DAILY COORDINATED MULTI-RESERVOIR OPERATING MODEL WITH MULTIPLE OBJECTIVES

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An efficient operating plan for multiple reservoir systems should be developed based upon the effect of long-term storage and short-term release policies. The short-term planning model is supposedly capable of achieving the long-term storage target while meeting the changes in hydrologic conditions and water demand. In order to analyze and determine the daily release decisions of each dam in coordination with other dams in the basin for real-time operation, we developed a multiple objective mixed integer preemptive goal-programming (MOMIPGP) model. We assumed that the monthly target storages can be assessed by a stochastic monthly operating model in higher hierarchy of the decision process, and that the daily inflows for the next few days could be predicted in advance, while using the yearly averages thereafter. The monthly storage target may be provided by the sampling stochastic dynamic programming (SSDP) model based on ESP (Ensemble Streamflow Prediction), and that the monthly target can be attained by the Goal Programming approach.

The model is designed to simulate the coordinated daily operation among dams in the basin as a whole to provide information for establishing efficient daily operating policies. The logic behind the model is based on five principles. 1) Holistic approach, 2) Water conservation approach, 3) Deterministic approach, 4) Sustainable Water Supply, and 5) Assistance in decision making. To alleviate the inflow uncertainty, we use the results of the SSDP based on ESP as the long-term (monthly) storage target. The short-term operational characteristics such as river routing, and the nonlinear effect on hydro-electric power generation are also considered. To account for the effect of daily river routing, the concept of lagged time water conveyance is developed as a function of the volume of water released. This concept is incorporated into the mixed integer goal programming model to simulate the process of determining progressively the timing and the amount of water delivered to the downstream channel in each reach. An iterative linear approximation technique associated with the hydro-electric power generation is also used to deal with the nonlinear factor in hydro-electric energy maximization.

The basic objective function is represented by the weighted-sums of multiple objectives such as minimization of shortages, minimization of spill, maximization of storage, maximization of hydropower energy generation and attaining goal programming targets. However, some of multiple objectives conflict with each other, so we need multiple objective analysis. In the multiple objective analysis, it is desirable to provide a dam operator with a wide range of choices of Pareto-optimal solutions since the reservoir operation plan must be developed based on the dam operator's intuitive interpretation of storage variation of each reservoir as well as the utility values implied from the tradeoff relationships between storage and hydroelectric energy generation. Therefore, we focus on the ability of generating well-distributed Pareto-optimal solutions at each iteration and pinpointing a final solution properly. To facilitate pinpointing a final solution, we suggest the use of the CBITP (Convex hull of individual maxima Based Interactive Tchebycheff Procedure), which would provide the DM with the most preferred daily release decisions in coordination with other dams in the basin. It parameterizes the Pareto-frontier via the set of the reference point vectors instead of varying weight vectors as in the interactive Weighted Tchebycheff Procedure. It uses a sequence of a progressively reduced subset of reference points interacting with the dam operator so that he can choose a sequence of the Pareto-optimal solutions. Using well-distributed reference point vectors, we could identify widely distributed Pareto-optimal solutions and reduce the chance of losing the most preferable Pareto-optimal solution from the dam operator's utility point of view. And object-oriented techniques are employed, so that facilities in the basin can easily be added, modified or deleted.

Keywords: Mathematical model; Daily reservoir operation; Multiple objective model; Tchebycheff reference point approach, Well-distributed Pareto-optimal solutions; Water supply; Multiple reservoir operation