FEFLOW piMIKE 1D

User Guide

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1   Introduction

The former IfmMIKE11 is now officially replaced by FEFLOW piMIKE1D. This solution offers a native coupling between FEFLOW engine and MIKE 1D engine for surface water modelling. MIKE 1D is a superior surface water engine and is the successor of the former MIKE 11. MIKE 1D engine is part of MIKE Hydro River and MIKE+ products.

FEFLOW piMIKE1D supports the coupling between an existing FEFLOW Fluid-Transfer BC and a river network file from MIKE 1D. If the user imports an old MIKE 11 file, the file will be converted automatically to the new MIKE 1D format.

This page does not replace any existing documentation of MIKE 1D. If you are a former MIKE 11 user and would like to migrate to the MIKE 1D engine, we recommend you to look the MIKE 1D Reference Manual or in corresponding documentation of MIKE+ and/or MIKE Hydro River.

1.1   Supported systems

The current implementation is only supported in Windows OS. The details about the supported OS for FEFLOW can be found in the software release notes. In a future release, piMIKE1D will be also supported under Linux OS. The proper operation of piMIKE1D requires the installation of .NET Runtime 5.x.

FEFLOW piMIKE 1D was developed to support MIKE 2022 version and FEFLOW 7.5. No previous versions of FEFLOW and MIKE will support the new coupling system. In the case of the coexistence of multiple MIKE versions, the appropriate MIKE 1D version will be selected automatically.

1.2   Supported file format

FEFLOW piMIKE1D supports both *.mhydro* and *.m11* file formats to represent river model set-ups. In the future with the Linux support, the solution will support *.m1dx* files.

1.3   Current restrictions

The current implementation supports flow simulations only. A future release will incorporate the coupling of mass transport (water quality). The flow coupling is only supported in transient state.

2 Licensing

The proper operation of FEFLOW piMIKE 1D requires that both systems (FEFLOW and MIKE 1D) are licensed. FEFLOW piMIKE 1D also requires a license, separate to the FEFLOW license.

3 Activation of the Hydrodynamics module in FEFLOW

Differently to all existing FEFLOW customized modules (plug-ins), FEFLOW piMIKE 1D provides a much intuitive operation within the FEFLOW graphical interface.

The activation of FEFLOW piMIKE 1D happens directly to the FEFLOW **Problem Settings** dialog (see figure below). All the required settings for the coupling are also to be defined in the new page **Hydrodynamics**.
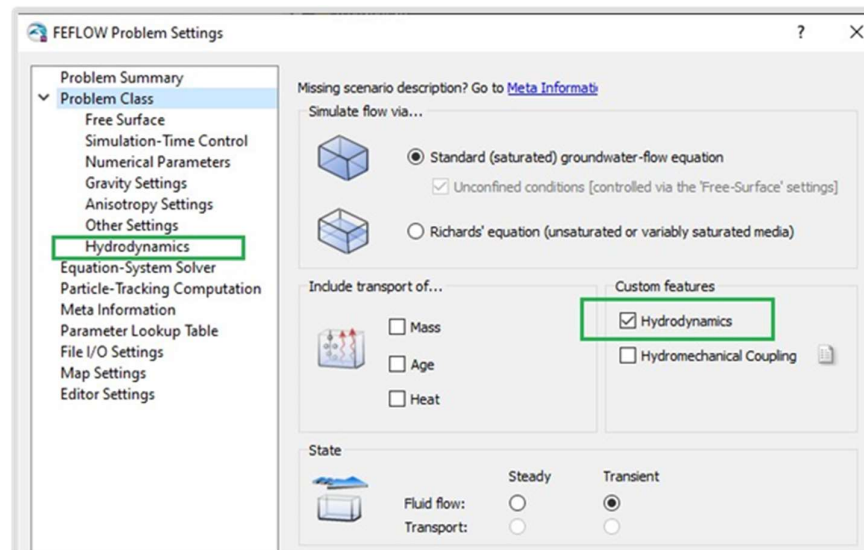
New customer features "Hydrodynamics" in the FEFLOW Problem settings dialog.

