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Integrating historical information, systematic data, and rainfall-runoff modelling to improve flood frequency estimates

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Abstract

Flood frequency curves are usually fitted to short time series of observations, leading to great uncertainties mainly for high return periods. However, reliable estimates are required for designing and assessing safety of hydraulic infrastructure, such as bridges and dams. Therefore, flood frequency analyses based on instrumental data collected at gauging stations can be improved by incorporating available information about historical floods before the beginning of the systematic period. This study presents how to identify and integrate all the information available, in order to improve flood frequency curve estimates. The Cuevas de Almanzora Dam located in southeast Spain is selected as case study.

The Cuevas de Almanzora Dam catchment has an area of 2122 km^2 with a mean annual precipitation of 316 mm. However, daily precipitation can be higher, such as 600 mm for the 1973 flood event. Flood data are available at a gauging station located in the River Almanzora upstream of the dam, with a draining catchment of 1850 km^2. The systematic period is 1963-2008 with information about 36 annual maximum floods. The largest flood in the 20^{th} century was recorded at the gauging station in 1973. A two-dimensional (2D) hydrodynamic model of the River Almanzora was calibrated with such information.

Historical information about floods has been collated from local newspapers, books, chronicles, research papers, photographs, national archives of historical floods, and municipal archives. The three largest floods in the River Almanzora between 1830 and 1963 were identified, extending the systematic period to a total period of 191 years. Information about water depths and flood extensions at different cross sections of the River Almanzora were collected. The 2D hydrodynamic model was used to estimate the peak discharges in such historical flood events.

After the end of the systematic period, the hydrograph of the great 2012 flood event was estimated from the data recorded at the Cuevas de Almanzora reservoir. A rainfall-runoff model was calibrated in the catchment with 1-h precipitation data to estimate the flood hydrograph at the gauging station.

The five historical floods that exceed the perception threshold in the period 1830-2020 were

integrated with the annual maximum floods extracted from the systematic data, using five techniques to incorporate historical information in the flood frequency curve. The Generalized Extreme Value (GEV) and the Two-Component Extreme Value (TCEV) distribution functions were considered. The best fit was selected considering the accuracy and the uncertainty of estimates by a stochastic procedure. Flood quantiles for the highest return periods triple the estimates obtained by using only the systematic data.

The methodology proposed can improve the reliability of flood quantile estimates, mainly in arid regions where the lack of information about the rare greatest flood, which can exceed several times the mean magnitude of floods in the systematic period, can lead to strong underestimates for the highest return periods that are needed to design and assess the safety of hydraulic infrastructure.

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