

DEVELOPMENT OF A SENSITIVITY ANALYSIS APPLICATION FOR AN EVENT-BASED HEC–HMS RAINFALL-RUNOFF MODEL

A. Building and running the hydrological model

Hydrological modeling can be used for many purposes:

- forecasting flood events;
- representation of hydrological processes in natural or influenced environments (for continuous/ long-term simulations);
- estimating different components of the hydrologic systems that are important in water resources management or data analysis, but difficult to obtain through measurements/ direct observations etc.;
- estimating the impact of climate change on the hydrological regime of a basin area, by applying climate scenarios.

Once the purpose of the modeling is established, the user can decide on the type of software to use (physical, mathematical or analog model), choice that is dependent on the data available for the study area, as well as on the degree in which the basin area is known in terms of physical characteristics and processes.

Another step before building a model for the study area is to analyze and decide on the models/ methods to use for modeling each process of the system, because each method uses a set of equations that demand specific parameters. These parameters are to be determined/ established through calculations, from literature and/ or through calibration/ optimization.

HEC-HMS is a program that uses “collections” of mathematical models/ methods, each “collection” representing/ simulating a different hydrological process. All models in HEC-HMS are deterministic (use equations that describe known processes), but from case to case they can be lumped or distributed, empirical or conceptual, using measured or fitted parameters. Because of the multitude of models implemented in the program, HEC-HMS can be used for both, event or continuous modeling, but mainly for event simulation (with time intervals between a few hours and a few days).

The program needs 4 types of inputs: (i) state variables (that describe the known conditions met in a basin area, e. g.: the states of the soil), (ii) parameters (values that help describe the relation between inputs in the model and the output flow; these values can be modified to fit the model to the observed flow in the calibration/ optimization phase), (iii) initial conditions (values that describe the initial state of the basin, e. g.: the state of the soil, in terms of moisture, at the beginning of the simulation), (iv) boundary conditions (the factor that cause changes in the basins' system – most often: precipitation).

To build a model, the user has to follow four main steps:

1. Set up gage data, with meteorological and hydrological data series, read from file or manually entered): precipitation, air temperature, discharge (for optimization step) etc.

2. Create the basin model and choose the methods by which the main hydrological processes will be simulated:

a) The runoff volume model that determines what part of the rainfall infiltrates, what part runs off and when the runoff starts; for this module, the program has implemented 7 models/ methods. For the Siron river study case we used the SCS Curve Number method. This method uses (i) an initial condition: *initial abstraction* (the amount of precipitation infiltrated before surface excess flow results – it can be calibrated); (ii) a state variable: *impervious* (the impervious share of the basin area – it is calculated based on land cover types) and (iii) a parameter: curve number (expresses the runoff potential in relation to soil permeability, land cover and basin area – it can be calculated, approximated from literature and tables, as well as calibrated), with possible values between 0 and 100, where lower values indicate more permeable soils, thus a low runoff potential and conversely.

b) The direct runoff model that computes the hydrograph resulting from the effective rainfall. From the 7 models/methods available, the most suitable for our basin was considered the Snyder Unit Hydrograph. The two parameters to be calibrated are: *standard lag* (the time between the centroid of excess rainfall and the centroid of the resulting hydrograph) – dependent on some physical characteristics of the basin such as: basin area, slope, river network length, curve number (namely soil and land cover characteristics) and peaking coefficient.

c) The baseflow model which estimates the share of the discharge coming from the unsaturated zone and the sub-surface flow. The exponential recession method was chosen for Siron river simulation model (out of 4 other methods). We had to specify the *initial discharge*, the *recession constant* (can be calibrated or calculated by analyzing the hydrograph of observed discharge (in periods when the direct runoff stops) and a threshold (ratio to peak or discharge, here the first option was used) that can be approximated or calibrated (with values from 0 to 1).

3. Create the meteorological model, in which there has to be specified what method will be used for precipitation interpolation as well as the methods for computing evapotranspiration and snowmelt. For the storm event in our example we used just the precipitation model – Gage weights method.

4. Set the control specification, meaning the start and end date and time for the computation, as well as the time step (preferably of a higher resolution than the input data).

The next step in obtaining satisfactory results from the simulation is to perform a sensitivity analysis, by modifying the parameters and the state variables one by one, running the model after each change and comparing the results. The objective is to establish which are the parameters/ state variables that cause the most significant

changes to the hydrograph. These will be the parameters/ state variables that will be calibrated in the optimization phase.

After the sensitivity analysis, which can be accomplished with the applications developed in accordance with the assignment, we proceed to the next step, optimization of the model. This part consists in estimating the ranges (minimum and maximum values) in which each parameter/ state value is allowed to vary. The ranges for some of them can be set in accordance with the specifications found in the specialized literature. In calibrating state variables we must keep in mind what they express in terrain and not exaggerate their values just because the model fits better. The consequence of choosing a set of calibrated values that does not preserve the real conditions of the system is that the model will not give good enough results in tests and validation.

The outputs after running the program are processed precipitation files and data series on each type of flows: baseflow, excess runoff (coming from effective rainfall), infiltrated rainfall, total surface flow. Assessing all the result files after an attempt to optimize the model can provide essential information on what “goes wrong” and what parameters/ state values need further changes.