4 Definition of the simulation period

FEFLOW piMIKE 1D offers two possibilities to control the simulation period for the coupled calculation.

- Option 1: The simulation starts at the MIKE 1D start date. The end date of MIKE 1D will be adjusted to match the FEFLOW simulation duration, calculated as the difference between FEFLOW's *Final Simulation Time* and *Initial Simulation Time* (in days).

- Option 2: User-specified initial and final date-time in the new *Hydrodynamics* page in the FEFLOW Problem Settings dialog. The MIKE 1D start/end simulation will be adjusted to what is specified. The user should make sure the period is covered by required inputs for MIKE 1D, e.g. any time series for boundary conditions. The FEFLOW's *Final Simulation Time* will be adjusted accordingly.

4.1 Fundaments of the hydrodynamic coupling

The river network in MIKE 1D consists in multiple geometrical information such as reaches, nodes, grid points, cross-sections and structures:

- A reach is a one-dimensional connection between two nodes in a network. The reach has many synonyms within different domain applications. In sewer models it is often called a link or pipe, in river models a branch, stream, canal or channel, and in graph and network theory it is called a link or an edge.

- Points associated with reach ends and reach junctions are called nodes. Each reach has one node in each end. A node is associated with at least one reach, but an arbitrary number of reaches can be attached to a single node, defining the junction of all the reaches. A node is always present in a junction in the network.

- Grid points are the computational points in a reach. At each grid point a dependent variable is defined. For a flow model this is either water level (H-grid) or discharge (Q-grid).

- A cross section is the 2D intersection of a channel, typically a river or a sewage pipe, perpendicular to the channel direction. Among other things, cross sections determine the volume of water in a channel for a given water depth.

- A structure is a parameterised model that can calculate a flow over or through the structure based on an upstream and downstream water level. Examples are weirs, gates, orifices and pumps. A structure grid point has an associated structure, that calculates the discharge over the structure depending on the water levels on each side of the structure.

5   Mapping FEFLOW and MIKE 1D discretization

The current coupling implementation carries out an automatic mapping between the FEFLOW nodes (associated to an existing Fluid-Transfer BC) and MIKE 1D H-grid points. This means that each of the FEFLOW boundary nodes will be mapped to the closes H-grid point based on the Euclidian distance. FEFLOW piMIKE 1D considers no possibility of exclusion of FEFLOW boundary nodes. An example about the mapping between FEFLOW nodes and H-grid points is shown below.
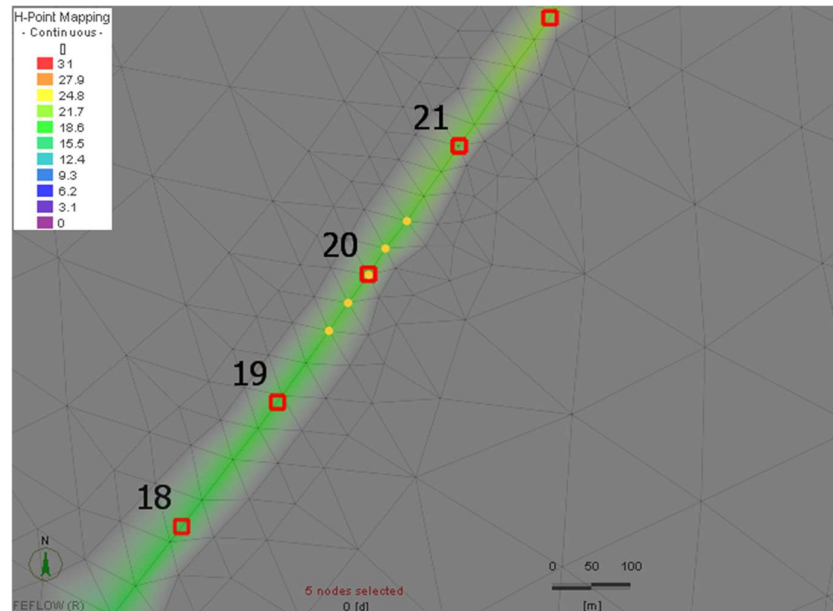

Example of the mapping between FEFLOW boundary nodes (current selection) and H-grid point (ID 20).

