A Reservoir Operation Scheme for Integrated Water Resource Modelling

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There are more than 2700 dams in Japan with the purpose of flood control, power generation, irrigation water and industrial water, etc. Dam operation has considerable potential impact on water cycle. This study developed a reservoir operation scheme for integrated water resources modelling. An operation rule was developed for each reservoir based on effective reservoir capacity, purposes, dam inflow, seasons, and water demand in the downstream. Taking Nagano and Gifuprefectures as case study, 12 dams with storage capacity more than 10 million cubic meters were selected. To date, the validation by comparing simulated dam outflow and observations indicated 10 of dams had the value of NSE > 0.5. In the near future, this scheme was validated by changes in the performance of an integrated water resource model with this scheme or not in the Kisogawa River Basin. Then, future changesin water resources and river discharge under climate changewill be predicted by using the integrated water resources model with reservoir operation schemein the Kisogawa River Basin.
Keywords: Dams, water resource model, hydrology, irrigation

1. Introduction

In Japan, more than 2700 dam reservoirs have beenconstructed for various purposes such as power generation, disaster management, irrigation waterand industrial water, etc.Water regulation by dam operations has considerable effects on natural water cycle. For example, storing water in rainy season and releasing in dry season may decrease base flow of downstream in rainy season and increase it in dry season. It is necessary to consider dam reservoir operations in water resource modelling. The problem is how to incorporate reservoir operations into water resource models. This study developed a new algorithm for simulating individual dam operation in a water resource model.

2. Methods

2.1 Reservoir operation scheme

According to the requirements of the water resource model development by our research group, the dams were divided into two categories based on intended purposes. First category is the dams for irrigation water or disaster management (drought and flood). Second is the ones without the purposes of irrigation water and disaster management. For the second one, the dam outflow was set same as inflow. For the first category, the operation rules were shown in Fig.1The dam capacity was divided into three levels, minimum capacity (Vmin), normal top capacity (Vuc, the values in rainy and dry season would be different) and effective top maximum (Vmax). The algorithm is:

$$Q = 0 \quad if\ V \le Vmin$$

$$\mathrm{Q} = \begin{cases} Qwet & if\ Vmin < V \le Vuc\ in\ rainy\ season \\ Qdry & if\ Vmin < V \le Vuc\ in\ dry\ season \end{cases}$$

$$Q = k \times \left(\frac{V - Vuc}{Vmax * r}\right)^{p} \quad if\ Vuc < V < Vmax$$

$$Q = inflow \quad if\ V \ge Vmax$$

whereQwet and Qdry are certain percentiles of daily inflow; k, r and p are coefficients. If outflow (Q) less than downstream water demand (Qdemand) multiplied by the coefficient of a, then Q = a*Qdemand.

The value of each parameterwasevaluated by sensitivity test. The Qwet and Qdry were 85% and 45% percentile of inflow. The values of k, r, p were 0.8, 0.02 and 0.35 respectively.

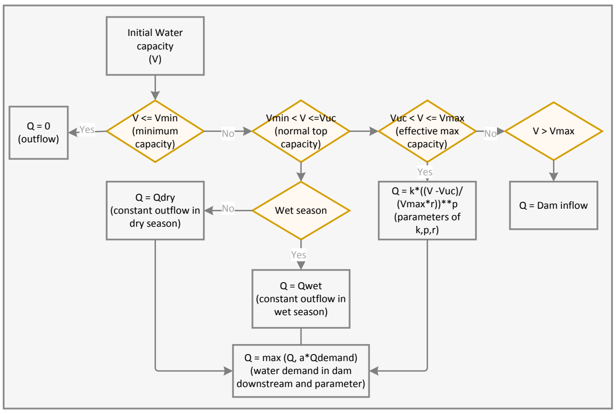

Figure 1Schematic diagram of dam operation

2.2 Case study

The integrated water resource model was applied in Nagano and Gifu prefectures to validate the model performance and evaluate the effects of climate change on water resource and river discharge. First, 12 dams with storage capacity more than 10 million cubic meterslocated at Nagano and Gifu prefectures (shown in Table 1) were selected to validate the performance of developed operation scheme. Using observationsof dam inflow as input, the performance in terms of Nash-Sutcliffe Efficiency (NSE) was estimated by comparing the simulated and observed outflow. Then, the performances of integrated water resource model with the reservoir operation scheme or not were evaluated by comparing simulated and observed river discharge at several stations located at the downstream of dams in the Kisogawa River Basin. The index of Root Mean Square Error (RMSE) andNSE were used.There are 7 of 12 dams in the Kisogawa River Basin. Finally, the water resource model including reservoir operation scheme was used to predict the future changes in water resources and river discharge in the Kisogawa River Basin.

3. Results and Future

The results of validation on 12 dams were shown in Table 1. For the dams with the ratio of effective top capacity and annual mean total inflow less than 0.2, the performances were better than the ones with the value more than 0.2. The values of NSE were more than 0.5 in 10 of 12 dams. This scheme cannot present the outflows in Iwaya dam and Tokuyama dam. The reason requires more study in depth. The inflow, simulated outflow and observed outflow at the dams of Misogawaand Omachi were indicated in Fig.3. To date, the results on the application of water resource model in the Kisogawa basinand water resource prediction are not completed, which will present in the future.

Table 1 Validation results on the dams with capacity more than 10^6 m^3

Dam name	Data period	NSE	Effective capacity/annual mean total inflow
Misogawa	1996-2014	0.53	0.577
Omachi	1993-2014	0.97	0.052
Koshibu	1993-2014	0.594	0.181
Miwa	1993-2014	0.697	0.051
Tokuyama	2008-2014	<0	0.433
Yokohama	1993-2014	0.791	0.032
Iwaya	1993-2014	<0	0.203
Maruyama	1993-2014	0.882	0.008
Agigawa	1993-2014	0.514	0.401
Origawa	2005-2014	0.644	0.019
Susobana	1993-2014	0.824	0.03
Makio	2002-2014	0.565	0.134

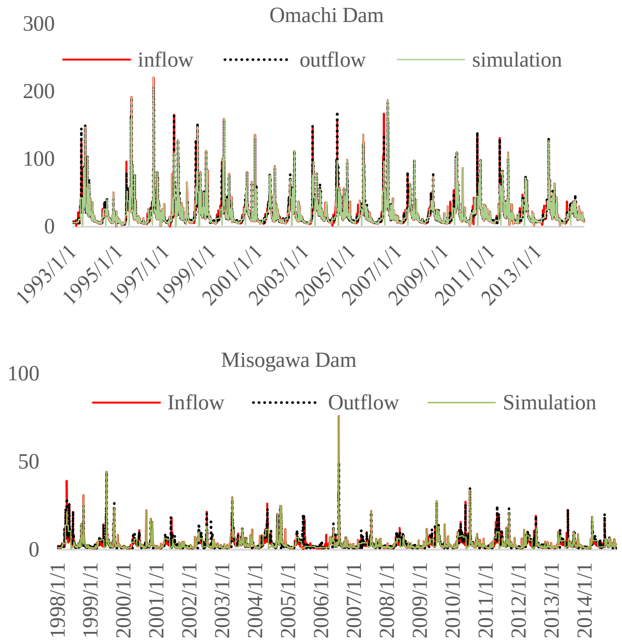

Figure 2 Inflow, outflow and simulations at Misogawa and Omachi dams