MULTI-CRITERIA DECISION MAKING FOR WATER ALLOCATION IMPROVEMENT IN LARGE IRRIGATION SYSTEM

INTRODUCTION

Agriculture is the major income of the population in Thailand. The Government needs to raise agricultural productivity through improvement of irrigation and drainage services of the existing irrigation systems. Improving of water resources management become very urgent issue and the irrigation systems are necessary to support in order to achieve the better water management.

Performance of irrigated agriculture is a very complex subject. Irrigation systems often have a number of competing objectives and are assessed by interest groups with differing values and perspectives, a wide range of performance indicators is thus required. Performance indicators may be used for several purposes. Indicators can be used by system managers to compare actual results to planned target.

The irrigation practice in each irrigation projects, these can only be achieved by paying attention to internal details. The specific details addressed by Rapid Appraisal Process (RAP) are improving water control throughout the project, and improving the water delivery service to the users. In this study, we can set the pilot irrigation projects for learning the irrigation practices by RAP in 3 groups as Pitsanulok irrigation project, Upper east bank and Upper west bank of Chao Phraya Delta area. In each groups were consisted of 4 Operation and Maintenance (O&M) projects. The specific details will be concluded by questionnaire. The questionnaire by FAO guideline, which it was modified by Bert (2001), will be used for specific detail questions. The result of RAP will be illustrated in qualitative indicators.

From the different index values and the objective function in large irrigation project, a Multi-Criteria Decision Making (MCDM) can be useful for managers to plan the water resources management of large irrigation systems. This research, many indicators will be used to set an Analytic Hierarchy Process (AHP). The consideration for irrigation performance assessment, we can set in two criteria for assessment as qualitative indicators and quantitative indicators. In each criteria consist of sub-criteria, which will be used to evaluate irrigated areas in differential situation. The results of calculated and MCDM approach will be finding the water allocation improvement in for large irrigation system.

OBJECTIVES

The main objective of this research is to set the criteria for water allocation assessment in large irrigation system. The specific objectives of the study are as following:

1. To define and evaluate qualitative indicators for irrigation practices in irrigated areas using the Rapid Appraisal Process (RAP);

2. To conclude and set the criteria of performance indicators for large irrigation systems in the Chao Phraya River Basin; and

3. To propose a methodology using a multi-criteria decision making to improve water allocation in large irrigation system.

The scope of this research is to develop a water allocation assessment methodology applicable to large irrigation systems as follow;

1. The pilot irrigation projects in the Chao Phraya river basin are the study area to be used in evaluating water allocation in large irrigation project;

2. A Rapid Appraisal Process (RAP) will be used to evaluate the water allocation practices in large irrigation system. The process is a tool to evaluate qualitative values of water allocation in 12 pilot irrigation projects. The results will illustrate general irrigated practices in each pilot irrigation project;

3. The available hydrologic data (such as rainfall data, water supply, irrigated areas, cropping pattern, yields, etc.) will be supported by the Royal Irrigation Department;

4. The irrigation water requirement for large irrigation system will be simulated in weekly format using water balance model;

5. The data collections of large irrigation projects, including organization parameter, will be used to evaluate the irrigation performance indicators. The results of this evaluation will provide variable values of these indicators;

6. The variable values of the key performance indicators will be used in the MCDM for deriving the water allocation improvements for Plaichumpol O&M projects ; and

7. From the results and methodology of MCDM for large irrigation system in Chao Phraya river basin can be adapted to evaluate other large irrigation system for water allocation improvement.

LITERATURE REVIEW

1. Irrigation Performance Indicator

Styles and Marino (2002) study in the title: "Water delivery service as a determinant of irrigation performance" and represent about, Performance of the irrigation system is measured levels of achievement in terms of one or several parameters that are chosen as indicators of the system's goals. The purpose of this paper is to utilize and refine a set of evaluation indicators that can be used to describe the irrigation performance for sixteen international irrigation projects in developed countries. The irrigation performance of many international irrigation projects in less-developed countries has been reported as poor. The cause of the poor irrigation performance has been blamed on technical, financial, managerial, social, and/or institutional causes. They study about the specifically designed to evaluate whether irrigation project performance could be improved with modern irrigation design. A key feature of the new standards will be to provide irrigation project managers the information required to effectively improve the operations and service within a project. Results of this project indicate a need for a combination of both management and hardware improvements in every project visited. The primary conclusion is far-reaching and extremely significant for the future of irrigated agriculture in less-developed countries -- increased levels of water delivery service (flexibility in flow rate, duration, and frequency) is a key determinant of improved performance of the farmers within the irrigation project (increased fields). The results are very clear -- modernized irrigation design can positively impact irrigation project performance.

A considerable amount of work has been undertaken in the past 10 years to develop a framework for irrigation performance. Irrigation water delivery should be evaluated on the dimensions of adequacy, timeliness, and equity. Sometimes, other terms are also used: efficiency in water use, predictability and reliability of water supply. These are, however, not separate but are associated with adequacy and timeliness. Water quality may be an additional important dimension in some system. (Rao, 1993)

1.1 Adequacy

Bos and Nugteren (1990) describe about Irrigation Efficiency was widely used to assess the efficiency of water supply to meet the crop water requirements. In the study of rice system, Relative Water Supply (RWS) has also been extensively used and its role as an explanatory variable for studying the implications for system management deserves careful attention. In principle, irrigation efficiency and RWS are the reciprocal in each other.

In actual application of these concept and methodologies, there are different interpretations and practice. For example, the definition of crop water requirement in the Gezira witch includes all field losses below the field outlet pipe differs from the normal definition used in other countries. This implies field application efficiency (e_a) of 100 percent. However, the field efficiency defined more traditional, is estimated at about 75 percent. (Plusquellec, 1990)

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$$\mathrm{RWS} = \frac{\text{Irrigation} + \text{Effective Rainfall}}{\text{Crop Water Requirements} + \text{Losses}} \qquad (1)$$

Adequacy need to be measured over a time period for it to be effective as an indicator. RWS can be calculated for a certain period such as a week, a mouth, or a season (Mainuddin, 2000). Mainuddin (2000) refers to Molden and Gate (1990) as that the measurement of performance, relative to adequacy for a region R served by the system over the time period T (by) becomes:

$$P_A = \frac{1}{T}\sum_{t}\left(\frac{1}{R}\sum_{R} P_A\right) \quad (2)$$

Where

$P_A = Q_D/Q_R$ if $Q_D \le Q_R$

$P_A = 1$ otherwise

$Q_D(x,t) =$ actual amount of water delivered by the system at a point x at time t

$Q_R(x,t) =$ amount of water required for consumptive and other uses downstream of the delivery point x at time t

1.2 Timeliness

There are two quite distinct dimension included in the question of timing of water delivery. Rio(1993) was distinguish these by the terms “timeless” and “reliability”. Timeliness means correspondence of water deliveries to crop needs. It can be considered on the Basis of the accuracy of fit between two times history curves, one of which represents the evapotranspiration needs of the crop throughout its season, and the other the actual deliveries of water.

Reliability, on the other hand, means the degree to which the irrigation system and its water deliveries conform to the prior expectations of the users. Can the farmer feel certain that he knows whether water will come to his field channel on a given day, and in what rate and quantity it will flow? Reliability is very important, affecting the efficiency of various field activities. It includes the concept of predictability of flows as indicated by water delivery schedule or operational plan without which the concept of reliability does not make sense. (Rio, 1993)

Where the water allocation, distribution, and delivery are supply-based and controlled and regulated by an irrigation agency, the most important question is whether the agency prepares and operational plan and water delivery schedules to guide its operation of regulator and control, monitors the operations, revises the plan and schedules as needed in a systematic manner, and communicates the revision of the farmers. If the water delivery schedules exist and are implemented, there should be no difficulty in computing the reliability of supply with respect to time, if not respect to the quantity of supply. However, if no measurement is made and no record kept, there is no way of knowing if the operation of recording to the schedule, which existed on the paper. In many projects, there is not information on volume of water delivered at various levels (tertiary, secondary. etc.); and even where it exists, it is often unreliable.

Question of operational plans and timeliness are much more complex, given the dynamic nature of the states of water resource and the irrigation systems. Operation plans depend on the strategies selected, resource allocations and priorities. Even in systems backed by reservoir storage, it is only at the beginning of the dry season, when the storage volume is known definitely, that allocation decisions and decision on extend of cropped area to be irrigated can de made with certainly. In wet season, the reservoir fills with the progress of the seasonal, allocation and crop's planning decisions cannot be made without taking some risk. Even the decision on when the season starts to finish. The important dimension of timeliness at macro level is not easy to make. Farmers also make their decision on crop choices and planted dates in the face of uncertainly of occurrence of rainfall and the building-up of storage in the reservoir. (Rio, 1993)

Assumption made regarding land preparation time and staggering of land preparation by different sections of farmers often prove erroneous and the operational plans and water delivery schedule prepared on the basis of such assumption do not hold good and must to revised on the basis of information obtained from the field. This emphasizes need for feedback, communication and interaction between the farmers and the agency, the ability and the willingness on the part of agency to be responsive and flexible within a certain range of predetermined parameter, and a physical infrastructure that enable controlled regulation and implementation of the operational decision made. There should also be a clear policy and understanding on how to cope with shortage in the storage volume of water if they occur towards the letter part of the season. The making of decision can become even more complex in diversified cropping systems and in system involving conflicting water rights.

The burden of the argument is that the timeliness dimension is intricately connected with allocation and distribution issues, which naturally imply issues of adequacy and equality, and need to be treated in a more holistic manner than in a disaggregated fashion. However, an operational strategy and water delivery schedule are primary prerequisites to any determination or reliability in supply-based systems. Their existence comprises one of the important process indicators of performance.

1.3 Efficiency

Most of the definition for irrigation indicators is based on ratios of water volume. Moldem and Gates (1990) defined the measure of irrigation efficiency as the spatial and temporal average of the ratio of the amount of water required (Q_R) to the amount of water delivered (Q_D) by the system:

$$P_F = \frac{1}{T}\sum_{t}\left(\frac{1}{R}\sum_{R} P_F\right) \tag{3}$$

where,

$P_F = Q_R/Q_D$ for $Q_R \leq Q_D$

$P_A = 1$ other wise

1.4 Equality

Levine and Coward (1989) point out that the system that is considered fair by most farmers is more likely to be productive and efficient than one that the state has design on the basic of productivity and efficiency but which is considered unfair by farmers. The dynamic nature of the context within which irrigation occurs frequently necessitates changes in physical infrastructure and organizational arrangement, including those, which determine system operation and maintenance. Rule and operating procedures are implemented by the use of the physical works as well as by the actions of the controlling agency and the farmers. Thus decisions about the physical structures and procedures of the operating agency and the rules of water users much to made with explicit consideration of their interaction nature.

The equality in water allocation and distribution has different dimensions. In situations where the stored volume of water in the reservoir is not adequate to meet the demands of the full command area over the entire season, the command area may be divided into a number of zone and available water allocated to a few of the zone in such as a way that supply and demand are matched. Then, equality in allocation in various zones sought to be achieved by appropriate rules that govern allocations over a number of seasons or years. This requires good record keeping and formal institution mechanisms involving agency personal and farmer representatives from various zones.

Equality, as related to water delivery systems, can be defined as the allocation of a fair share of water to each sub-area in a large irrigation system. A fair share of water may be based on a legal right of water, as in prior appropriation system, or may be set as a fixed proportion of the water supply. Equality of water delivery is a difficult objective to measure because there are many factors that determine the meaning of fair share (Mainuddin, 2000).

The proposed indicators by Bos *et al.* (1994) is that equality is the same as equality and can be easily addressed by statistics measures of deviation on the mean. Abernethy (1986) deals with performance measurement in canal water management and make two important contributions regarding measurement of equality. He defines two measure of equality, I_1 and I_2. The inter-quartile ratio (IQR) I_1 is defined as

$$I_1 = \frac{h_{75}}{h_{25}} \tag{4}$$

where,

h_{25} = the depth of water such that one quarter of all the land receives less than this

h_{75} = the lower limit of the most favored quarter.

And I_2 is modified inter-quartile ratio:

$$I_2 = \frac{\text{Average depth received in the best quarter}}{\text{Average depth received in the poorest quarter}} \tag{5}$$

Bos *et al.*(1994) introduced an indicators, based on the inter-quartile ratio of Abernethy (1986), that uses Delivery Performance Ratio(DPR), which can also be used to give a quick view of overall equality:

$$\text{Modified Interquartile Ratio} = \frac{\text{Average DPR of Best 25\% of the System}}{\text{Average DPR of Worst 25\% of the System}} \tag{6}$$

and a performance measure relate to equality , P_E (Molden and Gate, 1999) as

$$P_E = \frac{1}{T}\sum_{T} CV_R \left(\frac{Q_D}{Q_R} \right) \tag{7}$$

where, CV= Spatial coefficient of variation over the region R

1.5 Productivity

Agriculture production performance indicators include cropping intensity, ratio of area planted and area harvested, annual yield, productivity of land, and productivity of water. The importance of particular indicators depended on the relative scarcity of land and water, as well as cropping patterns and sequences (Rao, 1993).

In the planning, design and operation of irrigation schemes, it is necessary to analyze the effect of water supply on crop yield. If water supply is less the crop water requirement and the actual evapotranspiration less than the potential evapotranspiration, there are affected to crop grown and crop yield. The different level on irrigation has been considered, therefore actual crop yield related to water supply. There are necessary to be quantified for analysis of crop benefit. The relative yields of different crops due to deficit irrigation supply have been calculated using empirical crop production function presented by Doorenbos and Kassam (1977) which is stated as follows;

$$\frac{Y_a}{Y_p} = 1 - K_y\left[1 - \frac{ET_a}{ET_b}\right] \quad (8)$$

Where,

Y_a = actual yield;

Y_p = the potential yield that will be obtained at potential evapotranspiration;

ET_a = actual evapotranspiration;

= (1-d/100)NIR+ER

ET_p = potential evapotranspiration;

= NIR+ER

NIR = Net Irrigation Requirement

ER = Effective Rainfall

K_y = yield response factor (find in FAO report no. 56); and

d = deficit percentage

Burt and Stuart (1999) refer to IWMI indicators of irrigated agricultural output in FAO water report No.19, where IWMI provides four external indicators of agricultural outputs; these are:

$$\text{Output per croped area}\left(\frac{\text{US\$}}{\text{ha}}\right) = \frac{\text{Production in US\$}}{\text{Irrigated cropped area }(A_{\text{cropped}})\text{ in ha}} \tag{9}$$

$$\text{Output per unit command}\left(\frac{\text{US\$}}{\text{ha}}\right) = \frac{\text{Production in US\$}}{\text{Command area }(A_{\text{command}})\text{ in ha}} \tag{10}$$

$$\text{Output per unit irrigation supply}\left(\frac{\text{US\$}}{\text{m}^3}\right) = \frac{\text{Production in US\$}}{\text{Diverted irrigation supply }(V_{\text{div}})\text{ in m}^3} \tag{11}$$

$$\text{Output per unit water consumed}\left(\frac{\text{US\$}}{\text{m}^3}\right) = \frac{\text{Production in US\$}}{\text{Volume of water consumed by ET }(V_{\text{consumed}})\text{ in m}^3} \tag{12}$$

Production is the output of irrigated area in terms of the gross or net value of production in local or world prices.

Irrigated cropped area is the sum of the area under cultivation during the time period of analysis, which equals the command area or equipped area multiplied by the cropping intensity.Command area is the nominal or design area to be irrigated. Diverted irrigation supply is the volume of surface irrigation water diverted to the command area, plus net removals from groundwater. Volume of water consumed by ET is the actual evapo-transpiration of crops, ET_{crop}.

