



MIKE 21 FLOW MODEL

HINTS AND RECOMMENDATIONS IN APPLICATIONS WITH SIGNIFICANT FLOODING AND DRYING

This note is intended as a general guideline to setting up a standard MIKE 21 model for applications with significant flooding and drying. Guidelines in the document are especially relevant to floodplain and storm surge applications.

For all MIKE 21 applications the most important input parameter is the bathymetry (or DEM or topography). The second most important set of parameters are the forcing specifications (boundaries, rainfall, evaporation, etc.) followed finally by the traditional calibration parameters like eddy viscosity and bed friction.

Bathymetry

Often the bathymetry (or DEM) is available in GIS. GIS surface data may be imported using the GIS-tool '*Grd2Mike*' in the MIKEZero Toolbox. When importing GIS surface data for a MIKE21 bathymetry, always ensure that the '*True Land*' value is set to a sufficiently large value as these nodes **never** become active computational nodes within the model domain.

If the bathymetry is located significantly above mean sea level rounding errors may become an issue. The standard MIKE 21 solution uses single precision with a rounding error on the 6th digit of the single precision representation. Model domains at high altitudes may produce model results with an order of accuracy insufficient to describe the flow behaviour in the study area. For example, a model domain at an altitude of 1000m above mean sea level in standard MIKE21 will produce water depths with an accuracy of ± 0.1 m. Often results of this accuracy will not be acceptable for floodplain applications. MIKE 21 does however provide the flexibility to improve the model accuracy in two ways. You may increase the relative accuracy of results by **either** lowering the relative model domain altitude by subtracting the mean altitude value **or** use the double precision option in the MIKE 21 computations.

The mean relative altitude of the model domain can be lowered simply by using the *GridEditor* tool.

To enable double precision in your model computation you should add the following line to the hydrodynamic option section in the *.M21 pfs file (look for the [OPTION_PARAMETERS] section within the [HYDRODYNAMIC_MODULE] section,

```
Include_DB_computations = true
```

The pfs file you can be adjusted by either opening the *.M21 file using a text editor (e.g. Wordpad or Notepad) or using the *PfsEditor* which is part of your MIKE 21 installation (c.f. Fig 1). The *PfsEditor* is located in the MIKEZero\bin directory.