For each FEFLOW boundary node, FEFLOW piMIKE1D searches for the closest H-grid point and store this connectivity for further use. If the H-grid points are non-equidistant, the resulting "snapping" distance could be distinct between upstream and downstream.

During the model run a nodal distribution under the name "*H-Point Mapping*" is automatically created in FEFLOW. This is of great help to evaluate the mapping between the two meshes.

Due to the current way of mapping the two meshes, it is strongly recommended that the user verifies whether the current grid spacing in the surface water project is appropriate for the coupling with FEFLOW. The *Grid spacing* is controlled through the Computational control parameters as shown below in the MIKE Hydro River GUI.
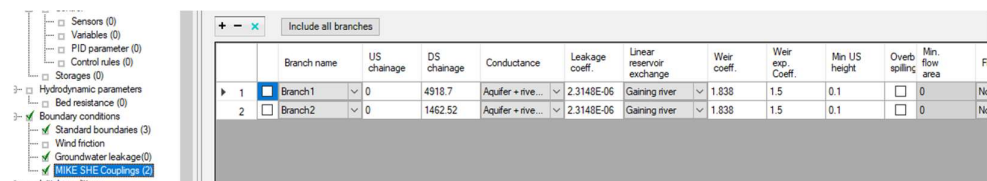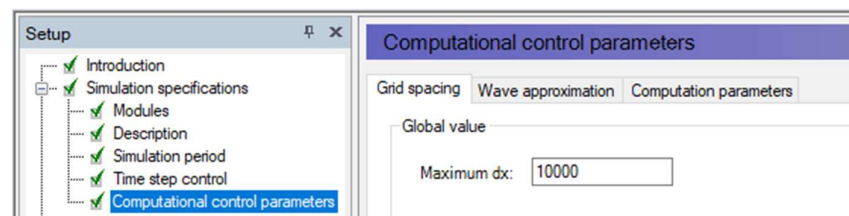

MIKE Hydro River GUI with the grid spacing option.

6 Calculation of exchange rates

The exchange rates between the river and the aquifer are defined by the equation below, where PHI [m^2/d] is the product of the exchange area [m^2] and the leakage parameter [1/d]. The exchange area is the current wetted perimeter at the H-grid point multiplied with the sum of half the distances to the up- and downstream H-grid points. The wetted perimeter is based on the current water level and the cross-section geometry and is directly extracted on run-time from MIKE 1D. The leakage coefficient or factor (or named in FEFLOW as *Transfer Rate* In/Out) is directly extracted from the river model set-up in MIKE Hydro River.

$$q = \Phi \cdot \left(h_{ref} - h \right)$$

The leakage coefficient is defined through the section Boundary Conditions - MIKE SHE Couplings as shown in the Figure below. The leakage coefficient is a parameter that is branch-dependent.

Definition of the leakage coefficient in the surface water set-up.

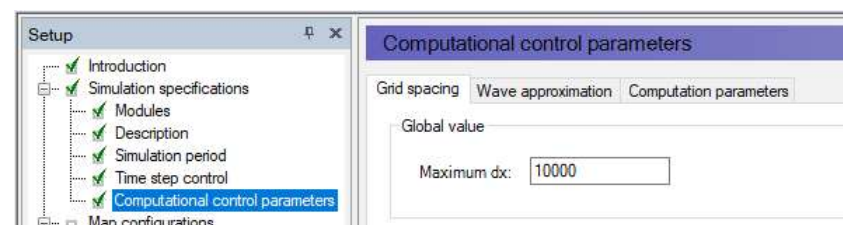# 7 Discretization of the river network

The discretization level in the river network plays a significant role for the success of the coupling. piMIKE1D will always find a FEFLOW boundary node to be linked with a H-grid point. But if the number of H-grid points is limited, the spatial changes of water level in FEFLOW may not be optimal reflected.

