HYDROLOGICAL PROCESSES MODELLING USING ADVANCED HYDROINFORMATIC TOOLS

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ABSTRACT. Hydrological processes modelling using advanced hydroinformatic tools. The water has an essential role in the functioning of ecosystems by integrating the complex physical, chemical, and biological processes that sustain life. Water is a key factor in determining the productivity of ecosystems, biodiversity and species composition. Water is also essential for humanity: water supply systems for population, agriculture, fisheries, industries, and hydroelectric power depend on water supplies. The modelling of hydrological processes is an important activity for water resources management, especially now, when the climate change is one of the major challenges of our century, with strong influence on hydrological processes dynamics. Climate change and needs for more knowledge in water resources require the use of advanced hydroinformatic tools in hydrological processes modelling. The rationale and purpose of advanced hydroinformatic tools is to develop a new relationship between the stakeholders and the users and suppliers of the systems: to offer the basis (systems) which supply useable results, the validity of which cannot be put in reasonable doubt by any of the stakeholders involved. For a successful modelling of hydrological processes also need specialists well trained and able to use advanced hydro-informatics tools. Results of modelling can be a useful tool for decision makers to taking efficient measures in social, economical and ecological domain regarding water resources, for an integrated water resources management.

Keywords: water, hydrological process, modelling, hydroinformatic tools.

1. INTRODUCTION

The water has an essential role in the functioning of ecosystems by integrating the complex physical, chemical, and biological processes that sustain life. Water is a key factor in determining the productivity of ecosystems, biodiversity and species composition. Water is also essential for humanity: water supply systems for population, agriculture, fisheries, industries, and hydroelectric power depend on water supplies.

The modelling of hydrological processes is an important activity for water resources management, especially now, when the climate change is one of the major challenges of our century, with strong influence on hydrological processes dynamics.

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Terrestrial phase of the water cycle is the hydrological system. Inputs in the hydrological system, the total precipitation, are given by the sum of the amount of rainfall in the liquid and solid form, and of water result from condensation process from the soil surface. Final outputs are solid and liquid flow drained into the river, and the concentration of chemicals in the water (Fig. 1).

Hydrological system components are: runoff on hillslopes, groundwater runoff formation, solid and liquid flow into the river; component related to human influence.

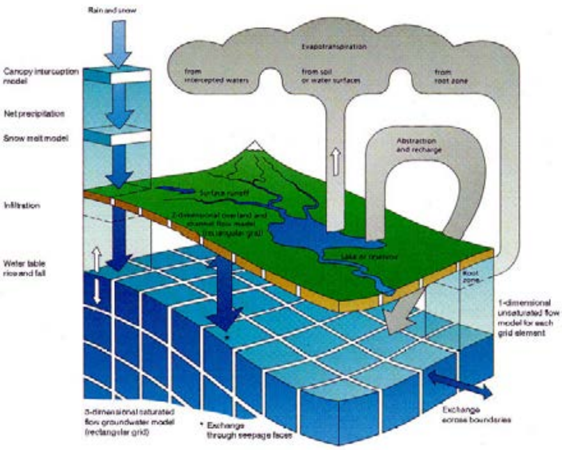

Fig. 1. Hydrological system (DHI – MIKE SHE)

Hydrological system consists of several phases. In a first phase, precipitation is intercepted by vegetation cover and then the depression areas of the earth's surface where water stagnates. From the rest of the water that reaches the soil surface result the superficial flow, respectively increases the soil humidity reserve, in the unsaturated zone. The second phase consists in two sub-phases, one in which part of the infiltrate water percolating in deep of soil or participate to forming underground leakage.

The second sub-phase is the groundwater, which flowing near the earth's surface, emerging after some time from the earth's surface, thus constituting hypodermic flow.

Phase three is the groundwater which percolating in deep of soil, being run underground, thus fueling groundwater accumulations, from which the water drained again reach the earth surface. (Apostol, 2011).

Hydrological response on a catchment is influenced by following factors that are related to: climatic conditions of the environment; rain (intensity and rain duration, spatial and temporal distribution); watershed morphology (shape, dimension, hillslopes' orientation); physical properties of the watershed (soil characteristics, vegetal coverage); structure of the hydrographic network (dimensions, hydraulic properties); previous soil humidity state.

Mathematical modeling of hydrological processes shows the huge complex concepts: concepts based on empirical observations, statistical and empirical concepts, and then progressing to conceptual modeling based on unit hydrograph, which combines laboratory research with reality, making modeling of the river basin through a system of canals and reservoirs that simulates translation and attenuation, and later to adopt the physical modeling on hydraulic principles of leakages in the river basins, approached the solving of processes by finite difference equations or finite element (Apostol, 2011).

