to the project similar to the MOUSE engine. The log-file is called Simulation ID + Scenario ID + _ErrorLog.html. However it should be noted that the file is created also if no errors occur.

Further, a summary file is created after end of simulation containing similar information as for the MOUSE engine. The summary-file is named Simulation ID + Scenario ID + _Summary.html.

The result files from MIKE 1D all have the extension *.res1d regardless of the content. This is consistent with MIKE's other engines, but different from the MOUSE engine where the extension denoted the content.

The name of the result file follows the common principle from MIKE URBAN e.g. Simulation ID + Scenario ID, however a further suffix of the name now denotes the content. As an example the result file from a runoff simulation will have the suffix "RR" and hence the result file name could become "CityABaseRR.res1d".

File Type	Suffix
Runoff result file	*RR.res1d

Catchment discharge result file	*CatchmentDischarge.res1d
Catchment discharge AD results	*CatchmentDischargeAD.res1d
RDI Additional output result file	*Add.res1d
Additional output as specified in the dhiapp.ini file	*ADDOut.res1d
User specified result file	UserSpecified."resultSpec.MUID".res1d

Results from a MIKE 1D simulation can be viewed directly in MIKE URBAN. When loading a res1d-file most things will be similar to loading a PRF-file.

In MIKE View, one thing to note is that when selecting results the distinction between pipes and nodes is in the Data Type and not in a separate filter - e.g. the water levels in pipes are found under the data type "Water level" and the water levels in nodes are found under "Water level Node".
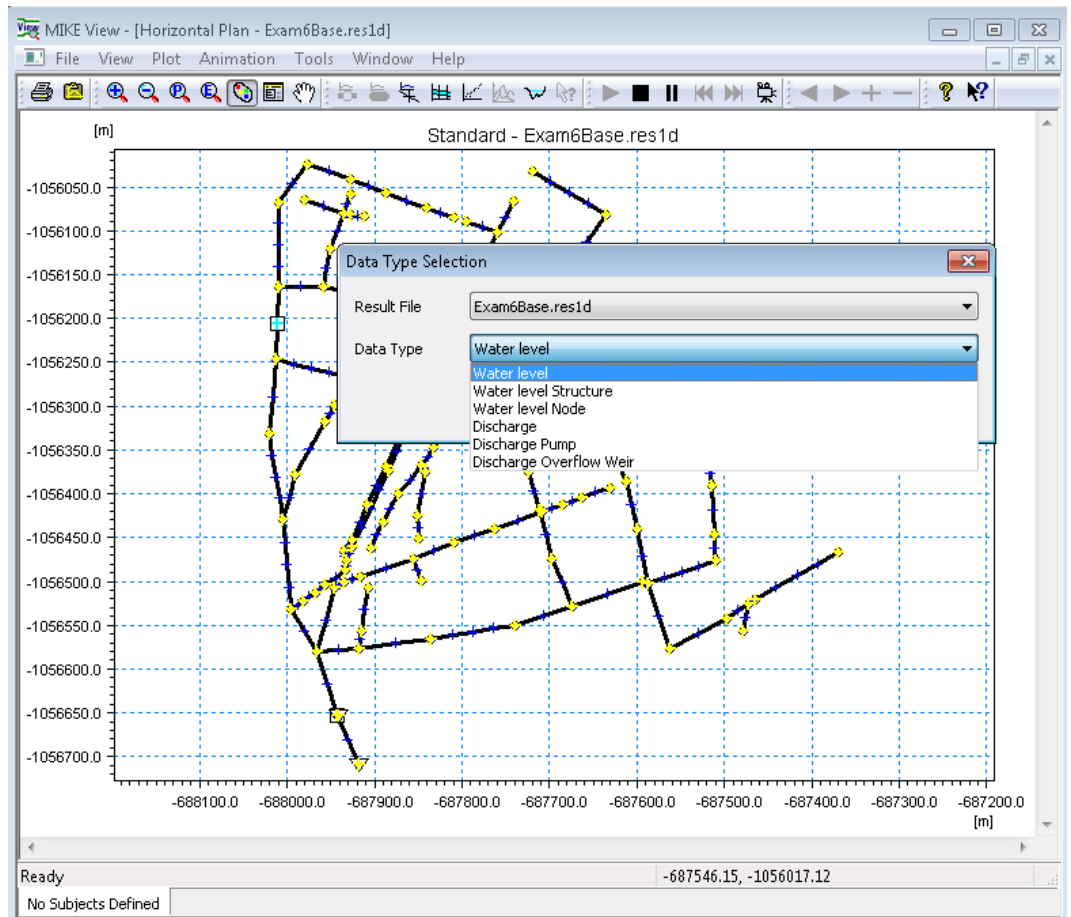
When selecting using the map, the user should select directly the grid-point on the link which should be plotted. The same method as used when selecting results in MIKE URBAN.