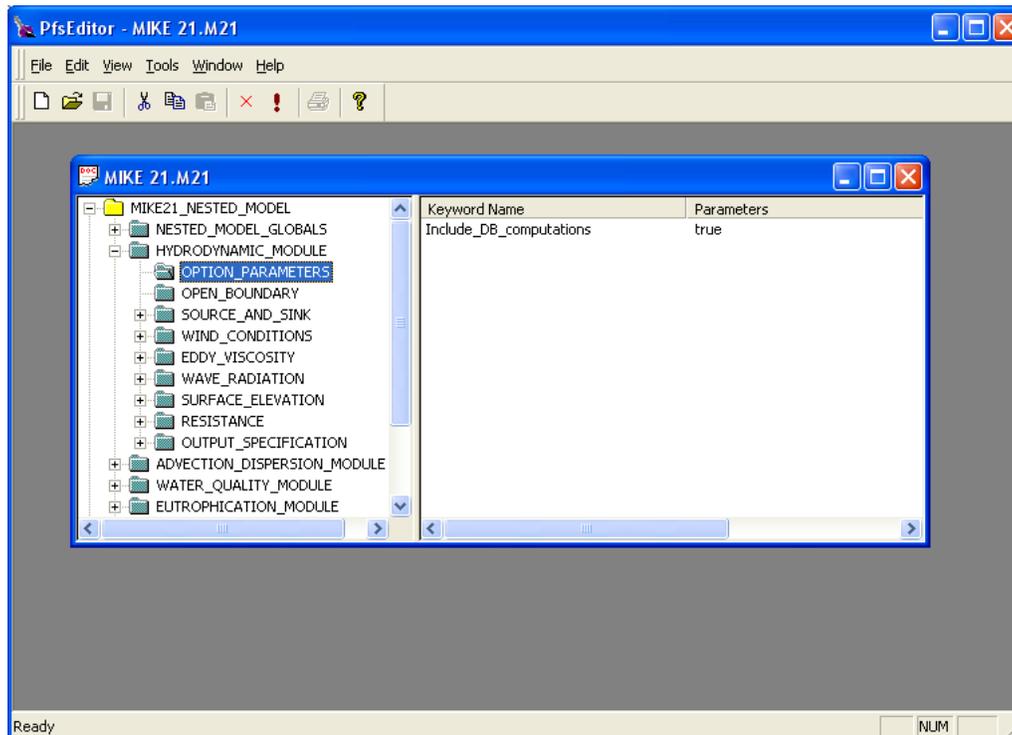


Figure 1 Editing the *OPTION_PARAMETER* section of the *HYDRODYNAMIC_MODULE* in a *MIKE 21* setup using the *PfsEditor*

Information for transferring MIKE grids into and out-of GIS applications. The current MIKE 21 tools assume that the GIS grids are non-rotated. This is NOT usually equivalent to a zero orientation defined in MIKE 21. GIS assumes zero rotation relative to the projection axis. MIKE 21 assumes zero rotation at the origin relative to True North. So in this sense, when importing a DEM or GIS grid, the orientation angle at the MIKE 21 grid origin should equal the convergence angle at that location. The orientation angle in MIKE 21 is ONLY equal to zero if the origin is located exactly on the central meridian of that projection. This needs to be resolved in the beginning of most all projects if results are to be compared to other geo-referenced materials. Also recall that a MIKE 21 bathymetry requires a *custom block* (M21_Misc) be present. Custom blocks can be added and modified using the *GridEditor* tool or the *Data Utility* tool.

Boundaries

At present MIKE 21 cannot accommodate drying of grid cells at open boundaries. There are two alternative approaches to ensuring that this criteria is met. You can either ensure that the model domain is either enclosed by '*True Land*' or that defined open boundaries in the model domain remain wet boundary nodes throughout the simulation period. An exception to this rule for open boundaries is that if discharge boundaries are specified as source points instead of as open boundaries, source points can be initially dry.

The location of model boundaries is an important consideration in the development of a model domain. Model boundaries should be located so as to minimize the impact of boundary effects such as 'artificial' backwater influence from outflow (downstream) boundaries and jetting of flows at inflow (upstream) boundaries.



There are several approaches to applying model boundaries to inland model domains that are dependent on the particular model application. In some instances, complex model bathymetries near the edge of a model domain make it difficult for the modeler to make a prior decision about how flow might leave the model domain in a controlled manner. In these instances you may decide to simplify the flow exit issue by adding a wall all away around the model domain in order to avoid defining complex downstream boundaries. If, following initial model trial simulations it becomes evident that a large accumulation of flow is occurring at the closed boundaries (identifiable by 'puddling' or ponding of flow at the edges of the model) you may need to apply a model 'sink' at these locations to allow the flow to leave the model domain.

There are fundamentally three ways for you to apply a flow 'sink' in the model. The simplest way to achieve the flow relief is to define a 'Sink' at with a large discharge rate at the appropriate locations in the model to 'suck' the water out before it has the chance to accumulate. 'Sinks' work on initially dry grid cells without extracting more water than what is available within the grid cell. This approach is best applied if there is flow accumulation at a limited number of distinct and constrained locations near the edge of the model. If you require more realistic model results close to these locations at the edges of the model, then a more controlled approach to this outflow issue would be to apply a 1D MIKE Flood link at the boundary location. The 1D MIKE Flood link will enable you to apply a rating curve boundary to the outflow location. This type of boundary allows the flexibility of a controlled variable outflow from the model, based on a rating curve approach. The rating curve boundary can be developed using available channel or floodplain survey data and average flood surface slopes. Information on applying boundaries in this mode is available in the MIKE Flood manual (Section 2.1 – Standard Link.)

