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Technological Aspect of Irrigation System in Paddy Land Area
—— On the Nong Wai Pioneer Agriculture Project in Thailand ——

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Field surveys on the irrigation system were conducted in the Nong Wai Pioneer Agriculture Project Area in 1984 and 1985.

The purpose of this research is to clarify the technological aspects on irrigation system in tropical paddy area.

Investigations were made on the following three items.

1. The functions of main conveyance system with check gates were reviewed. In addition, the merit and demerit of the check gate was discussed.

2. The unit water requirement and its components were comparatively investigated. As the result, it was pointed out that the term of horizontal percoration should be counted in the water requirement.

3. There are three types of farm level irrigation systems, i. e. rain-fed system, extensive system and intensive system. The characteristics of those systems were analyzed and the advantages of each system were evaluated.

INTRODUCTION

The economical situation of rice culture in the Monsoon Asia has very important role of grain production in the world.

Agriculture is based on the historical and natural features and deeply related to the way of life in a region. Introducing a new irrigation system advances the development of regional agriculture with some temporally slight confusion.

The purpose of this report is to review the irrigation system introduced recently in the Nong Wai Pioneer Agriculture Project from a view point of irrigation engineering. The field surveys were conducted in 1984 and 1985 in Khon Kaen Province, Thailand.

OUTLINE OF IRRIGATION PROJECT

The Nong Wai Pioneer Agriculture Project is Located in Khon Kaen Province in the North-east, Thailand. The command area of the project covers 15,000 ha, in which the net beneficial area is 10,840 ha (67,735 rai). The project area is bounded by the Nam Pong River on the east, the Nam Chi River on the south and the Right Main Canal on the west.

The main objective of the project is accomplishment of water conveyance system and land consolidation with ditch improvement.

The topography of the area is flat plain. The elevation is about 150 m [MSL], although the area located 400 km inland from the Gulf of Siam. There are partially gentle ups and downs about ±5 m or so in the plain, and villages straggle in comparatively high part of elevation.

1. Layout of Irrigation System

The layout of the main irrigation system and project area is shown in Fig. 1.

The source of water supply is the Ubolratana Reservoir which is dammed up by the rock-fill dam named the Ubolratana Dam. Irrigation water is conveyed through the Nam Pong River to the Nong Wai Diversion Dam located 25 km downstream of the Ubolratana Dam.

The diversion dam has two water intake gates at the right side and the left side. The irrigation water taken in from the left side gate (max. discharge; 35.0 m^3/sec) is conveyed to the Nam Pong Stage I project and the Nam Pong Stage II Project (both command area ; 29,800 ha) through the Left Bank Main canal.

The irrigation water from the right side gate (max. discharge; 15.8 m^3/sec) is conveyed to the Nong Wai Pioneer Agriculture Project through the Right Bank Main Canal. The Nong Wai Pioneer Agriculture Project which is surveyed and investigated area in this research is, therefore, one of the three projects supplied water from the Ubolratana Reservoir.

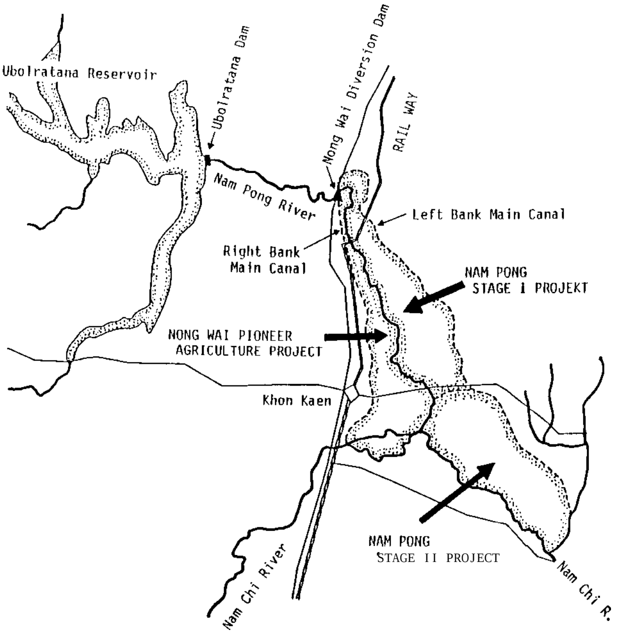

Fig. 1. Nong Wai Pioneer Agriculture Project (after Kathpalia, 1983)