The river discretization is controlled directly by the parameter Maximum dx in the property page of MIKE 11 or MIKE Hydro River.

Discretization settings in MIKE 11.

Discretization settings in MIKE 11.

The discretization level in the river network plays a significant role for the success of the coupling. piMIKE1D will always find a FEFLOW boundary node to be linked with a H-grid

point. But if the number of H-grid points is limited, the spatial changes of water level in FEFLOW may not be optimal reflected.

8 Getting started with piMIKE1D

The new surface water - groundwater coupling solution does not require any nodal reference distribution as it was the case with its predecessor ifmMIKE11. The only mandatory settings are available through the FEFLOW Problem settings dialog.

8.1 Activation of the Hydrodynamics module in FEFLOW

Differently to all existing FEFLOW customized modules (plug-ins), FEFLOW piMIKE 1D provides a much intuitive operation within the FEFLOW graphical interface.
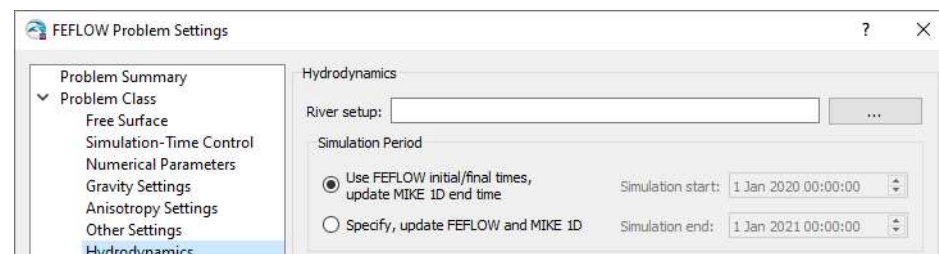
The activation of FEFLOW piMIKE 1D happens directly to the FEFLOW **Problem Settings** dialog (see figure below). All the required settings for the coupling are also to be defined in the new page Hydrodynamics.
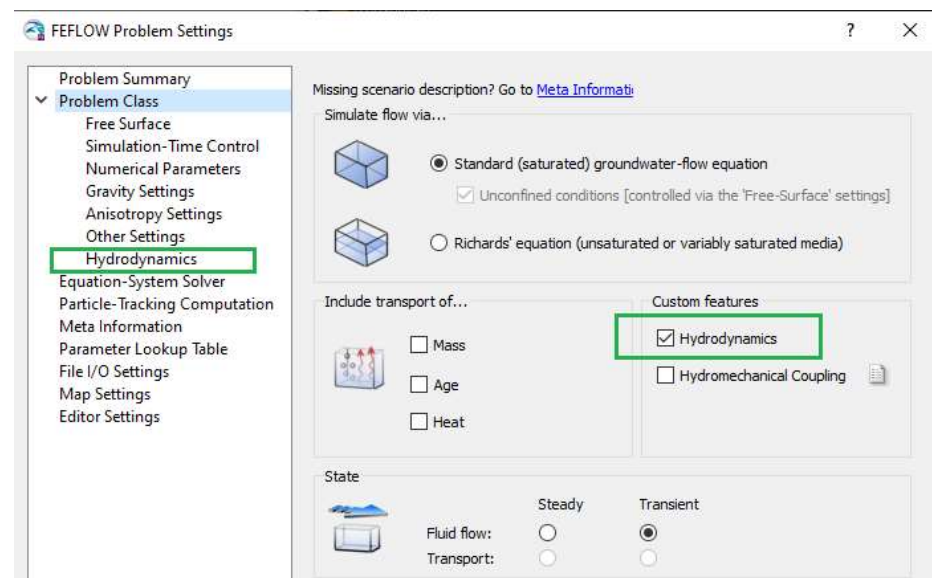
New Custom features "Hydrodynamics" in the FEFLOW Problem settings dialog.