Alternatively if there are multiple, unconstrained locations where flow needs to exit the model, you can add a trench partially or totally around the model domain such that the water spills out of the part of the model where flow behaviour information is required and into the artificial trench. The trench should be defined to be lower than the lowest adjacent boundary points to ensure that water does not re-enter the model domain. Adopting this approach you then specify an open boundary as a constant level boundary where the water collects in the trench. Also, make the trench a minimum of 3-5 grid points wide and possibly also add a sloping transition area in the grid between the trench and the model domain such that the transition becomes less abrupt. The width of the transition slope will depend on how steep this area part of the model is.

In many riverine floodplain applications a hydrograph will be the inflow boundary to MIKE 21. There are basically two ways of applying an inflow hydrograph. You can either specify the hydrograph as an open boundary condition or as a source point. If the open boundary approach is adopted it may be necessary to introduce a 'platform' transition zone from the edge grid cells of the model into the model domain proper. This platform transition zone will prevent water from spilling off in all directions and potentially drying out the open boundary nodes. It is important to note that boundaries are sensitive to numerical 'shocks' and reflective waves which can be introduced from irregularities in the bathymetry near open boundaries and this may be a source of instabilities in the model simulation. Smoothing the bathymetry nearby the open boundary and making a smooth transition between the boundary and the interior of the model is a way to minimize these problems. Common sense also is needed to check that the inflow hydrograph can actually be accommodated by the physical size of the model boundary and geometry defined for the input platform and transition. For instance it does not make sense to specify a flow rate of 100 m³/s through a 1 meter wide open boundary. In instances such as this the boundary should be widened to accommodate the specific flow conditions.



If you're using *Internal Open Boundaries* the same constraints apply as for normal open boundaries. Also note the general limitations of *Internal Open Boundaries* (c.f. MIKE 21 User Guide).

Initial Surface Elevation

In many floodplain applications the initial surface elevation can be set to be a constant value. In some applications however, it is necessary to use an initial spatially varying water surface that matches the actual water distribution and levels in the model domain at the start of the model simulation. A spatial map can be easily created using the bathymetry as basis and then modifying the relevant areas using the *GridEditor* tool. In some cases, where the initial surface elevation can be assumed to be at ground level, the bathymetry file may also be used as initial surface condition.

