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Runoff from snowmelt modeling with advanced hydroinformatic tools

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Abstract: Fast snow melting may trigger floods, landslides and debris movements, phenomena that can have serious consequences: loss of life and socio-economic damage. By modeling this phenomenon with advanced hydroinformatic tools can forecast with acceptable accuracy the maximum water discharges and levels in sections where a risk of significant damages is high, for various scenarios of snowmelt processes. In the case study, for modeling was used MIKE by DHI - MIKE11 software.
Keywords: runoff, snowmelt, hydroinformatic tool, modelling.

1. INTRODUCTION

Surface runoff resulting from snowmelt is an important factor of the water cycle. In areas with colder climates a great part of runoff in spring and river discharges arises from melting of ice and snow. Fast snow melting may trigger floods, landslides and debris movements, phenomena that can have serious consequences: loss of life and socio-economic damage (Figure 1). Flash floods that occur due to fast melting of snow are called nival floods.

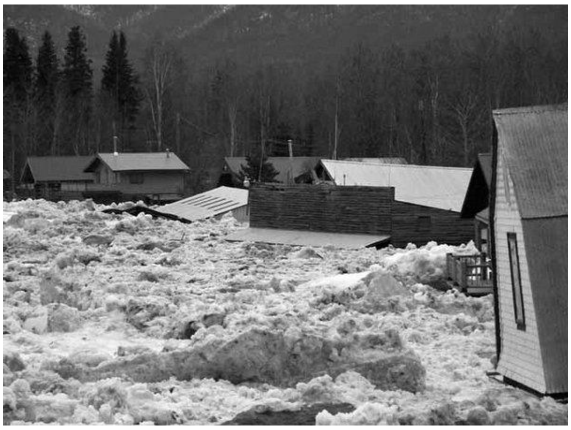

Figure 1. Floods caused by snowmelt (https://commons.wikimedia.org)

The factor that determine melt of ice and snow is temperature, which influences the formation of liquid and solid flow in rivers, through freezing - thawing phenomenon, also result the intensifies disintegration process of rocks. An accelerated increase in spring temperatures bring to sudden melting of snow and ice, with the consequence of the relatively fast growth of water levels and discharges and thaw formation in bends and in narrow cross-sections of watercourses (Figure 2).

Figure 2. Thaw (www.behance.net/gallery)

The landscape is natural factor with key role in the formation of the runoff, conditioning both the movement of water on hillslopes and solid particle motion. The characteristic elements of land topography by influencing runoff are: height, slope, shape, length and exhibition.

Other factors involved in the formation of runoff are: soil, vegetation, lithological factors or bedrock and social - economic factors (anthropogenic factors).

Modelling of runoff from snow and ice melt have importance especially in mountain and hillslope areas due to the fast concentration of runoff because of higher values of the slopes, in sections where are social-economic objectives in danger of being flooded.

Predicting snowmelt runoff from a drainage basin may be a part of designing water and soil erosion control projects. Also, simulation results can be the basis for development of exploitation regulations for those hydrotechnical arrangements.

Based on the results of modelling, local authorities and emergency inspectorates can prepare plans for warning and defense in case of dangerous phenomena caused by fast melting of snow. Also, measures to reduce the negative effects of fast snow melt must be included in river basin management plans.

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The simulation models of runoff from snowmelt are needed as primary data: the average temperature of the day, extending the area covered with snow and snow depth.

2. MIKE11 HYDROINFORMATIC TOOL

MIKE11 is an advanced hydroinformatic tool, professional engineering software package for simulation of one-dimensional flows in water bodies. MIKE11 is a 1-dimensional river model. It was developed by DHI Water • Environment • Health, Denmark.

MIKE11 have the following modules: Hydrodynamic Module (HD), Rainfall-Runoff (RR) Module, Sediment Transport (ST) Module, Water Quality (WQ) Module. The RR module includes the following methods: UHM, NAM, SMAP, Urban, FEH, DRiFT.

The snowmelt component of the runoff is incorporated as an integrated module within NAM (Figure 3); the temperature data is only required for simulation.