2. Dimensions of Reservoir

The Ubolratana Dam was built across the Nam Pong River in 1965 by the Electricity Generating Authority of Thailand (EGAT). The dam has the multi purposes for electric power generation, flood control, irrigation use and domestic water supply.

The Ubolratana Reservoir has been operated and maintained by EGAT. There are two ways for discharging water from the reservoir. One is through the generator and the another is direct discharging to the Nam Pong River for irrigation with additional small amount of domestic use.

For irrigation, water discharge of 30-40 m^3/sec (max. 50 m^3/sec) is continuously supplied during the cropping season from the reservoir. The discharge for irrigation is requested from the Royal Irrigation Department (RID) to EGAT. The prediction and discussion for adjustment of water demand and supply is to be usually held weekly.

The dimensions of the Ubolratana Reservoir are as follows (Asian Development Bank, 1983 ; Kathpalia, 1983).

Catchment area ; 11,980 km^2
Surface area ; 410 km^2
Full reservoir level ; 182.0 m [MSL]
Full storage capacity ; 25.5 $X\ 10^8 m^3$
Minimum operational level for generation ; 173.8 m [MSL]
Dead water capacity ; 4.7 $x\ 10^8 m^3$
Available depth ; 8.2 m

Now, this dam is under construction to improve the flood control capacity for a high flood which may occur once in a hundred years. The dam crest will be raised up 3.6 m from 185.0 m [MSL] to 188.6 m [MSL] to increase flood absorption capacity. The spillway crest will be lowered to increase the releasing capacity of flood.

When the construction is completed, the both of the availability of water use and the flexibility of reservoir operation will be more improved.

3. Improvement of Diversion Dam

The Nong Wai Diversion Dam was built as one of the main facilities in the Nam Pong Irrigation Project in 1966 by RID.

In rainy season, 15.8 m^3/sec of water discharge, same as the water right, was able to be taken in from the diversion to the Nong Wai Pioneer Irrigation Project Area through the Right Side Main Canal. On the other hand, in dry season, the limited discharge of 13-14 m^3/sec was only available, because of unable keeping at the sufficient required water head at the diversion. The crest elevation (162.4 m [MSL]) of the diversion dam was, therefore, raised up 60 cm with rubber weir in 1985 and now it is available to take in the discharge of 15.8 m^3/sec in any season.

EVALUATION OF CONVEYANCE SYSTEM

The maximum discharge of 15.8 m^3/sec is taken in at the Nong Wai Diversion Dam to serve a net command area of 10,615 ha in the Nong Wai Pioneer Agriculture

Project.

The main irrigation system in the Project consists of one main canal, seven lateral canals and eight sub-lateral canals.

The length of the main canal is 47.5 km and the length of secondary and tertiary canal is 32.5 km. The total length is 80 km.

The canal system has 248 irrigation ditches which are connected to the canal system through the double orifice gates for controlling the discharges from the canal to each ditch.

In general, the canal system has to convey the designed flow rate and also the water surface in the system should be kept the sufficient elevation to deliver irrigation water to each ditch and field block, because flow phenomena in the canal system depend on the driving force caused by gravity.

The topography in the area is very flat, and the longitudinal slope of main canal is small. To keep the water surface in main canal, there are nine check structures in the canal.

The mean velocity of uniform flow in the canal is given by Manning Equation.

$$V=\frac{1}{n}R^{2/3}i^{1/2} \tag{1}$$

in which, V ; mean velocity, n ; coefficient of roughness, R ; hydraulic radius, i ; bed slope (equal to surface slope).

