iRIC Software

Changing River Science

Morpho2DH

Solver Manual

- Mud flow -

Produced by Hiroshi Takebayashi

Contents

I. Outline

I.1 Morpho2DH

Morpho2DH is a calculation solver that a mud flow model is added to Morpho2D.
Morpho2D is the unsteady horizontal two dimensional bed deformation analysis solver which is developed by Hiroshi Takebayashi, Kyoto University. The governing equations are written in boundary fitted general coordinate system. In 2009, the solver was installed to RIC-Nays Version 1.0 which is the free software developed by RIC. Some functions are added to the original version and the improved version is installed into iRIC Version2.0 on March 2011. Morpho2D was unified with Nays2D and Nays2DH was developed. Hence, the development of Morpho2D was stopped on March 2014.

Morpho2DH is the horizontal two dimensional mud flow analysis solver which can reproduce the transport and deposition process of mud flow due to the landslides. Structures (ex. sabo dam, weir, house and so on) and horizontal distribution of erosion depth can be considered in the analysis.
Additionally, the unsteady horizontal two dimensional bed deformation analysis which can be performed using Morpho2D can be performed as it used to be.

I.2 Characteristics of flow model

① TVD-MacCormack scheme (2nd order accuracy) is used for the convection term in the momentum equations as the difference method.

② Energy dissipation is calculated by the constitutive lows of two layers model. The laminar flow layer near the bed and the turbulence flow layer on the laminar flow are considered in the two layer model.

③ Movements of the mixtures of water and sediment due to landslides are used as the initial conditions of debris flow

④ The horizontal distribution of maximum erosion depth can be considered.

⑤ Structures (ex. sabo dam, weir and so on) can be considered by use of the height data of the non-erosion area.

⑥ Obstacles (ex. houses and so on) in the calculation domain can be considered.

⑦ Vegetation can be considered as a drag force acting on the flow. The cover rate and the height of vegetation can be considered to estimate the drag force by introduction of the vegetation cover rate file and the vegetation height file.

II. Governing equations

II.1 Governing equations of flow

II.1.1 Governing equation (Takebayashi, Egashira and Fujita, 2014)

The mass conservation equation of water and sediment mixture is as follows (Egashira & Itoh, 2004);

$$\frac{\partial h}{\partial t}+\frac{\partial hu}{\partial x}+\frac{\partial hv}{\partial y}=\frac{E}{c_*} \tag{1}$$

where, t is the time, h is the flow depth, u and v are velocity in x and y directions, respectively. c_* is the deposition concentration of sediment in the static deposition layer, E is the erosion velocity of bed and the following equations are used here (Egashira & Itoh, 2004);

$$\frac{E}{\sqrt{u^2+v^2}}=c_*\tan\left(\theta-\theta_e\right) \tag{2}$$

where, θ is the bed slop along the flow direction and is calculated using the following equation;

$$\sin\theta=\frac{u\sin\theta_x+v\sin\theta_y}{\sqrt{u^2+v^2}} \tag{3}$$

where, θ_x is the bed slope in x direction and θ_y is the bed slope in y direction, θ_e is the equilibrium bed slope in flow direction refer to the depth averaged sediment concentration $\bar{c}$. As shown in Figure 4, if it is assumed that the laminar flow layer is formed near bed and the turbulence flow layer is formed on the laminar layer with constant depth averaged sediment concentration $\bar{c}$, following relationship is obtained.