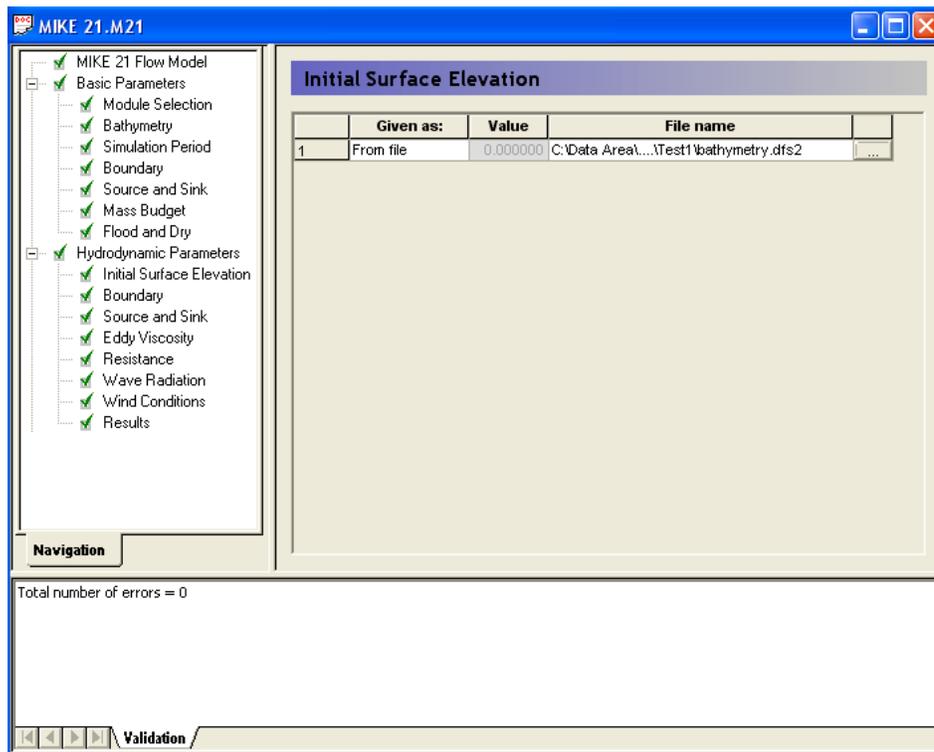


Figure 2 Specifying the Initial Surface Elevation in a MIKE 21 set-up

Rainfall and Evaporation

When applying rainfall and evaporation to standard MIKE21, it is important to note that rainfall and evaporation is applied only at wet computational cells. To activate calculations in dried cells (i.e. over the whole model domain) you need to apply two OPTION parameters in the hydrodynamic section of your *.M21 file (c.f. **Bathymetry** for details on how to do this)

```
RainOnDryLand = true
Include_DB_computations = true
```

The first option is a switch to allow rainfall to accumulate on dry land cells and the second parameter activates the double precision calculation mode. The double precision mode is generally needed to accumulate small amounts of volume per time step. Without operating in



double precision mode you may find that small increments of rainfall do not accumulate as you might have expected due to round-off of the numeric precision.

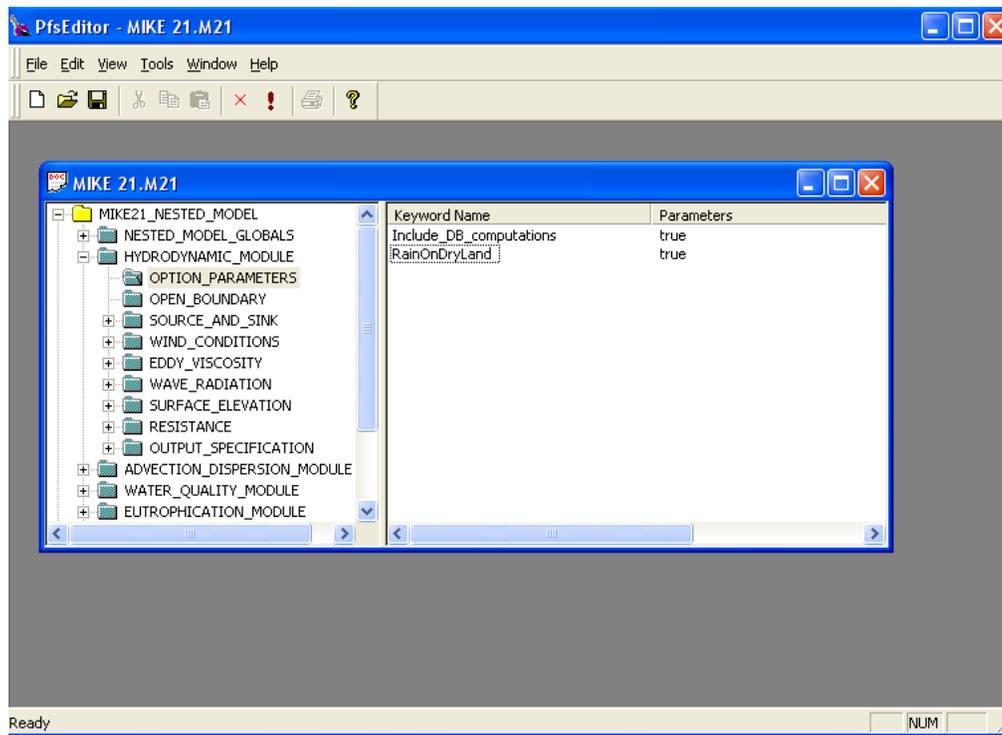


Figure 3 Adding the *RainOnDriedLand* option to the *OPTION_PARAMETER* section of the *HYDRODYNAMIC_MODULE* in a MIKE 21 setup using the *PfsEditor*

Note that the rainfall and evaporation intensity is in mm/day. Also note that when using rainfall, the user assumes 100% runoff, which may or may not be appropriate if significant infiltration and storage can occur in the soil or ground material.