When selecting in a list it should be noted that for some results (e.g. catchments or structures) will have a suffix indicating the nature of the result. For example, an output file

from a combined runoff with RDI + Kinematic Wave (B) will have three results per catchment (as for the existing engine) where the suffix of the catchment is respectively "- RDI" and "- Kinematic Wave (B)".

4.3   Boundary Conditions

Boundary conditions work the same way in MIKE 1D as in the MOUSE engine with one exception. In MIKE 1D all catchment related boundaries are calculated with the runoff simulation and all network related boundaries are calculated with the network. This means that the catchment discharge specified under "MOUSE | Boundary Conditions | Catchment Loads…" will be included in the runoff simulation.

In the MOUSE engine catchment discharges were included in the network simulation by using a catchment load referring to a catchment boundary. This functionality is discontinued in MIKE 1D and a warning will be issued that these boundaries are ignored in a network simulation.
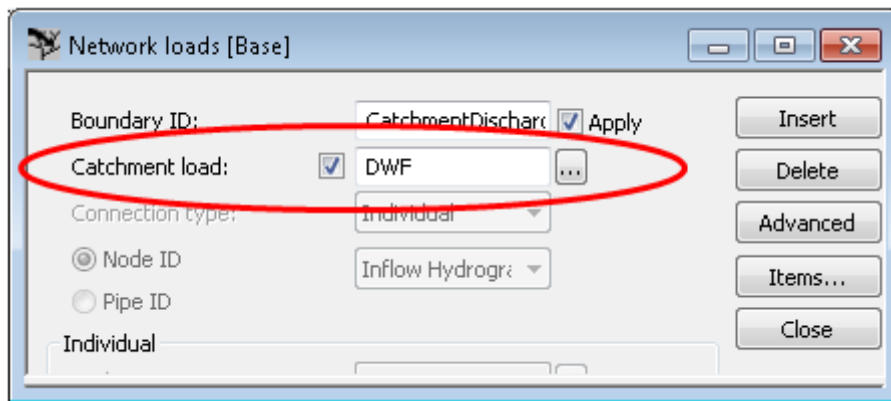
When using catchment discharge in MIKE 1D everything is configured in the GUI as previously in the catchment load dialogue.
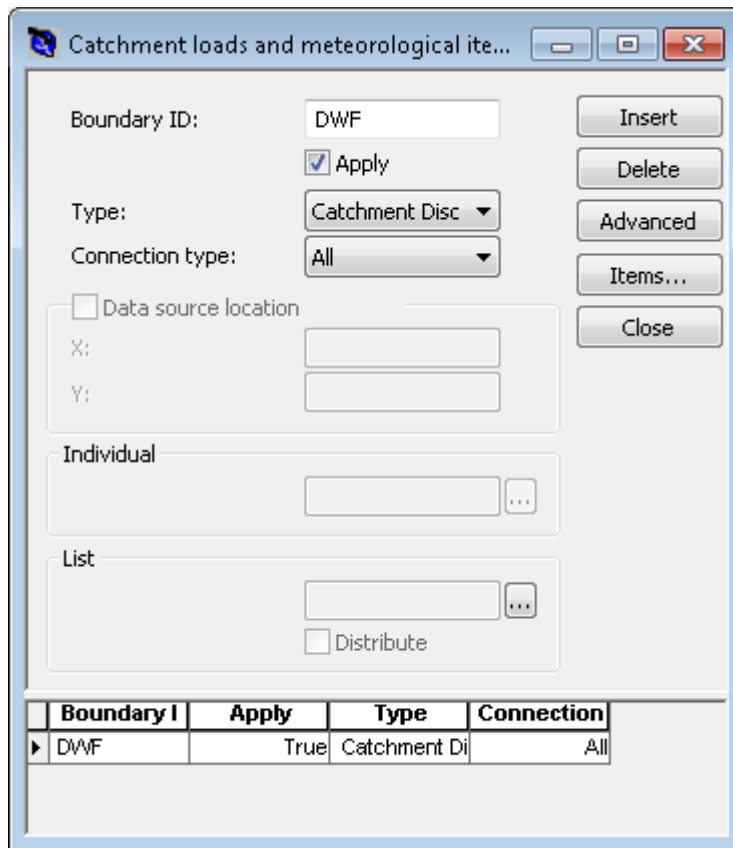
After end of the simulation two result files will be created; One that contains the runoff and one that contains the catchment discharge. Both the runoff result file and the catchment discharge file should be attached as a boundary condition (either on the simulation dialogue or in the network loads).

