



## Bivariate flood frequency analyses using Copula function

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The objective of the study was (1) to perform all steps in flood frequency analyses using Copula approach, (2) to select the most appropriate Copula function and (3) to evaluate the conditional bivariate return periods for the next pairs of variables: peak-volume, volume-duration and peak-duration, respectively.

Flood frequency analyses are usually made by univariate distribution functions and in most cases only peaks are considered in analyses. However, hydrological processes are multidimensional, so it is reasonable to consider more than one variable in analyses. Different marginal distributions can be used for Copula modelling. Copula function successfully models dependence between two or more depended variables and determination of marginal distributions and Copula selection are two separate processes.

Hydrological station Litija on the Sava river is one of the oldest stations in Slovenia and it lies in eastern part of country. 58 years of annual maximums were used for analyses and three-points graphical method was used for base flow separation. The log-Pearson type 3 distribution was selected as marginal distribution of peaks and durations, the Pearson type 3 distribution was chosen as marginal distribution of volumes. Some frequently used Copula functions from the Archimedean (Gumbel-Hougaard, Frank, Joe, Clayton, BB1 and Ali-Mikhail-Haq), Elliptical (Student-t and Normal) and Extreme value (Galambos, Hüsler-Reiss and Tawn) families were applied to the data. Copula parameters were estimated with the method of moments based on the inversion of Kendall's tau and with the maximum likelihood method. Graphical and statistical test were applied for the comparison of different Copula functions.

For the pair peak-duration the Kendall correlation coefficient was negative and only Copulas able to model negative dependence were used. The Gumbel-Hougaard, Frank and Ali-Mikhail-Haq Copulas were selected as optimal based on tests results for the pairs: peak-volume, volume-duration and peak-duration, respectively. Conditional return periods, including OR and AND cases, were determined as results of the study.