BOUSSMO – A BOUSSINESQ APPLICATION FOR MODRAVA CATCHMENTS

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Mathematic model solving groundwater flow with Boussinesq equation for sloping bedrock was applied on Modrava 2 catchments in the Bohemian Forest in the Czech Republic. On Modrava 2 micro scale experimental mountain catchmet (0.17 km^2) are shallow haplic Podzol soils with forest clearing and young forest cover (Figure 1). Bedrock forms granite and gneiss weathered on the top or their detritus. Rainfall and outflow are measured in watershed outlet 50 m from spring of small stream. For derivation of one dimensional groundwater flow equation was used Boussinesq first approximation based on Dupuit. Equations were solved with finite difference method and Gauss elimination for sparse matrix a linearization was managed iteratively.

Figure 1. Experimental catchment Modrava 2

For application of mathematical model were used lumped and distributed approaches. Recharge to groundwater table was derived from measured rainfall reduced by interception and transformed with linear reservoir. Results show the possibilities of using groundwater flow model for simulation of stream response on mountain watershed with steep slopes and shallow soils.

The Boussinesq equation was used in following form.

$$\frac{n_e}{K\cos\alpha}\frac{\partial h}{\partial t}=\frac{R(t)}{K}\left(1+\tan\alpha\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial x}\left(h\frac{\partial h}{\partial x}\right)-\tan\alpha\frac{\partial h}{\partial x}$$

Where n_e is effective porosity, K hydraulic conductivity (L.T^{-1}),h – hydraulic head (L), R(t) – time dependent recipitation, α – the angle of plane. Using a simple iterative finite difference approach the equation was solved in following form

$$\frac{n_e}{K\cos\alpha}*\frac{h_{i,t2}-h_{i,t1}}{t_2-t_1}=\frac{R(t)}{K}+\frac{R(t)}{K}*\tan\alpha*\frac{h_i-h_{i-1}}{x_i-x_{i-1}}-\tan\alpha*\frac{h_i-h_{i-1}}{x_i-x_{i-1}}+$$
$$+\frac{\frac{guess_{i+1}+guess_i}{2}*\frac{h_{i+1}-h_i}{x_{i+1}-x_i}-\frac{guess_i+guess_{i+1}}{2}*\frac{h_i-h_{i-1}}{x_i-x_{i-1}}}{x_{i+1}-x_i}$$

Where $guess_i$ is a guess of hydraulic head at i – node.

This model was build as a sort of grey box approach. The catchment is assumed to behave similar to a flow on a sloped plane of a certain characteristics. The plane consists of both saturated and unsaturated zone. The dominance of unsaturated zone in this particular case is assumed to be of minor importance compared to the saturated zone. Recently no water content data are available for that catchment, thus a full black box approach was considered for the unsaturated zone, based on API indexing as the only possible solution. According to previous researches we assume that the catchment run-off is based just on a ground water flow. The value of the API index is related to a run-off retardation. If we assume, that the catchment behave as a sloped plane of certain characteristics, the whole problem is further converted into a so called grey box approach, as usual in hydrology, with its particular parameters which are going to be calibrated on using an inverse modeling methods.

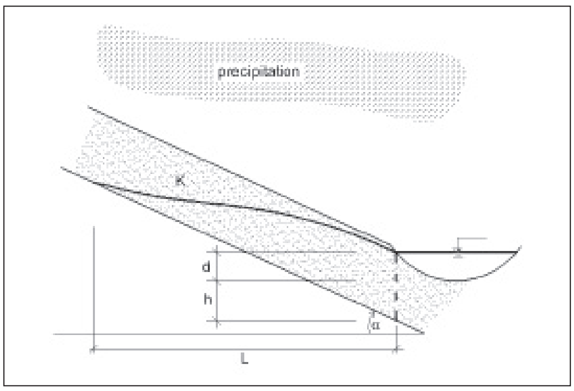

Figure 2. Hillslope profile for groundwater flow modeling, L – length of hillslope, α – slope of bedrock, h – depth of bedrock below the channel bottom, d – water depth in channel

The water profile is divided into two parts (Figure 2), the depth bellow the channel (h) and the channel depth. Water flow through the depth d goes directly to the channel and will be measured in closure profile. Water flow of channel depth h goes bellow the channel and is assumed to form an under leak, which is not possible to measure. Characteristics of plane – length L, h – depth, d – depth and b – width of the plane, α – angle formed with horizontal plane, will be analyzed on using inverse modeling methodology. Hydraulic conductivity is one of the few known values from hydropedological research. A run-off model on one dimension assumption will be constructed with aim to simulate episode events on catchment for some further research at our department.