On the simulation dialogue both the runoff and catchment discharge file is included on the network parameter tab under "Network load input".
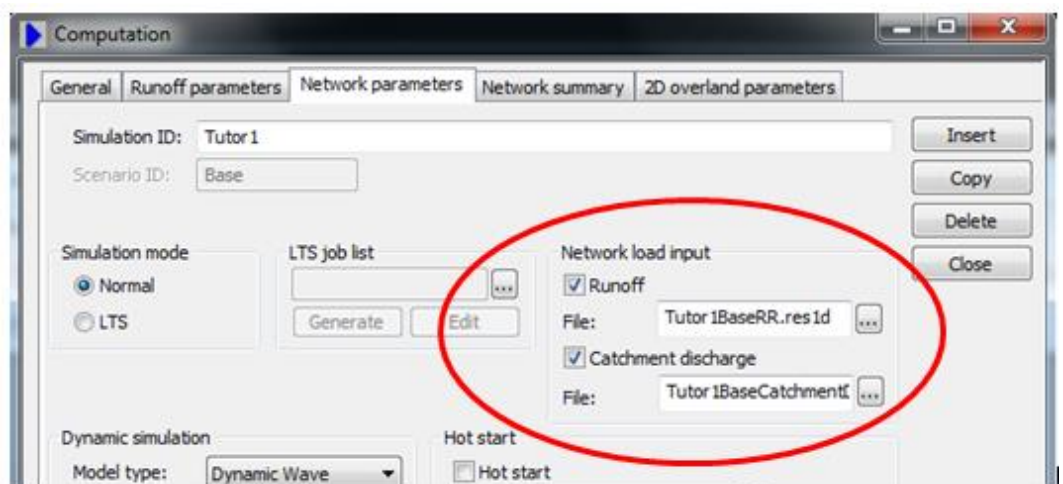
Special notice should be made for setups which only contain catchment discharge and not rainfall runoff. For the MOUSE engine only a network simulation was needed due to the functionality of the catchment loads in the network loads, but for the MIKE 1D simulation first a runoff (catchment) simulation should be run to produce the catchment discharge result file followed by the network simulation.

If Transport (AD) is enabled in a setup containing catchment discharge, and there are component items on the catchment discharge load boundaries, a catchment discharge AD result file is created. This catchment discharge AD result file must be added as a network load boundary item in order to include catchment discharge component loads in the network simulation.
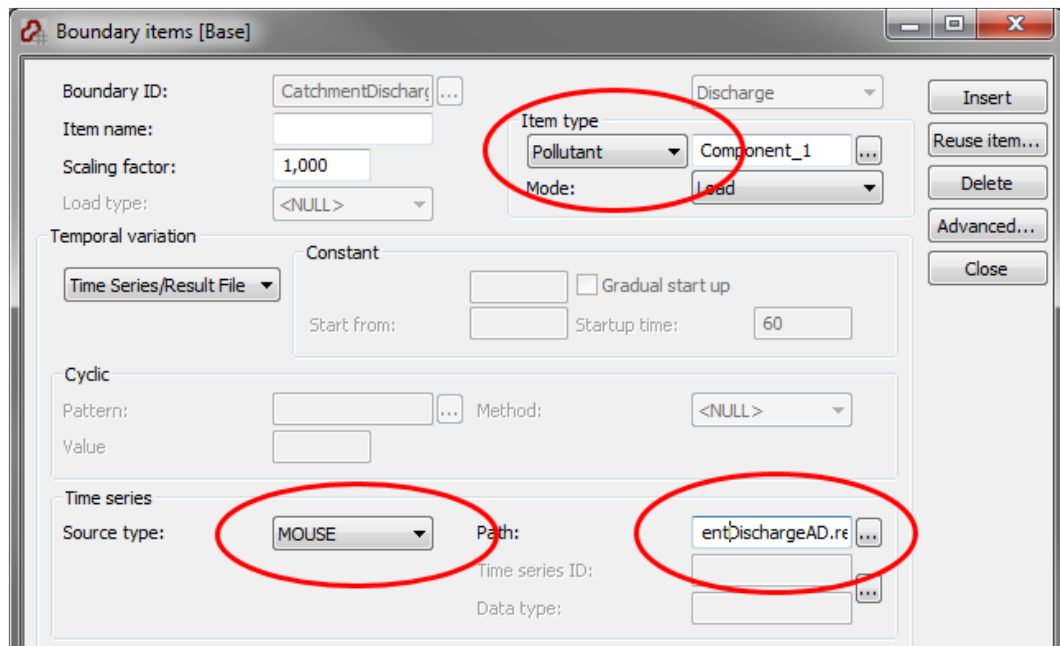
4.4 Running water quality analysis with MIKE ECO Lab

