

## Development of Hydrological Information System in the Chao Phraya River Basin

Yoshio HAYASE<sup>1\*</sup>, Kaichi KOSEKI<sup>2</sup>, Kumjon LAPCHAROEN<sup>3</sup> and Attaporn BUDDHAPALIT<sup>3</sup>

<sup>1</sup> Department of Regional Resources, National Research Institute for Rural Engineering (Tsukuba, Ibaraki 305–8609, Japan)

<sup>2</sup> Irrigation Engineering Center, Royal Irrigation Department (Samsen Rd., Dusit, Bangkok 10300, Thailand)

<sup>3</sup> Hydrology Division, Royal Irrigation Department (Samsen Rd., Dusit, Bangkok 10300, Thailand)

### Abstract

Many hydrological observation stations for rainfall, pan evaporation and stream flow, etc. were installed by the Royal Irrigation Department for agricultural development. Collected data are processed in a mainframe computer and published in the form of a Water Year Book every year. However, many technicians prefer to consult hydrological data such as hydrographs and discharges on an individual basis. In order to promote the effective utilization of hydrological data, it is important that the data be available to the technicians at their station. Therefore, personal computer software for observed hydrological data suitable for the Microsoft Windows operating system was developed by the authors.

**Discipline:** Agricultural engineering

**Additional key words:** tank model, runoff analysis

### Introduction

In Thailand, which is enjoying remarkable economic growth, shortage of water resources and degradation of farmland around large cities are becoming more serious along with the concentration of population and industrialization in low-lying areas. On the other hand, in recent years, farmers have frequently experienced extremely unstable water conditions such as drought and flooding associated with climatic changes. Therefore, the stabilization of water conditions by flood water control in low-lying areas, and development of water resources and water management for agricultural areas are essential.

### Hydrological environment

#### 1) Meteorological conditions

Southeast Asia is located between the Indian Ocean to the south and the Himalayas to the north and belongs

to a monsoon region in which the monsoon air current in the lower troposphere moves to an opposite direction when the season changes. From November to April, the intertropical convergence zone in the north moves south and remains near the equator. As a result, the dry season sets in owing to the dry wind of the northeast air monsoon. On the other hand, the intertropical convergence zone which lies in the southern districts of Thailand in May moves to the north in June. This zone stops in northern Thailand from June to September. Thereafter, this zone returns to the south in October. During these months, rainy days continue owing to the wet winds of the southwest monsoon from the Indian Ocean. The region along this intertropical convergence zone, in particular, receives a large amount of rain and the rainy season sets in.

#### 2) Physiography of the basin

The physiography of the Chao Phraya River Basin (162,000 km<sup>2</sup> in area) in Thailand is as follows: In the

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Present address:

<sup>1</sup> General Affairs Department, Ishikawa Prefectural Government (2–1–1 Hirosaka, Kanazawa 920–8580, Japan).

\*Corresponding author: fax +81–76–223–9610, e-mail [hayase@pref.ishikawa.jp](mailto:hayase@pref.ishikawa.jp)

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upstream basin, since the mean land gradient is sufficiently steep, irrigation and drainage can depend solely on gravity. The ratio of catchments to paddy area in the basin is high enough, so that irrigation of all of the basins becomes possible. The upstream basin is occupied by rainfed and irrigated paddy fields that have developed in small basins surrounded by mountains.

The midstream basin can be divided into fan-terrace complex areas and plugged river areas<sup>4)</sup>. Fan-terrace complex areas cover gently sloping mountain-foot zones extending along the margin of the Central Plain. The greater part of this area experiences chronic water shortage. Plugged river channel areas form depressed stretches along the Nan and Yom Rivers and have an extremely high stream density. As the ratio of catchments to paddy area is about 33, the water level rises very rapidly after the first rains of the wet season and the level remains high long after the end of the rainy season. The inundation reaches a depth of more than 1 m and about 4 m in depressed ground. The level of the inundated area decreases depending on how flood flow in the river subsides in October. In these areas, floating rice has been cultivated for centuries.