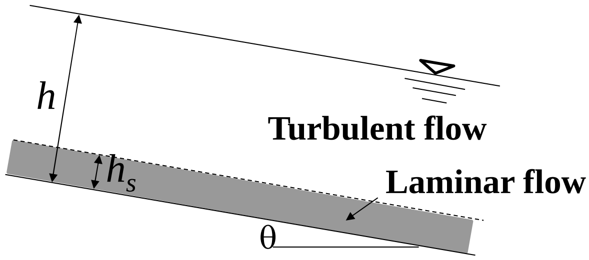

Figure II-1 Two layer mud flow model

$$\tan\theta_e = \frac{(\sigma/\rho-1)\bar{c}}{(\sigma/\rho-1)\bar{c}+1}\frac{h_s}{h}\tan\phi_s \tag{4}$$

where, ϕ_s is the angle of repose. The momentum conservation equations are as follows (Egashira & Itoh, 2004);

$$\frac{\partial hu}{\partial t}+\frac{\partial huu}{\partial x}+\frac{\partial huv}{\partial y}=-gh\frac{\partial z_b}{\partial x}-\frac{1}{\rho_m}\frac{\partial P}{\partial x}-\frac{\tau_{bx}}{\rho_m} \tag{5}$$

$$\frac{\partial hv}{\partial t}+\frac{\partial huv}{\partial x}+\frac{\partial hvv}{\partial y}=-gh\frac{\partial z_b}{\partial y}-\frac{1}{\rho_m}\frac{\partial P}{\partial y}-\frac{\tau_{by}}{\rho_m} \tag{6}$$

where, g is the gravity acceleration, z_b is the bed elevation, P is the pressure and is assumed to be the static pressure. ρ_m is as follows;

$$\rho_m = (\sigma-\rho)\bar{c}+\rho \tag{7}$$

where, ρ is the water density, σ is the sediment density, τ_{bx} and τ_{by} are shear stress in x and y directions, respectively. When the turbulence flow region is dominant, the shear stress is as follows;

$$\tau_{bx} = \left\{\tau_y + \rho f_b\left(u^2+v^2\right)\right\}\frac{u}{\sqrt{u^2+v^2}} \tag{8}$$

$$\tau_{by} = \left\{\tau_y + \rho f_b\left(u^2+v^2\right)\right\}\frac{v}{\sqrt{u^2+v^2}} \tag{9}$$

where, τ_y is the yield stress as follows;

$$\tau_y = \left(\frac{\bar{c}}{c_*}\right)^{\frac{1}{n}}(\sigma-\rho)\bar{c}gh\cos\theta\tan\phi_s \tag{10}$$

where, f_b is the friction coefficient as follows;

$$f_b = \frac{C_{mu}}{8}\alpha^2 \qquad \alpha = \kappa/6 \tag{11}$$

$$f_b = \frac{4}{25}\left\{k_f\frac{\left(1-\bar{c}\right)^{\frac{5}{3}}}{\bar{c}^{\frac{2}{3}}}+k_d\frac{\sigma}{\rho}\left(1-e^2\right)\bar{c}^{\frac{1}{3}}\right\}\left(\frac{h}{d}\right)^{-2} \tag{12}$$

where, C_{mu} is the resistance coefficient of mud flow. k_f=0.16, k_d=0.0828, e is the reflection coefficient, d is the mean diameter of the sediment. Bed elevation equation is as follows (Egashira & Itoh, 2004);

$$\frac{\partial z_b}{\partial t} = -\frac{E}{c_*} \tag{13}$$

＜References＞

Hiroshi Takebayashi, Shinji Egashira, Masaharu Fujita: Horizontal two dimensional analysis of mud flow occurred in Izuoshima Island on October 2013, Advances in River Engineering, Vol. 20, 2014.

Shinji Egashira, Takahiro Itoh: Numerical simulation of debris flow, Journal of Japan Society of Computational Fluid Dynamics, Vol. 12, No. 2, pp. 33-43, 2004.

III. Calculation condition

In this chapter, calculation condition of Morpho2DH is described by use of the setting dialog of iRIC.

III.1 Setting of calculation parameters

Calculation type and data (ex. calculation time and so on) are set.