8.2 Definition of the river set-up

FEFLOW piMIKE1D supports both *.mhydro* and *.m11* file formats to represent river model set-ups. In the future with the Linux support, the solution will support *.m1dx files.

8.3 Definition of the simulation period

FEFLOW piMIKE 1D offers two possibilities to control the simulation period for the coupled calculation:

- Option 1: The simulation starts at the MIKE 1D start date. The end date of MIKE 1D will be adjusted to match the FEFLOW simulation duration, calculated as the difference between FEFLOW's **Final Simulation Time** and **Initial Simulation Time** (in days).

- Option 2: User-specified initial and final date-time in the new **Hydrodynamics** page in the FEFLOW **Problem Settings** dialog. The MIKE 1D start/end simulation will be adjusted to what is specified. The user should make sure the period is covered by required inputs for MIKE 1D, e.g., any time series for boundary conditions. The option FEFLOW's **Final Simulation Time** will be adjusted accordingly.

8.4 Model results

The coupling solution utilizes the standard result formats in FEFLOW and MIKE Hydro River (or MIKE 11). If the option of FEFLOW Results *.dac file is activated before the model run, the user will be able to visualize the river changes through the values of Fluid Transfer BC.

Since the **Transfer Rates** in FEFLOW are not used for the calculation of the exchange flows, instead the rates are computed on runtime and passed directly to the FEFLOW kernel, the on-the-fly budget calculation using the Rate Budget panel in the DAC file may not be correct.

It is strongly recommended to create a nodal selection with the river nodes and activate the **Budget-History Charting -> BCs** before starting the simulation. This will assure that boundary budgets in the charts contain the real leakage coefficient.

Apart from the standard MIKE1D log files, a <model>_Summary.html file will be created in the same directory as the river setup. The file contains some general information on the MIKE1D model and the water balance. For debugging purposes, the section **"Couplings In-/Outflow mass error"** contains some hints about possible imbalances originated by the coupling.

8.4.1 Results in log files

There are several log files created on runtime for additional debugging purposes, which could be also used for visualization and verification of the mapping between the FEFLOW nodes and the MIKE1D H-grid points.

- <model>_HPoint2NodeTable.txt: mapping between FEFLOW nodes and H-grid points (similar to ifm-m11 "IfmMIKE11_Patchfefnodes.txt"):
    - H-ID: unique id of the H-grid point. This can be used to match the H-grid point to the other log files.
    - Chainage: M-location of the H-grid point along the river branch.

- H-X, H-Y, F-X, F-Y: coordinates (X,Y) of H-grid point and FEFLOW node, respectively.
- Branch: Name of the branch the H-grid point belongs to
- F-NODE: FEFLOW node number
- Slice: slice number of the corresponding FEFLOW node
- Branch: Name of the branch the H-grid point belongs to

- *<model>_HPoint2NodePoints.txt*: One record for each FEFLOW node and each H-grid point that is part of the coupling. No column headers
    - 0: json point-feature for the FEFLOW node/H-grid point
    - 1: branch name
    - 2: FEFLOW node number: empty for H-grid points

- *<model>_HPoint2NodeLines.txt*: One record for each mapping between a FEFLOW node and an H-grid point. No column headers
    - 0: json line-feature from node to H-grid point
    - 1: branch name
    - 2: H-grid point chainage

- *<model>_HPoints.txt*: Information on H-grid points.
    - H-ID: unique id of the H-grid point. This can be used to match the H-grid point to the other log files
    - Chainage: M-location of the H-grid point along the river branch
    - X, Y: coordinates
    - Branch: Name of the branch the H-grid point belongs to