In the downstream basin, flood water passing through the inundated zones of the midstream basin flows down and spreads over the ground surface of the vast delta. The depth of the floodwater increases from 50 cm to 1 m and the inundation continues from August to December. Flow of the downstream reaches of the Chao Phraya River is strongly controlled by daily tidal influence. Though the drainage capacity of the midstream point of the Tone River in Japan is  $233 \text{ m}^3/\text{s}/100 \text{ km}^2$ , that of the Chao Phraya River is only  $2.2 \text{ m}^3/\text{s}/100 \text{ km}^2$  and this considerably lower discharge value is due to a relatively weak flow controlled by tidal water and the gentle general slope.

### 3) Flood disaster in 1995

Recently, prevention of inundation has become important because people who used to live in traditional houses with a high floor level and to move by boat during the inundation period now live in modern houses with a low floor level and own a car.

As several typhoons hit the upstream basin of the Chao Phraya River in August 1995, serious flood occurred with extensive inundation of agricultural lands, residential quarters and commercial districts of the basin for a few months. Fig. 1 shows the stage hydrographs at Nakhon Sawan (C.2) which is located in the midstream of the Chao Phraya River. Maximum water level during the flood was the largest in spite of the construction of the Bhumibol and Sirikit dams.

## Hydrological information and application system

### 1) Hydrological information

Farmers in Southeast Asia select the most suitable paddy cropping method to match the water conditions of their paddy fields, including irrigated paddy cropping, rainfed paddy cropping and floating rice cropping. As the pattern and depth of rainfall vary considerably in space and time or year by year, rainfall data are essential for the farmers. Moreover, farmers need to collect hydrological and water management data in order to select rice planting areas in the rainy and dry seasons, to select methods of cultivation of rice, to prevent damage by drought during dry spells in the early days of the rainy season, to prevent submergence damage of rice from rapid swells of the river and to estimate the irrigation water volume. Information in these cases includes storage volume of upstream dams, water level and discharge of channels and rivers concerned, intake discharge of barrages and daily rainfall.

In the Chao Phraya River Basin, observations of water level and stream flow in the main river, released discharge of dam and intake discharge of barrages are carried out by the Royal Irrigation Department. Especially, the water level of all the observation stations is indicated as elevation above sea level. Since the relationship between the water level of rivers and elevation of back swamps, the relation of observed water level between upstream stations and downstream stations and volume of storage water of inundated areas, etc. are determined, information concerning the water level is highly valuable.

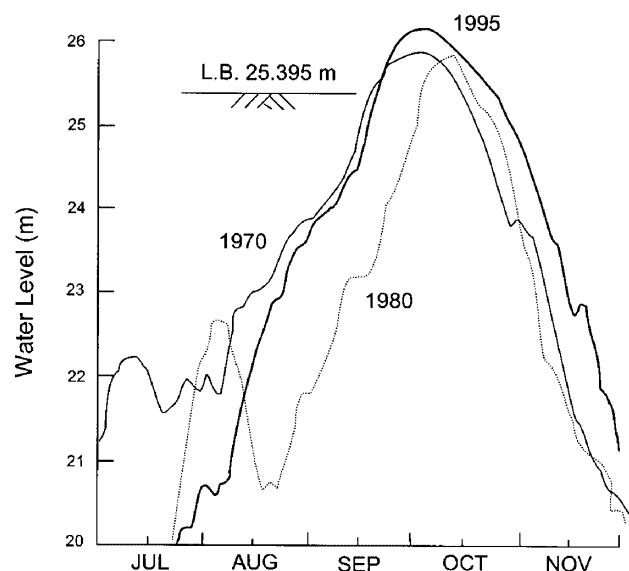


Fig. 1. Stage hydrographs at Nakhon Sawan (C.2)

As rainfall observation systems must be maintained using manpower, rainfall stations used to be installed at villages along the rivers or at the base of mountains accessible to all. Rainfall observation in mountainous areas is not performed. Therefore, as total rainfall increases in proportion to the increase in elevation in mountainous areas, in the case of heavy rainfall, it is very difficult to estimate areal rainfall. Because rain occurs in the form of local showers in tropical and subtropical regions, the density of rainfall observation stations should increase and the observation time of rainfall modified from a daily basis to an hourly basis. Moreover, for the forecasting of river flow and inundation damage caused by flooding, it is necessary to estimate the storage water volume of inundated areas. Accordingly, water level data from many stations distributed in space should be collected in future.

