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# VALUE OF INFLOW FORECASTS FOR RESERVOIR OPERATION OF THE MAE KLONG RIVER SYSTEM IN THAILAND

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## 1. INTRODUCTION

Is it beneficial to use inflow forecasts for reservoir operation, although the forecasts can never be perfect? The answer to this question is not unique but rather depends on respective problems and how one incorporates them into operation. This paper presents, considering the forecasts as a deterministic input, the assessment of their values under different forecasting accuracy ($R^2$) and forecasting period ($T$). The Mae Klong River system with the Khao laem and the Srinagarind reservoirs in Thailand is presented as a case study.

## 2. RESERVOIR OPERATION MODEL

Deterministic dynamic programming(DDP) is used up to the period where the forecasts are available and the rest, stochastic dynamic programming(SDP) is used (Figure 1). The backward computation starts from the future that far enough so that the steady state solution of SDP can be reached. Periodical first order Markov process is assumed for SDP where inflow distribution is estimated from historical records. SDP provides the cumulative system performances (associated with the state variables used) as the initial conditions for backward DDP. The release's decision is made at the current time for the one period ahead. At the end of current period, the storage is updated with observed inflow. This procedure is repeated, as the time proceeds, until the end of desired period.

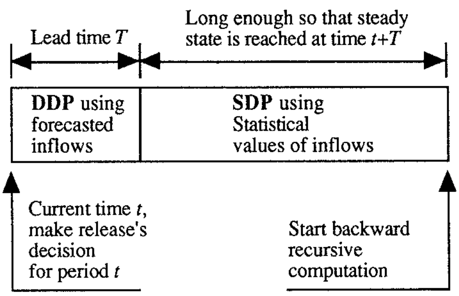


Figure 1 Schematic diagram of the reservoir operation model

## 3. GENERATED INFLOW FORECASTS

In order to evaluate the value of inflow forecasts with different forecasting accuracy ($R^2$) and forecasting period($T$), the forecasts are generated from the observed inflows perturbed by the forecasting errors (similar works, but not exactly equal, can be found from Yeh et al. (1982), Mishalani & Palmer (1988) and Takeuchi & Vanchai (1995)) as follows:

$$\hat{Q}_t = Q_t + cQ_te_t \qquad (1)$$

where $\hat{Q}_t$ and $Q_t$=forecasted and observed inflow in month $t$; $e_t$=random number N(0,1); $c=\sqrt{(1-R^2)/(1+C_v^2)}$ = level of uncertainty which reflect the forecasting accuracy, $R^2$, ($R^2=1-(\sigma_\varepsilon^2/\sigma^2)$). For instance, $c$=0 indicates the perfect forecast; $c$>0 indicates the level of uncertainty. $\sigma_\varepsilon^2$=variance of the forecasting errors; $C_V$ and $\sigma^2$= coefficient of variation and variance of historical inflows. The value of $c$ are selected to reflect $R^2$ of 1.0, 0.9, 0.8, 0.7 and 0.6, respectively.

## 4. ASSESSMENT

### 4.1 The Mae Klong River System(a case study)

The Mae Klong River basin is one of the large-scale complex water resource systems in Thailand covering an area of 30,800 km$^2$. There are two parallel reservoirs, Khao Laem and Srinagarind, located in the two main upstream tributaries serving for multiple purposes: hydropower, irrigation, domestic and industrial water supply, and salinity control (Figure 2). Irrigation demand, $W_4$, depends upon rainfall in the paddy fields and varies in between 24 to 345 m$^3$ s$^{-1}$, mostly during February to June. The mean annual inflows to the Khao Laem and the

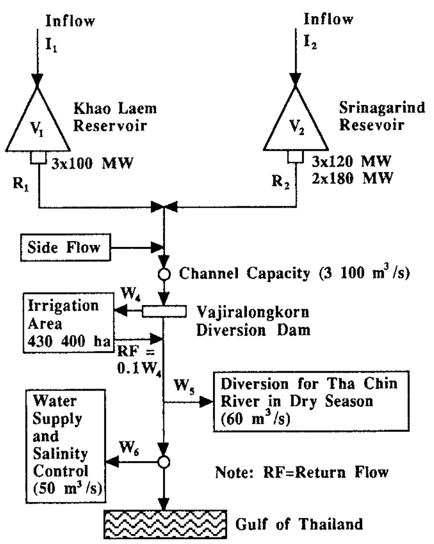


Figure 2 System configuration of the Mae Klong River basin

Srinagarind reservoirs are 4,925 and 4,355 $10^6$ $m^3$ while the ratios of their effective storage to the mean annual inflow are 1.20 and 1.71, respectively. The objective function is to maximize the annual hydropower from both reservoirs subject to reservoir characteristics, channel capacity and water demand constraints.