Eddy viscosity

The most suitable eddy viscosity formulation for models of this type is often the Smagorinsky model but this formulation may potentially create instabilities in combination with significant flooding and drying. The safe and recommended approach in such applications is to choose the constant eddy viscosity description. Furthermore, **the 'flux based' formulation is recommended** as practical experience has shown that the velocity based formulation can potentially cause numerical instabilities. A rule of thumb guesstimate of the eddy viscosity constant is

$$\text{constant eddy} = 0.02 \Delta x \Delta y / \Delta t \quad [\text{m}^2/\text{s}]$$

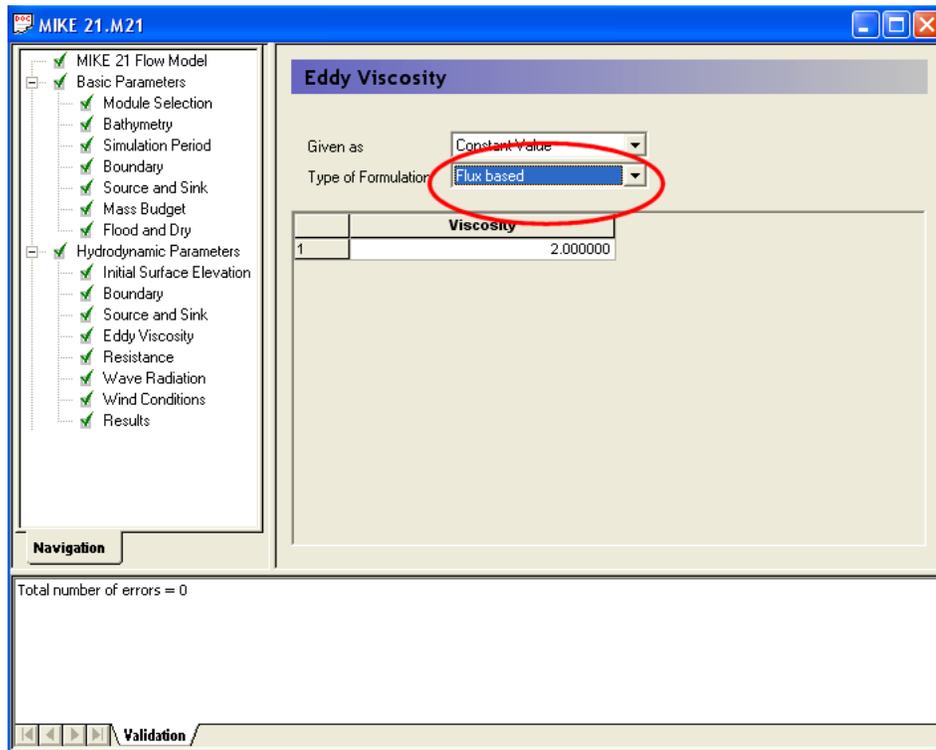


Figure 4 Selecting the Flux Based eddy viscosity formulation in a MIKE 21 setup

Bed Friction

In most applications the settings of the bed friction follows the standard settings for MIKE 21. A *Manning* number (c.f. MIKE 21 User Guide for definition of the Manning number) of 25 has been found to be a practical starting value in most floodplain applications. In many floodplain applications an important part of the calibration process is the development and application of a spatial roughness coefficient map reflecting the surface characteristics of the floodplain. For many inland applications the land use and vegetation coverage maps are available in GIS which then can be easily converted to a corresponding bed resistance map for application in the model.

