ABSTRACT

Dams and reservoirs with multiple purposes require effective management to fully realize their purposes and maximize efficiency. For instance, a reservoir intended mainly for the purposes of flood control and hydropower generation may result in a system with primary objectives that conflict each other. This is because higher hydraulic heads are required to achieve the hydropower generation objective while relatively lower reservoir levels are required to fulfill flood control objectives. Protracted imbalances between these two could increase the susceptibility of the system to risks of water shortage or flood, depending on inflow volumes and operational policy effectiveness. The magnitudes of these risks can become even more pronounced when upstream use of the river is unregulated and uncoordinated so that upstream consumptions and releases are arbitrary. As a result, safe operational practices and risk management alternatives must be structured after an improved understanding of historical and anticipated inflows, actual and speculative upstream uses, and the overall hydrology of catchments upstream of the reservoir. One of such systems with an almost yearly occurrence of floods and shortages due to both natural and anthropogenic factors is the dual reservoir system of Kainji and Jebba in Nigeria.

To analyze and manage these risks, a methodology that combines a stochastic and deterministic approach was employed. Using stochastic methods outlined by Box and Jenkins (1976), autoregressive integrated moving average (ARIMA) models were developed for forecasting stream inflows based on twenty-seven-year-long historical inflows (1970-1996) at the Kainji reservoir. These were then validated using seven-year inflow records (1997-2003). The model with the best correlation ($R^2 = 0.87$) was a seasonal multiplicative ARIMA (2,1,1)x(2,1,2) model. Supplementary validation of this model was done with discharge rating curves developed for the inlet of the reservoir using in situ inflows and satellite altimetry data. By comparing net inflow volumes with storage deficit, flood and shortage risk factors at the reservoir were determined based on (a) actual inflows, (b) forecasted inflows (up to 2015), and (c) simulated scenarios depicting undefined competitive upstream consumption.

Calculated high-risk years matched actual flood years again suggesting the reliability of the model. Monte Carlo simulations were then used to prescribe safe outflows and storage allocations in order to reduce futuristic risk factors. The safety levels achieved showed that this methodology is a powerful tool for estimating and managing flood and shortage risks in reservoirs with undefined competitive upstream consumptions.