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Development of Water Allocation Strategy to Increase Water Use Efficiency of Irrigation Project

Varawoot Vudhivanich[1], Jesda Kaewkulaya[1], Ponsatorn Sopaphun[1], Watchara Suidee[2] and Prapun Sopsathien[3]

ABSTRACT

In development of water allocation strategy to meet crop water requirement and to utilize rainfall effectively, a computerized water allocation scheduling and monitoring system named WASAM 2 was developed. Song Phi Nong irrigation project was selected as a case study. WASAM 2 was used for water allocation scheduling in Song Phi Nong project for 3 cultivation seasons of 1994 dry and wet seasons and 1995 dry season. The discharge at 5 key regulators which are the entrance to 5 water masters were monitored on daily basis. The actual delivery performance of the 3 studied seasons indicated that the actual measured discharge was about 20-30% higher than the recommended WASAM 2 discharge because Song Phi Nong project was the downstream project and had to take all the remaining water from the upstream Phanom Tuan project. It is recommended that the water allocation scheduling system of Song Phi Nong and Phanom Tuan projects will be combined into one system to increase the efficiency in water allocation. The average irrigation efficiency of Song Phi Nong was 37.6% in dry season and 28.5% in wet season. WASAM 2 increased the wet season efficiency by 3-5%. The irrigation efficiency in the dry season was on the average 7.7% higher than that in the wet season. Some water master has the efficiency up to 46.9% in dry season. The irrigation efficiency of the project is still low by two reasons : (1) being unable to completely control the discharge, and (2) high seepage loss in the canal system.

Key words : water allocation, water management, irrigation efficiency, Mae Klong

INTRODUCTION

Whenever the water available is less than the expected amount or the irrigation water requirements exceed the availability, the water shortage takes place even in the irrigated area. The issues of high irrigation water requirements is usually related to the efficiency in water delivery and application. As commonly known, the project irrigation efficiency in Thailand is still low at only 30-50%. If the project irrigation efficiency is increased, it can improve water shortage problem at more cost effectively than developing the new water resources project.

In order to improve the water deliverly, application efficiency and the equity of water

[1] Department of Irrigation Engineering, Kasetsart University, Kamphaengsaen, Nakhon Pathom 73140, Thailand.
[2] College of Irrigation, Royal Irrigation Department, Nonthaburi 11120, Thailand.
[3] Regional Office 10, Royal Irrigation Department, Kanchanaburi 71110, Thailand.

distribution among the head-and-end users, Royal Irrigation Department (RID) has developed various water allocation system including Water Management Systems (WMS) of the Greater Chao Phraya Irrigation Project having an irrigated area of over 7.0 million rai. The main feature of WMS is the prediction of planting area for 1-2 weeks in advance and the utilization of return flow in the downstream irrigation project. The computer program was developed for calculation of water requirements on block basis; each block representing an area of approximately 50,000 rai (Chalong, 1984). On the same purpose, Water Allocation Scheduling and Monitoring system or WASAM was developed for the Greater Mae Klong Irrigation Project (GMKIP). The main purpose of WASAM is to determine the required discharge of the canal section, 3,000-5,000 rai each, from the long term average potential evapotranspiration (ETo), crop coefficient (Kc) and the cropping pattern surveyed at the beginning of the season. The irrigation water requirements are adjusted according to the field wetness and the deviation of the actual rainfall from the anticipated value. The main improvement of WASAM is to incorporate the hydraulic properties of the canal in water allocation planning. Besides, the actual water distribution in the canal system (at several key regulators) is monitored on weekly basis in order to check field water delivery performance (Ilaco/Empire M&T, 1984; 1985; 1986(a); 1986(b); 1986(c)). Later on WASAM has been applied to Lam Pao (RID, 1988(a); 1988(c)) and Nong Wai (RID, 1988(d))irrigation projects in the Northeast of Thailand. Water Use Analysis (WUA) program was also developed to assist the irrigation engineer in evaluation of water use efficiency of the Lam Pao project at zone, water master and main canal levels (RID, 1988 (b)).

Although WMS, WASAM and WUA are good tools for project water allocation, they require a lot of field data including planting area, rainfall and flow measuring data. Good trained field staff and additional expenditures are needed to implement these water allocation system. This prohibits the application of these systems except in the irrigation project having water management expert and special funding system.

As mentioned above, the project water allocation techniques which responses to the crop water requirements, reduces the water losses and increases an effective use of rainfall in such way that the irrigation efficiency of an irrigation project increases, need to be developed. The objective of this research is to develop an effective water allocation scheduling and monitoring system of an irrigation project.