1.6 Financial Indicators

The production of irrigation projects will show the benefit of each project. In each project, there are operation and maintenance costs (O&M cost) for water supply and water delivery in the irrigated area. Burt and Stuart (1999) refer to IWMI financial indicators about financial self-sufficiency; which is a ratio of irrigation revenue and O&M expenditures. Sometimes, this ratio is called collection rate. Financial self-sufficiency should also include the ability to improve the infrastructure (as needed) and to repay original construction costs. Financial self-sufficiency is called percentage of O&M collected:

$$\text{Percentage of O \& M collected} = \frac{\text{Irrigation Revenues}}{\text{Total O \& M expanditures}} x100 \qquad (13)$$

Results Based Management by Royal Irrigation Department (RID) (2003) refers to Critical Success Factor (CSFs) for irrigation managements, One of the CSFs refers to utilization (economization and worth) of resources in irrigation projects. The RID includes an indicator to evaluate water management budget per rai. At the period of time, the best utilization of resource will be based on a decrease of this indicator value. This indicator is:

$$\text{Water management budjet} \left(\frac{\text{Baht}}{\text{Rai}}\right) = \frac{\text{O \& M cost}}{\text{Irrigated cropped area}} \qquad (14)$$

2. Rapid Appraisal Process for Modern Irrigation Water Control

Using the Rapid Appraisal Process (RAP) for diagnosing irrigation projects is not new. RAP has been used for identification of international irrigation projects, although variations of the RAP have been used since 1989 by the Irrigation Training and Research Center (ITRC) at California Polytechnic State University on dozens of irrigation modernization projects throughout the western U.S.A. The ITRC has used RAP techniques for several years while working with irrigation projects throughout the western United States (Burt et al., 1996). In some cases, the ITRC has used the RAP process for determining baseline data and statistical purposes, but in most cases the ITRC has been asked to perform a system diagnosis for modernization (Burt and Styles 1999). Plusquellec (1996) has also promoted the application of RAP for several years based upon his experience.

RAP of irrigation projects was introduced through a joint effort. The Food and Agriculture Organization of the United Nations (FAO), International Program for Technology and Research in Irrigation and Drainage (IPTRID) and World Bank publication entitled Water Reports 19 (FAO) – Modern Water Control and Management Practices in Irrigation – Impact on Performance (Burt and Styles 1999). This public research built upon previous work presented in World Bank Technical Paper No. 246 (Plusquellec et al. 1994). The publication provides an explanation of the RAP and also gives RAP results from 16 international irrigation projects (nine in Asia, two in Africa, and five in Latin America). The study found many examples of improved operation and performance due to management and hardware modernization. However, the research project did not find any complete modernization programs; instead, various components of modernization were found. The conclusions indicated the need for improvements in hardware, management and water management at the field level, training, and water user associations.

Water control at all system levels consists of flow measurement and communication capabilities, both of which are basic ingredients required for almost any irrigation system modernization program. The most effective manner for achieving operational objectives is for irrigation agencies to provide technical assistance as a service to farmers' organizations. Water allocations and deliveries should be considered individually according to the site-specific conditions of each irrigation project, including delivery locations relative to the water source, irrigated area, cropping pattern, infrastructure layout, and organizations. The technical feasibility of physical or operational interventions to improve the system must be analyzed before their implementation, and proper consideration given to the system constraints. It is also necessary to identify appropriate ways of operating the system for reliable water delivery (Skogerboe et al. 1998).

Renault (1998) described improved performance in irrigation water management and stated that it can usually be achieved through three types of interventions:

1) Rehabilitation, which consists of rebuilding deficient infrastructure to return it to the original conditions. Although "rehabilitation" usually applies to the physical infrastructure, it can also be applied to institutional arrangements;

2) Process improvement, which consists of operational interventions without changing the rules of the water management. For instance, the introduction of modern techniques is a process improvement; and,

3) Modernization, which is a more complex intervention, implying fundamental changes in the rules governing water resource management. It may include interventions in the physical infrastructure as well as in its management.

3. Irrigation System Water Balances

Irrigation system water balance is the relationship between in flow (I) and outflow (O) on the irrigation system. The different during inflow and outflow is the storage of water (ΔS) in the system as equation below;

$$I - O = \Delta S$$

Inflow to the irrigation system consists of the water delivery from the head regulator of the canal system (Q_c) and precipitation (P), while the outflow consists of evapotranspiration (ET) and Irrigation Return Flow (IRF) shown in Equation (15)

$$(Q_c + P) - (ET + IRF) = \Delta S$$

$$Q_c + P - ET - IRF = \Delta S$$

Also

$$RF + \Delta S = Q_c + P - ET \tag{15}$$

The IRF values in each irrigation system will be evaluated monthly based on available hydrological data (Q_c, P and ET). The assumption of this equation is that the water storage (ΔS) is zero

Water demands and return flows for irrigation blocks that are represented as the water balance. So, the calculation of irrigation demands for each time-step (month or week) of the simulation period is the result of irrigation water balance. The equation forms the basis of the irrigation demand calculation as following; (RID, 1999)

$$FWR_{ij} = \frac{(CU_{k,j} + LP_{i,j} + STO_{i,j} - EFR_{i,j} + PERC_i)}{Ef_i} \tag{16}$$

where,

$FWR_{i,j}$ = field water requirement for field i in time-step j (mm/time-step)

$CU_{k,j}$ = consumptive use for crop type k in time-step j (mm/time-step)

$LP_{i,j}$ = land preparation for field i in time-step j (mm/time-step)

$STO_{i,j}$ = change in storage depth for field i in time-step j (mm/time-step)

$EFR_{i,j}$ = effective rainfall for field i in time-step j (mm/time-step)

$PERC_i$ = percolation losses for field i (mm/time-step)

Ef_i = field efficiency for field *i* (ratio)

Consumptive use is computed according to the method recommended by the FAO-ID24, as follows.

$$CU_{k,j} = KC_{k,Cj} \times ETo_j \tag{17}$$

where,

$KC_{k,Cj}$ = crop coefficient for crop type k corresponding to time-step j

ETo_j = potential evapotranspiration of a reference crop in time-step j (mm/time-step)

The theoretical return flow from an irrigation block is computed as the difference between the water supplied (irrigation plus rainfall) and the water actually used in the field. The return flow from irrigation water demand and the return flow from rainfall runoff calculated by equation 18, 19, 20 and 21 respectively.

$$RFLOI_j = RFACT_j \times \sum_i^N \left[\frac{FWR_{i,j}}{E_{s,j}} - \left(CU_{i,j} + LP_{i,j} + STO_{i,j} - EFR_{i,j} \right) \right] \times A_{i,j} \quad (18)$$

where,

$RFLOI_j$ = volume of return flow from irrigation water demand in time-step j

$RFACT_j$ = return flow factor in time-step j

The return flow from rainfall runoff is calculated as the runoff from cropped areas, RRC, computed as:

$$RRC_j = RFACT_j \times \left[\sum_i^N (RAIN_j - EFR_{i,j}) \cdot A_{i,j} \right] \quad (19)$$

Plus the rainfall runoff from uncropped areas computed as:

$$(RAIN_i - EFR_{u,j})(AREA - \sum_i^N A_{i,j}) \quad (20)$$

to give the total rainfall runoff as:

$$RRUN_j = RRC_j + RRU_j \quad (21)$$

where,

$RRUN_j$ = rainfall runoff in time-step *j*

$RAIN_j$ = rainfall in time-step j

$EFR_{u,j}$ = effective rainfall on uncropped areas in time-step j

AREA = total irrigation block area (m^2)

$RFACT_j$ = return flow factor in time-step *j*

The return flow factor, RFACT, is used to reduce the theoretical return flow due to evaporation from canals, off channel storage, loss to deep percolation, and other factors which result in a loss of water from the drainage system. (RID, 1999)

For irrigation project planning purpose, the net irrigation requirement of the crops other than rice is estimated using the field water balance as; (Sahoo, 1998 refer to Doorenbos and Pruitt, 1984)

$$NIR = ET_{crop} - ER + LPR + P \quad (22)$$

where,

NIR = Net irrigation requirement in mm/day;

ER = Effective rainfall, mm;

LPR = land preparation and nursery requirement, mm;

P = Deep percolation requirement.

Gross Irrigation Requirement (GIR) is the total irrigation requirement for crops at the main intake point from the source. It can be expressed as;

$$GIR = (A \times NIR)/IE \quad (23)$$

Where,

GIR = gross irrigation requirement, m^3/day;

NIR = net irrigation requirement of a given crop, mm/day;

IE = Irrigation Efficiency;

A = area of crop, ha;

4. Multi-Criteria Decision Making

At present, decision-making is useful for managers in business, government and other organizations, which is important for determining the landscape of tomorrow's world. In seeking to join the decision-making process, the process needs to acquire a practical understanding afforded by computers. Failure to do so leaves the prospective manager at a severe disadvantage, because others are using computer systems to handle large volumes of complex data involved in making decisions. Also, we call these computer systems "The Decision Support System (DSS)" (Holsapple and Whinston, 1996). The Multi-criteria Decision Making (MCDM) method to be adopted and salient features that are required for the DSS to facilitate its usability. (Vihakapirom, 2003)

The problem that the MCDM aims to solve is evaluating a set of alternatives in terms of a number of criteria which is conflicting in nature. According to Triantaphyllou (2000), although this is a practice problem, there are a few methods available and "their quality is hard to determine". The MCDM methods that authors have considered are Simple Multi-Attribute Rating Technique (SMART), Multiple Attribute Utility Theory (MAUT), and Analytic Hierarchy Process (AHP).

Solving MCDM problem; Optimization deals with the problem of seeking solutions over a set of possible choices to optimize certain criteria. If there is only one criterion to consider, it becomes a single-objective optimization problem. If there is more than one criterion that must be treated simultaneously, we have a multiple-objective problem (Steuer, 1986 and Dev, 1995 represented by Gen and Cheng, 1999).

Gen and Cheng (1999) expanded a single-objective optimization problem that is usually given in the following form as shown in Equation 24.

$$\text{Max} \quad Z = f(x) \tag{24}$$

$$\text{Subject to} \quad g_i(x) \leq 0, \quad i = 1,2,....,m \tag{25}$$

where,

$x \in R^n$ is a vector of n decision variables;

x is set of real number in one criteria to consider

R^n is real functions

$f(x)$ is an objective function; and

$g_i(x)$ is an inequality constraint m functions, which form a area of feasible solution.

The first equation will find the maximum value of Z value from the function x. Function x will be set as one objective function and limited by a constraint or feasible solution (function $g_i(x)$).

We usually denote the feasible area in decision space by a set S, as the following;

$$S = \{x \in R^n \mid g_i(x) \leq 0, i = 1,2,...,m, x \geq 0\} \qquad (26)$$

where,

S is the feasible area space for a limited objective function.

Many decision problems can be modeled as multiple objective problems. They involve the determination of the solution that achieves a compromise among several usually conflicting objective functions, subject to some feasibility and operational restrictions (Wang, 1992).

From the concepts below, the multiple-objective problem includes both decision space and criteria space. S is used to denote the feasible region defined by the limits of the objective function in the decision space and Z is used to denote the feasible region in the criterion space.

$$Z = \{z \in R^n \mid z_1 = f_1(x), z_2 = f_2(x),....,z_q = f_q(x),\ x \in S\} \qquad (27)$$

where,

$z \in R^n$ is a vector of values of q objective functions

The fourth equation will show (Z_q) in q objective functions having many criteria $f_q(x)$. The x values are limited by the feasible region defined by the limits of the objective function.

In the same way, Wang (1992) describes a preference structure in the MCDM of solving the problem for convenience of description, and introduces some notation as follows. Suppose that $y, z \in R^n$, it denote

$$f(x) \quad = \quad (f_1(x),........,f_p(x)); \tag{28}$$

$$X \quad = \quad \{x \in R^n \mid g_i(x) \le 0, i = 1,2,...,p, h_j(x) = 0, \quad j = 1,2,.......,q;\} \tag{29}$$

Where,

$p \ge 2$ is an integer (Multi-Objectives), and

$f_k(x), g_i(x)$ and $h_j(x)$ are real functions defined on R^n.

From basic concepts of a solution in MCDM, which considered the multi-objective optimization problem, the variables have different based on each setting person, illustrated in the equation above. We can set multi-objective function in maximize or minimize terms for different problems. The Objective functions ($f_q(x)$) will be limited by constraint functions. In each objective function will be limited by one or more feasible areas. For example of maximize problem as following equation below.

$$\text{Maximize}(f_1(x),........,f_q(x)) \tag{30}$$

Subject to $g_i(x) \le 0, \quad i = 1,2,.......,n$

$h_j(x) = 0, \quad j = 1,2,.......,m$

where,

$f_q(x)$ is the objective function in q functions

$g_i(x)$ is the constrain of objective function in n functions

$h_j(x)$ is the constrain of objective function in m functions

$f_q(x), g_i(x)$ and $h_j(x)$ are real functions defined on R^n.

AHP was chosen for its ease of use and its successful track records in Industries. MAUT required a decision maker to specify the best and worse case for each criterion in order to generate the utility function (Olson 1996). SMART is a simplified form of MAUT (Edwards and Newman, 1982) and the decision maker has to follow the same procedure as in MAUT. AHP uses a simple method of pair-wise comparison of alternatives against criterion. AHP is widely applied successfully in a variety of industries.

AHP was developed in the early 1970s by Thomas L. Saaty (Saaty, 1980). It provides decision makers with a method to indicate his/her decisions by weighing the evaluation criteria and making pair-wise judgments of a set or subset of alternatives (Hanne, 2001). AHP is a popular method of MCDM which has been valuable used in many studies (Lequna *et. al*., 1999); which can be used to handle complex situations (tangible, intangible, quantitative, and qualitative factors) within a multiple criteria decision problem. AHP can also support a group of decision makers. Geometric means of individual judgments can be used to aggregate group preferences. AHP has successfully been applied in a range of fields, such as a plan to allocate energy to industries; designing a transport system; and designing future scenarios for higher education (Saaty, 1990).

A decision maker will start by brainstorming to find out all the related criteria, as well as all the alternatives, in order to structure the decision hierarchy. Both quantitative and qualitative criteria are handled. The pair-wise comparison technique utilizing a 9 points scale will assist the user to rank his preferences between two objects within each level of the hierarchy. The 9-point rating scale is easy to understand and easy to deploy in making decisions (Saaty, 1995). Since the 9-point scale can be interpreted as a linguistic sentence, it is therefore easier for decision makers to weight the importance objectively between two considered objects. The consistency of the judgment can also be validated by calculating the consistency ratio

(C.R.) and the inconsistency index. The final priorities can then be calculated and the result will provide the ranking of the alternatives. AHP is very easy to use and a powerful MCDM technique. The main merit of AHP is that the users do not have to understand the intricacy of the complex mathematics behind the technique before they can use it. AHP has therefore been adopted as the MCDM technique behind the system.