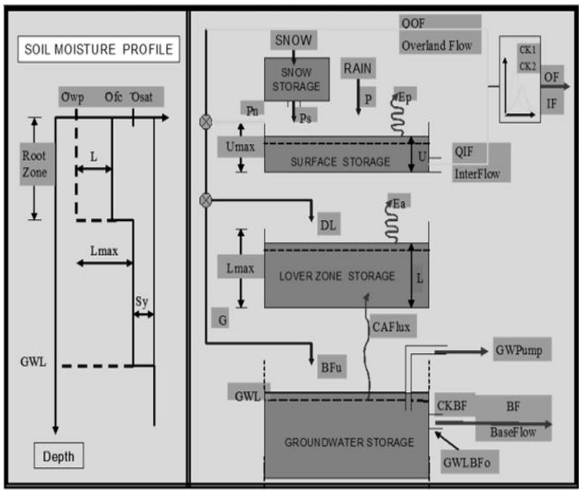

Figure 3. NAM model description (DHI, 2014)

Two different models can be applied; a simple lumped calculation or a more general approach that divides the catchment into a number of altitude zones with separate snow melt parameters, temperature and precipitation input for each zone. [3]

For this case study we use the simple lumped calculation method, because the studied watershed is small.

In the snow module it is assumed that the precipitation falls as rain when the air temperature is above a certain base temperature level, T_0, which can be specified by the user.

The snowmelt QS is calculated using the following equation:

$$QS = \begin{cases} C_{snow}\,(T - T_0) & \text{for } T > T_0 \\ 0 & \text{for } T \leq T_0 \end{cases} \qquad (1)$$

where C_{snow} is the degree-day coefficient. [3]

The generated melt water is retained in the snow storage as liquid water until the total amount of liquid water exceeds the water retention capacity of the snow storage. The excess melt water P_S is routed to the NAM model where it contributes to the surface storage. The excess melt water contribution P_S to NAM model is calculated by the following equation:

$$P_S = \begin{cases} Q_{melt} & \text{for WR} \geq C_{wr} \cdot S_{snow} \\ 0 & \text{for WR} < C_{wr} \cdot S_{snow} \end{cases} \qquad (2)$$

where WR is the water retention in the snow storage, C_{wr} is the water retention coefficient and S_{snow} is the snow storage. The new snow storage is calculated by subtracting the excess melt water P_S from the snow storage. Evaporation from the snow is neglected. [3]

3. CASE STUDY

In this case study was simulated the runoff from snowmelt by MIKE11 hydroinformatic tool in Valea Mare watershed, a component of Bega river catchments (Figure 4).

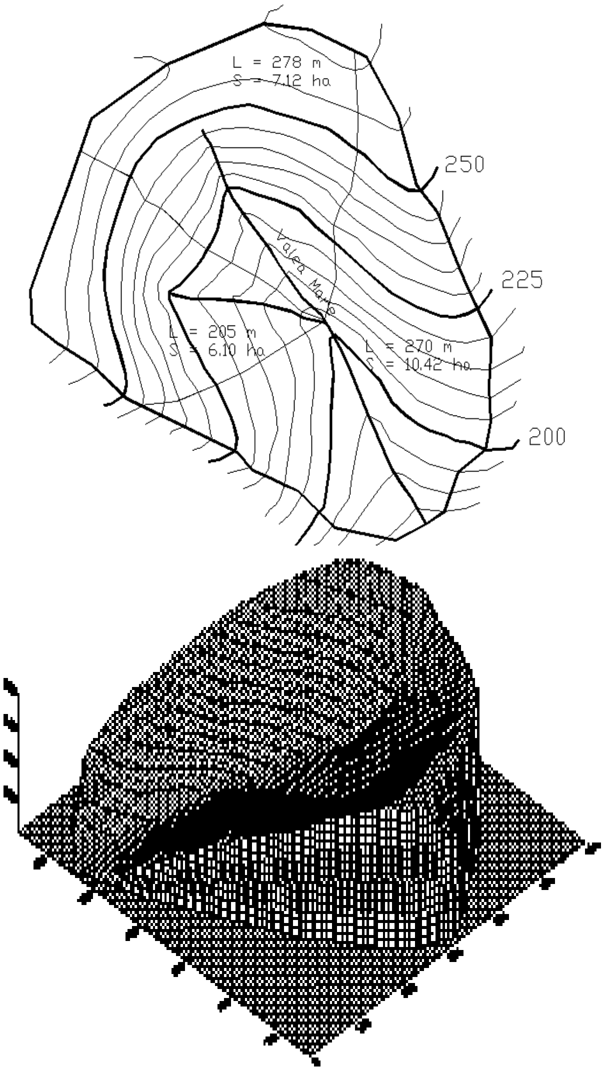

Figure 4. The studied area

Hypotheses and input data were:

- Catchment average slope - 20.64 %
- Total area - 23.54 ha
- Simulation period – 15 February 2016, 00:00 AM – 15 March 2016, 00:00 AM
- Time step – 30 minutes
- Rainfall is neglected
- Evaporation from the snow is neglected.