When check gate is operated, the flow changes from uniform flow to non-uniform flow. The mean velocity in this case is approximately given in Eq. (2), as the flow might be assumed quasi-uniform flow.

$$V'=\frac{1}{n}R^{2/3}I^{1/2} \tag{2}$$

in which, I ; surface slope (I <bed slope i).

Characteristics of check gate in canal flow is shown in Fig. 2. In usual, when

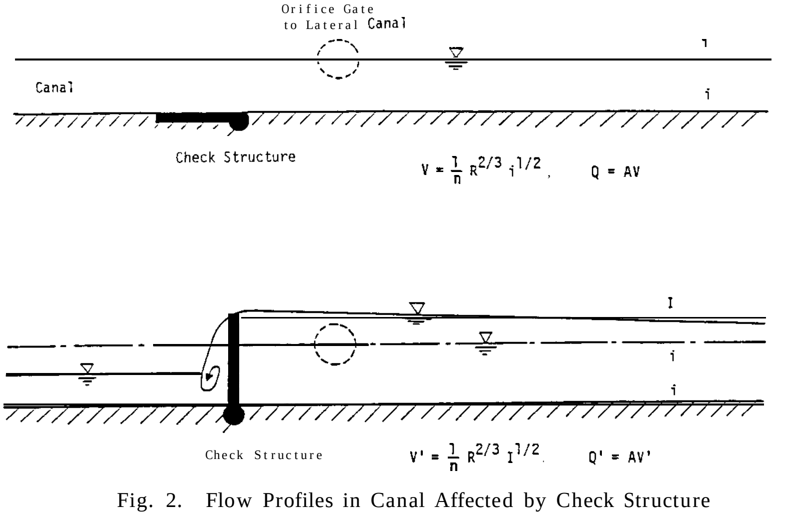

Fig. 2. Flow Profiles in Canal Affected by Check Structure

check gate is operated in the main canal the conveyance efficiency of the canal decreases and both of water head and flow rate in down-stream side of the check gate extremely decrease. Only up-stream side of the gate gets benefit.

The functions of the canal system are examined in field survey from the view point of topography, especially the differences of each elevation of the main canal, laterals and field blocks.

The obtained results are follows.

1. To keep the water level for distributing the irrigation water from the main canal to lateral canals, the check structures are indispensable.

2. The function of water conveyance in the main canal decrease with the check gate structures.

3. The operation of water conveyance system becomes very complicated and it takes many labor of well experienced.

4. There is delay of flow response due to check gate operation. This phenomenon relates to the increasing of the operation loss of irrigation water.

COMPARATIVE INVESTIGATION OF UNIT WATER REQUIREMENT

The unit water requirement in paddy field WR, is defined as Eq. (3).

$$WR, = ET + PV + PH \qquad (3)$$

in which, ET ; evapotranspiration, PV ; vertical percolation, PH ; horizontal percoration including levee percolation.

The net duty of water DW, is given as Eq. (4).

$$\begin{cases} DW_N = WR, - RE, & \text{when } WR, > RE \\ DW_N = 0, & \text{when } WR, < RE \end{cases} \qquad (4)$$

in which, RE; effective rainfall.

According to the report of Sanyu Consultants Inc., (1981), the unit water requirement in the Nong Wai Pioneer Agriculture Project was determined 6.7～8.2 mm/day in the planning which was previously established. This value is about a half of the unit water requirement of the Kase River Irrigation Project (Ikushima and Kuroda, 1973) locating in low lying delta in Kyushu, Japan.

The values of unit water requirement and those components in both projects are shown in Table 1.

The deference between the Nong Wai Pioneer Agriculture Project and the Kase River Irrigation Project are caused by horizontal percoration including levee percola tion.