AHP attempts to resolve conflict and analyze judgments through a process of determining the relative importance of a set of activities and criteria. AHP is an important modeling tool that can assist decision makers at all levels to tacking complex problems that contain a multitude of quantitative factors (Walls and Golden, 1991). Decision Making by the Analytic Hierarchy Process (AHP) is one method to analyze the best alternative for improve the target (Valawuth, 2003). The AHP has three considerations consist of structuring the hierarchy, calculation of relative priority, and consistency, which are described below. (Sahoo, 1998)

1. Structuring the hierarchy: The levels of AHP for deriving best alternatives consist of the setting of a target or goal, criteria, sub criteria and alternatives, which in each step will consist of many criteria. A typical hierarchy of a problem with multi-level criteria is shown in figure 1

2. Calculation of relative priority: The methodology of AHP is based on the concept of tradeoff and enables the decision-maker to develop the tradeoff implicitly in the course of structuring and analyzing a matrix having series of reciprocal pair-wise comparisons. This technique organizes the basic rational by break down problem into its smaller constitutes parts and calls for only simple pair-wise comparison judgments to develop the weighting in each hierarchy. Then, it determines the priority for each alternative. The importance or weighting that be should give into each alternative is determined by analyzing such a judgment matrix. (Sahoo, 1998)

3. Consistency. The original pair-wise matrix may not be consistent. We would like to measure of the error due to inconsistency. The results could seek

additional information and data to be used in constructing the scale, which could be reexamined in order to improve consistency.

Interaction matrix is once method to evaluate weighting factor in each considered indicator. A_{ii}, represent the parameter of the system to be investigated. The off-diagonal component, A_{ij}, represents the interface (or impact) of the parameter A_{ii} on A_{ij} and sometimes called as the one-way interaction component. The interaction matrix is not usually symmetric since interaction Aij is not always same as A_{ji} under the normal situation. Once the diagonal parameters, A_{ii}, are set, then the N2 diagram forces us to consider each interaction component, A_{ij}, to complete the matrix. Therefore, the interaction matrix can be used as a thinking tool to construct a system using parameters and interactions between those parameters. (Hudson, 1992) For matrix example shown in figure 2

This example in figure 2 has show in three parameters, consisted of A_{11}, A_{22} and A_{33}. This method is tool for evaluate relative impact factor or weighting factor of pair wise parameter such as A12 is the impact of A11 to A22 but A21 is the impact of A22 to A11.

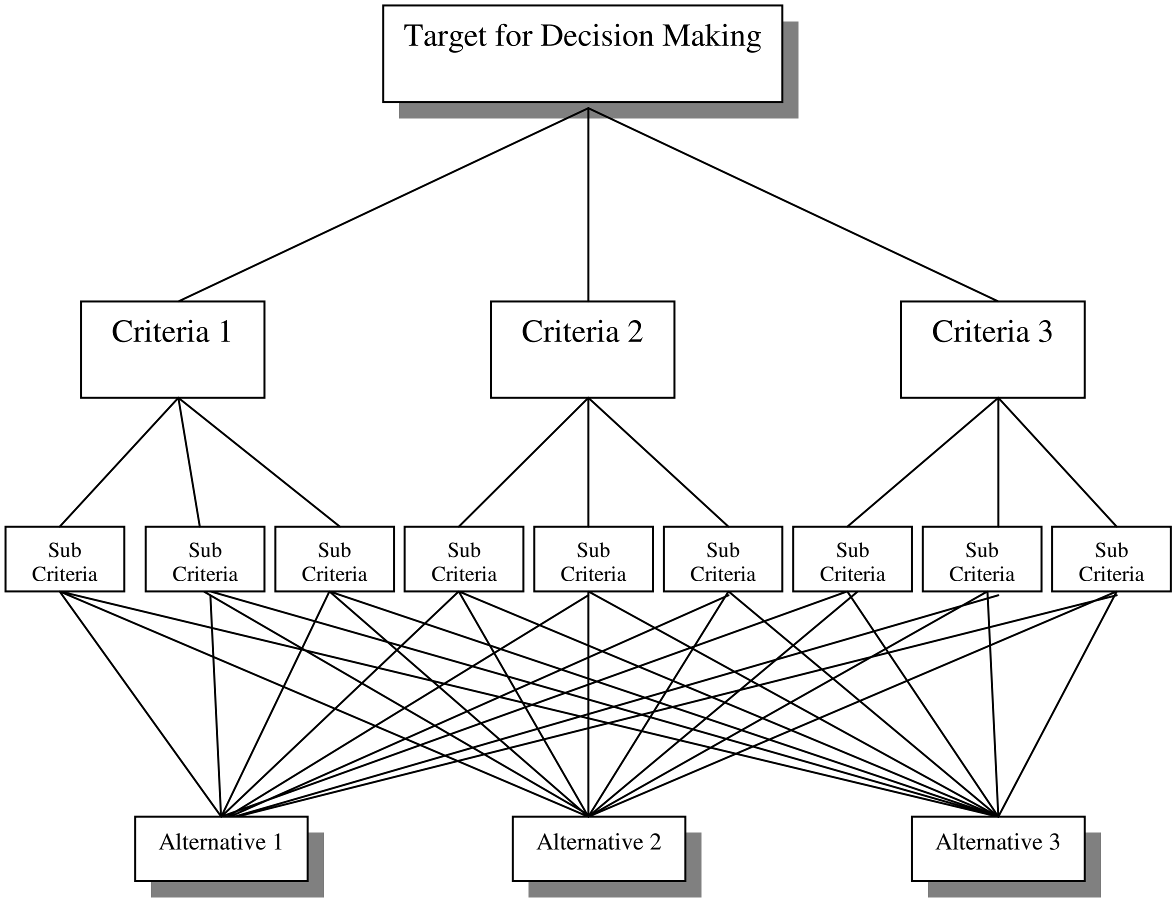


Figure 1 Schematic diagram of Analytic Hierarchy Process

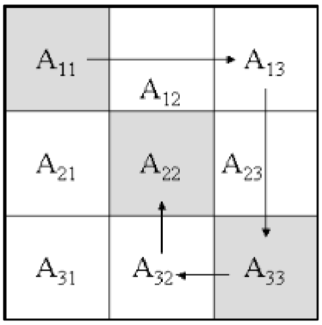


Figure 2 Interaction matrix 3×3 for relative impact

5. Uncertainly in Water Delivery System

Uncertainly is naturally associated with random phenomena because the exact realization of the phenomena cannot be determined with certainly. If the state of nature is basically random, it cannot be described to set irrigation scheduling. The conceivable and possible realizations may be described in terms of a range of probabilities, with their respective relative likelihood of occurrence (Tug and Tang, 1984). In the design, management and evaluation of irrigation water delivery system, uncertainties traditionally have been largely ignored, which have a significant affect on the prediction and assessment of system performance. There are four terms of uncertainty associates with the irrigation water delivery system such as hydrologic, hydraulic, management, and objective uncertainty (Gates et al., 1991)

Rhenals and Bras (1981) described a model for irrigation scheduling, in which the natural uncertainty for potential evapotranspiration (PET) was explicitly included. Weekly irrigation decisions were made after observing current soil moisture and available irrigation water, as well as PET in last week. They commented that PET uncertainly should be included in and the decision of irrigation scheduling

Rao *et al.* (1988) considered the problem of irrigation scheduling at weekly intervals for a single crop when water supply was limited. The mentioned that in applying the irrigation scheduling model to practical situations; uncertainly of weather data may affect the model result. The two input variables affected by this uncertainty are evapotranspiration and rainfall. Gates *et al.* (1991) described the parameter uncertainly on both supply and demand sides of irrigation system resulting from temporal and spatial variability and inadequate data. Measures for the objective of adequacy, efficiency, dependability and equity of water delivery were used to evaluate system performance.

Parameters representing physical properties and boundary conditions of irrigation canal systems may be classified as hydrologic, hydraulic or water managements (Gates and Alshaikh, 1993). Hydrologic parameters affecting the operation of irrigation systems include stream flow (discharges and water levels), crop evapotranspiration, precipitation and infiltration. Canal cross section, canal bottom slope, hydraulic resistance and coefficients associated with regulating and diversion structures are examples of hydraulic parameter. Management parameters include irrigation application efficiency and water delivery schedules. The values that these parameters assume in a system are often uncertainties due to temporal and spatial variability inherent to natural phenomena as well as introduced by human intervention. Furthermore, attempts to quantify parameters at space time points in a system are always impaired by measurement error and limited samples. (Mainuddin, 2000)

MATERIALS AND METHODS

Materials

1. RAP evaluation form;
2. Linear Programming Mathematical Software; and
3. Computer Notebook

Methods

1. Finding the Description of the Chao Phraya River Basin

1.1 Description of irrigation systems

The irrigation system consists of a (main) intake structure, a conveyance system, a distribution system, and a drainage system. The example of irrigation system was shown in figure 3.

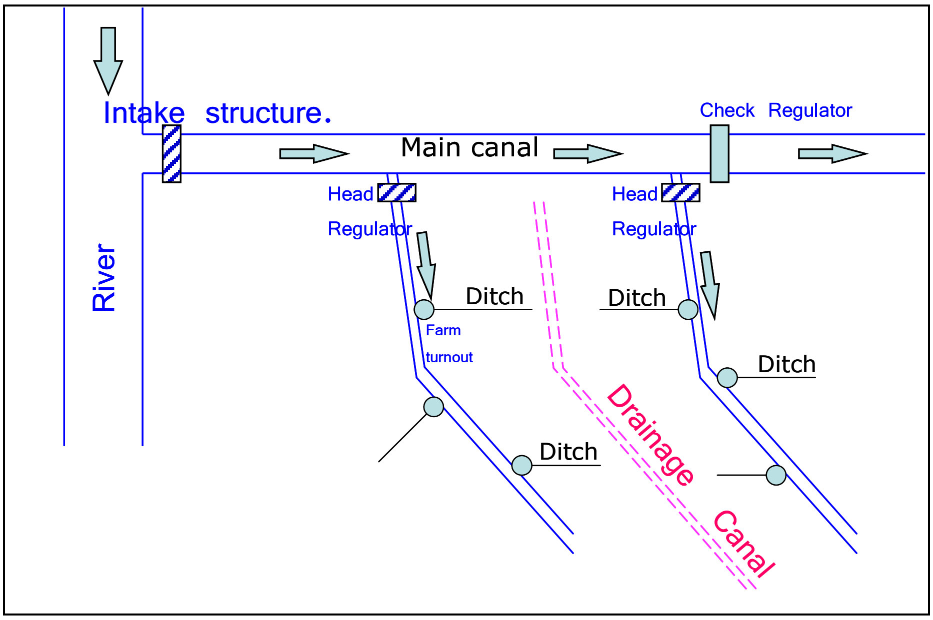


Figure 3 Example of Irrigation Systems

The intake structure is built at the entry to the irrigation system. Its purpose is to direct water from the original source of supply (lake, river, reservoir etc.) into the irrigation system. In some cases, the irrigation water source lies below the level of the irrigated fields. Then a pump must be used to supply water to the irrigation system.

The conveyance and distribution systems consist of canals transporting the water through the whole irrigation system. Canal structures are required for the control and measurement of the water flow. An open canal, channel, or ditch, is an open waterway whose purpose is to carry water from one place to another. Channels and canals refer to main waterways supplying water to one or more farms. Field ditches have smaller dimensions and convey water from the farm entrance to the irrigated fields. According to the shape of their cross-section, canals are called rectangular, triangular, trapezoidal, circular, parabolic and irregular or natural. The most commonly used canal cross-section in irrigation and drainage is the trapezoidal cross-section. For the purposes of this publication, only this type of canal will be considered.

A drainage system is necessary to remove excess water from the irrigated land. This excess water may be e.g. waste water from irrigation or surface runoff from rainfall. It may also include leakage or seepage water from the distribution system.

The classification of irrigation project was specified by National and Economic Social Development Board**.** There are three classes as large, medium and small project depended on reservoir capacity and irrigated area. The large irrigation project as the project has its water supply more than 100 MCM; or its irrigated area more than 12,800 ha. The definition of each class was definite in table 1

Table 1 The classification of irrigation project

Irrigation project	Reservoir Capacity (MCM.)	Reservoir Surface (km.^{2})	Irrigated area (Rais)
1. Large	more than 100	more than 15	more than 80,000 (more than 12,800 ha)
2. Medium	less than 100	less than 15	less than 80,000 (less than 12,800 ha)
3. Small	Construction (1-2 years) Cost (10-50 million baht)	-	less than 3,000 (less than 640 ha)

1.2 Description of the Chao Phraya river basin

The Chao Phraya river basin occupies 29 provinces; 13 provinces in the North and 16 provinces in the Central, which amounts to 157,925 km^2 or 30% of the whole country area. The Chao Phraya river has the origin in Northern Thailand. The river basin consists of the upper basins comprising Ping, Wang, Yom and Nan river basins, and the lower basins comprising Sakraekrang, Pasak, main Chao Phraya and Tha Chin river basins. The Chao Phraya river basin covers most of the central plain of Thailand including Bangkok down to the Gulf of Thailand in Samutprakarn province (Figure 4).

Due to the expansion of economy and population, water demands are increasing for agriculture, domestic consumption uses, tourist and industrial uses, and ecology at the downstream. Thus the problems of water management at the Bhumipol and Sirikit reservoir dams have occurred.

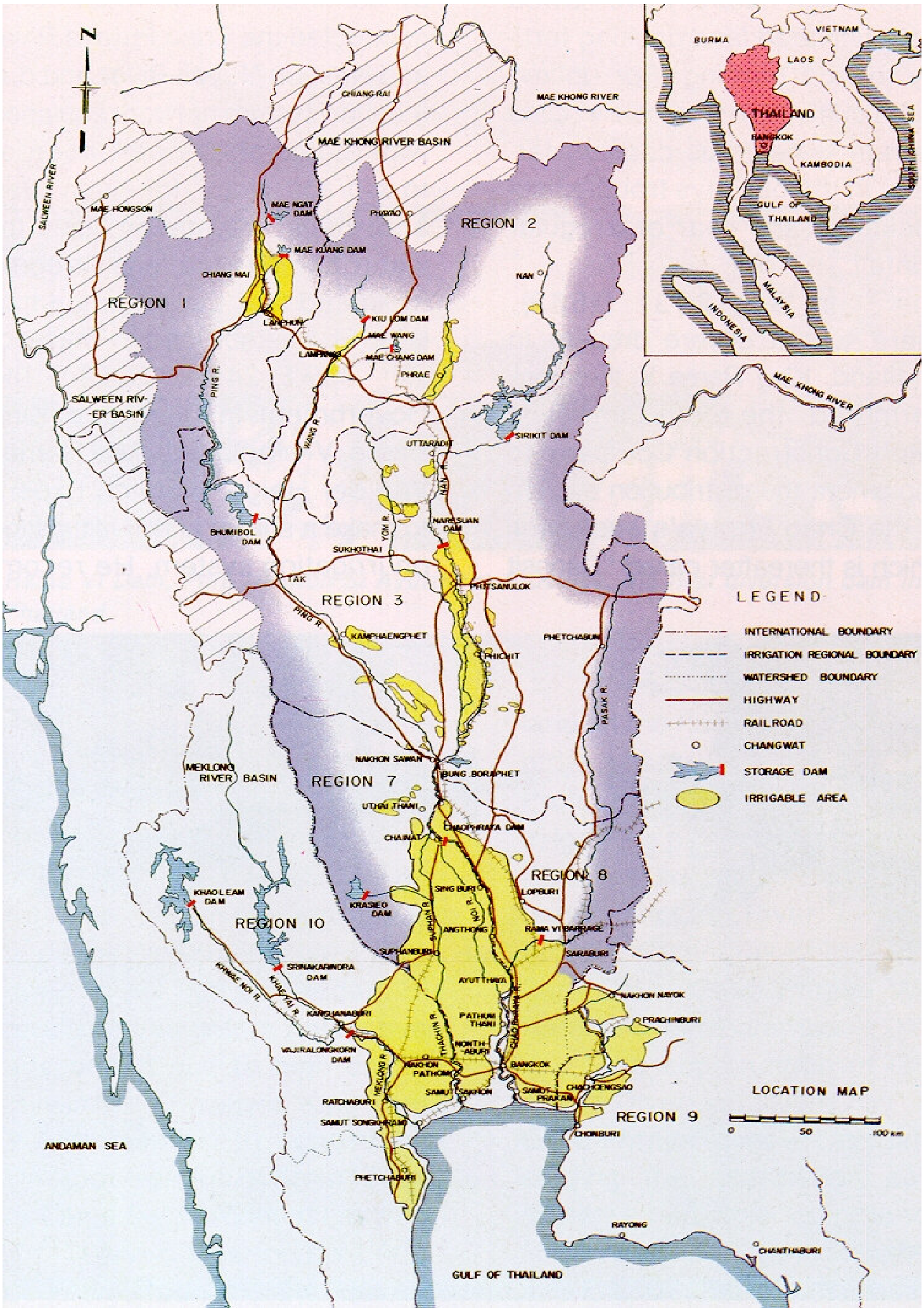


Figure 4 Outline of the Chao Phraya river basin

During the last 10 years, the Chao Phraya river basin has faced drought and flood disasters many times, especially in 1994 and 1998. The active storages of the Bhumipol and Sirikit reservoir dams at the beginning of January in those years were only 2,048 MCM and 3,900 MCM, respectively. This water shortage affected water use activities in the Chao Phraya river basin. The drought and flood situations in the Chao Phraya river basin in 1994, 1995and 1996 were increasingly serious.