MATERIALS AND METHODS

Song Phi Nong irrigation project in Suphanburi province which is a typical irrigation project in Mae Klong basin is selected for the study. The methods adopted for this research are :

(1) to study the existing method of water allocation in Song Phi Nong irrigation project, identify the problems and constraints,

(2) to evaluate irrigation efficiency of the present condition and use as a benchmark for evaluating the effectiveness of the improved water allocation method,

(3) to analyze the basic data and information required for effective water allocation and design the data collection and processing system which are appropriated to the project,

(4) to develop water allocation method which takes into consideration of crop water requirement, canal delivering capacity and effective utilization of rainfall.

(5) to Develop WASAM 2 computer program to be a tool for project water allocation.

Present water allocation practices of Song Phi Nong Irrigation Project

Song Phi Nong irrigation project is one of the 3 irrigation projects on the upper left bank of GMKIP, having the command area of 416,106 rai. Its upstream and downstream projects receiving irrigation water from the same 2L canal are Phanom Tuan and Banglane. The project divides the operation and maintenance responsibility into 5 water masters (43 zones) as shown in Table 1. There are totally 39 operation and maintenance staffs where 20 are zoneman. Each zoneman is responsible for O&M in an approximated area of 20,000 rai which is exceeding the normal criteria of RID, 5,000-10,000 rai per zoneman. Therefore, the project is in shortage of field O&M staff which may effect the water delivery control practices.

The principle of water allocation of GMKIP and Song Phi Nong irrigation project is to allocate water on weekly basis according to crop water requirements. Thursday (6.00 am.) is the first day of the irrigation week. Upstream control with continuous delivery is practiced in the main and lateral canals while rotation delivery is practiced at the tertiary level of paddy growing area (almost no on-farm water distribution system in sugarcane area). Each farm ditch has a fixed duration-varied discharge rotation schedule.

At the beginning of irrigation week (Thursday at 6:00 pm), all the regulators are adjusted by zoneman according to the new water allocation schedule. The adjustment normally starts in sequence from the most upstream to the downstream regulators according to the upstream control concept. In order to check the actual water distribution, Song Phi Nong project has set the flow monitoring points at the head regulator of 5L-2L, the main intakes to water master section 2, 3, 4 and 5, and at the cross regulator of 2L at km 22.700, the main headworks of the project. However, the project is lack of field staff to do the routine daily measurement and most of the regulators are uncalibrated.

At the present, the management of Song Phi Nong project faces the following problems :

(1) unreliable water supply since Song Phi Nong is located on the downstream of Phanom Tuan project,

(2) too few number of rain gages, only 4 stations (Uthong, Song Phi Nong, Kamphaengsaen and Phanom Tuan), are used in water allocation scheduling,

(3) most of the key regulators are not calibrated, assuming 0.7 of the discharge coefficient, resulting in uncorrected delivery and distribution of water to the farm land,

(4) many farmers in water master 2 and 3 pump water directly from the main canal because

Table 1 Division of responsibility for O&M in Song Phi Nong Irrigation Project.

Water master	Responsible area	Zone	Command area (rai)	Main crop
1	Bor Suphan	1-8	92,734	Sugarcane
2	Nong Phaw	9-18	106,421	Sugarcane
3	Talad Khet	19-25	59,904	Sugarcane
4	Jorrakhe Sarmpun	26-32	55,375	Paddy (2 crops a year)
5	Sra Punglarn	33-43	101,672	Paddy (2 crops a year)
Total			416,106	

of lack of farm turn outs, making difficulty in the water delivery control and oftenly unfair water distribution to tail-end users.

The existing WASAM computer program which was originally developed by Ilaco/Empire M&T for GMKIP in 1985 had some drawback in real practices. It requires a large number of field data exceeding the capability of field staff to handle the daily data collection effectively. WASAM has no capability for evaluation of management performance of an irrigation project. Lastly the WASAM computer program is not user friendly making it difficult to use. Therefore, the existing WASAM needs improvement.

RESULTS AND DISCUSSIONS

Development of WASAM 2

Due to the shortcoming of the existing WASAM as mentioned earlier, WASAM 2 was developed to help the irrigation engineer in charge of an irrigation project in calculation of the required discharge of the regulators, in evaluation of the water management performance and in monitoring analysis of the actual water distribution. The differences between WASAM 2 and the existing WASAM are shown in Figure 1.