It is only allowable to plan without counting horizontal percolation in unit water requirement, when the irrigation system has the reuse function of water. Because horizontal percolation appears in drainage canal as return flow and can be repeatedly used in plots locating in lower elevation. In low lying flat area, however, pumping facilities are inconveniently requested for reusing the return flow.

The area belongs to the Nong Wai Pioneer Agriculture Project is very flat plane

Table 1. Unit water requirement and its component.

Item	Nong Wai P. A. P. (after Sanyu Consultants Inc., 1981)	Kase River I. P. (after Ikushima and Kuroda, 1973)
Evapotranspiration	5.2 mm/day	6.2 mm/day
Vertical Percolation	1.5~3.0 mm/day	0.9 mm/day
Horizontal Percolation (including Levee Percolation)	none	8.3 mm/day
Unit Water Requirement	6.2~8.2 mm/day	15.4 mm/day
Effective rainfall		
rainy season	2.9 mm/day	
dry season	none	

and it is supposed very difficult to supply the sufficient amount of water to each plot without counting horizontal percolation or without operating pumping facilities.

WATER BALANCE IN EXTENSIVE SYSTEM AND INTENSIVE SYSTEM

There are two types of paddy field irrigation system called the intensive irrigation system and the extensive irrigation system in the Nong Wai Pioneer Agriculture Project.

The intensive irrigation system is characterized by the perfect land consolidation which includes various works of irrigation canal, drainage canal, farm road, land leveling and land readjustment.

The extensive irrigation system is usually distinguished as the simplified land consolidation which gives priority to irrigation ditch improvement.

From the viewpoint of cost saving, the extensive system is rather adopted than the intensive system by the Royal Irrigation Department from 1981.

Just outside of the project area, there widely lie scattered the rain-fed paddy fields which are one of the traditional irrigation system in this province area.

1. Rain-fed System and Extensive System

The layout of rain-fed system is shown in Fig. 3 and the layout of extensive system is shown in Fig. 4, respectively.

The water flow in both of rain-fed system and extensive system is illustrated in Fig. 5. The water balance in these system is expressed as follows.

$$\left.\begin{aligned} Qin_1 &= ET_1 + PV_1 + PH_1 + Qout_1 \\ Qin_2 &= Qout_1 + PH_1 = ET_2 + PV_2 + PH_2 + Qout_2 \\ &\cdots\cdots\cdots\cdots\cdots\cdots \\ Qin_N &= Qout_{(N-1)} + PH_{(N-1)} = ET, + PV_N + PH_N + Qout_N \end{aligned}\right| \quad (5)$$

