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Identifying the critical rainfall hyetograph for peak discharge estimation for design purposes

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The selection of the critical rainfall, i.e. the identification of the hyetograph duration and shape, is a crucial aspect of design flood estimation. Experienced engineers and hydrologists often assume that the rainfall duration coincides with the time of concentration of the catchment, which is then determined by using one of the widely applied empirical equations, or by comparing the results obtained by applying several of them. Once the duration is fixed, the total rainfall depth is generally derived from intensity-frequency-duration curves for a given return period and then distributed over the duration according to an a priori chosen pattern (e.g., uniform, triangular, Chicago etc.).

The purpose of this study is to investigate the effect on the estimation of the peak discharge by using: i) different equations for the time of concentration; ii) different hyetograph shapes; iii) different criteria for obtaining the excess rainfall hyetograph from the total rainfall one; iv) an iterative, model-based approach to determine the critical rainfall duration. The model used for calculating the excess rainfall is based on the SCS-CN equation, while the time-area method is applied for simulating runoff propagation over the catchment. Uniform and triangular shaped rainfall hyetographs are considered, while ten empirical formulae for determining the time of concentration are tested.

The study is performed on over 1,700 small catchments (< 2 km2) located in Valtellina, a mountain area in northern Italy highly exposed to flood risk. The results obtained with a 10-year return time rainfall show that, in general, a substantial underestimation of the peak discharge occurs (for both hyetograph types) when the rainfall duration is set equal to the time of concentration. In fact, a high difference between the times of concentration and the critical rainfall durations calculated with the iterative model-based approach was found in all catchments, with the latter exceeding the time of concentration of several times and peak discharge 20 to 80% higher.

We conclude that the incorporation of a critical rainfall duration concept, consistent with the modelling approach that is adopted, may contribute to improve the peak discharge estimation for design purposes. Additional research efforts will be aimed at the analysis of further hyetograph shapes and the consideration of a broader range of catchment areas to derive a practical and effective peak discharge estimation procedure.