In calculation of the required discharge, the Song Phi Nong Irrigation Project is divided into 57 canal sections as shown in Figure 2. Each canal section is the canal reach between two regulators. The irrigation water requirements of each canal section is first calculated using the following equations :

$$R(N) = \frac{\sum_{I=1}^{NC}[EV(ES)*CF(w1,I)+LP(w1,I)+COR-RE(RS)]*A(I,N)}{378{,}000*\ SUE(w1,I)} \quad ....(1)$$

R(N) = Irrigation water requirement of canal section N in week W (cms)

EV(ES) = Weekly potential evapotranspiration of station ES (mm)

CF(w1,I) = Crop factor of crop I at the age of w1 weeks

NC = No. of crop types (there are 6 types of crop ; 1 = dry season paddy ; 2 = wet season paddy ; 3 = sugarcane ; 4 = upland crop ; 5 = fruit tree and 6 = fish pond)

LP(w1,I) = Weekly land preparation and percolation of crop I at the age of w1 weeks (mm)

COR = Correction factor due to rainfall or field wetness conditions

RE(RS) = Expected rainfall of station RS (mm)

A(I,N) = Area of crop I in canal section N (rai)

SUE(w1,I) = Service unit irrigation efficiency of crop I at the age of w1 weeks

The required discharge of any canal section (N) is calculated as follow :

$$Q(N) = R(N)+\sum_{I=1}^{M}Q(I)+LOSS(N) \quad .... (2)$$

Where

Q(N) = Required discharge of canal section N (cms)

R(N) = Irrigation water requirements of canal section N (cms)

Q(I) = Required discharge of the downstream canal section I (cms)

LOSS(N) = Conveyance losses from the source of water supply to canal section N (cms)

The calculated Q(N) is thus adjusted according to the following water distribution criteria :

(1) If Q (N) < 0.4 Q_{min}(N) (the discharge is too small)

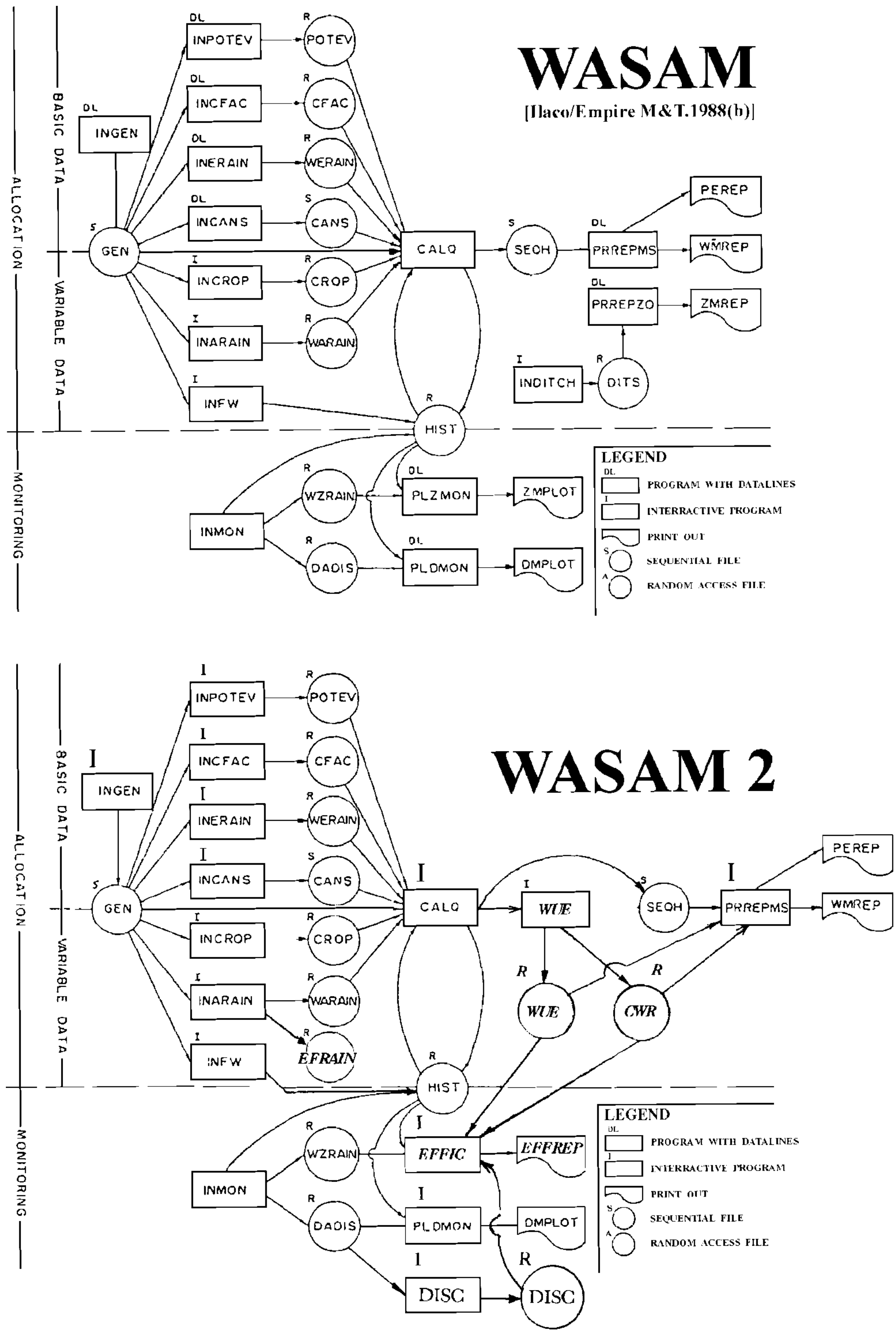


Figure 1 Comparison of the structure of the WASAM 2 and WASAM (Vudhivanich *et al.*,1998).