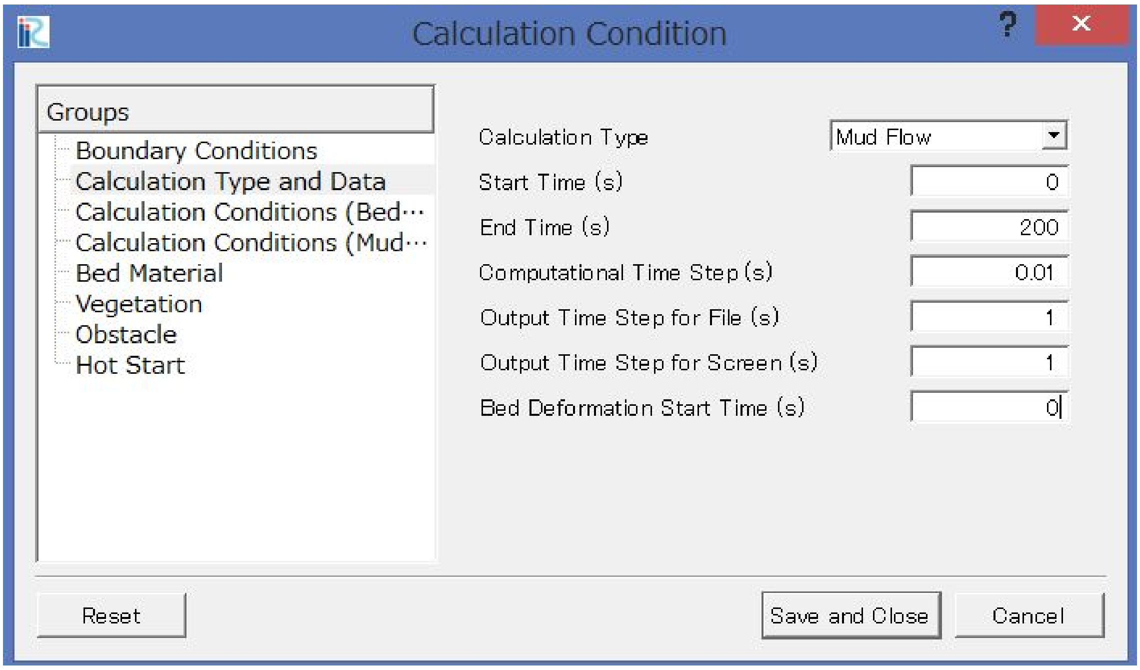

Figure III—1　Setting window of Calculation type and data

Table III—1　Explanation of setting of calculation parameters

#	Items	Setting method	Else
1	Calculation Type	Select [Flow only] for flow calculation or [Bed material load] for bed deformation analysis by bed material load or [Mud flow] for bed deformation analysis by mud flow	
2	Start Time (s)	Start time of the calculation is set.	Unit is second.
3	End Time (s)	End time of the calculation is set.	Unit is second.
4	Calculation Time Step (s)	Time step Δt is set.	Unit is second. The time step is decided considering CFL condition.
5	Output Time Step for File (s)	Output time step for file is set.	Unit is second.
6	Output Time Step for Screen (s)	Output Time Step of calculation condition for Screen is set.	Unit is second. Short time step

			makes the calculation time longer.
7	Bed Deformation Start Time (s)	Start time of bed deformation is set. Initial flow condition is made by the normal flow condition. In other words, the initial flow condition is not fit the governing equations of horizontal two dimensional flow. Hence, if bed deformation stars at the same time as the flow calculation, there is possibility that strange calculation results are obtained. Bed deformation analysis should be started after obtained the stable flow conditions. 0 must be used always for Mud flow calculation	Unit is second. When the calculation domain is long or water discharge is small, start time of the bed deformation should be late.

III.2 Setting of calculation conditions

Calculation conditions are set.