2. HYDROINFORMATIC TOOLS

The term hydroinformatics was introduced by Prof. M.B. Abbott in 1992 and the inventor of the then neologism defined it as the integration of computational hydraulics and of artificial intelligence. Hydroinformatic put together single science disciplines in water management (hydrology, hydrogeology, water resources management, hydraulic) and informatics.

Computational hydraulics is the fusion of numerical methods of applied mathematics, hydrodynamics and hydraulics. Numerical simulation and modelling is integrated with artificial intelligence in single tools. The most consensual definition would be today that ”hydroinformatics is about making the best use of information technologies to manage water in the environment”. The management here means dealing with whole gamut of information, such as: data collection, measurement, interpretation, such as design of river basin management strategies including civil engineering structures, such as modelling (simulation) of river, groundwater and coastal flows and water quality to forecast natural events (floods) as well as the impacts of human activities. (EuroAquae, 2011)

Intense development of computer technique and referring areas, measurement technique, methodology of collection and data processing, results into creating tools for modelling of different water-related processes (hydrological, hydrogeological, hydraulical processes).

Use of hydroinformatic tools affects not only economic, ecological but also social aspects of environment. One from most widely used tools of hydroinformatic is mathematical model. (Mrnco et al., 2009)

Meanwhile in the recent past serious extreme hydrological phenomenas (floods, drought, pollution) occurred in Europe, EU member countries have been working on the implementation of the Water Framework Directive & Flood Directive. Huge infrastructural investments are and will be running. There is a need for proper understanding of hydrological system and landscape behaviour, possible prevention and measures, how to deal with potential damages and losses and having specialists skilled in the field related to development of water management infrastructure as well as in system operation, who are familiar also with the newest technological achievements, capable to develop area-adjusted solutions by understanding the national/country specific environmental processes. Flood risk management plan (must be finalized by end of 2015) is a communicator and disseminator tool of the knowledge gained during two previous stages across the horizontal structures of governmental and non-governmental bodies dealing with flood protection, flood mitigation and flood struggle in general. They mainly include proposals on how to reduce the losses of lives, property and environmental through flood prevention, protection of vulnerable areas and increased flood preparedness in each river basin.

The way of processing of flood, drought and pollution risk management plans on IT platforms changes the information stream flow. Future development plans of regions and cities will get a proper guidance and platforms for future feasibility studies. (David et al., 2011)

Some of the most powerful and used hydroinformatic tool for modelling of water-related processes are MIKE 11 (for surface water), developed by Danish Hydraulic Institute DHI -Water • Environment • Health.

3. MIKE 11

MIKE 11 is a hydroinformatic tool that simulates discharge and water level, water quality and sediment transport in rivers, flood plains, irrigation canals, reservoirs and other inland water bodies. MIKE 11 is a 1 dimensional river model. MIKE11 has long been known as a software tool with advanced interface facilities. Since the beginning MIKE11 was operated through an efficient interactive menu system with systematic layouts and sequencing of menus. It is within that framework where the latest 'Classic' version of MIKE 11 – version 3.20 was developed.

The new generation of MIKE11 combines the features and experiences from the MIKE 11 'Classic' period, with the powerful Windows based user interface including graphical editing facilities and improved computational speed gained by the full utilization of 32-bit technology.

The computational core of MIKE 11 is hydrodynamic simulation engine, and this is complemented by a wide range of additional modules and extensions covering almost all conceivable aspects of river modeling.

The most important modules of MIKE 11 are:

- HD module: it provides fully dynamic solution to the complete nonlinear 1-D Saint-Venant equations, diffusive wave approximation and kinematic wave approximation, Muskingum method and Muskingum-Cunge method for simplified channel routing. It can automatically adapt to subcritical flow and supercritical flow. It has ability to simulate standard hydraulic structures such as weirs, culverts, bridges, pumps, energy loss and sluice gates.
- RR module: it is rainfall runoff module, including the unit hydrograph method (UHM), a lumped conceptual continuous hydrological model and a monthly soil moisture accounting model. It includes an auto-calibration tool to estimate model parameter based on statistic data of comparison of simulated water levels/discharges and observations.
- AD module: it is advection-dispersion module. It simulates transport and spreading of conservative pollutants and constituents as well as heat with linear decay.
- ST/GST module: it is noncohesive sediment module. It simulates transport, erosion and deposition of non-cohesive and graded noncohesive sediments, including simulations of river morphology.
- ACS module: it is cohesive sediment module. It has 3-layer bed description, including quasi-2D erosion.