## 2) Software application for hydrological data

Many hydrological observation stations for rainfall, pan evaporation and stream flow, etc. were installed by the Royal Irrigation Department for agricultural development. The observation works of these stations have been continued over a long period of time. Though the recorded data of some of the stations are transmitted to an observation center on-line, that of most stations is collected by manpower. Collected data are processed in a mainframe computer and published in the form of a Water Year Book every year. However, many technicians prefer to consult hydrological data such as hydrographs and discharges on an individual basis.

In order to promote the effective utilization of hydrological data, it is important that the data be available to the technicians at their station. Therefore, personal computer software for observed hydrological data suitable for the Microsoft Windows operating system was developed by the author, as shown in Figs. 2 and 3<sup>1,2</sup>.

The application of the software is as follows. When the user clicks the menu bar commands of the software using a mouse, the gauging station map appears, as shown in Fig. 2. Next, when the user clicks a given observation station on this map, the corresponding hydrograph appears. As the user can open some child windows of the hydrograph, he can easily compare each hydrograph, as shown in Fig. 3. Moreover, the user can easily obtain a discharge map of all the observation stations on a given date, as shown in Fig. 2. He can add or subtract one day to or from the given date by pushing the right or left button of the mouse, respectively and obtain several child windows which will display an other requested date on the parent window. He can analyze the total stream flow regime on the date he requested and

compare it with each of the other flow regimes.

## 3) Software application for runoff analysis

### (1) Tank model

Since runoff characteristics differ depending on the type of land utilization and conditions of water use, which vary with the rice cropping methods, basins should be divided into mountainous land, rainfed paddy fields and irrigated paddy fields based on land utilization. Runoff simulations of the respective sub-basins are carried out using a tank model corresponding to each type of land use. The tank model, which was developed by Sugawara<sup>3</sup>), is basically composed of 4 tanks laid vertically in series.

In order to construct a simulation model for the expansion and contraction of wet areas in non-paddy areas such as mountainous areas, these areas were divided into 3 zones S<sub>1</sub>, S<sub>2</sub> and S<sub>3</sub>. Though the areal ratios of zones are important parameters, information about the hydrological, topographical and geological characteristics of the basins is lacking or very limited. Therefore, these values were expressed by geometrical progressions for convenience.

$$S_1 : S_2 : S_3 = 4^2 : 4 : 1$$

As a part of runoff water of non-paddy areas flowing into rainfed paddy fields through small rivers, rainfed paddy areas are assigned to the fourth zone, namely the riverside tank (S<sub>4</sub>) which represents the ratio of rainfed paddy areas to the basin area minus irrigated paddy areas.

Moreover, irrigated paddy fields are divided into paddy fields in the first cultivation season and paddy fields in the second cultivation season. The latter paddy fields are allocated to the upstream area of the former paddy fields from the viewpoint of irrigation water management. Parameters of the tank model representing paddy fields are identified to express the conditions under which the notch height is 10 cm, required irrigation water for puddling is 300 mm and the daily water requirement is 11 mm/day.

As there is a wide area of swampland, depressed land and back swamp along the main rivers, these areas store up a very large volume of rainwater in the rainy season. The storage function of these areas is expressed as secondary river channel storage, which is located along the primary river channel storage, as shown in Fig. 4. Runoff water from non-paddy areas and paddy areas fills, at first, primary river channel storage, and then, gradually, flows into secondary river channel storage.