The monthly temperature in the Chao Phraya river basin fluctuated between 21.8 and 31.7 degree Celsius and the annual average temperature was 27.45 degree Celsius. The annual rainfall of river basin is 1,135 mm. per year on average and range between 812 and 1,464 mm. per year.

Runoff level of the Chao Phraya river basin fluctuated between 131 and 638 mm. per year, with the average runoff level at 240 mm. per year. The annual average runoff of the Chao Phraya river basin is about 36,833 MCM.

Table 2 Rainfall and runoff level at the Chao Phraya river basin

River Basin	Catchment area (km^2)	Annual rainfall (mm)		Annual runoff	
		range	average	MCM	Litre/sec./km^2
Ping	33,898	844-1377	1,056	8,800.80	8.23
Wang	10,791	950-1200	1,048	1,624.43	4.77
Yom	23,616	893-1260	1,118	3,683.63	4.95
Nan	34,330	933-1619	1,243	11,936.36	11.03
Sakraekrang	5,192	900-1500	1,190	1,080	6.60
Pasak	16,292	900-1400	1,150	2,823.26	5.50
Thachin	13,682	950-1200	1,075	2,449.19	5.68
Main Chao Phraya	20,125	1100-1300	1,200	4,435.19	6.99
Chao Phraya	157,925		1,135	36,832.70	6.72

Source: RID (2002)

Chao Phraya river basin has the catchments area occupying about 30% of whole country; the population is about 23.02 million or 38% of the whole country; the gross product is about 2,693,542 million Baht or 58% of whole country. The largest gross product comes from the main Chao Phraya river basin followed by Tha-Chin and Ping river basins. These three river basins have the water resources development and irrigation projects more than the others.

About 53% of the total land use of the Chao Phraya river basin is occupied by agriculture, 40.13% by forest, 0.87% by water surfaces, 2.78% by residential areas and 3.22% by others.

The reservoirs in the Chao Phraya river basin which distribute water to the Greater Chao Phraya Project area are Bhumipol, Sirikit, Tap-Salao, Pasak, Krasiew, Naresuan, Rama VI and Chao Phraya dams. There were two problems concerning water: water shortage and flood.

During the dry season water is always insufficient because water demand for domestic consumption and agriculture exceed the capacity of water supply. In rainy season sheet floods will occur due to the heavy rainfall from monsoon and storm. For coping with these problems, the concerning government departments have action programs such as the flood mitigation in Bangkok and its surrounding areas by Bangkok Metropolitan Authority, the construction of flood protection facilities along the Chao Phraya river by Public Works Department, water shortage solution for the agriculture in the lower Chao Phraya Delta by Royal Irrigation Department and so on.

The large irrigation projects in the Chao Phraya River Basin serve approximately 1.57 million ha, with 1.24 million ha in the Main Chao Phraya and Tha Chin, or 80% of the large irrigated area in the Chao Phraya River Basin. These irrigation projects are listed by sub-basin in table 3.

Table 3 The large irrigation projects in the Chao Phraya River Basin.

Sub-basin	Watershed area (Million ha)	Number of large irrigation projects	Irrigation Area (ha)
Ping	3.39	9	125,264
Wang	1.08	1	20,800
Yom	2.36	1	35,840
Nan	3.43	4	106,736
Pasak	1.63	1	21,648
Sakae Krang	0.52	1	22,960
Main Chao Phraya and Tha Chin	2.01	27	1,238,471
Total	14.42	44	1,571,719

Source: RID (2000)

The Greater Chao Phraya Project is the Chao Phraya river basin development project for benefiting cultivation areas in the central plain located in both sides of the Chao Phraya river and branch rivers from Chainat down to the coast area. Formerly, the cultivation area in such areas mainly used water from rain together with water from rivers and canals. When the water level was high flood would naturally flow to the field. It was advantageous for the paddy cultivation. As for the cultivation in the highland area, only the water from rainfall was used. Thus, the farmers always got into trouble when there were less rains than usual.

In Mr. Homan Van der Heide, former Director General at that time recommended constructing the Greater Chao Phraya project; it was not materialized because of the large amount of expenditure. In 1915 the Barrages Department constructed the Pasak-Tai O&M Project that was the sub-project of the Greater Chao Phraya Project and was firstly established in Thailand. Thereafter, many sub-projects were implemented namely, Suphan river O&M Project (Pho Phraya, Samchuk and Makham Thao Irrigation Projects), Chiengrak-Klong Dan Irrigation Project, Irrigation Projects (water storage type) in the western bank of Chao Phraya river. Next RID recommended to construct the greater Chao Phraya Irrigation Project, and constructed the diversion dam across the Chao Phraya river in Chainat province. Many distribution canals were excavated in the area where the government approved to operate according to the government's request in 1950. RID started the construction works in 1952 and completely finished the works in 1964 according to the plan. The significant works are as follows:

1.2.1 Diversion dam and the facilities

The Chao Phraya diversion dam with a navigation lock was constructed across the Chao Phraya river at Bang Luang sub-district in Chainat province for raising the water level of the Chao Phraya river high enough to supply water to distribution canals and to cultivation areas in projects, and for allowing the navigation to travel along the river as usual. The foundation stone lying ceremony of diversion dam was held on 6^{th} February 1953 (B.E. 2496). The Chao Phraya diversion dam is the largest diversion dam in Thailand. The characteristics of the dam were reinforcing concrete dam that obstruct the river route. The dam was divided into 16 reinforce concrete channel sections with width of 12.50 m each. The arc shape bar gates at a height of 7.50 m. were installed to each channel. Maximum release discharge through the dam is about 3,300 m^3/s. The open-close winch bar gates were installed on top of the dam structure. The bridge, width 7 m. can be passed by 20 tons truck. The navigation lock was constructed on the right side of diversion dam with a width of 14m and consisted of the channels for passing raft-boats. The bridge across the navigation lock is an elevation bridge. The left side of foundation of diversion dam was designed for generating electricity by windmill power at 300 kilowatt for operating the bar gate and navigation lock.

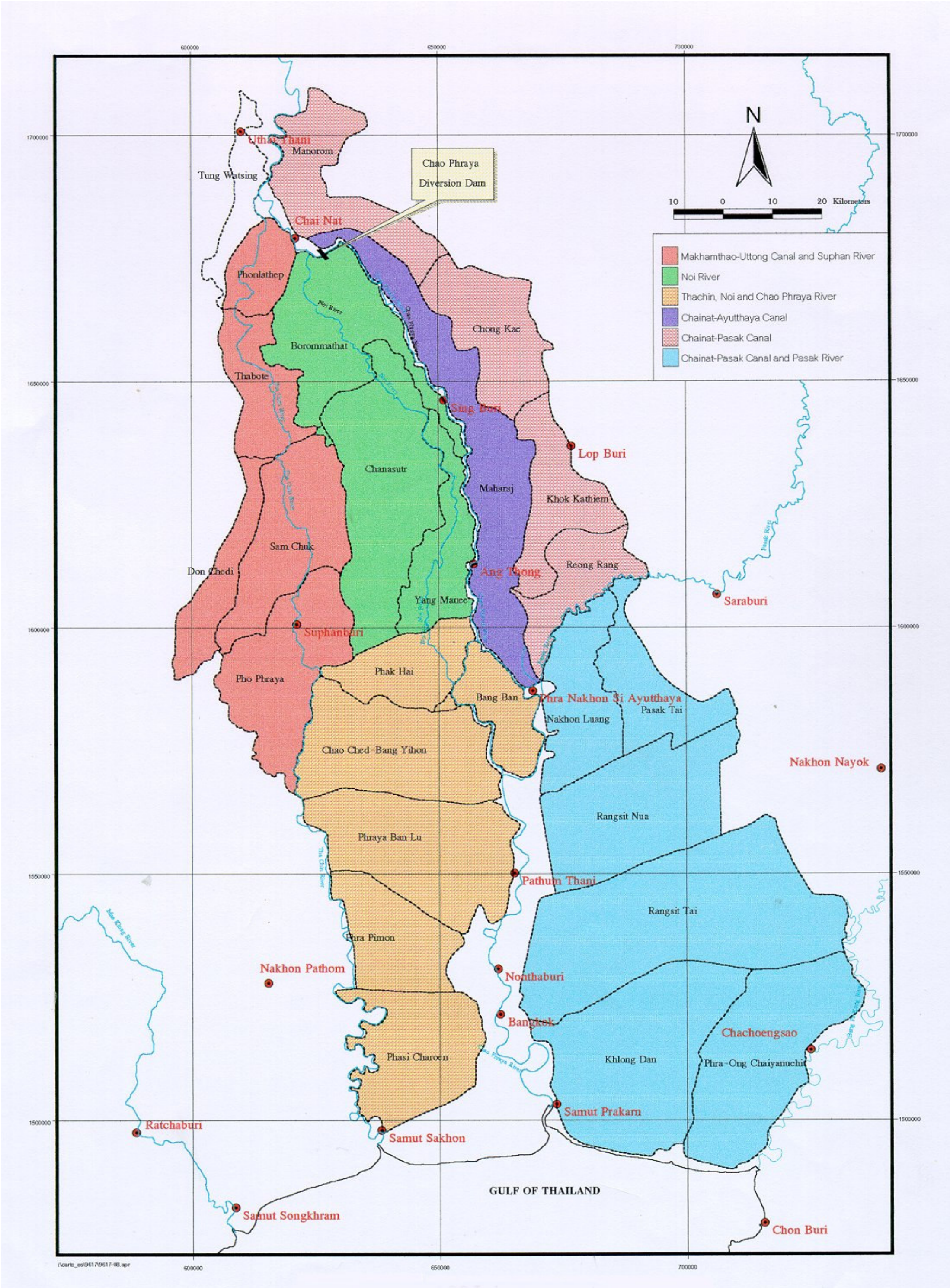


Figure 5 The Greater Chao Phraya Project

Source: RID (2003)

1.2.2 Distribution system

Diversion dams and other facilities were constructed under most of distribution system. Moreover, some works in the water distribution area of the greater Chao Phraya Project have finished as below:

- Chieng Rak-Khlong Dan Irrigation Project started in 1922, finished in 1931, 110,400 ha of beneficiary area
- Pho Phraya Irrigation Project started in 1923, finished in 1932, 59,200 ha of beneficiary area
- Samchuk Irrigation Project started in 1935, finished in 1955, 48,800 ha of beneficiary area
- Makham Thao Irrigation Project started in 1929, finished in 1963, 15,360 ha of beneficiary area

The western projects of the Chao Phraya river was started construction in 1939, and finished in 1963, with 716,800 ha of beneficiary area.

Total water distribution system of the greater Chao Phraya Project have many distribution canals of several scales with the facility along the canals to deliver water to the cultivation areas in several provinces in both sides of the Chao Phraya river. The details of the significant water distribution systems are as follows:

- Water distribution system of Suphan river is located on the right side of the Chao Phraya river. The main distribution canal is Suphan river with a length of 115 km. In addition, Makham Thao-Uthong canal with a length of 104 km was excavated to be another main distribution canal. Water distribution system in Suphan river divided the area into 5 sub-projects namely, Makham Thao, Tha Bot, Samchuk, Pho Phraya and Don Chedi Projects. Each project has constructed the regulators for diverting Suphan river and the navigation locks so that the raft-boats could pass all year round. Moreover, 108 the lateral and sub-lateral canals were constructed with a total length of about 780 km.

- Water distribution system of Noi river is located on the right side of Chao Phraya river between Suphan river and Chao Phraya river. The main distribution canal is the Noi river with a length of 127 km. Water distribution system in the Noi river divided the area into 4 sub-projects namely, Borommathat, Channasutr, Yang Manee and Pak Hai Projects. Each project has constructed the regulators for diverting Noi river and navigation lock so that the raft-boats could pass all year round. Moreover, 107 lateral and sub-lateral canals were constructed with a total length of about 1,050 km.

- The upper west bank project of Chao Phraya river has the Project areas in the north of the Chao Ched and Bang Yi Hon canals. Pak Hai-Chao Ched distribution canal (about 15 km) was excavated from the Pak Hai regulator for delivering the water from the main canal of the Noi river. There are regulators at the head and the tail of the canal for storing the water and delivering to the cultivation areas in the west bank projects of the Chao Phraya river down to the southern coast areas.

- Water distribution system of Chainat-Ayuthaya canal is located on the left side of the Chao Phraya river. The Chainat-Ayuthaya main canal which intakes water in the front of Chao Phraya diversion dam was constructed as the main distribution canal along the Chao Phraya river bank down to Phra Nakorn Sri Ayuthaya district in Phra Nakorn Sri Ayuthaya with a length of 120 km. And 23 laterals and sub-laterals were constructed for delivering many fields with a total length of 250 km.

- Water distribution system of Chainat-Pasak canal has the project areas on the left bank area of the Chao Phraya river, located east of the command area of the Chainat-Ayuthaya distribution canal. The Chainat-Pasak canal was constructed to receive water upstream of Chao Phraya diversion dam at Manorom district in Chainat province. It is a large irrigation canal which flows down to the Pasak river upstream of Rama VI dam. It has a length of 132 km. Operation areas are divided into 4 small projects which are Monorom, Chong Khae, Khok Krathiam and Roeng Rang

Projects. In each project, large regulators were established for diversion as well as navigation locks to let the raft-boat pass all year round. Moreover, 81 laterals and sub-laterals with a length of 725 km were constructed.

- Since Chao Phraya diversion dam can divert water to Pasak river just upstream of Rama VI dam, the latter can irrigate water to the Pasak Tai Project all year round and has enough water for expanding irrigable area in the future. For this reason, the Nakhon Luang Project was established by the excavation of the main canal of 56 km branching from Raphephat canal, which is the main distribution canal of the Pasak Tai Project. In addition, the laterals and sub-laterals were constructed with a total length of 120 km.

- For the Chiang Rak-Khlong Dan Project, the northern part of the project area is along Rangsit canal. When the construction of the Greater Chao Phraya project was completed, it could receive water from Chainat-Pasak canal and irrigated to the Rangsit bank and bank of the Chiang Rak-Khlong Dan Project for storage in other canals for fruitful completion of the project.

Drainage System: The drainage system of logged water in the swamp in rainy season and extra irrigation water from cultivation plots included rehabilitation of irrigation canal in deep area and natural canal re-excavation for transforming into drainage canals. Additionally, various kinds of structure were constructed in the drainage canal. Total length of drainage canal was 4,156 km. The construction started in 1952 and was completed in 1982.