$$\therefore Qin_1 = \Sigma\ ET_i + \Sigma\ PV_i + PH_N + Qout_N \quad (6)$$

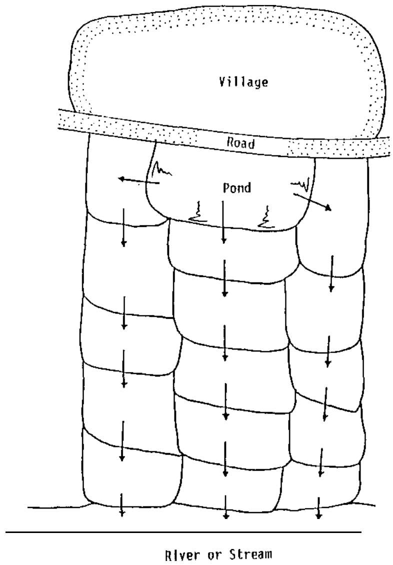

Fig. 3. Layout of Rain-fed Paddy Fields System

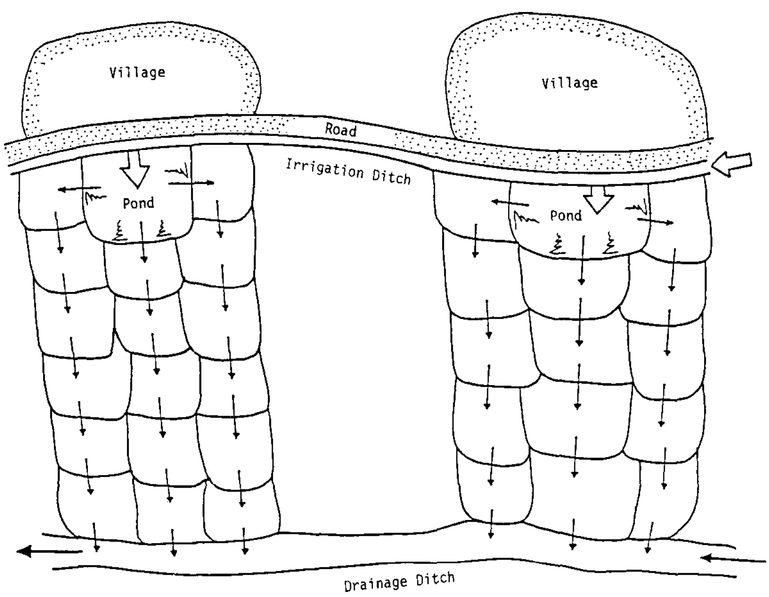

Fig. 4. Layout of Extensive Irrigation System

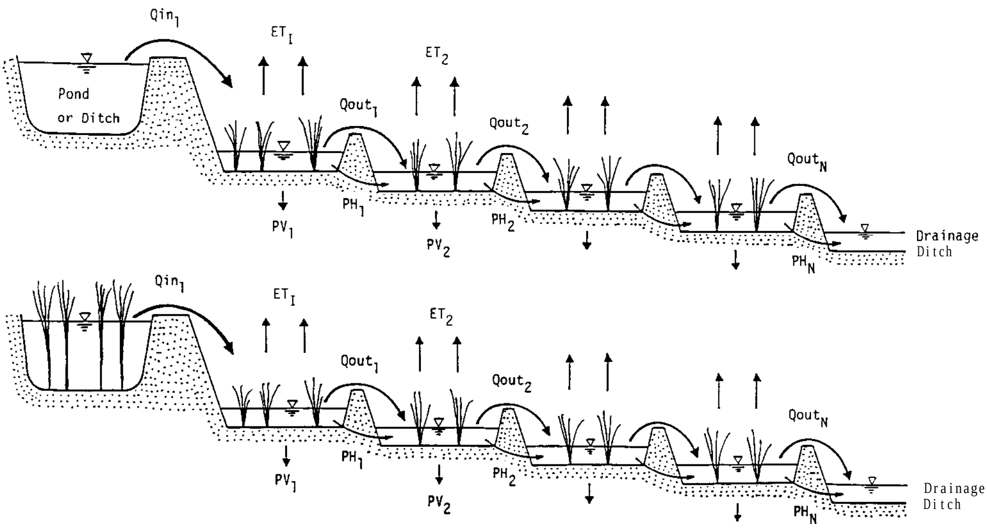

Fig. 5. Illustration of Water Balance in Fields (Extensive System and Rain-fed System)

then, the irrigation loss in these systems IL ;

$$IL = PH_N + Qout_N \tag{7}$$

and the management loss ML ;

$$ML = Qout_N \tag{8}$$

The irrigation loss and the management loss in the rain-fed system and in the extensive system occurs only on the plot locating in the most downstream side in the system, and this phenomenon is very effective for saving irrigation water.

In the rain-fed system, there is a custom on the precedence of water application to each plot, according to the elevation and location of the plot. But the phenomenon above mentioned is only effective in rainy season, as water resource from rain-fed is absolutely limited in dry season.

In the extensive system, the custom of the precedence of water application is still remained. The extensive system has a suitable characteristic for saving water in irrigation, because seepage (horizontal percolation) water and drained water from upper plots are repeatedly used in lower plots, and the water demand in the system decreased with this phenomenon.

In other hand, the extensive system has some limitations for mechanization of farming. The plots belonging to the system are usually narrow and not rectangular shape. In addition, there are some differences of elevation among each plot.