Flooding and Drying

In certain situations, MIKE 21 may yield negative water depths. This can occur for instance in areas with very steep gradients in the bathymetry (or DEM or topography) or by a relatively large time step in the model. In such cases MIKE 21 will automatically reset the water depth to a small positive value. However, in doing so the model may potentially create mass (volume). To minimize the potential for mass falsification you should generally use very small flood and dry levels. Again, the double precision simulation mode may be required to use such a small and fine tolerance in flooding and drying levels. A rule of thumb guesstimate of appropriate values are:

Drying Depth = 0.01 m
 Flooding Depth = 0.02 m

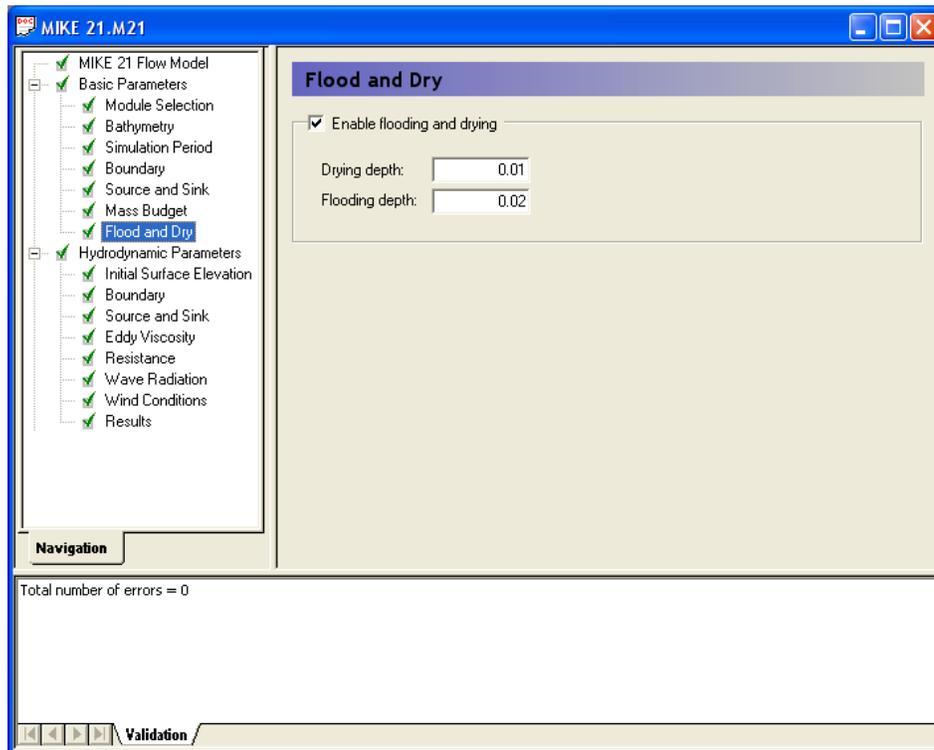


Figure 5 Specifying the Flooding and Drying Depths in a MIKE 21 setup

Inundation Statistics

MIKE 21 has the ability to calculate some additional inundation statistics. Please see a **separate note** on these features available on www.dhisoftware.com.

Hydraulic Structures

MIKE 21 includes a limited number of hydraulic structures. Please see a **separate note** on these. Applications that require more complex structures that are not part of the standard MIKE 21 can be accommodated by applying a MIKE Flood modelling approach.

Quality Assurance

In every model application an important component of the modeling process is a quality check of the model output. It is strongly recommended that all model output is checked using alternative techniques and common sense. A simple QA check is to calculate the mass balance periodically. This is fairly easy as long as water only enters the model and there's no outflow.

If the input is a (time varying) hydrograph, the time series may be cut and pasted into Excel and do a simple integration of the cumulative volume that then can be compared to what is actually on the model.