1.2.3 Water allocation in Chao Phraya River Basin.

1) Rainy season: Water allocation plans in rainy season from July to December are not made as weekly water usage plan like in the dry season. It is to use the rain in cultivated areas as much as possible in accordance with storage level of farm ditch. Operations of water management are in response to rain conditions, runoff, runoff level evaluation, natural water level in Chao Phraya river basin

particularly the runoff from Nakornsawan Province which is the storage water of Chao Phraya River banks to be used as water management in Chao Phraya Project. Nevertheless, if runoff and rain conditions are not enough or drought period happens, water is released from Bhumibol and Sirikit reservoir dams to promote cultivation. Regarding to water releasing, the water allocation plans have to be adjusted in accordance with rain condition situations. Therefore, there is no obvious water allocation plans in terms of the amount of water to be released.

2) Dry season: The water allocation in dry season depends on storage water in Bhumibol and Sirikit reservoir dam. The water allocation plans are very limited. The Ministry of Agriculture and Cooperatives has appointed the committee of plans and dry season crop cultivation promotion. The committee consists of representatives from concerned departments which are the major part to set up policies and objectives in dry-season cropping cultivation. RID and Electricity Generating Authority of Thailand (EGAT) will estimate storage water level of Bhumibol and Sirikit reservoir dam on 1st January in order to set up the water level from Bhumibol Dam and Sirikit Dam which will be used in the dry season, to aim on dry season paddy fields, field crops and vegetables in accordance with water level allocation from these two dams according to the weekly water drainage. Regarding to arranging water allocation plans in the river basin of the RID, water distribution and maintenance from January to June, the project will organize a meeting to inform the farmers in the targeted areas about the water allocation. As a matter of the water allocation in dry seasons, the water allocation is planned to supply water works, salinity control and navigation in Chao Phraya river and Tha Chin river.

1.3 Phitsanulok Irrigation Project

The Phitsanulok Irrigation Project lies at the north-most extremity of Thailand’s central plain, between the Nan and Yom River. This system has been developed as a part of the general development of Nan river basin. Its establishment followed the construction of Sirikit dam, which is the major storage dam at the upper reaches of the river and the Naresuan dam adjacent to the irrigation system, which acts as its diversion structure. So the total available water at irrigation system depended on the release policy of these two dams. The Sirikit dam was inaugurated in 1972 and the Naresuan dam in 1980. Construction of the irrigation system began in 1977 and completed in 1985.

The irrigation system consisted of right bank and left bank of Nan river. On the left bank is Naesuan project only which have command area about 94,700 rais.(15,152 ha). The system on the right bank has been divided into three sub-systems, called respectively (from upstream to downstream) Plaichomphol, Dong Setthi and Tha Bua; it covers an irrigated area about 91,584 ha which are shown in figure 6 and figure 7

The water distribution system is complex, and difficult to manage. One main canal (canal C-1) runs through the entire system, and has a total length of 175 km. From this, secondary canal are taken off to irrigate the system. There are in all 107 secondary canals and tertiary canals which are identified by sequential numbers C-2, C-3 etc. These include 38 secondary canals which draw their water directly from the main canal. The remaining 69 are tertiary canals which draw their water from some of these secondary canals. In this study, we mainly focus on the water distribution of Plaichumpol O&M project as shown in figure 8.

There are many water control facilities in the system which flow or water level control. These controls fall into three principal categories as:

- Head regulators at intakes to the main canal and each secondary or tertiary canal
- Check structures across the main (24 check structures) and the principal secondary.
- Constant-head orifices at the turnout to each service unit.

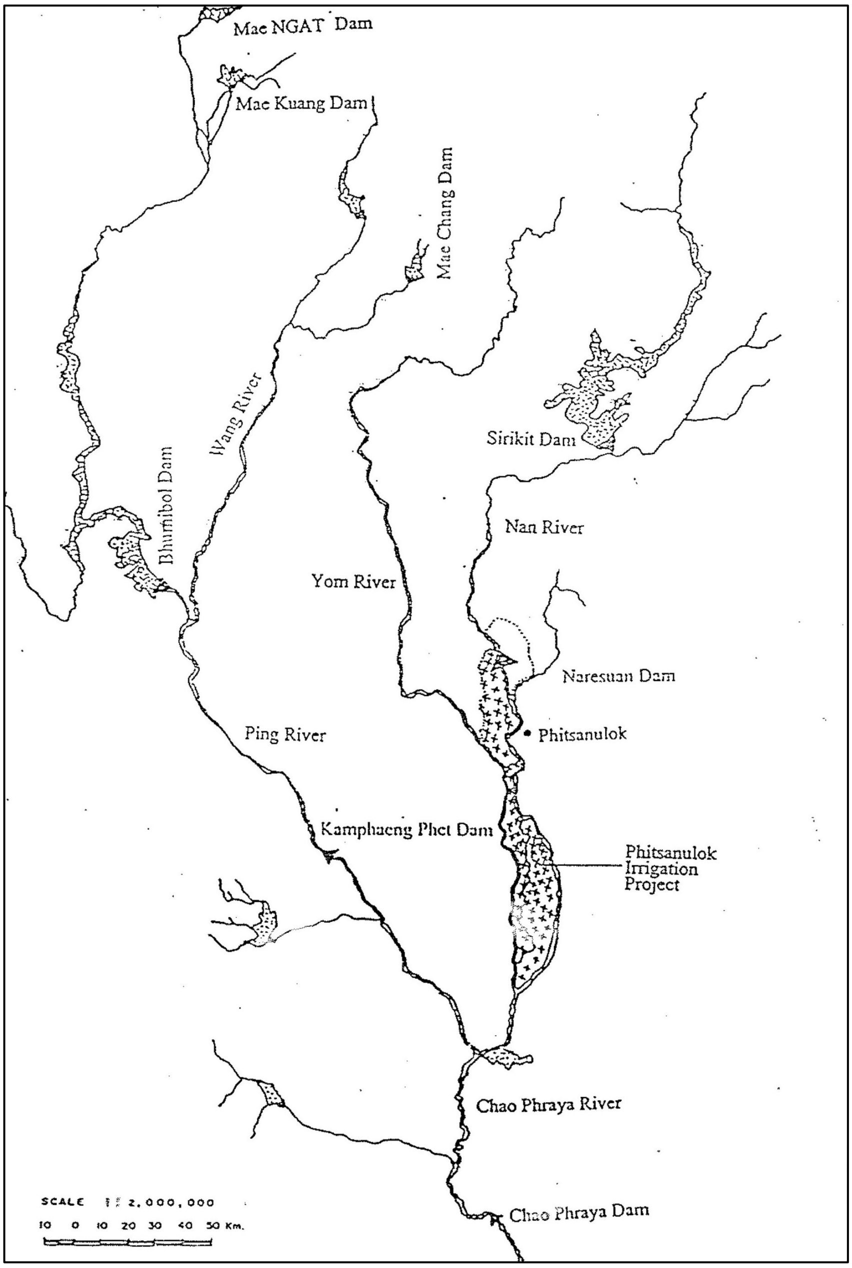


Figure 6 Pitsanulok Irrigation Project.

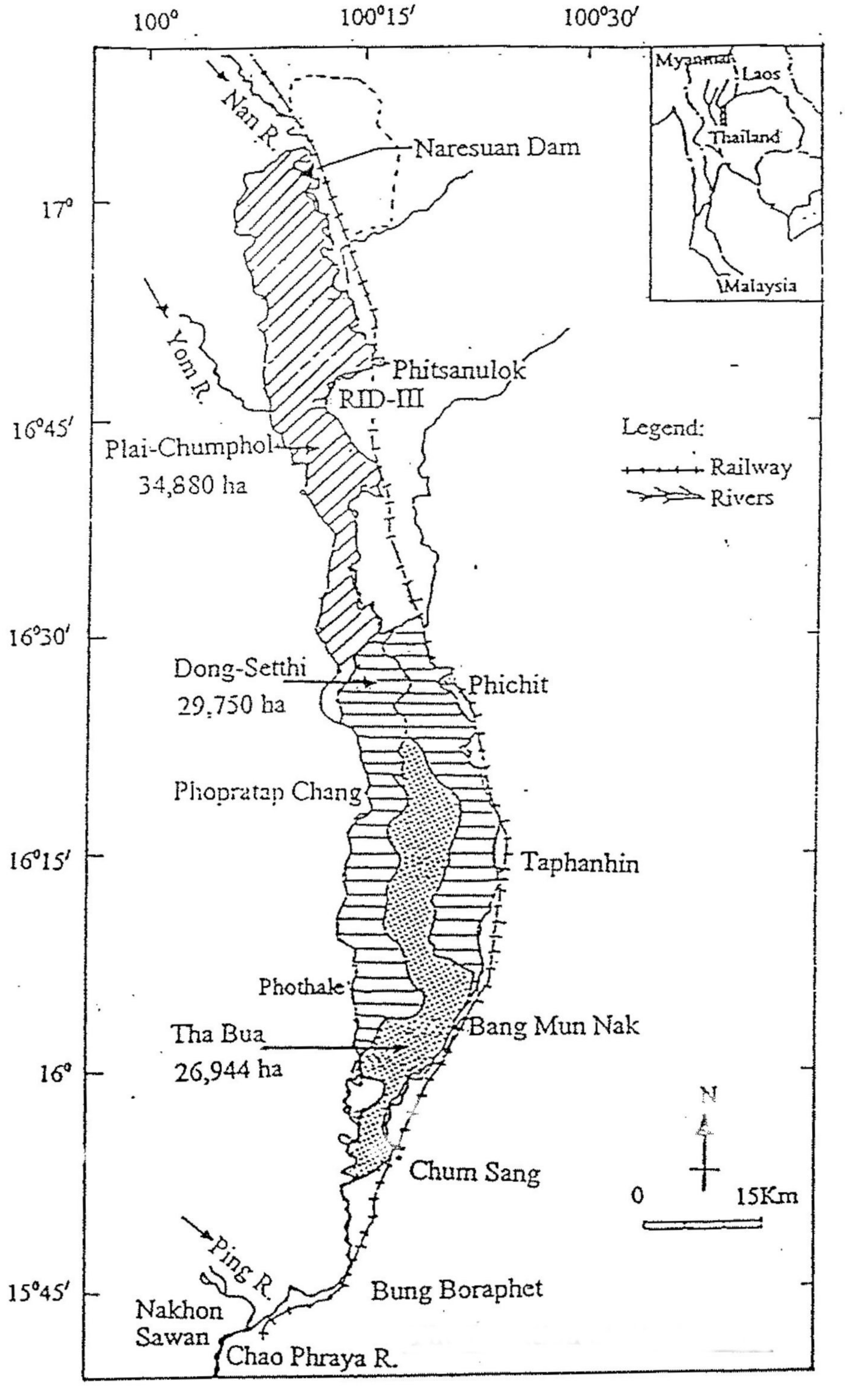


Figure 7 Plaichumpol, Dong Setthi and Tha Bua O&M project.

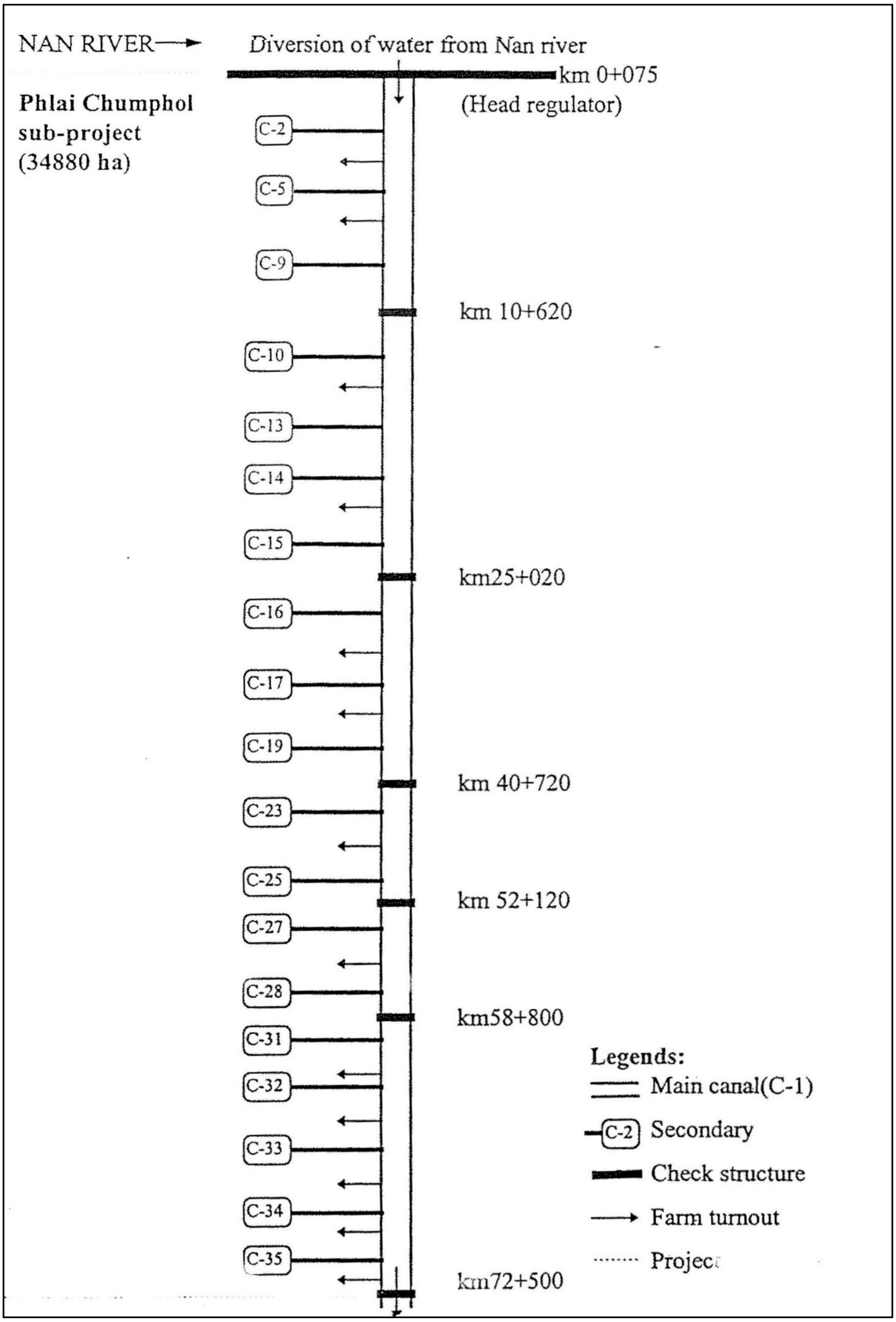


Figure 8 The water distribution of Plaichumpol O&M project.

Cropping pattern: Before the construction of these river-control facilities, much of area produced rice as a rain-fed crop. Rice remains the principal crop. However, before the irrigation system established, it was expected that there would be amount of cultivation of non-rice crop in dry season. The existing cropping pattern of Plaichumpol O&M irrigation project for the dry season is shown in figure 9, and the cropping pattern for other sub-system, namely, Dong Setthi and Tha Bua O&M irrigation project is shown in figure 10. Non-rice crop are grown only in dry season. In the dry season, non-rice crop are planted in Dong Setthi and Tha Bua one week behind Plaichumpol because the water reaches in the main canal of these sub-system about one week after opening of the headwork. Water management planning is based on the assumption that the date of rice planting will be spread over the range of 5 weeks for Plaichumpol, and 6 weeks for Dong Setthi and Tha Bua. For upland crops this is one week for all the sub-system. The land preparation time for rice is two weeks.