- ECO Lad module: it is ecological modeling. It can simulate BOD/DO, Ammonia, Nitrate, Eutrophication, Heavy metal and Wetlands. It includes standard templates that are well documented and have been used extensively in numerous applications worldwide. Based on predefined process templated, one can develop his/her own templates.

MIKE11 has been used in hundreds of application around the world. Its main application areas are flood analysis and alleviation design, real-time flood forecasting, dam break analysis, optimization of reservoir and canal gate/structure operations, ecological and water quality assessments in rivers and wetlands, sediment transport and river morphology studies, salinity intrusion in rivers and estuaries.(DHI, 2011)

4. EXAMPLE OF MIKE 11 APLICATION

For the rainfall-runoff hydrological process modeling was chosen the representative hydrographical basin Sebeş - Romania (Fig. 2). The representative hydrographical basin Sebeş is located in the north-west of the massive Muntele Mic, which is part of Ţarcu Mountains group (group Retezat-Godeanu, Carpathians). Sebeş River, with a length of 20,1 km in the closing section, drains an area of 142 km², is the right tributary of the river Timiş, the confluence is situated in Caransebeş town.

Because the data they provide, the representative hydrographical basins complement the work undertaken at experimental stations and basins, activity which is more accurate than in large river basins.

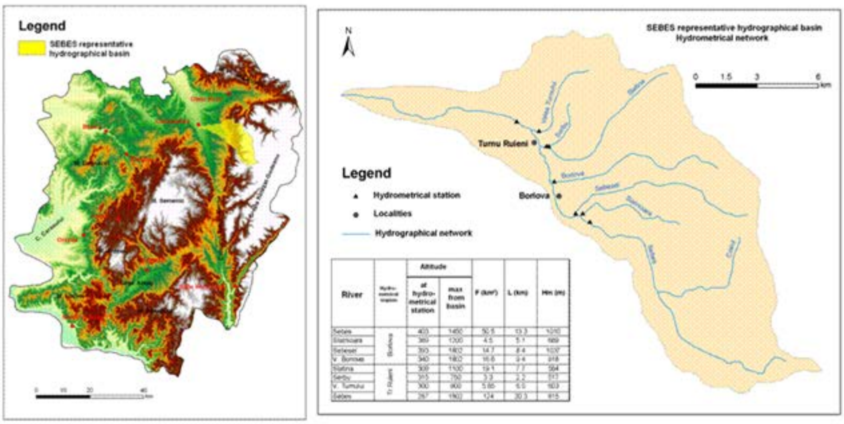

Fig. 2. Representative hydrographical basin Sebes in Caras – Severin county, Romania

In developing the network of representative hydrographical basins were taken into account to obtain information about the average, maximum and minimum flow, discharge of sediment transport, temperature of air and water, rainfall and river frost phenomena evolution. Considering the written above, was organized Sebeş representative hydrographical basin.

The representative hydrographical basin location took into account a number of physical and geographical criteria, and not only (various physical and geographical conditions, different shapes of watersheds, unimportant changes of natural runoff, groundwater flow uniformity, the existence of meteorological stations, the existence of electrical power network up to high altitudes, the existence of human settlements closer the observation points) (Fig. 2).(ANAR, 2012)

Input data requirements:

• Area of the subcatchment (GIS) – 50,50 km^2

• Hydraulical Lenght (GIS) – 13,30 km

• Land Use and percentage area of individual categories - mixed forest - coniferous, deciduous

• Soil Hydrologic Groups (A-D) and percentage area of individual categories – C

• Initial value of CN – 75

• Average Slope in the catchment (GIS) – 0,506

• Observed values: Rainfall: 1-7 August 2005, Borlova hydrometrical station, Runoff (for calibration): 1 – 7 August 2005, Borlova hydrometrical station

• Base flow – 1,07 m^3/s

• Time series step – 1 day

• Time step for simulation – 12 hours

The results of simulation are presented in Figure 3.

Model calibration consist in the comparison between the simulated hydrograph and observed flood event hydrograph (Fig. 4); the goal is that both hydrographs should be similar and the purpose is to get a real model of rainfall-runoff relationship in an individual catchment based on real observed data. For calibration can be use two methods for modifying uncertain parameters (CN curve numbers or Lag time).