The parameter values can be seen in the figures 5, 6, 7 and 8.

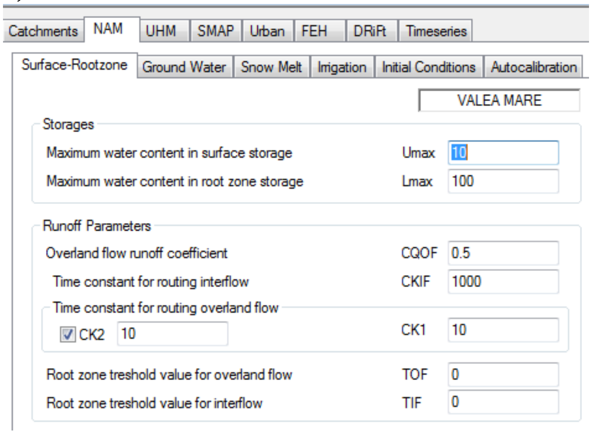

Figure 5. Surface – root zone parameters

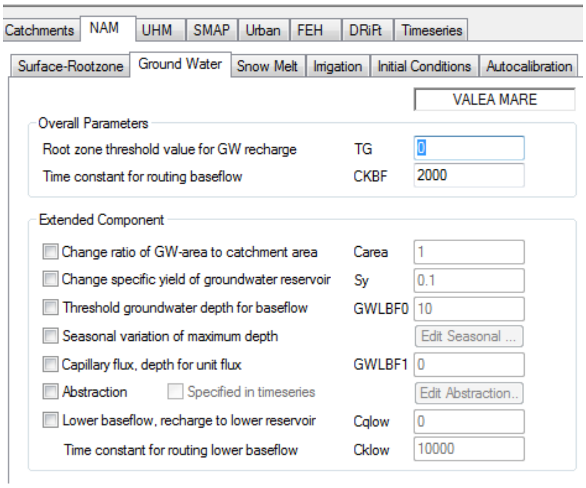

Figure 6. Ground water parameters

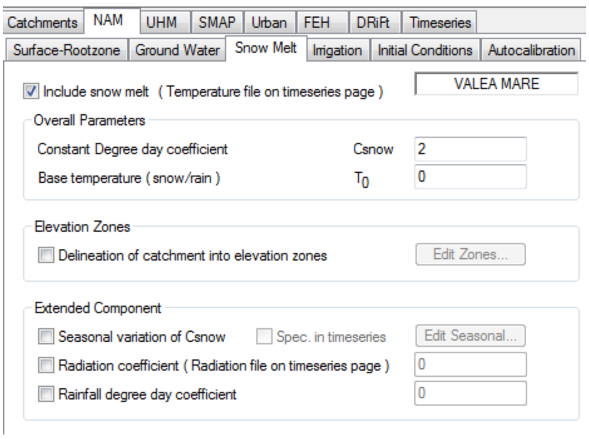

Figure 7. Snow melts parameters

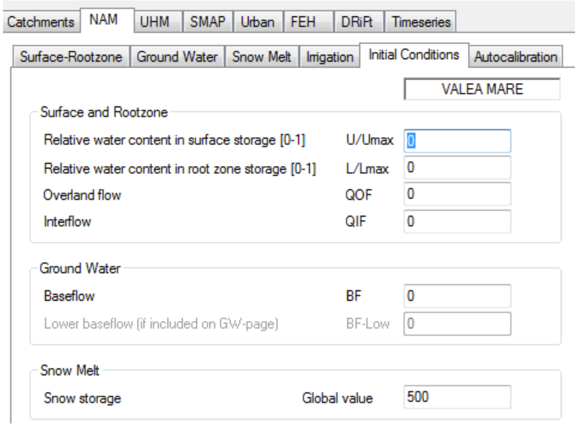

Figure 8. Initial conditions

The used time series are illustrated in figure 9.