Water allocation activities: the irrigation system has been developed as a part of the general development of Nan river basin. Its establishment followed the construction of Sirikit dam Sirikit dam the major storage dam at the upper reaches of the river; and Naresuan dam acts as its diversion structure. So the total available water at the irrigation system depends on the release policy of these two dams.

Water allocation planning process: The Phitsanulok irrigation project draws its water from single intake on the Nan river. This river is one of the principal tributaries of the Chao Phraya river basin. The Sirikit dam is major storage dam of Chao Phraya river basin and electricity-generating sources of the Thailand. Thus, water planning for Nan river basin must be integrated into the Chao Phraya basin framework as follows:

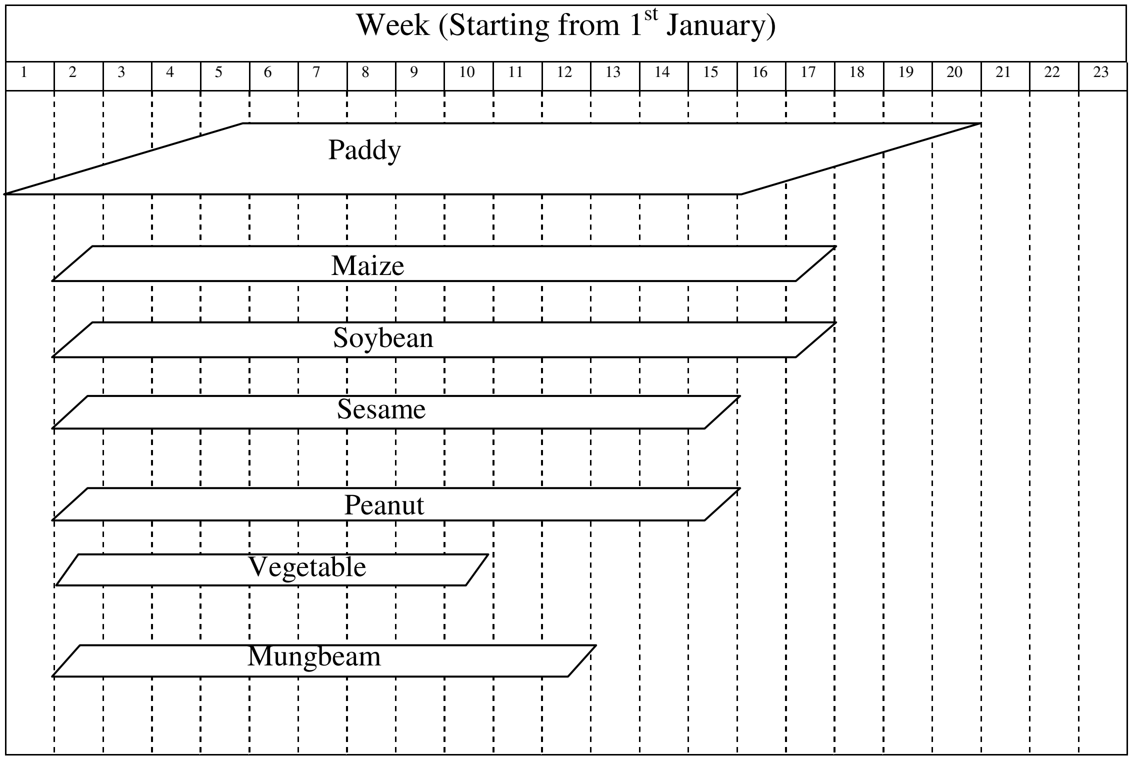


Figure 9 Existing dry season cropping pattern of Plaichumpol O&M project

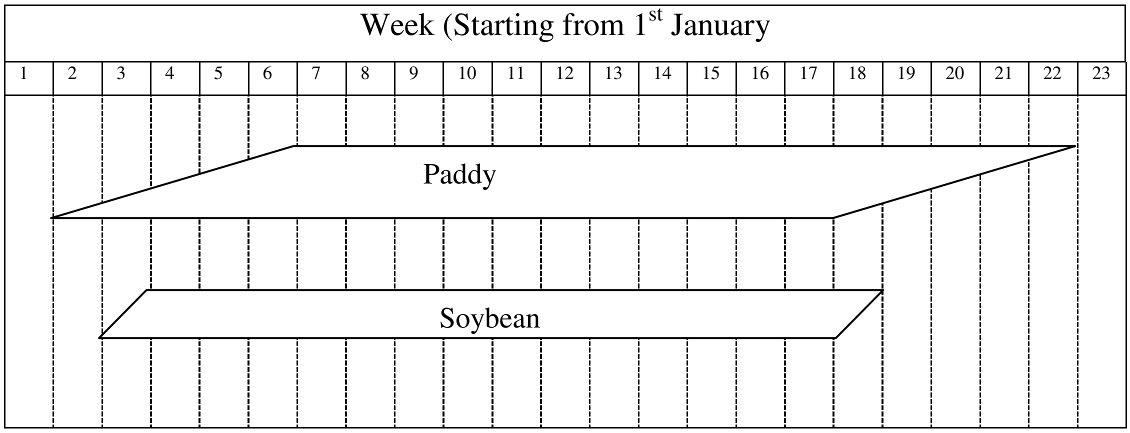


Figure 10 Existing dry season cropping pattern of Dong Setthi and Tha Bua O&M project

1) Pre-season Planning Process: Since there are many users, the priority will be firstly given to fixed water supply of Bangkok metropolitan, navigation, domestic water uses along the river and salinity control. The remaining water is planned for irrigation. Power generation will be produced according to the release patterns for all users. No additional release is given for power generation during dry season. These competing factors, the water planning process is essential, and any such system can affect the water allocation to the Phitsanulok irrigation project.

In dry season, each O&M irrigation project will specify the cropping target areas. The O&M irrigation project proposes the locally planned area inside the project and prepares pre-seasonal plan by weekly basic based on historical data of cropping pattern, rainfall etc. The pre-seasonal plan is submitted by a report format to Regional Irrigation Offices (RIOs), after that RIOs report to Office of Hydrology and Water Management; and then they will prepares a weekly irrigation requirement for Phitsanulok irrigation project and Chao Phraya irrigation project, and informs to the EGAT.

2) In-season Planning Process: In-season requirement is planned week by week not like pre-seasonal plan. The information of this week will be used for the next week because it was affected by the actual information of water discharge, crop water requirement and rainfall in the irrigation project area. In case of Phitsanulok irrigation project, the opening and closing farm turnout gate and actual water level in canal inform by Zone-men and local staff of irrigation project, will be used to estimate in-seasonal water requirement in next week instead of actual rainfall, actual discharge and actual crop water requirement. After getting the in-seasonal plan proposed by Phitsanulok irrigation project and Chao Phraya irrigation project through respective RIOs, Office of Hydrology and Water Management will prepares an in-seasonal weekly plan for the whole Chao Phraya river basin and proposes the in-seasonal plan to EGAT for releasing water accordingly.

2. Rapid Appraisal Process

This research used an application of RAP, a technique has been used in the diagnosis of irrigation project. The specific details addressed by RAP are improving water control throughout the project, and improving the water delivery service to the users. The two basic components for diagnostic irrigation practices are given below.

The specific details which were used for irrigation practice assessment was presented in table 4. These details for irrigation project diagnosis have been concluded in a worksheet which was developed by FAO/IPTRID/World Bank (Burt and Styles 1999). Many of these items are described in the form of internal indicators, with assigned values of 0-4 (0 indicating least desirable, and 4 denoting the most desirable). Most of the internal indicators have subcomponents, called sub-indicators. Each of the sub-indicators is assigned a weighting factor. In this study, a detailed questionnaire was reviewed and understood by the evaluators to obtain information for evaluation of the water control and management practices in the 12 pilot irrigation projects.

A 7-10 day visit by evaluators was made to the project. First, one or two days were spent in the office to examine system maps and to review the baseline project data that had been prepared. But most of the time was spent in the field with engineers and operators, making observations and collecting the data needed for internal process indicators. The field work included:

- Visits to the main canal, some secondary canals, tertiary canals and water delivery structures;
- Observations regarding the types of structures, general conditions, operator instructions, quality of flow rate and water level control, and other operational indicators;
- Informal interviews with operators and farmers, and observations and recording the methods and hardware used for water control; and,
- Visits to selected water user associations.

As an example of the usage of internal indicators, Primary Indicator I-1 is used to characterize the actual water delivery service to individual ownership units. Primary Indicator I-1 has four sub-indicators:

I-1A. Measurement of water volumes delivered to the field;

I-1B. Delivery flexibility to the field;

I-1C. Delivery reliability to the field; and,

I-1D. Apparent water distribution equity.

Each of the Sub-Indicators (e.g., No. I-1A) has a maximum potential value of 4.0 (best), and a minimum possible value of 0.0 (worst). The value of each Primary Indicator (e.g., No. I-1) is computed automatically in the Internal Indicators worksheet. The specific details for evaluation of water control and management practices in irrigation are concluded by internal indicator values. The internal indicator values show actual physical structures, management and service of the entire irrigation project. The complete picture will show where the changes are required and how the changes will have an influence. When the internal indicators are collected, RAP will indicate the list of items that are needed for a modernization plan.

The pilot irrigation projects were established for learning about the irrigation practices through application of the RAP in three groups (12 irrigation projects) as shown in table 5. The first group is located in Nan sub-basin, and the second and third groups are located in Main Chao Phraya and Tha Chin sub-basin. The located of the pilot irrigation projects is given in Figure 11.

Table 4 The specific details for water control evaluation and management practice in irrigation.

No.	Irrigation Performance	Questions
1	Project office question	1.General project condition 2.Water supply 3.Project Operation
2	Project Employees	1. Varies indicators regarding project employees
3	Water User Association (WUA)	1.General description 2.WUA budgets 3.WUA activity 4.Water Charge
4	Main canal; Second level canal; and Third level canal	1.General condition 2.Control of flows/Operation 3.Level of maintenance 4.Main canal cross regulator hardware 5.Main canal communication/transportation 6.Main canal off-take 7.Scheduling of flow from main canal off-take 8.Turnout indicators 9.Actual service
7	Final delivery	1.Actual service provided at the most downstream point operated by a paid employee 2.Final distribution to individual ownership units 3.Actual service received by individual units

Table 5 The pilot irrigation projects included in the RAP.

Groups	Location in the Chao Phraya river basin	O&M irrigation project	Irrigated area (ha)
1	Pitsanulok irrigation project	Naraysuan dam	15,152
		Plaichumpol	34,880
		Dong Setthi	29,760
		Tha Bua	26,944
2	Upper east bank of lower Chao Phraya river basin	Manorom	41,956
		Chong Khae	38,198
		Khok Krathiam	32,875
		Roeng Rang	32,605
3	Upper west bank of lower Chao Phraya river basin	Phonlathep	15,408
		Tha Bot	31,443
		Samchuk	48,800
		Pho Phraya	59,200

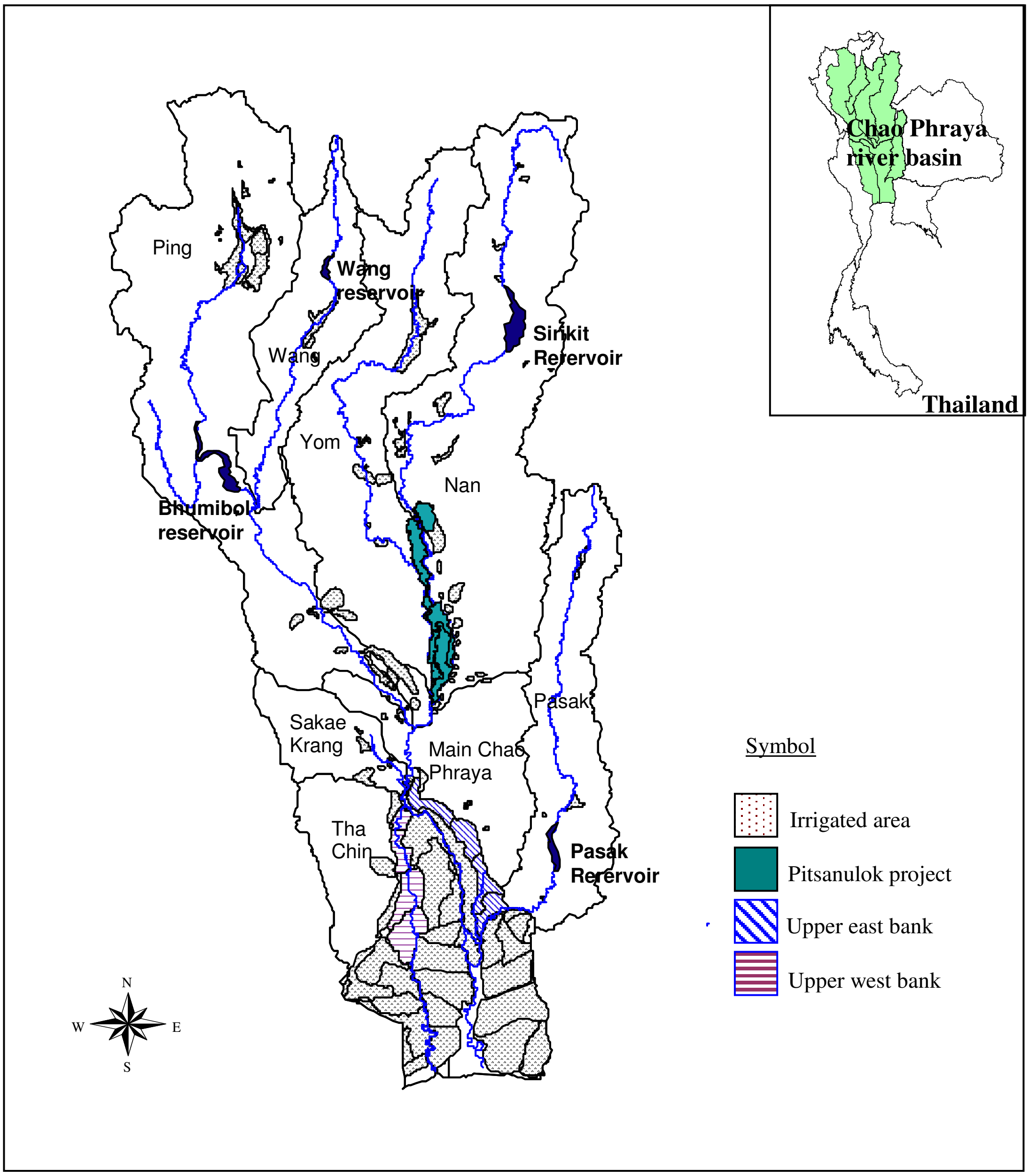


Figure 11 The pilot irrigation projects in the Chao Phraya river basin.

The study on uncertainly of water allocation practices: The qualitative analysis has been modified from RAP because this process should be applied based on the necessary of project evaluation. The RAP have to get more data from project office and field visit in a short time ; and need the person who have more experience and really understand on irrigation water allocation and project evaluation. There are many conflicts between results of evaluation and realization in the filed in several times. So, we should monitor and evaluate based on the water allocation planning. The result can be guided for water allocation improvement during the season on pre-season. The main objective of project assessment for large irrigation system should be considered for the operation and maintenance in main canal.

3. Irrigation Performance Indicators for Water Allocation Improvement

Learning the water allocation using RAP, there are many problems for evaluation as time to collect the data and much more data to input, some indicator doesn't understand to be used and the result of evaluation doesn't clear to specific for water allocation problems. Nevertheless, the learning process using RAP and the result of evaluation 12 O&M irrigation project can be guided to set the key performance indicators for Multi-Criteria Decision Making (MCDM).

