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Application of stochastic differential equation to reservoir routing with probabilistic inflow forecasting and flood control risk analysis

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Real-time flood control of a reservoir system involves various uncertainties including the prediction uncertainty of inflow flood events, uncertainties in boundary conditions such as the reservoir storage curve, release capacity curve, and the uncertainty within the reservoir flood routing model itself. In this study, the hydrologic uncertainty processor (PUB) under the framework of Bayesian forecasting system (BFS) is adopted to quantify the uncertainty of flood prediction, providing with the probabilistic forecasting for real-time flood events. A Gaussian form of distribution is used to describe uncertainty of reservoir storage or release capacity; parameters of the distribution are estimated by historical measurements. In order to route the flood hydrograph with probability feature, i.e. a probabilistic forecasting flood event, stochastic differential equation (SDE) is introduced to build the reservoir flood routing model. By introducing a Gaussian white noise term, the traditional reservoir's water balance equation is altered to a kind of Ito stochastic differential equation. The solutions of Ito equation provide a probabilistic form of forecasting for reservoir stage process and outflow hydrograph. Both the analytical and numerical approaches are applied to solve the Ito stochastic differential equation, and their applicability for reservoir stochastic flood routing is testified. By assigning a specific flood limit level or reservoir beginning water level on which a real-time flood event is started to route through using the SDE, a corresponding probabilistic reservoir stage processes can be forecasted. For a designed control water level (DCWL), the risk rate or the largest probability that the forecasted reservoir stage excesses DCWL can be computed. Setting a series of flood limit levels, for a forecasted probabilistic inflow hydrograph, there obtains the corresponding reservoir stage processes, and in turn the risk rate of flood protection. By checking if the risk rate is less than a preassigned acceptable risk or flood control standard, a reasonable flood limit water level is determined to raise the utilization ratio of flood resources. As an example, the approach is applied to Dahuofang reservoir, which is located on Hun river in Northeast China. A typical flood event occurred in the flooding season of 2005 is analyzed to demonstrate the application of proposed procedure.