MIKE ECO Lab is a highly flexible framework for defining water quality models. MIKE ECO Lab utilises a concept of templates where water quality models are defined with equations and variables. A MIKE ECO Lab template implements a specific set of water quality related equations. It is important to note that the MIKE ECO Lab coupling is exclusively available with the MIKE 1D engine.

Water quality modelling in MIKE URBAN is possible by means of a set of four MIKE ECO Lab editors.

- MIKE ECO Lab Templates and Assignments
- MIKE ECO Lab State Variables
- MIKE ECO Lab Constants
- MIKE ECO Lab Forcing

In the following a description of the procedure to run a Water Quality analysis in MIKE 1D is presented:

The MIKE ECO Lab template must be imported to the database through the "*ECO Lab Templates and Assignments*" editor. In the editor the template can be loaded through the

"*ECO Lab name*:" field. Once the template is located, clicking on the "*Import*" button will transfer all relevant information about state variables, forcings and coefficients to the database.
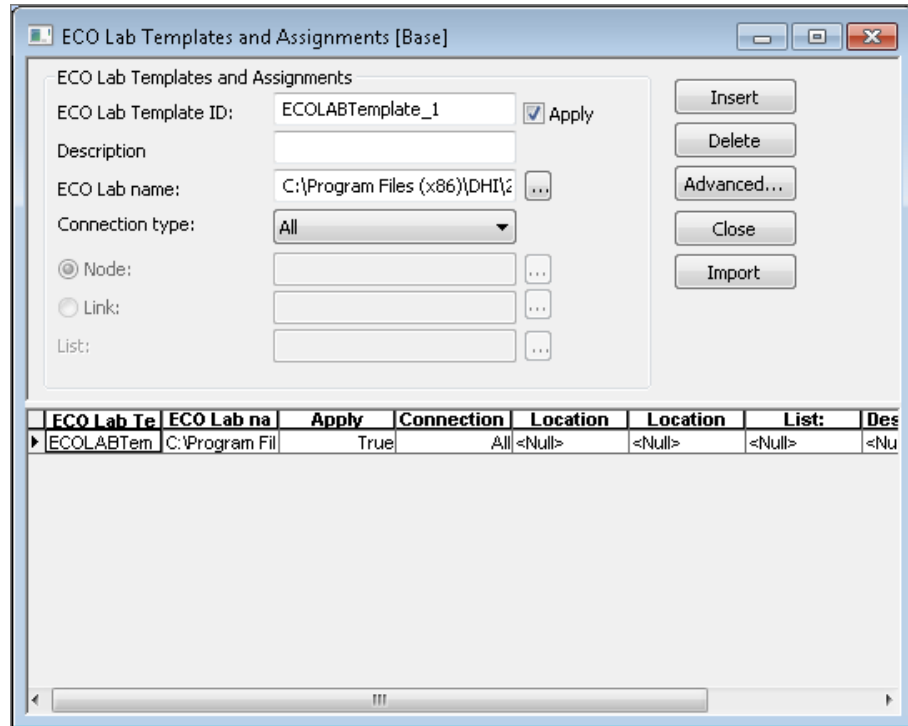
The template can be connected to the hydrodynamic model through nodes or links. The usual options to connect the database are available, all elements, a single link/node or a selection of links/nodes. The "*Apply*" check box can be used to disable the template.