3.1 MCDM by Analytic Hierarchy Process

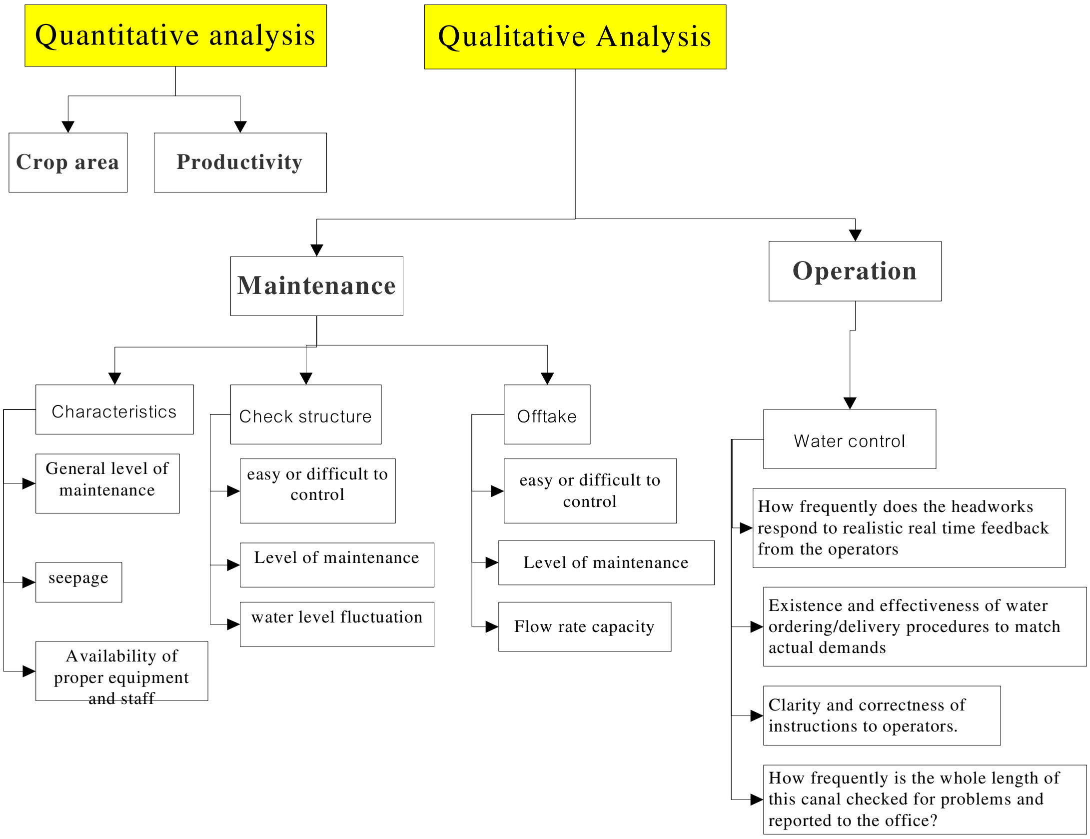
Results-based management of large irrigation systems is the evaluation of irrigation performance indicators, both qualitative indicators and quantitative indicators. The results of the evaluation will be applied using a Analytic Hierarchy Process to find the priority adjustments for the water allocation improvement. The aim of the water allocation assessment is to provide a toolbox to be used in strategic planning and decision-making concerning water allocation improvement in large irrigation systems. One tool in the toolbox can be characterized as a process support tool through which synthesis of different results are made. A wide range of process support tools for interactive Multi-Criteria Decision-Making (MCDM) exist today.

The objective of this project is to select, test and modify a suitable MCDM that fits the water allocation improvement approach for the large irrigation system.

Performance of water allocation is complex subjects. Irrigation systems often have a number of competing objectives and are assessed by interest groups with differing values and perspectives. A wide range of performance indicators is thus required. Performance indicators may be used for several purposes. Indicators can be used by system managers to compare actual results to planned targets.

From the different index values and the objective function of water allocation in large irrigation project, a Multi-Criteria Decision Making (MCDM) can be useful for managers to plan the water allocation of large irrigation systems. In this research, many indicators will be used to set an AHP. For irrigation performance assessment, we can set in three main criteria for assessment can be established such as qualitative indicators, and quantitative indicators. The data sources for each criterion will be computed by different methods. The results of a irrigation water balance study will be used to evaluate the quantitative indicators. The second criteria, qualitative indicators, are result from applying RAP. Each criterion consists of sub-criteria, which will be evaluated in irrigated areas based on differential situations. The results from the calculated indicators inserted into MCDM approach will be finding the best alternative for irrigation improvement in a large irrigation system. Structuring the AHP for water allocation improvement can be shown in figure 12.

MCDM for irrigation Performance indicators was set by AHP. From steps of AHP, we can divide the consideration for irrigation performance indicators in two criterions as qualitative and quantitative indicators. The criterions will be evaluated in different sources. In each criterion was divided in many sub-criterions. Its will be used to evaluated alternative based on interesting areas. The result will show indicator values, it is used to set the priority of areas for improvement. We can set multi-objective function in two main functions which as qualitative indicators and quantitative indicators.



Analysis	Data	Tool	Result
Spatial Temporal	1. Field data 12 Irrigation Projects 2. Hydrological data, Water Supply, Cropping pattern	1.1 Applied RAP 2.1 Water Balance 3.1 Interaction Matrix 4.1 MCDM	1.1.1 Qualitative Indicators 2.1.1 Quantitative Indicators 3.1.1 Weighted Factors 4.1.1 Priority to improve

Figure 12 Analytic Hierarchy Process for water allocation improvement in large irrigation system.

3.2 Quantitative Indicators

Quantitative indicators will be specified on crop area and productivity. The Crop area will focus on water adequacy in irrigation project because among of water supply in early season will be informed for cropping pattern. The productivity criteria will focus on water efficiency, outcome and income. The description in each criteria were presented in table 6.

Table 6 Quantitative indicators were specified on water allocation assessment in large irrigation system

Indicators	Formula	Variable
Crop area (I1)	Adequacy $P_A = \frac{1}{T}\sum_t \left(\frac{1}{R}\sum_R P_A \right)$	$P_A = Q_D / Q_R$ $Q_D(x,t) =$ actual amount of water delivered by the system at a point x at time t $Q_R(x,t) =$ amount of water required for consumptive and other uses downstream of the delivery point x at time t
Productivity (I2)	Efficiency $P_F = \frac{1}{T}\sum_t \left(\frac{1}{R}\sum_R P_F \right)$	$P_F = Q_R / Q_D$ $Q_D(x,t) =$ actual amount of water delivered by the system at a point x at time t $Q_R(x,t) =$ amount of water required for consumptive and other uses downstream of the delivery point x at time t

3.3 Qualitative Indicators

Qualitative indicators from RAP will be specified by the Operation criteria and Maintenance criteria which will be focus on main canal evaluation; the description and sub-criteria were shown in table 7.

Table 7 Qualitative indicators were specified on water allocation assessment in large irrigation system. (Continued)

Criteria	Sub-criteria	Ranking Criteria
Operation	**I3 Water control**	
	I3.1 How frequently does the headworks respond to realistic real time feedback from the operators	4 - If there is an excess or deficit (spill or deficit at the tail ends), the headworks responds within 12 hours. 2.7 - Headworks responds to real-time feedback observations within 24 hours 1.3 - Headworks responds within 3 days. 0 - Headworks responds in a time of greater than 3 days.
	I3.2 Existence and effectiveness of water ordering/delivery procedures to match actual demands	4 - Excellent. Information passes from the lower level to this level in a timely and reliable manner, and the system then responds. 2.7 -Good. Reliable procedure. Updated at least once every 2 days, and the system responds. 1.3 - The schedule is updated at least weekly with meaningful data. Changes are actually made based on downstream requirements. 0 - Perhaps the schedule is updated weekly, but with data that is not very meaningful. Corresponding changes may not actually be made.

Table 7 Qualitative indicators were specified on water allocation assessment in large irrigation system. (Continued)

Criteria	Sub-criteria	Ranking Criteria
	I3.3 Clarity and correctness of instructions to operators.	4 - Instructions are very clear and very correct. 2.7 - Instructions are clear, but lacking in sufficient detail. 1.3 - Instructions are unclear, but are generally correct. 0 - Instructions are incorrect, whether they are clear or not.
	I3.4 How frequently is the whole length of this canal checked for problems and reported to the office?	4 - Once/day 2.7 - Once/2 days 1.3 - Once per week 0 - Once per month or less often
Maintenance	**I4 Characteristics of main canal**	
	I4.1 General level of maintenance	4 - Excellent. 3 - Good. The canal appears to be functional, but it does not look very neat. 2 - Routine maintenance is not good enough to prevent some decrease in performance of the canal. 1 - Decreased performance is evident in at least 30% of the canal. 0 - Almost no meaningful maintenance. Major items and sections are in disrepair.
	I4.2 Seepage/Loss	4 - Very little seepage (less than 4%) 3 - 4-8% of what enters this canal. 2 - 9 - 15% along this canal 1 - 16-25% along this canal.

Table 7 Qualitative indicators were specified on water allocation assessment in large irrigation system. (Continued)

Criteria	Sub-criteria	Ranking Criteria
		0 - Extremely high levels of undesired seepage. Provides severe limitations to deliveries.
	I4.3 Availability of proper equipment and staff	4 - Excellent maintenance equipment and organization of people. 3 - Equipment and number of people are reasonable to do the job, but there are some organizational problems. 2 - Most maintenance equipment functions, and the staff is large enough to reach critical items in a week or so. Other items often wait a year or more for maintenance. 1 - Minimal equipment and staff. Critical equipment works, but much of the equipment does not. Staff are poorly trained, not motivated, or are insufficient in size. 0 - Almost no adequate and working maintenance equipment is available, nor is there good mobilization of people.
	I5 Check structure in main canal	
	I5.1 Easy or difficult to control	4 - Very easy to operate. Hardware moves easily and quickly, or hardware has automatic features that work well. Water levels or flows could be controlled easily if desired. Current targets can be met with less than 2 manual changes per day.

Table 7 Qualitative indicators were specified on water allocation assessment in large irrigation system. (Continued)

Criteria	Sub-criteria	Ranking Criteria
		3 - Easy and quick to physically operate, but requires many manual interventions per structure per day to meet target. 2 - Cumbersome to operate, but physically possible. Requires more than 5 manual changes per structure per day to meet target, but is difficult or dangerous to operate. 1 - Cumbersome, difficult, or dangerous to operate. In some cases it is almost physically impossible to meet objectives. 0 - Communications and hardware are very inadequate to meet the requirements. Almost impossible to operate as intended.
	I5.2 Level of maintenance	4 - Excellent preventative maintenance. Broken items are typically fixed within a few days, except in very unusual circumstances. 3 - Decent preventative maintenance. Broken items are fixed within 2 weeks. Reasonable equipment is available for maintenance operations. 2 - Routine maintenance is only done on critical items. Broken items are noticeable throughout the project, but not serious. 1 - Even routine maintenance is lacking in many cases. Many broken items are noticeable, sometimes on important structures. 0 - Large-scale damage has occurred due to deferred maintenance. Little or no maintenance equipment is in working order.

Table 7 Qualitative indicators were specified on water allocation assessment in large irrigation system. (Continued)

Criteria	Sub-criteria	Ranking Criteria
	I5.3 Water level fluctuation (Maximum unintended weekly fluctuation of target water levels in the canal, expressed as a percentage of the average water level drop across a turnout.)	4 - less than 10% 3 - more than 10% to 20% 2 – more than 20% to 35% 1 – more than 35% to 50% 0 – more than 50%
	I6 Turnout from main canal	
	I6.1 Easy or difficult to control	4 - Very easy to operate. Hardware moves easily and quickly, or hardware has automatic features that work well. Water divisions or flows could be controlled easily if desired. Current targets can be met with less than 2 manual changes per day. 3 - Easy and quick to physically operate. Flow rate or target measurement devices are reasonable but not excellent. 2 - Cumbersome to operate, but physically possible. Flow rate measurement devices or techniques appear to be poor, along with poor calibration. 1 - Cumbersome, difficult, or dangerous to operate, and in some cases almost physically impossible to meet objectives. 0 - Communications and hardware are very inadequate to meet the requirements. Almost

Table 7 Qualitative indicators were specified on water allocation assessment in large irrigation system. (Continued)

Criteria	Sub-criteria	Ranking Criteria
		impossible to operate as intended.
	I6.2 Level of maintenance	4 - Excellent preventative maintenance. Broken items are typically fixed within a few days, except in very unusual circumstances. 3 - Decent preventative maintenance. Broken items are fixed within 2 weeks. Reasonable equipment is available for maintenance operations. 2 - Routine maintenance is only done on critical items. Broken items are noticeable throughout the project, but not serious. 1 - Even routine maintenance is lacking in many cases. Many broken items are noticeable, sometimes on important structures. 0 - Large-scale damage has occurred due to deferred maintenance. Little or no maintenance equipment is in working order.
	I6.3 Flow rate capacity	4 - No problems passing the maximum desired flow rates. 2 - Minor problems 0 - Serious problems - many structures are under-designed.

3.4 Weighted Factor Analysis

The AHP application in this research, the relative impact or weight factor of each criterion will be compute by the relationship between sub-criteria and sub-criteria. The collection data and calculated result will be used on it. For this study, the weighted factor will be analyzed in different methods as 1) weighted Factors analysis of quantitative Indicators will be analyzed based on uncertainly of irrigation water requirement in large irrigation system; and on the other hand, 2) weighted factors analysis of quantitative Indicators will be analyzed based on relative impact of each sub-indicator. A pair-wise comparison reciprocal matrix is used to compare the relative contribution of sub-indicators in level of hierarchy.