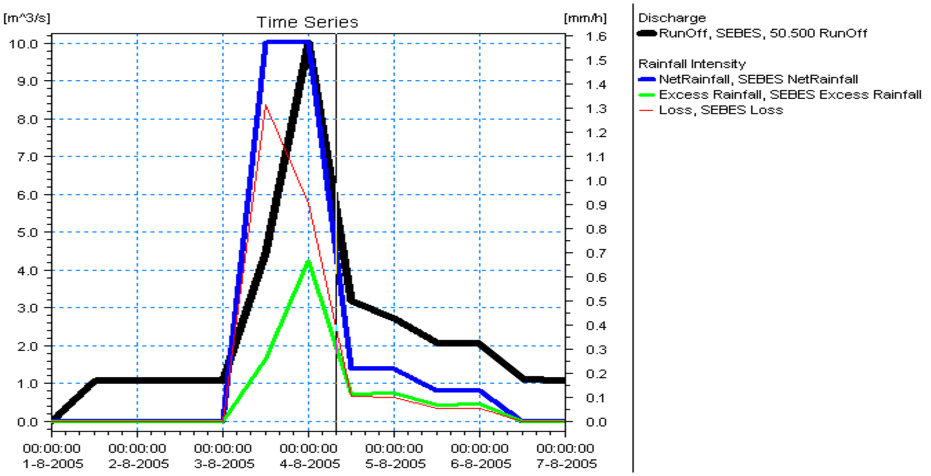

Fig. 3. Net rainfall, excess rainfall, loss and simulated runoff

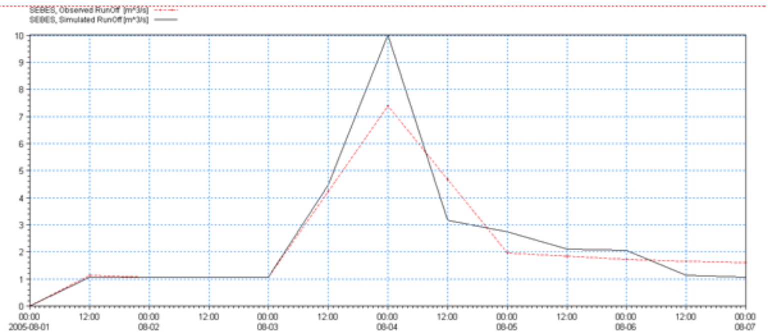

Fig. 4. Comparison between the simulated hydrograph and observed flood event hydrograph

Modification of CN curve consist in change the hydrological group of soil or change the CN curve number inside an default interval. For example mixed forest: minimum: 38 (HG A), respectively maximum: 81 (HG D). Do not go pass the limits. Modification of the Lag time make according to a geomorphological characteristics of an individual sub-catchment.

For this model calibration was modified CN curve number. For the value of CN 65, the maximum simulated discharge value result approximately equal with observed discharge (7,4 m^3/s) (Fig. 5). The differences between the observed and simulated hydrograph shape is due to the presence of small tributaries on the studied river. For a more accurate modeling should be known in detail the characteristics of these small tributaries and built a complex hydrodynamic model. Since it is a mountainous area may have difficulty in elevation data collection for longitudinal profiles and cross sections on these sectors.

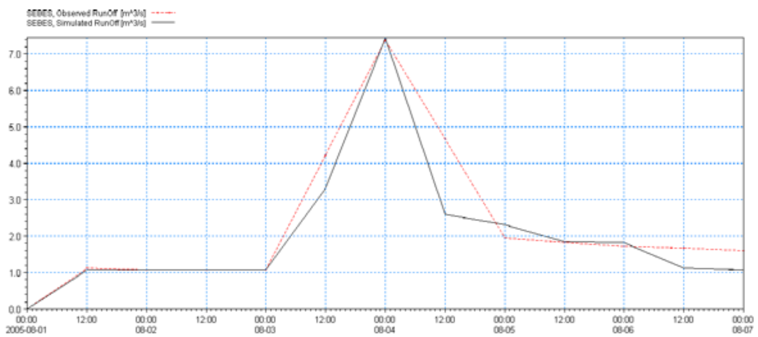

Fig. 5. Model calibration

5. CONCLUSIONS

For satisfactory precision of simulation results is needed more accurate measurements and data updates for studied hydrographical basin. This requires the development or updating of topographic surveys data, geomorphological data, climatic data, soil data, data about soil erosion and degradation, hydrological data, hydrogeological data, geotechnical data, vegetation and socio – economical data.

Simulation of rainfall-runoff phenomenon provides data on the characteristics of floods in downstream of closing sections of small watershed (discharges, levels). Based on these data may establish measures necessary to protect population and social – economical goods in zone of flash flood occurrence. The results of rainfall-runoff phenomenon simulation can use as input for the hydrodynamic module, allowing the flood wave propagation modeling in the main rivers from hydrographical basins.

For a successful modelling of hydrological processes also need specialists well trained and able to use advanced hydro-informatics tools. Results of modelling can be a useful tool for decision makers to taking efficient measures in social, economical and ecological domain regarding water resources, for an integrated water resources management.

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