While importing a template warnings can be issued indicating the need to change or adjust parameters after importing the template. See the examples below:
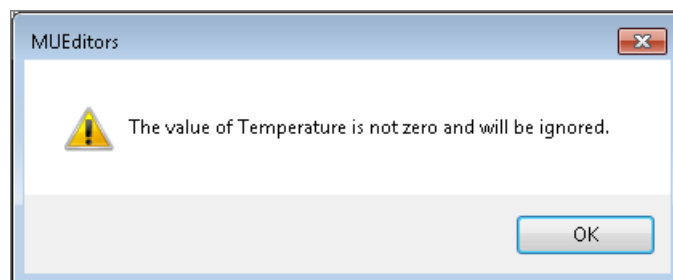
With the template properly imported then is necessary to link the *ECO Lab State Variables* with the AD components (the user is required to create entries for these components in the *AD Components* editor). Clicking on the ellipses button in the *AD Component* ID allows the user to link the *State Variables* to the *AD components*.

The initial conditions of each component are defined in the *AD Components* editors.

In the *ECO Lab Constants* editor all the coefficients and units defined in the template are presented.

The *ECO Lab Forcings* are presented in the editor, The forcings are constant or temporal varying external factors.
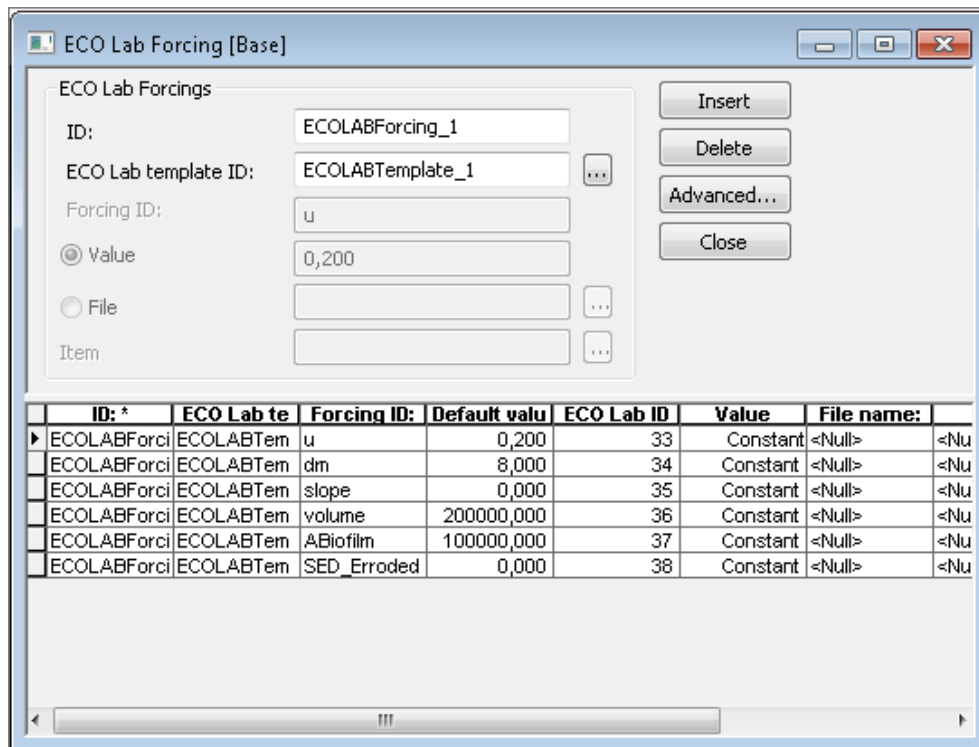
Once the parameters have been defined appropriately in MIKE URBAN, the user is ready to run a MIKE1D Water Quality analysis simulation. In the simulation editor choose MIKE 1D engine as the simulation engine (the old MOUSE engine does not support MIKE ECO Lab analysis), go to the "*Network parameters*" tab and in the "*Pollutants*" group tick the *Transport AD* and the *ECO Lab* checkbox.