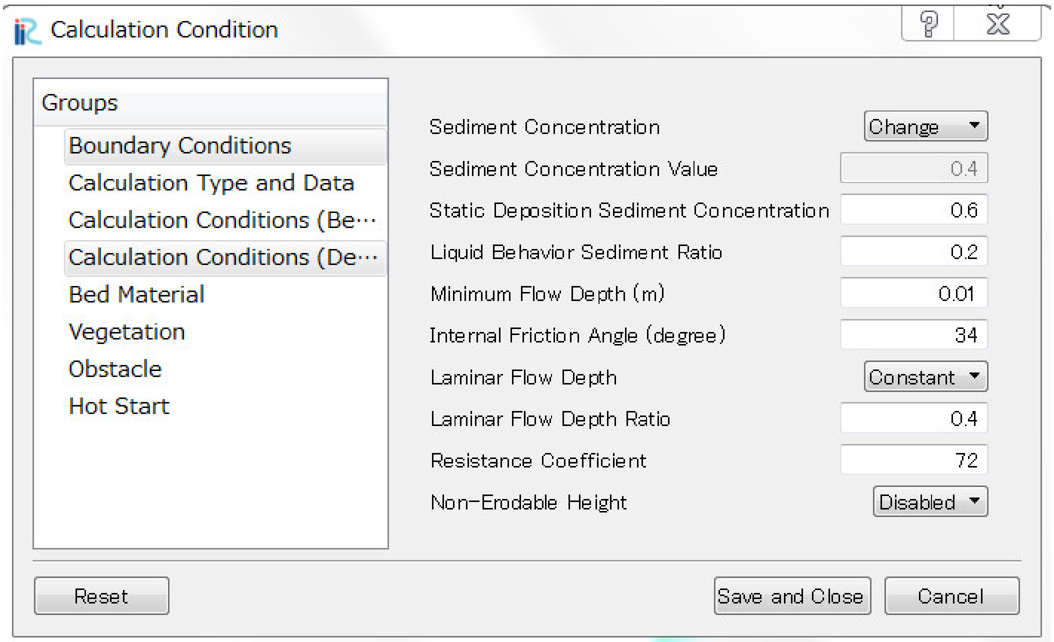

Figure III—2 Setting window of calculation conditions

Table III—2 Explanation of setting of calculation conditions

#	Items	Setting method	Else
1	Sediment Concentration	Please select [Constant] in case of mud flow, because temporal change of sediment concentration of mud flow is small under much condition.	
2	Sediment Concentration value	Sediment concentration of debris/mud flow is very high. The value must be smaller than 0.4.	
3	Static Deposition Sediment Concentration	Static deposition sediment concentration is between 0.54 and 0.8.	
4	Liquid Behavior Sediment Ratio	Fine material behaves as liquid phase. 0.2mm and finer diameter is rough standard to decide the value.	
5	Minimum Flow Depth	Minimum flow depth must be set to get stable calculation results. Smaller value is recommended. The unit is m.	
6	Internal Friction Angle	Input measured internal friction angle of the sediment.	
7	Laminar Flow Depth	When the temporal change of laminar flow depth is considered, please select [Change].	

8	Laminar Flow Depth Ratio	When the flow characteristics are debris flow, the laminar flow depth ratio is about 1. When the flow characteristics are mud flow, the laminar flow depth ratio must be smaller than 1.	
9	Resistance Coefficient	Value of resistance coefficient must be set to reproduce flow depth.	
10	Non-Erodible Height	When some parts of the bed composed of rock or sabo dams is set in the calculation area, please select [Enable] in [Non-erodible Height]. When [Non-erodible Height] is [Enable], the non-erodible height area must be set using polygons.	

III.3 Setting of bed material conditions

Bed material conditions are set.