### (2) Software application for tank model

To identify the large number of parameters of the tank model, after calculation, hydrographs with observed results and calculated results must be compared and the

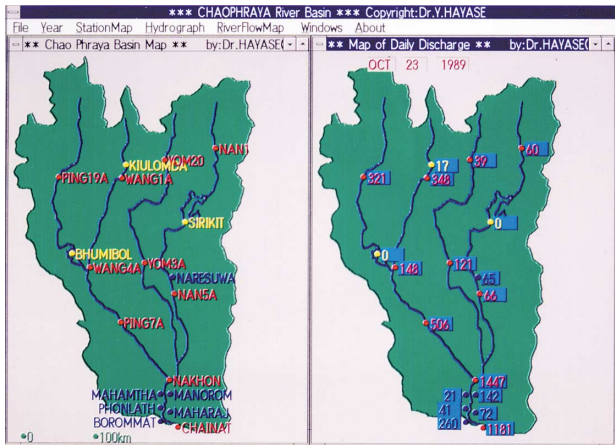


Fig. 2. First sample of hydrological information software presented

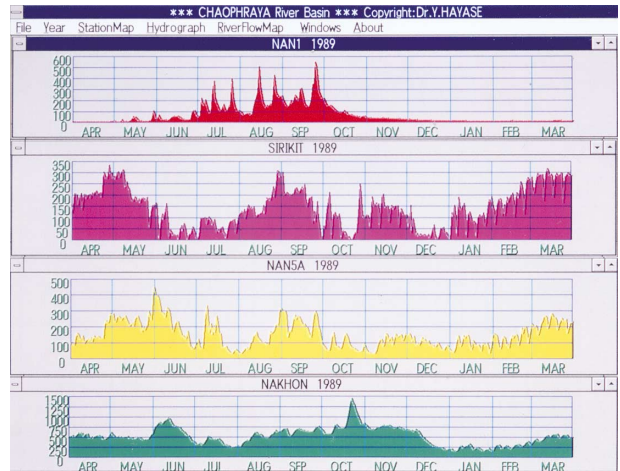


Fig. 3. Second sample of hydrological information software presented

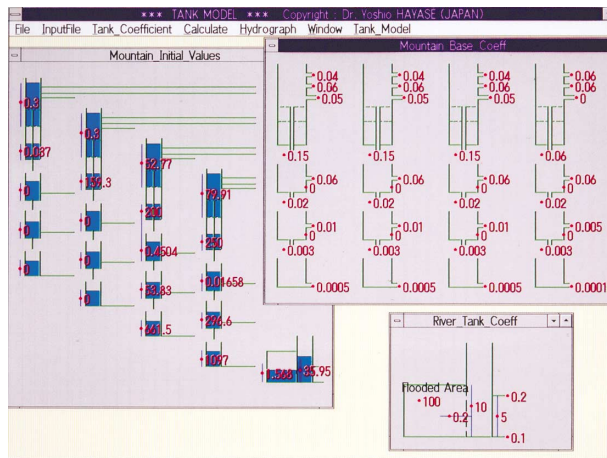


Fig. 4. Child windows of tank model for Windows

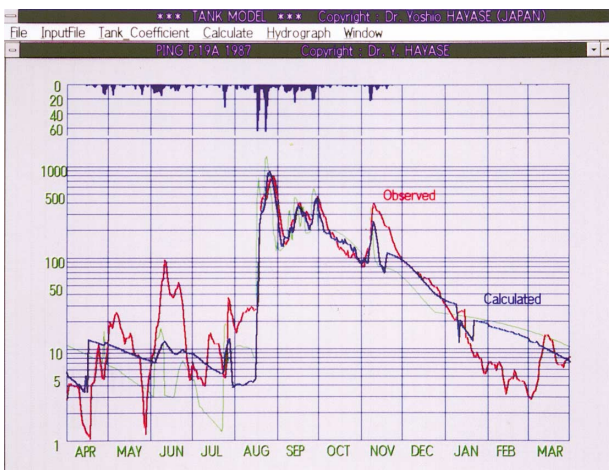


Fig. 5. Comparison of hydrographs with observed and calculated values in the Pin River Basin (P.19A) in 1988