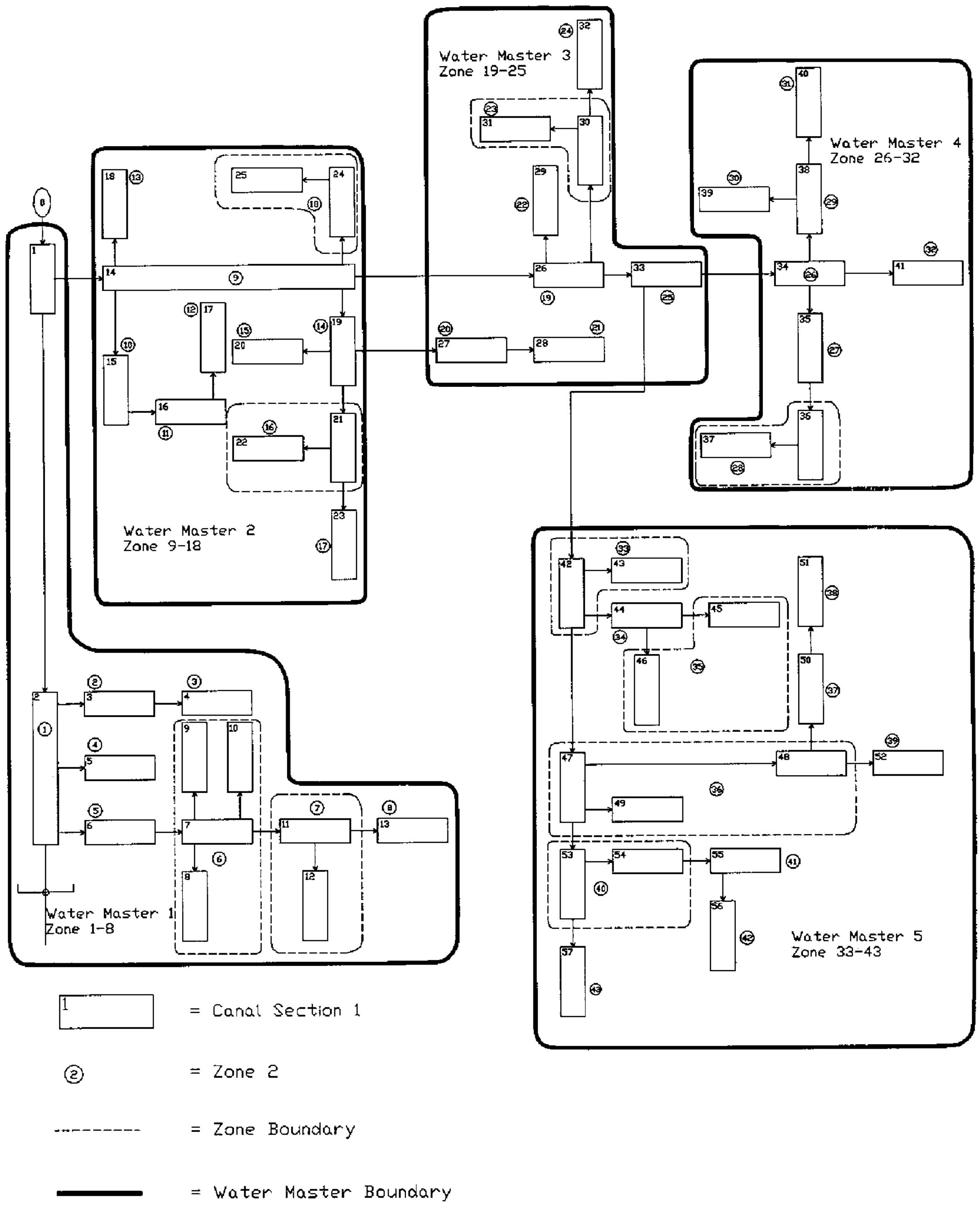


Figure 2 Schematic diagram showing the structure of canal sections of Song Phi Nong Irrigation Project.

Q (N) = 0

and D (N) > 0 (special counter for shortage)

(2) If 0.4 Q_{min}(N) < Q (N) < Q_{min}(N)

Q (N) = Q_{min} (N) (to maintain the minimum supply level in section N)

Except R (N) = 0 and the canal sections branching off directly from section N do not require to maintain the minimum supply level in N.