In this dialogue the user can choose the integration method to run the MIKE ECO Lab simulation. The default method is EULER, but the user can choose between Runge-Kutta, Runge-Kutta Quality Control and EULER. For further information about these numerical integration methods, please refer to the MIKE Zero ECO Lab documentation.
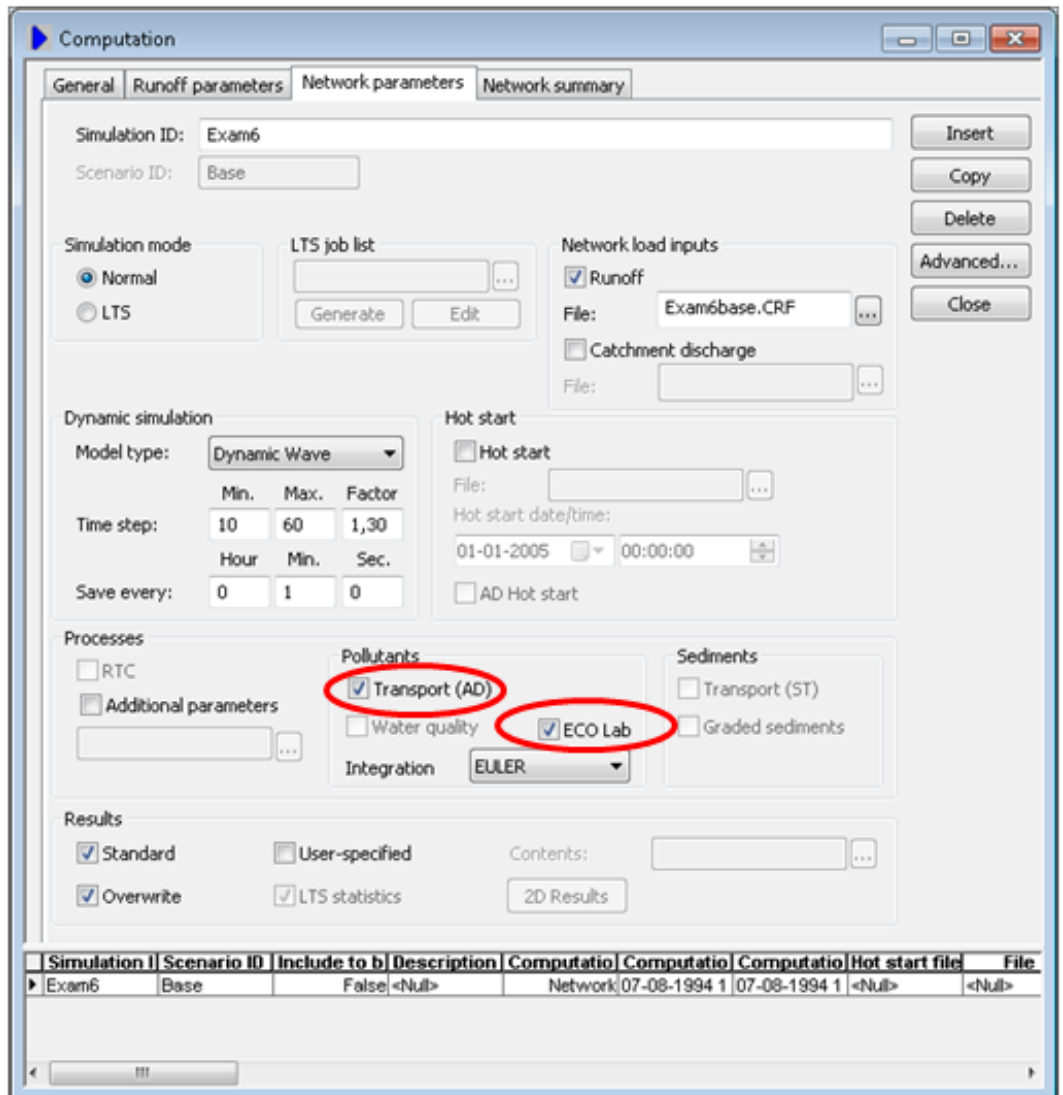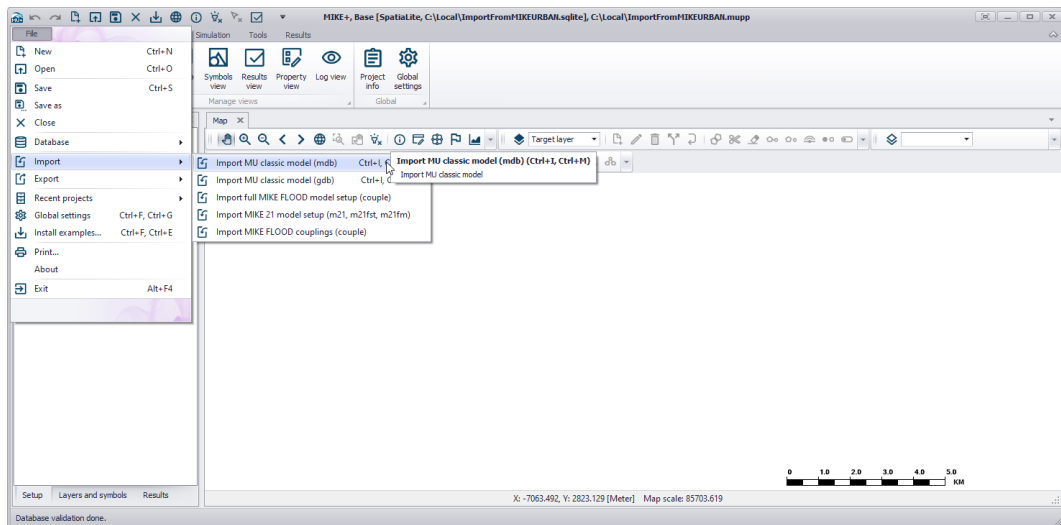
4.5 Import to MIKE+