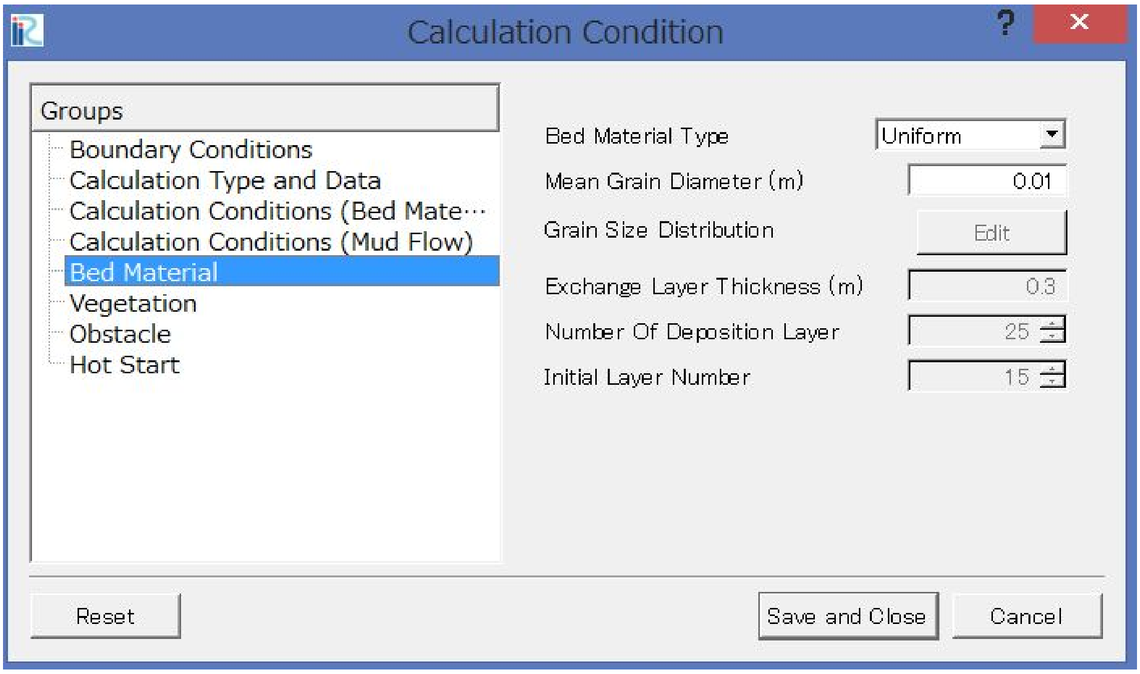

Figure III—3 Setting window of bed material conditions

Table III—3 Explanation of setting of bed material conditions

#	Items	Setting method	Else
1	Bed Material Type	When mud flow calculation is performed, please select [Uniform].	
2	Mean Grain Diameter (m)	Input mean grain diameter. This function is available only for uniform sediment.	Unit is m. In Morpho2D, mean diameter is used for the threshold value to judge wet areas or dry areas.

III.4 Setting of vegetation conditions

Vegetation conditions are set.