If Q (N) has to increase to Q_{min} (N), the excessive allocation water, V = Q (N)-Q_{min} (N), will be distributed to the M downstream canal sections according to the following rules :

- allocate V to the canal section with D(I)>0 by the amount of D(I),

- allocate the remainder V to increase the discharge of the M downstream sections to Q_{min},

- allocate the remainder proportionally to the allocated amount.

(3) If Q_{min} (N) < Q (N) < Q_{max} (N)

No adjustment is needed.

(4) If Q (N) > Q_{max} (N)

Q (N) = Q_{max} (N)

Water deficit will take place.

P (deficit) = Q (N) - Q_{max} (N)

The deficit P is allocated to the M downstream canal sections proportionally to the allocated amount.

The irrigation efficiency is calculated by the following equation :

$$IE(L) = \frac{\sum_{I=1}^{J} R'(N)}{Q_{supply}} \quad \text{.....................................} (3)$$

Where

IE(L) = Irrigation efficiency of water master L (%)

R'(N) = Net irrigation water requirements of canal section N (cms)

$$R'(N) = \frac{\sum_{I=1}^{NC} [EV(ES) * CF(w1, I) + LP(w1, I) - ER(RS)] * A(I, N)}{378,000} \quad \text{.............} (4)$$

J = No. of canal section in water master L

ER(RS) = Effective rainfall of station RS (mm)

Q_{Supply} = (Q_{in}–Q_{out}) of water master L (cms)

Required basic data for water allocation by WASAM 2

As Shown in Figure 1, the basic data required for water allocation are

- the potential evapotranspiration (ETo)
- the expected rainfall and effective rainfall
- the crop coefficients
- the land preparation water requirements
- the percolation in paddy field
- the canal system data
- the discharge monitoring points

The monthly ETo of 2 stations ; (1) Kamphaengsaen located on the south of the project and (2) Uthong on the north, was calculated via the CROPWAT 5.7 computer program (Smith, 1992). The monthly ETo calculated from the long term average agroclimatological data (more than 20 years) is shown in Table 2.

The simple average rainfall is used as the expected rainfall in WASAM 2. The effective rainfall was derived by the simulation model via Water Use Study Model Version 4 (Kamnertmanee, 1989). In the simulation, it is assumed that the maximum, normal and minimum water levels are 130, 100 and 70 mm respectively for paddy and 0, 0, and –65 mm for non-paddy. The daily rainfall of 4 stations having the reconds of more than 40 years (1953-1992) was used to derive the relationship between rainfall and effective rainfall on weekly basis. The formula is shown below :

If $R \leq R^*$; RE = R

If $R > R^*$; RE = AxR+B........................(5)

Table 2 Monthly potential evapotranspiration (ETo) in mm at Kamphaengsaen and Uthong stations.

Month	Station		%
	Kamphaengsaen	Uthong	Difference
Jan.	116.8	118.2	1.19
Feb.	123.2	125.9	2.13
Mar.	164.6	171.6	4.07
Apr.	168.3	177.6	5.23
May.	152.6	166.7	8.41
Jun.	128.1	138.6	7.53
Jul.	134.5	142.9	5.88
Aug.	126.2	136	7.2
Sep.	116.4	119.5	2.59
Oct.	116.3	118.3	1.7
Nor.	111.6	117.9	5.35
Dec.	111.3	117.8	5.51

Where

R = the weekly rainfall (mm)

RE = the weekly effective rainfall (mm)

R*,A,B = the constants which depend on the crop types and the month of year, see Table 3.

WASAM 2 was designed to calculate the water requirements of fish pond and 5 different crops including dry season paddy, wet season paddy, sugarcane, upland crops, fruit tree. The weighted crop coefficients are shown in Table 4.

The land preparation water requirement is 250 mm for paddy and 50 mm for sugarcane. The land preparation is progressed at decreasing rate of 25.2, 22, 18.8, 15.2, 12 and 6.8 % of the total area from week 1 to week 6 respectively for paddy and at uniform rate during Jan.-Apr. for sugarcane. The percolation in paddy field is 0.5 mm/day in wet season and 1 mm/day in dry season (Ilaco/Empire M&T, 1984).

The canal conveyance loss measured by Inflow-Outflow Method from 3 different locations on 3 types of canal showed that the loss rate was very high as shown in Table 5.

The canal system of Song Phi Nong Irrigation Project is divided into 57 sections for water allocation calculation by WASAM 2. The detail of the canal sections are the name, location, canal section number, number of the upstream section, maximum and minimum discharges, conveyance loss rate, zone, water master section, ETo station number, rainfall station number, command area, etc, (Vudhivanich *et al.*, 1998).