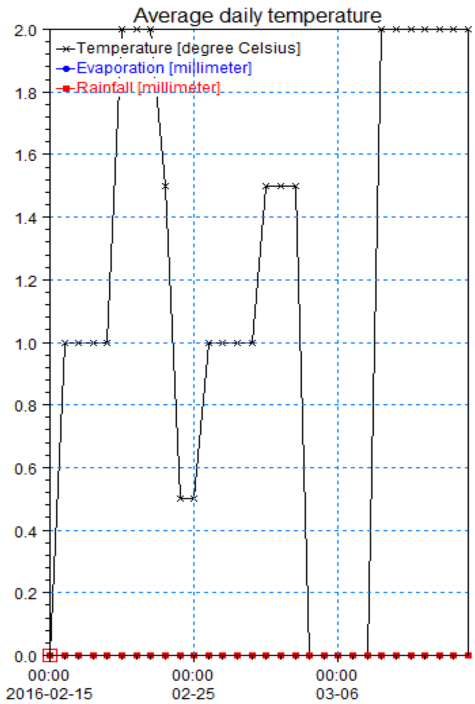

Figure 9. Time series

The obtained results from simulation are shown in figures 10 and 11.

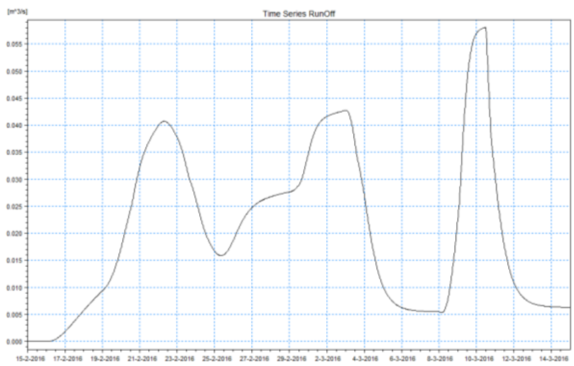

Figure 10. Time series runoff

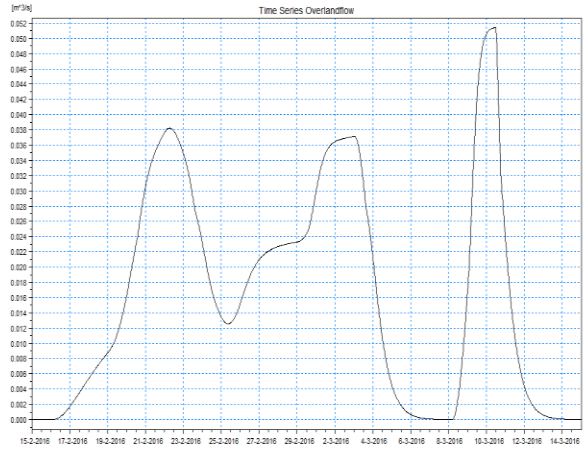

Figure 11. Time series overland flow

The maximum value of runoff is 0.055 m^3/s and maximum value of overland flow is 0.052 m^3/s.

The variation of snow cover thickness in simulation period is shown in figure 12.

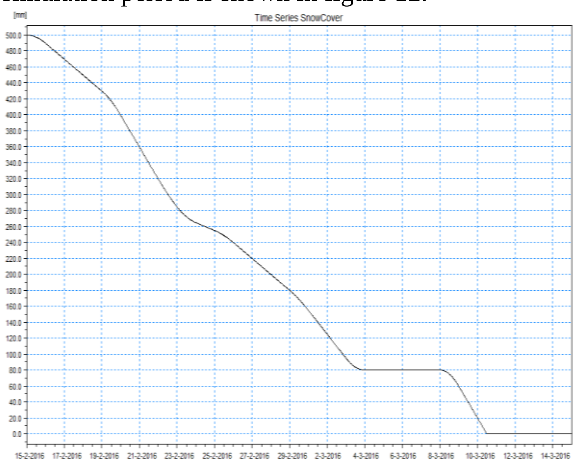

Figure 12. Variations of snow cover thickness

The discharges resulting from snow melting are not very high, because the average daily temperatures in the calculation period were within the specific climatological norms. If, however, the average daily temperatures were higher, then the resulting discharges would have higher values.

4. CONCLUSIONS

The anthropogenic greenhouse gas emissions, which increasing in last decades, have a disastrous impact on the global climate, which materialize in continental and regional scale changes in precipitation and temperature regimes. These changes can determine significant variations, in the negative sense, in the hydrologic regime, affecting surface and ground water resources.

The advanced hydroinformatic tools can be applied to evaluate the effect of a changed climate on seasonal snow cover and runoff. Based on the results obtained from modeling with these tools, in different scenarios, could be realized defense plans in case of floods in watershed with risk of flooding caused by fast melting of snow.

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