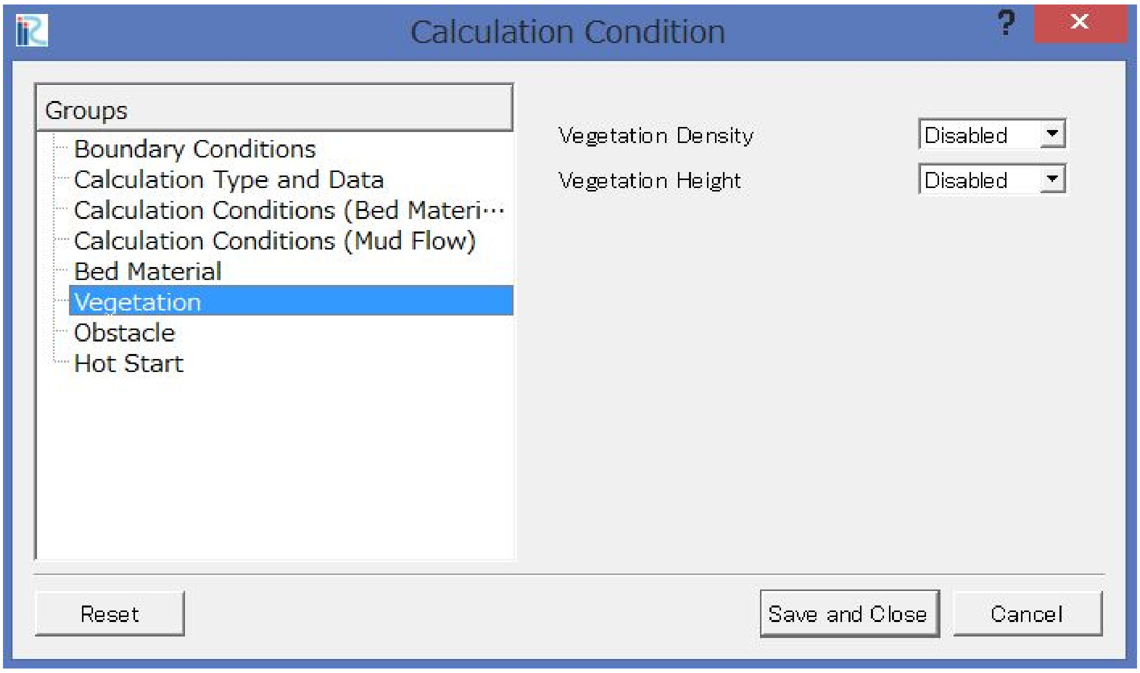

Figure III—4 Setting window of vegetation conditions

Table III—4 Explanation of setting of vegetation conditions

#	Items	Setting method	Else
1	Vegetation Density	If vegetation is considered, [Enabled] is always selected in [Vegetation Density]. Polygons of vegetation regions must be set and the vegetation density values must be inputted.	
2	Vegetation Height	If vegetation height is considered, [Enabled] is selected in [Vegetation Height]. Polygons of vegetation regions must be set and the vegetation height values must be inputted. If [Disabled] is selected in [Vegetation Height], the vegetation height becomes infinity.	

III.5 Setting of Obstacle condition

Obstacle conditions are set.