For monitoring and evaluation purposes, the discharge of 5 main regulators as shown in Table 6 were measured on daily basis. The zonemen

Table 3 R*, A and B in effective rainfall formulas.

Month	For paddy			For non-paddy		
	R*	A	B	R*	A	B
Nov.-Apr.	59	0.55	26.10	29	0.78	6.38
May.	53	0.44	29.68	25	0.63	9.25
Jun.	55	0.46	29.70	27	0.70	8.10
Jul.	60	0.75	15.00	26	0.65	9.10
Aug.	50	0.56	22.00	25	0.64	9.00
Sep.	42	0.39	25.62	22	0.42	12.76
Oct.	30	0.25	22.50	18	0.27	13.14

Table 4 Weighted crop coefficients.

Week	Types of Crop						
	Dry season paddy	Wet season paddy	Sugarcane		Upland crops	Fruit tree	Fish pond
			5 years	3 years			
1	0.13	0.13	0.47	0.48	0.3	0.5	1.0
2	0.36	0.36	0.47	0.48	0.3	0.5	1.0
3	0.57	0.57	0.46	0.47	0.3	0.5	1.0
4	0.76	0.76	0.44	0.43	0.3	0.5	1.0
5	0.91	0.91	0.44	0.43	0.7	0.5	1.0
6	1.03	1.03	0.44	0.43	0.7	0.5	1.0
7	1.07	1.07	0.44	0.43	0.7	0.5	1.0
8	1.09	1.09	0.60	0.58	0.9	0.5	1.0
9	1.10	1.10	0.70	0.64	1.2	0.5	1.0
10	1.10	1.10	0.70	0.64	1.0	0.5	1.0
11	1.10	1.10	0.70	0.64	1.0	0.5	1.0
12	1.11	1.09	0.80	0.74	0.7	0.5	1.0
13	1.14	1.08	0.91	0.87	0.5	0.5	1.0
14	1.17	1.07	0.91	0.87	0.5	0.5	1.0
15	1.20	1.06	0.91	0.87	0.5	0.5	1.0
16	1.21	1.04	0.91	0.87		0.5	1.0
17	1.17	1.02	1.06	1.03		0.5	1.0
18	1.02	0.9	1.06	1.03		0.5	1.0
19	0.77	0.69	1.06	1.03		0.5	1.0
20	0.52	0.48	1.06	1.03		0.5	1.0
21	0.3	0.28	1.12	1.1		0.5	1.0
22	0.11	0.09	1.15	1.13		0.5	1.0
23			1.15	1.13		0.5	1.0
24			1.15	1.13		0.5	1.0
25			1.16	1.14		0.5	1.0
26-29			1.19	1.18		0.5	1.0
30-37			0	0		0.5	1.0
38-41			1.18	1.17		0.5	1.0
42			1.04	11.00		0.5	1.0
43-45			1.02	0.98		0.5	1.0
46-52						0.5	1.0

Table 5 Canal conveyance loss rate.

Types of canal	Conveyance loss rate (% of Qmax/km)
Lined main canal	0.44
Lined lateral	0.91
Unlined lateral	2.35

is responsible for the measurement and report to the water management officer of Song Phi Nong Irrigation Project by Wednesday. All the five regulators were calibrated in field for the accurate control of the discharge.

Performance analysis of water allocation with WASAM 2

WASAM 2 was used for water allocation of Song Phi Nong Irrigation Project for 3 consecutive seasons of ;

- dry season 1994 (Feb.-Jun.)
- wet season 1994 (Jul.-Nov.)
- dry season 1995 (Feb.-Jun.)

On weekly basis, the ETo, rainfall, planting area, canal system data and field wetness conditions were analyzed by WASAM 2 on Tuesday. The irrigation water requirements of each canal section were calculated using Equation 1. Consequently, the discharge allocated to the 5 main regulators and each canal section were calculated using Equation 2. The water management performance of the past week, in terms of irrigation efficiency, of the 5 water master sections and of the project was evaluated.

The weekly allocated discharge or "adviced discharge" of the 5 main regulators was compared with the actual discharge in Figure 3. The project and water master irrigation efficiency of the 3 seasons was compared with the values during 1991-1993, the period before WASAM 2 was used, as shown in Figure 4.

Dry season 1994

Figure 3(1) – Figure 3(5) show the actual discharges of water master section 1 to be very close to the WASAM 2 adviced discharge. The actual discharges of water master sections 2-5 were about 10-50% higher than the adviced values, particularly during the last few weeks of the dry season. The analysis of the actual water distribution found that although the 2L cross regulator at km 22.700 (Figure 3(1)) was one of the two head regulators for the project; it was the tail end structure of Phanom Thuan Irrigation Project. By the present water management practice of Song Phi Nong, this regulator controlled water distribution to the most upstream area of the project (zone 1 of water master section 1). Zoneman usually tried to control the discharge as WASAM 2 adviced. On the opposite, the 5L-2L head regulator at km 0.020 (Figure 3(2))

Table 6 Discharge monitoring points.