The GridEditor Tool may be used to check what is on the model for a given period in time, using the statistics output

$$\text{Volume} = H_{\text{mean}} N_{\text{Wet Points}} \Delta x \Delta y$$

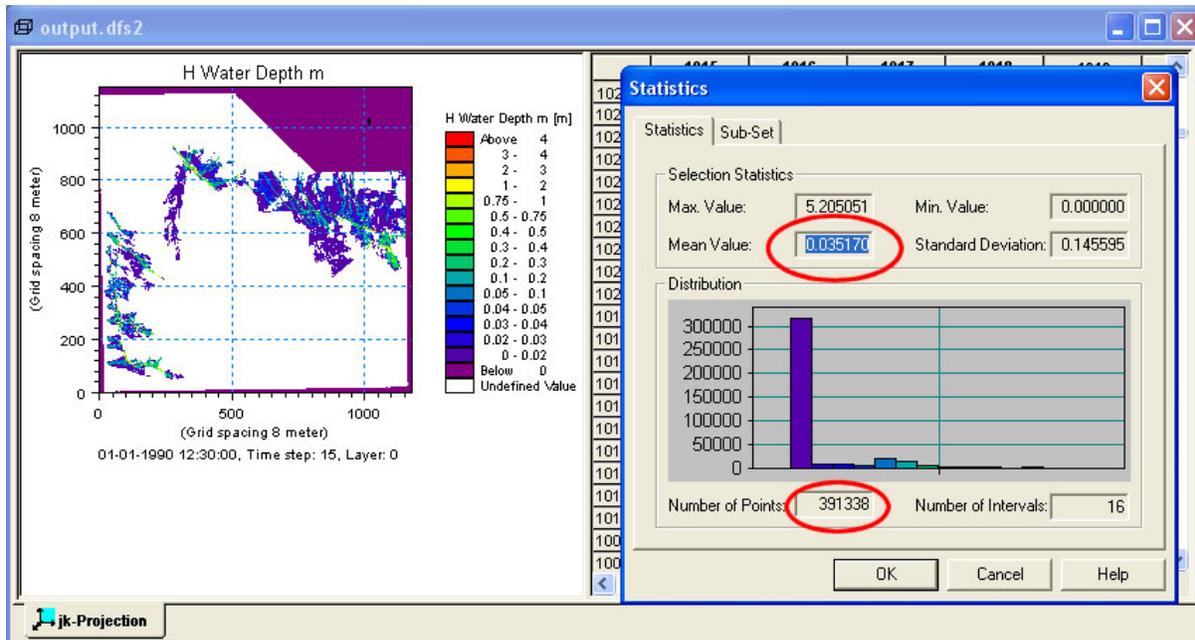


Figure 6 Checking the mass balance using the Statistics feature of the GridEditor tool

The flow volume out of the model over the corresponding period can also be calculated using the discharge calculation facility in the MIKE 21 toolbox.

Large discrepancies between the volume in, and volume on/out of the model are often associated with numerical instabilities occurring in the model. It is also possible, in a smaller set of cases that mass balance discrepancies may be associated with round-off errors in single precision computations. Going to the double precision solution may help solve this problem. Alternatively, the topography can be shifted downwards so that the highest elevation in the model is transformed to mean sea level. This can work well when time constraints dictate that it is necessary to maintain single precision computations.

Note that if open boundaries are used these nodes should be **excluded** in the mass balance calculations according to the numerical implementation of open boundaries.

Note also that dried cells are stored as empty cells in the output file despite that in some instances some water volume is stored in these cells. The amount of water stored is dependent on the drying depth setting. This water volume re-enters the calculation once the cells become wet again. Unless all computational cells are wet some minor mass falsification may occur.

Another easy and useful QA check, which is also a useful troubleshooting tool, is to use the *Maximum Statistics* from the *MIKEZero Toolbox* to compute the maximum speed at all grid points for all time steps. Check the result for high velocities and check that the Courant number based on

$$Cr = U_{\max} \Delta t / \Delta x$$

is not exceeding unity. This approach can be especially useful to highlight potential instabilities near open inflow boundaries. High velocities can indicate that the inflow platform and transition width should be increased and smoothed.