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Should we use peak discharge or hydrograph volume and shape in the probabilistic design of dam spillways?

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Probabilistic analyses are fundamental for the proper evaluation of hydrological dam safety for a given spillway configuration. An inflow hydrograph arriving into a reservoir produces different peak outflows (and maximum reservoir levels) depending on the reservoir and spillway characteristics. Therefore an integral analysis is necessary for the probabilistic evaluation of hydrologic dam safety. In the usual professional practice this process is based on simplifying hypotheses which introduce significant uncertainties on the safety level of the design. In cases where the peak flow attenuation due to the routing effect is considered small, peak inflow may be directly used for the design of the spillway, since the uncertainty associated to the estimation of peak inflow for a given return period is similar to the uncertainty introduced by the additional hypotheses on hydrograph shape and volume which are required to account for the peak attenuation effect. In cases where peak attenuation is considered important, the probabilistic analysis is usually carried out before hand, deciding on a "design flood" associated to a given probability of exceedance or return period. The design flood is then routed through the reservoir to obtain the maximum reservoir level, which is assumed to correspond to the same return period as the design flood. In this paper, a fully integrated probabilistic methodology is presented. The methodology aims at the characterization of the ensemble of hydrographs that constitute the hydrologic forcing of a dam under flood conditions. A Monte Carlo simulation framework was been developed to generate a large number of cases of flood hydrographs, which were routed through the reservoir. The methodology was used to asses the necessity to fully characterize the inflow hydrograph (volume and temporal distribution) in the evaluation of hydrologic dam safety. The methodology is based on results obtained from the analysis of a large number of reservoir configurations (190) in 22 dam sites located in Spain. As result, the analysis shows that the attenuation coefficient (ratio of peak outflow to peak inflow) can be estimated from the reservoir routing coefficient (ratio of the inflow hydrograph volume for a given return period to the reservoir flood control volume). This coefficient is easily computed from usually available information and can be applied to estimate the peak flow attenuation effect in most reservoirs. As conclusion, the methodology allows, according to the peak flow attenuation effect and a given threshold, to decide whether to use the peak inflow or to carry out further analysis to fully characterize the ensemble of inflow hydrographs and route them through the reservoir in order to design a dam spillway or to evaluate the safety of an existing dam.