Monitoring point no.	Canal section no.	Location	Main regulators of water master section
1	2	2L cross regulator at km 22.70	1
2	14	5L-2L head regulator at km 0.020	2,3,4 and 5
3	26	5L-2L cross regulator at km 9.813	3,4 and 5
4	34	5L-2L cross regulator at km 26.401	4
5	42	3R-5L-2L head regulator at km 0.020	5

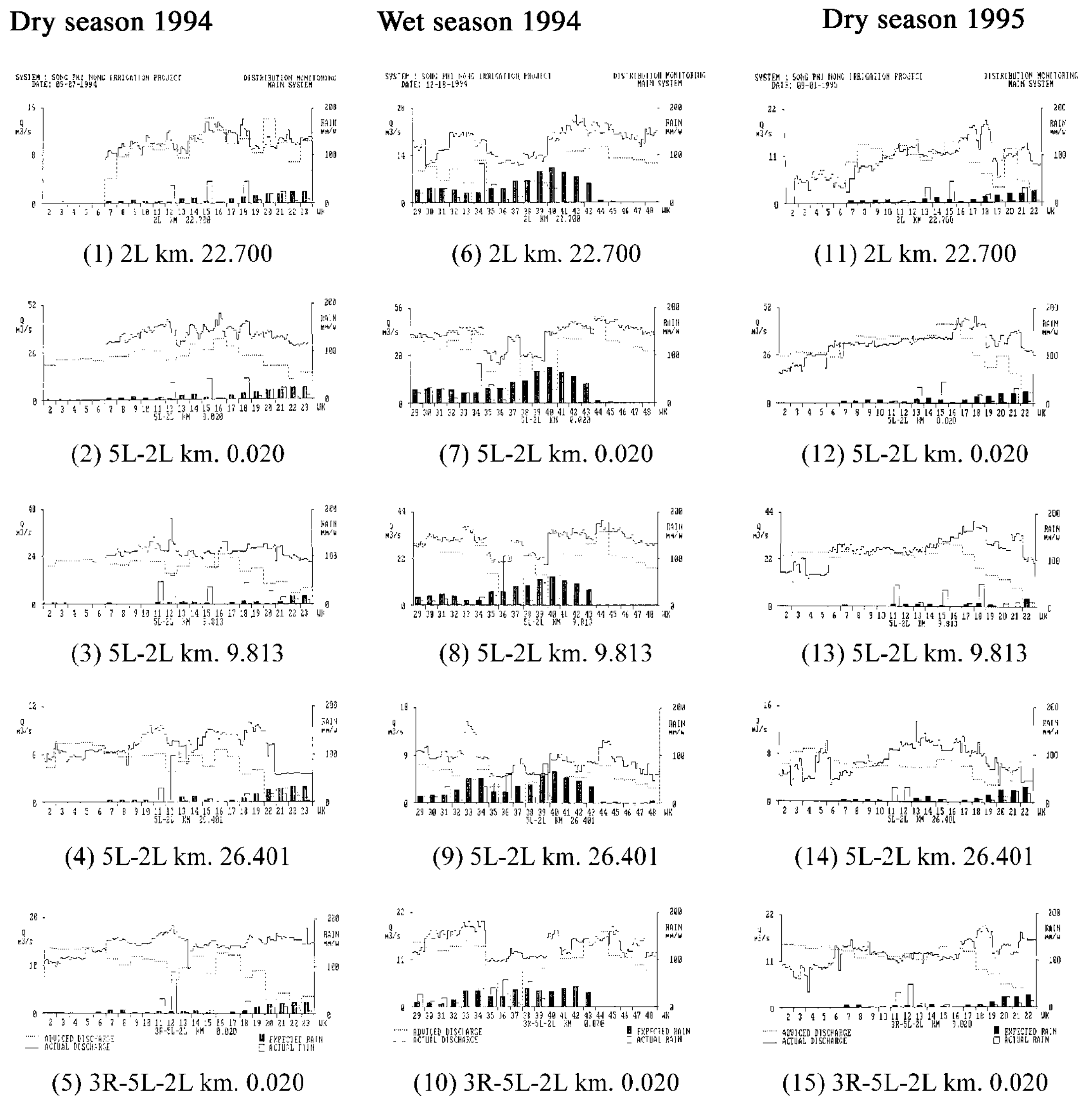


Figure 3 Comparison of WASAM 2 adviced discharge and actual discharge at 5 main regulators in dry and wet season 1994 and dry season 1995.

which was the entrance to water master section 2-5, was recognized as the tail part of the system. Whenever there was the excess water from Phanom Thuan, it would distribute to this regulator and it would do so for the water deficit. The degree of the problem was higher for the further downstream regulators. This could be seen by the delivery performance of 3R-5L-2L head regulator at km 0.020 (water master section 5) where the actual and the adviced discharges were most different.