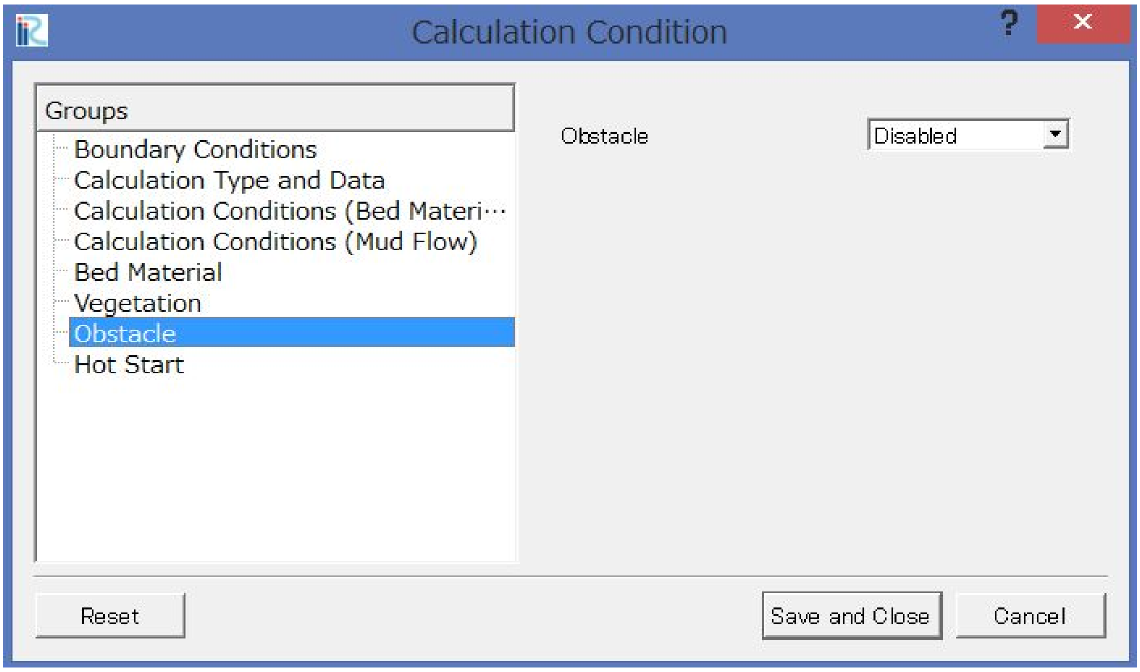

Figure III－5 Setting window of obstacle conditions

Table III－5 Explanation of setting of obstacle conditions

#	Items	Setting method	Else
1	Obstacle	If obstacles are considered, [Enabled] is selected in [Obstacle] and polygons of obstacle regions must be set.	

III.6 Setting of Hot start function

Hot start function is set.

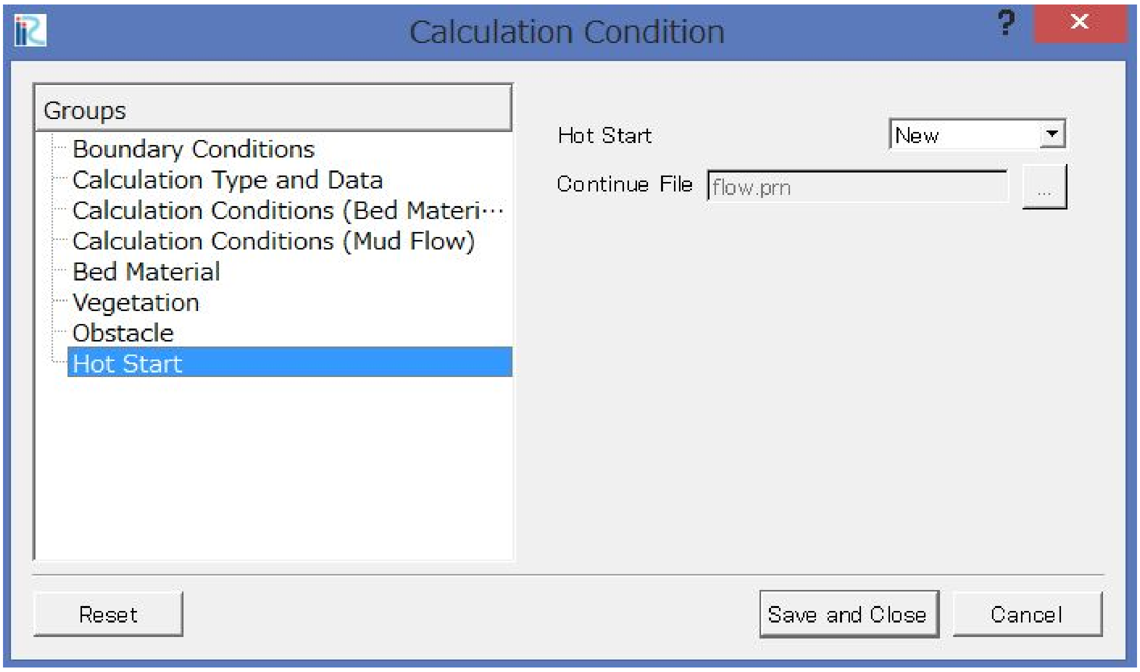

Figure III−6 Setting window of Hot start function

Table III−6 Explanation of setting of Hot start function

#	Items	Setting method	Else
1	Hot start	When users perform new calculation, please select [New]. When users want to start the calculation from the end of the previous calculation, please select [Continue].	
2	Continue File	In case of continue calculation, please load files in the previous calculation.	