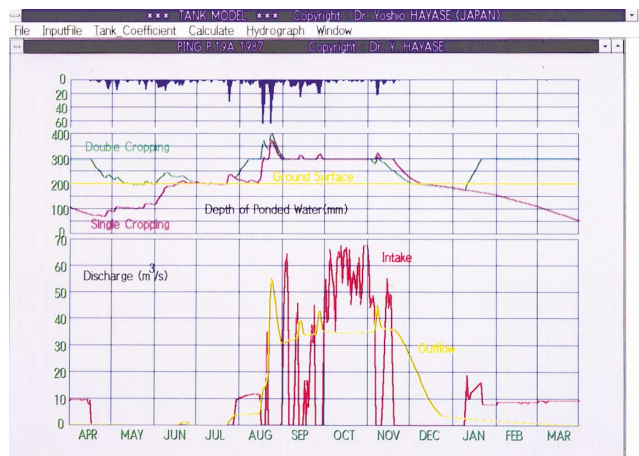


Fig. 6. Graphs with calculated values of ponded water and intake discharge and outflow of irrigated paddy fields in the Pin River Basin (P.19A) in 1988

values of the tank model must be readjusted so that the hydrographs with calculated results agree well with those with observed results. Calculated results cannot be visualized only with a line printer or plotter device. Parameter identification work is time-consuming, tedious and laborious. Therefore, software of the tank model for Microsoft Windows operating systems has been developed by the authors<sup>1,2)</sup>. The user can easily and instantaneously select input data files, input of renewal values of model parameters, calculation of models and display of calculated results by clicking the menu bar commands of the parent window using a mouse. The user can simultaneously compare a few calculated results using multi-windows of the Microsoft Window system.

Moreover, the user can easily obtain daily graphs of water depth, intake discharge and outflow of irrigated paddy fields in this tank model software. If a beginner tries to identify parameters of the tank model many times using this software as if playing a computer game, he can easily obtain images, which express the relationships between varying amounts of model parameters and those of calculated results. Then he can construct an optimum tank model in a short period of time.

### (3) Example of analysis using the tank model

An example of analysis in the Pin River Basin (catchment area 14,023 km<sup>2</sup>) which is located upstream of the Chao Phraya River is presented. Total paddy area of this basin is 1,613 km<sup>2</sup>, which consists of 969 km<sup>2</sup> of rainfed paddy fields, 644 km<sup>2</sup> of irrigated paddy fields in the rainy season and 78 km<sup>2</sup> of irrigated paddy fields in the dry season. Required data for analysis include pan evaporation, areal rainfall, observed discharge of the downstream end station (P.19A), rice cropping pattern and water depth data corresponding to each rice growing stage from puddling to harvest. Parameters of the tank model are shown in Fig. 4. If the mouse clicks a red circle corresponding to the parameters to be corrected, input window appears and the user can input correct values. Final results are shown in Fig. 5, in which hydrographs with observed and calculated results from observation station P.19A in 1988 were compared. Graphs with calculated values of stored water, intake discharge and outflow of irrigated paddy areas are shown in Fig. 6.

Dry season recession curves, as shown in Fig. 5, indicated that the calculated values were higher than the observed values. Based on Fig. 6, maximum intake discharge for irrigated paddy fields was 85 m<sup>3</sup>/s and occurred in the puddling season in August. Intake discharge on fine days was 67 m<sup>3</sup>/s with a value of 9 mm/

day. Outflow discharge of irrigated paddy fields on fine days was 35 m<sup>3</sup>/s with a value of 4.7 mm/day. The difference between the intake and outflow discharge on fine days was 4.3 mm/day and corresponded to evapotranspiration. In the dry season, about 10 m<sup>3</sup>/s of river water corresponded to the intake for irrigated paddy fields with a value of about 11 mm/day.

## Research required

As large river basins in Southeast Asia have low-lying areas with gently sloping land, runoff velocity in the rainy season is very low because of the storage of rainwater and inundation in these basins. Inundation from flooded areas and swampland in deltas continues for several months. Although attempts to transform these inundated areas into well-drained paddy fields were made, it may be difficult to substantially increase the drainage capacity of rivers even if river works aimed at widening the cross-sectional area of rivers are conducted. If upland areas with water shortage are irrigated, return flow will be concentrated in flooded areas downstream and the depth of inundation in these areas will be greater than presently. Moreover, if embankments enclose the flooded areas, inundation of areas outside of the polder will become more serious. If the authorities concerned request that rainwater in the rainy season be drained away, then water shortages in the dry season are likely to become more serious. For a gently sloping land, few locations are suitable for the construction of a dam with a large storage depth. In conclusion, it is difficult to address the problems of drought and flooding at the same time.

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