To import a MIKE URBAN project to MIKE+, first open MIKE+ and create a new project.
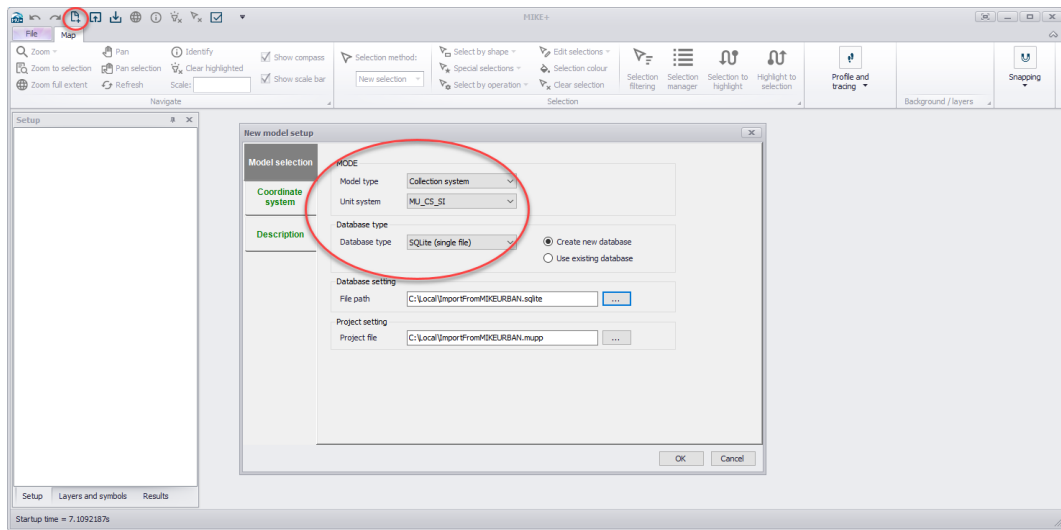
Select the model type and unit system as desired. Also select a database type: the SQLite format is the default format, for use with a local database file.

Then use the predefined import routine from File | Import | Import MU classic model.

Refer to the MIKE+ documentation index for more information on how to use MIKE+.

5 Note for MIKE 11 Users

When using MIKE 1D, the file extension for result files is *.res1d, no matter if the simulation is performed with MIKE 11 or MIKE URBAN. This result file can be opened as usual with MIKE View.

When viewing result files with MIKE View: For MIKE 11, result files generated with MIKE 1D engine store the structures location, which is identified with specific icons on the Horizontal Plan. With this new file format, all results related to structures are now directly accessible from the Horizontal Plan, which means that results previously accessed from the Plot > TS of System Data menu are now simply accessed by using the 'Select gridpoint' tool and clicking on the desired structure.