This study indicated that the water management of the large scale irrigation project such as GMKIP was a lot more difficult than a small irrigation project. The water management practices of the upstream project such as Phanom Thuan had a direct effect to the downstream project such as Song Phi Nong.

The irrigation efficiency of dry season 1994 was 39.8 % which was about the average value for an irrigation project. However, it was about 2-3 % higher than that of the dry season irrigation efficiency of 1991-1993 which had the efficiency between 36.7-38.3 %.

The irrigation efficiency of Song Phi Nong was not high because of 2 reasons. First, the seepage loss in the canal system was high. Second, the actual discharge was higher than the adviced one because the water management practices of Phanom Thuan had some effects on Song Phi Nong as mentioned before.

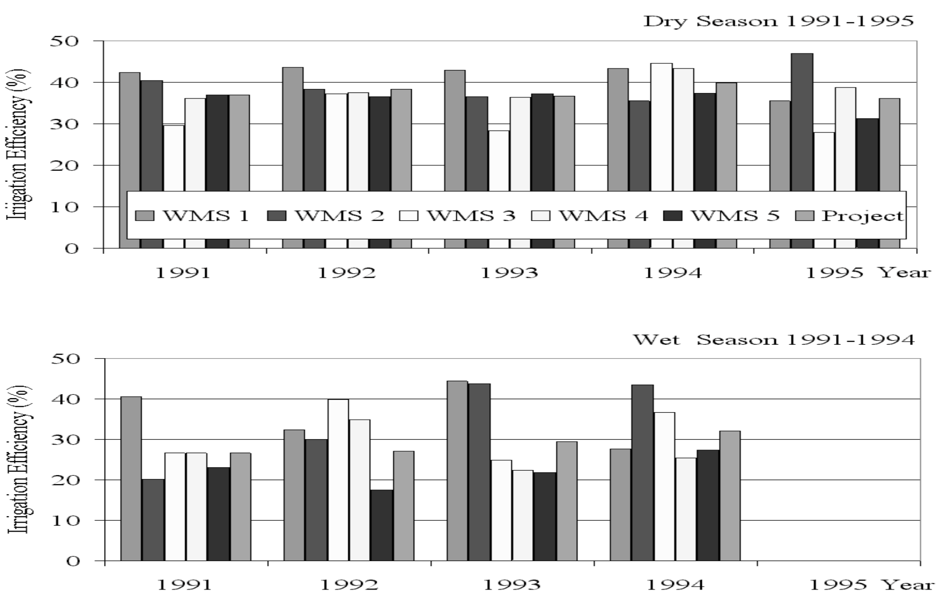
Wet season 1994

Figure 3(6) – Figure 3(10) show the actual discharges delivered to the 5 water master sections to be 20-30 % higher than the WASAM 2 adviced discharges in most of the wet season (week 29-48). This was caused by the excess water from Phanom Thuan Project . Song Phi Nong was unable to completely control the flow. The operation of Phanom Thuan Project could affect the water supply to Song Phi Nong. However, the excess water affected the water distribution of the 5 water master sections almost equally.

The irrigation efficiency was 32.1 %. It was 3-5 % higher than the efficiency during 1991-1993 because WASAM 2 used the rainfall more effectively.

Dry season 1995

As shown in Figure 3(11) - 3(15), the actual discharge during week 7-16 (Feb.-Apr.) was very close to the adviced discharge, except the case of



WMS = Water Master Section

Figure 4 Irrigation efficiency of Song Phi Nong Irrigation Project and 5 water master sections during 1991-1995.

5L-2L cross regulator at km 26.401 (the downstream regulator). The actual discharge of this regulator was 20-30 % higher than the adviced one, However during the later period of the season (week 17-22), all 5 water master sections got water more than the WASAM 2 adviced value similar to the situation of the previous 2 seasons.

CONCLUSION

The performance of WASAM 2 for water allocation analyzed from the comparison of the actual and the adviced discharges and the irrigation efficiency indicated that WASAM 2 could help improing the irrigation efficiency in wet season more than dry season. However the irrigation efficiency in the dry season was on the average 7.7% higher than that of the wet season.

The difficulty in discharge control was found. The actual discharge was about 20-30 % higher than the WASAM 2 adviced value because of the operation effect of the upstream Phanom Thuan Project. This reduced the irrigation efficiency of Song Phi Nong Project. It is recommended that the water allocation system of the two projects is to be integrated in one system in order to improve the water management of Song Phi Nong Project.

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