2. Intensive System

The layout of intensive system is shown in Fig. 6 and the water flow is illustrated in Fig. 7. The water balance in the system is given as follows.

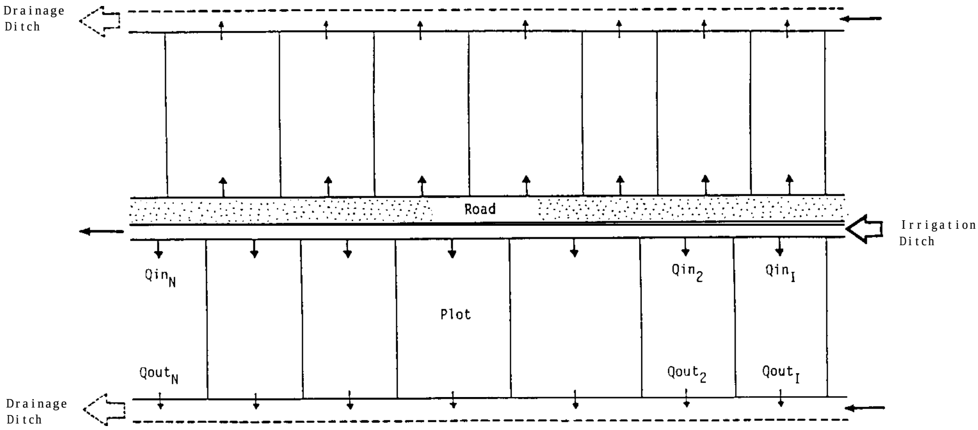

Fig. 6. Layout of Intensive Irrigation System

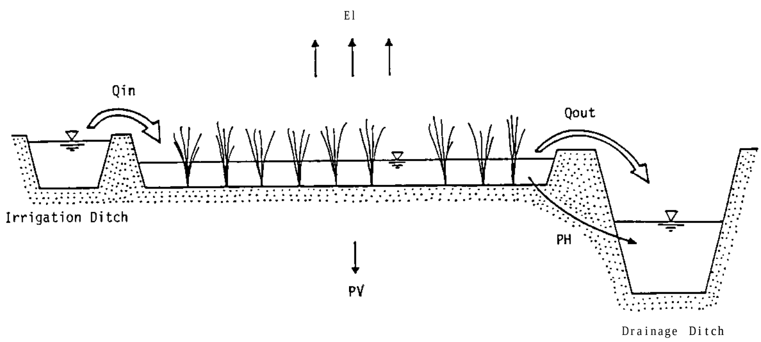

Fig. 7. Water Balance in Field (Intensive System)

$$\left.\begin{array}{l} Qin_1 = ET_1 + PV_1 + PH_1 + Qout_1 \\ Qin_2 = ET_2 + PV_2 + PH_2 + Qout_2 \\ \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\ Qin_N = ET_N + PV_N + PH_N + Qout_N \end{array}\right\} \quad (9)$$

The total amount of taken water into the intensive system TQ_{in} is given as

$$TQ_{in} = \Sigma\ Qin_i = \Sigma\ ET_i + \Sigma\ PV_i + \Sigma\ PH_i + \Sigma\ Qout_i \quad (10)$$

then, the irrigation loss in the system IL ;

$$IL = \Sigma\ PL_i + \Sigma\ Qout_i \quad (11)$$

and the management loss ML ;

$$ML = \Sigma\ Qout_i \quad (12)$$

The water balance in the intensive system is characterized by the individual water application to each plot, because each plot faces to both irrigation ditch, and drainage ditch. The irrigation loss IL in the system is, therefore, defined as the summation of the loss factors on each plot, shown in Eq. (11) and (12). The water demand in the system increases rather than the demand of the extensive system.

From a view point of saving water, the intensive system is not so suitable.

But this system has other merits. The rotational use of the plots for paddy and other crops is easily available in this system. In addition, this system has availability and potentiality for modernization and mechanization of farming.

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