### 4.2 Selection of reference case

Reference case is defined as the case that uses no forecasts for reservoir operation. The table policies obtained by DDP that use monthly mean inflows is the best among the others in this study and is selected as reference. The benefits obtained from the forecasts are then compared with those produced by the reference one.

### 4.3 Simulation analyses

Simulations were made assuming the historical inflow records from 1965 to 1991 (27 years) as true realization and ten sets of $e_t$ in equation (1) were used in order to avoid the sampling variation of the forecast series. The average of their results were adopted.

## 5. RESULTS AND DISCUSSIONS

Lead time 0 is the reference case without forecasts. The simulations with forecasts show the benefits of forecast both in terms of higher average total annual energy (Figure 3(a)) and smaller standard deviation (Figure 3(b)) for different lead time and forecasting accuracy. The longer the lead time is, the higher the benefits are. The benefit of forecasts drops when the forecasting accuracy decreases. The increase of benefits gained is very sharp for the one-month forecast and is rather mild beyond that. Some contradictions are found for the case of forecasting accuracy $R^2$=0.9 in Figure 3(a). Those unreasonable fluctuations might also be attributed to the round-off errors due to discretization in DP. Figure 4 shows the time-based reliability of irrigation water $W_4$ and water supply $W_5+W_6$ in Figure 2 to be met. Irrigation has higher reliability than water supply because it situates upstream and has higher priority when compared with water supply. It is revealed that, with forecasts, both demands can be met more reliable compared with the case of no forecasts, even if the forecasting accuracy $R^2$=0.6.

## 6. CONCLUDING REMARKS

The methodology presented here provides an easy and direct way to incorporate the inflow forecasts for reservoir operation. The value of inflow forecasts generally increases with the lead time and the forecasting accuracy. The degree of increase depends on particular problem. The results from a case study indicate that lead one forecasts is significant even though the forecasting accuracy is as poor as $R^2$=0.6. This suggests how to select the appropriate lead time of forecast and its accuracy required for implementing the real-time reservoir operation.

## REFERENCES


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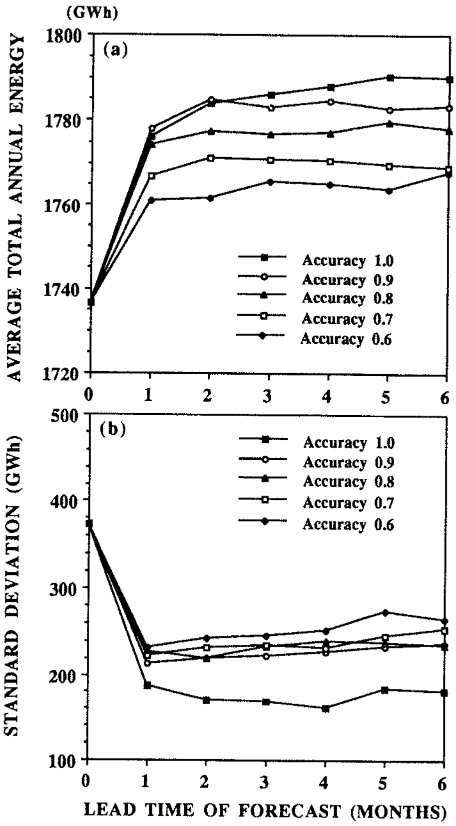


Figure 3 (a) Average total annual energy from the Khao Laem and the Srinagarind reservoirs (b) The corresponding standard deviation

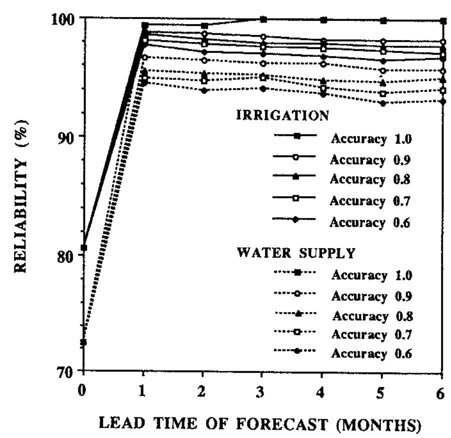


Figure 4 Time-based reliability of irrigation and water supply