3.4.1 Weighted factors analysis of quantitative indicators

In this study, the hypothesis is that uncertainly of irrigation water requirement is main factor for water allocation practices in large irrigation system. The two input variables affected by this uncertainty are evapotranspiration (ETo) and rainfall (Rn). Weighted Factors analysis of quantitative indicators will be evaluated based on spatial and temporal situations. The example of weighted score in different ETo and Rn as presented in table 14

3.4.2 Weighted Factors of Qualitative Indicators

The interaction matrix form was prepared to collect about pair-wise relative importance among the different criteria and sub-criteria. The main criteria of qualitative indicators were specified on operation and maintenance. In each criterion will be defined in any sub-criteria which were described in table 8. A field visit was conducted to collect the individual preference through the interaction matrix form from 20 RID Officers. The result of weighted factors analysis through interaction matrix process as shown in figure 13 to 17. and the conclusion of the relative important value of qualitative indicators as shown in table 9

Table 8 The example of weighted score in different ETo and Rn

Variation	If	Then, Score is
ETo	$0 \leq \mathrm{ETo} \leq \frac{(\mathrm{ETomax} - \mathrm{ETomin})}{4}$	1
	$\frac{(\mathrm{ETomax} - \mathrm{ETomin})}{4} < \mathrm{ETo} \leq \frac{(\mathrm{ETomax} - \mathrm{ETomin})}{2}$	2
	$\frac{(\mathrm{ETomax} - \mathrm{ETomin})}{2} < \mathrm{ETo} \leq \frac{3(\mathrm{ETomax} - \mathrm{ETomin})}{4}$	3
	$\frac{3(ETo\max - ETo\min)}{4} < ETo \leq (ETo\max - ETo\min)$	4
Rn	$0 \leq Rn \leq \frac{(Rn\max - Rn\min)}{4}$	4
	$\frac{(Rn\max - Rn\min)}{4} < Rn \leq \frac{(Rn\max - Rn\min)}{2}$	3
	$\frac{(Rn\max - Rn\min)}{2} < Rn \leq \frac{3(Rn\max - Rn\min)}{4}$	2
	$\frac{3(Rn\max - Rn\min)}{4} < Rn \leq (Rn\max - Rn\min)$	1

	Column				
Row	1	2	3	4	SUM
1	**How frequently does the headworks respond to realistic real time feedback from the operators**	2			**2**
2		**Existence and effectiveness of water ordering/delivery procedures to match actual demandsต์**			**0**
3		1	**Clarity and correctness of instructions to operators.**		**1**
4	2			**How frequently is the whole length of this canal checked for problems and reported to the office.**	**2**
SUM	**2**	**3**	**0**	**0**	

Indicators	Row Score	Column Score	Total Score	**Weight Score**
How frequently does the headworks respond to realistic real time feedback from the operators	2	2	4	**0.400**
Existence and effectiveness of water ordering/delivery procedures to match actual demandsต์	0	3	3	**0.300**
Clarity and correctness of instructions to operators.	1	0	1	**0.100**
How frequently is the whole length of this canal checked for problems and reported to the office.	2	0	2	**0.200**
Total	5	5	10	**1.000**

Figure 13 The relative important value of sub indicators specified on water control in main canal

	Column			
Row	1	2	3	SUM
1	Level of maintenance	3		3
2		Seepage		0
3	2	2	Availability of proper equipment and staff	4
SUM	2	5	0	

Indicators	Row Score	Column Score	Total Score	**Weight Score**
Level of maintenance	3	2	5	**0.357**
Seepage	0	5	5	**0.357**
Availability of proper equipment and staff	4	0	4	**0.286**
Total	7	7	14	**1.000**

Figure 14 The relative important value of sub indicators specified on characteristics of main canal

	Column			
Row	1	2	3	SUM
1	**Level of maintenance**		3	3
2		**Water level fluctuation**	3	3
3			**Water level fluctuation**	0
SUM	0	0	6	

Indicators	Row Score	Column Score	Total Score	**Weight Score**
Level of maintenance	3	0	3	**0.250**
Water level fluctuation	3	0	3	**0.250**
Water level fluctuation	0	6	6	**0.500**
Total	6	6	12	**1.000**

Figure 15 The relative important value of sub indicators specified on Head Reg. and Check Structure in main canal

	Column			
Row	1	2	3	SUM
1	Easy or difficult to control			0
2	2	Level of Maintanance		2
3	1		Limit of Flow rate Capacity	1
SUM	3	0	0	

Indexs	Row Score	Column Score	Total Score	**Weight Score**
Easy or difficult to control	0	3	3	**0.500**
Level of Maintanance	2	0	2	**0.333**
Limit of Flow rate Capacity	1	0	1	**0.167**
Total	3	3	6	**1.000**

Figure 16 The relative important value of sub indicators specified on Off-take (Head reg. from main canal to Secondary)

	Column					
Row	1	2	3	4	5	**SUM**
1	**Characteristics of main canal**	2	2	2	2	8
2		**Head Reg. and Check Structure**	3		3	6
3			**Off-take (Head reg. from main canal to Secondary)**		2	2
4		2	2	**Water control in main canal**	3	7
5					**Water Delivery Service (Qualitative Indicators)**	0
SUM	0	4	7	2	10	

Figure 17 The matrix of relative important value of qualitative indicators

Table 9 The conclusion of the relative important value of qualitative indicators

Indicators	Row Score	Column Score	Total Score	Weight Score
Characteristics of main canal	8	0	8	**0.174**
Head Reg. and Check Structure	6	4	10	**0.217**
Off-take (Head reg. from main canal to Secondary)	2	7	9	**0.196**
Water control in main canal	7	2	9	**0.196**
Water Delivery Servise (Quantitative indicator)	0	10	10	**0.217**
Total	**23**	**23**	**46**	**1.000**

4. Uncertainly of Water Allocation Planning in Large Irrigation System

Uncertainly of water allocation evaluation for large irrigation projects have to be carefully if the assessment is a part of project improvement plan. The result of water allocation evaluations (quantitative and qualitative analysis) will be affected by many factors. The quantitative analysis will be analyzed in early season for cropping pattern planning and crop yield prediction; otherwise the qualitative analysis will be used for the evaluation of water allocation practices during season. The study area is Plaichumpol O&M project. The three factors which are affected on water allocation evaluation were described as follow;

2.1 Cropping Pattern Planning

The parameters used for cropping pattern conditions of Plaichumpol O&M Project will be classified to water supply and water demand. The water supply parameters include level of irrigation and rainfall; and the water demand parameters are cropping pattern and ETo;

2.1.1 Level of irrigation

Full irrigation is justified when water availability is adequate to provide as the irrigation water requirement. One of the main objectives of all O&M irrigation projects is to reach the maximum irrigated area under irrigation. However, the limited of water availability in dry season could be irrigated to gain the most crop area under the certain level of deficit irrigation. The description of the level of irrigation will be divided into four categories; there are no deficit irrigation, 10%deficit irrigation, 20% deficit irrigation and 30% deficit irrigation.

2.1.2 Rainfall

The rainfall intensity shows significant contribution to crop water requirement, although the major water source comes from irrigation during dry season. Whatever, it is difficult to know how much water will be obtained from rainfall become the rainfall intensity varies greatly from year to year. Probability rainfall analysis of long term rainfall records can provide a good solution to this uncertainty. The daily rainfall data of Phitsanulok meteorological station has been collected for 30 years (1975-2004). The rainfall analysis has been summarized in weekly basis. Later, the different probability distribution has been tested to examine the best fitted distributions. The best fitted distribution has been selected by Kolmogorov-Smirinov (K-S) test and Chi-square test. FAO defined rainfall intensity with a 20%, 50% and 80% probability of exceedence representing as wet, normal and dry year respectively. (Mainuddin,2000). The weekly rainfalls in different probability of exceedence have been calculated.

2.1.3 Reference crop evapotranspiration

For this study, the reference crop evapotranspiration (ETo) was estimated using Penman Montheith method. There are two agro-climatic station located near the project area. One is at the northern end of the irrigation system namely Phitsanulok meteorological station; and the other at the southern end of the irrigation system namely Nakorn Sawan meteorological station. Daily meteorological data such as maximum and minimum temperature, maximum and minimum relative humidity, wind speed, sunshine hour, rainfall are collected from these two stations for 10 years (1995-2004). These parameters along with the information of meteorological station such as latitude, longitude and evaluation are used to estimate weekly ETo by apply the Evapotranspiration model which is sub-model of Acers Irrigation Support Package (AISP) Mathematic model. These are summarized on weekly basic. The weekly reference crop evapotranspiration of Phitsanulok meteorological station; by Penman-Montheith method by mm/day unit is shown in table 10.

Loof et al. (1999) and Mainuddin (2000) estimate ETo for three sub-system following rules were applied;

ETo of Plaichumpol is 100 % of Phitsanulok meteorological station;

ETo of Dong Setthi is sum of 50% of Phitsanulok and 50% of Nakorn Sawan meteorological station; and

ETo of Tha Bua is sum of 25% of Phitsanulok and 50% of Nakorn Sawan meteorological station.

Table 10 Weekly reference crop evapotranspiration of Phitsanulok by Penman-Montheith method (mm/day)

Week	Year									
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1	3.39	3.30	3.14	3.63	3.50	2.51	3.03	2.61	2.81	2.40
2	3.29	3.04	3.89	3.37	3.56	3.01	3.11	2.91	2.70	2.81
3	3.03	3.29	3.47	3.26	3.31	3.30	3.04	3.21	3.00	3.09
4	3.30	3.43	3.46	3.23	3.23	2.96	3.47	3.01	3.24	3.31
5	3.63	4.30	3.59	3.84	3.67	3.57	3.20	3.01	3.33	3.66
6	3.77	4.46	4.09	3.99	3.61	3.86	3.36	3.91	3.29	4.06
7	4.01	4.47	4.50	4.80	4.11	4.26	4.09	4.63	3.71	4.06
8	4.97	4.66	4.89	4.91	4.01	4.53	4.40	4.44	3.84	3.44
9	4.21	5.26	4.94	5.44	4.79	3.80	4.49	4.43	4.09	3.54
10	4.31	4.14	3.79	5.06	5.56	4.87	4.86	4.59	4.33	4.71
11	5.47	5.47	5.53	4.63	5.37	5.00	4.80	4.11	5.43	5.30
12	5.36	6.00	6.01	5.46	6.07	5.53	5.41	3.99	4.53	5.39
13	6.04	5.91	5.47	6.04	6.03	5.80	6.07	3.71	4.40	5.76
14	5.79	6.09	6.20	6.16	5.44	5.60	5.47	4.96	4.83	4.93
15	6.21	5.94	6.94	5.96	6.71	6.13	5.39	5.06	5.09	5.00
16	5.33	5.01	6.84	4.87	6.80	6.39	6.07	5.03	4.94	4.59
17	5.77	5.40	6.44	5.71	5.67	5.96	6.67	5.46	5.04	4.07
18	4.87	4.63	6.43	5.49	6.10	6.29	6.41	5.31	4.74	3.91
19	6.11	4.79	6.30	5.53	6.21	6.37	6.40	3.57	3.66	4.27
20	5.86	4.41	4.57	5.27	5.56	5.69	5.13	3.74	3.83	4.46
21	6.44	5.57	5.01	4.39	5.14	5.56	4.44	4.17	4.44	4.04
22	5.37	4.00	3.40	4.37	4.66	5.81	3.61	3.80	3.83	3.83
23	4.01	3.37	4.37	4.27	3.83	4.41	5.17	4.00	3.21	4.34
24	3.91	3.49	2.97	4.47	3.43	4.60	5.37	3.46	3.94	3.86
25	4.46	4.50	4.46	3.64	3.74	4.20	4.51	2.66	3.97	4.04
26	4.66	4.24	3.86	3.27	3.54	2.97	3.51	3.07	3.80	4.31
27	2.61	3.94	3.77	3.23	3.67	3.70	4.24	3.53	2.93	3.84
28	3.53	4.66	4.36	4.36	4.10	2.96	3.07	2.73	3.86	4.71
29	4.09	4.27	5.04	3.51	3.50	4.81	4.39	3.07	3.46	3.50
30	4.19	4.80	3.81	2.86	3.16	3.17	4.80	3.07	3.14	2.43
31	4.07	2.84	3.34	3.79	3.69	2.91	3.66	2.76	3.51	3.17
32	5.11	4.27	4.24	4.70	3.40	3.71	4.17	3.30	3.03	3.43
33	4.26	4.01	4.26	5.47	2.70	3.66	2.96	2.87	2.73	3.54
34	3.29	3.74	4.27	4.91	3.51	4.11	3.11	3.14	3.37	3.80
35	4.26	4.20	3.73	3.71	3.40	4.37	3.71	2.44	3.06	4.71
36	3.36	4.26	3.91	4.24	3.54	4.39	3.14	3.93	3.50	4.09
37	4.26	3.86	4.24	3.29	3.70	3.94	3.91	3.03	3.10	3.24
38	3.34	3.76	4.24	3.81	3.99	3.13	3.83	3.23	3.61	3.46
39	3.53	4.26	4.04	3.36	3.60	3.61	4.24	3.49	3.71	3.09
40	3.89	3.40	3.76	3.70	3.77	3.74	3.89	3.69	3.20	3.17
41	3.76	2.99	3.61	3.80	3.69	4.26	4.36	3.70	3.06	3.94
42	4.40	2.97	3.63	3.33	3.84	2.56	3.73	3.51	3.44	4.34
43	4.20	3.71	4.14	4.06	4.13	3.16	3.93	3.39	3.31	3.34
44	3.71	3.40	4.36	4.09	3.14	3.09	4.17	3.13	2.70	3.24
45	2.91	3.61	3.77	3.63	3.10	3.93	3.96	3.07	2.86	3.29
46	3.37	2.66	3.99	3.49	2.97	3.26	3.81	3.11	2.81	3.47
47	3.23	2.96	3.40	3.46	2.99	3.44	3.37	3.03	3.10	3.06
48	3.66	3.51	3.40	3.10	3.81	3.26	2.97	2.49	2.70	3.33
49	2.97	3.19	3.00	3.29	3.80	3.20	3.66	2.94	2.86	3.29
50	2.83	2.84	3.10	3.19	2.73	3.54	2.80	2.40	2.44	3.20
51	3.00	3.11	3.06	3.30	2.81	3.34	3.31	2.96	2.99	3.29
52	3.14	3.49	3.29	3.21	2.10	2.71	2.90	2.70	2.90	3.10
Average	4.20	4.11	4.31	4.19	4.09	4.13	4.18	3.53	3.57	3.81

2.2 Crop Yield Prediction

Due to irrigation project planning purpose, the net irrigation requirement of the crops other than rice is estimated using the field water balance as;

$$NIR = ET_{crop} - ER + LPR + P \quad (31)$$

where,

NIR	=	Net irrigation requirement in mm/day;
ER	=	Effective rainfall, mm;
LPR	=	Land preparation and nursery requirement, mm;
P	=	Deep percolation requirement.

Gross Irrigation Requirement (GIR) is the total irrigation requirement for crops at the main intake point from the source. It can be expressed as;

$$GIR = (A \times NIR)/IE \quad (32)$$

where,

GIR	=	Gross irrigation requirement, m^3/day;
NIR	=	Net irrigation requirement of a given crop, mm/day;
IE	=	Irrigation Efficiency;
A	=	Area of crop, ha;

The dry season, the net irrigation water requirement of paddy crop and non-paddy crop are estimate using equation(33) And the gross irrigation requirement is computed using the equation(34) for the plant area. As many factors are involved in the operation of irrigation system and in order to fulfill all of the system objective within the water availability, in real practice, it becomes for the system management to supply deficit irrigation contradictory to prediction. In order to investigate the consequence of the effect of deficit irrigation for analysis crop yield, the GIR at 0%, 10%, 20% and 30%.The result of GIR estimation presented in Appendix B

The relative yields of different crops due to deficit irrigation supply have been calculated using empirical crop production function as follows;

$$\frac{Y_a}{Y_p} = 1 - K_y\left[1 - \frac{ET_a}{ET_b}\right] \quad (33)$$

where,

Y_a = actual yield;

Y_p = the potential yield that will be obtained at potential evapotranspiration;

ET_a = actual evapotranspiration;

= (1-d/100)NIR+ER

ET_p = potential evapotranspiration;

= NIR+ER

K_y = yield response factor (find in FAO report no. 56); and

d = deficit percentage

In case of deficit condition, the land preparation and percolation have been considered same as full irrigation. Therefor;

$$ET_a = (1\text{-}d/100)NIR+ER - LPR\text{-}P \quad (34)$$

So, the actual yield, cost of production and net benefit at no deficit, 10%, 20%, 30% and 50% deficit irrigation at 20%, 50% and 80% probability of exceedence. The information regarding the yield, cost investment and unit price of different crops of the year 2004 have collected from Office of Agricultural Economics located in Bangkok the results of yield and benefit have been presented in Appendix B.

5. Crop yield Analysis for Water Allocation Planning

The main objective of water allocation in Irrigation Project is to maximize the high productivity (which reflects to high income) and crop areas at different resource reliabilities which are level of irrigation, rainfall reliability level, cropping pattern and reference crop evapotranspiration (ETo). The available resources have varied influence in real situations. The application of Linear Programming (LP) model in cropping pattern planning is to optimize crop productivity, crop areas in order that minimum available water supply and other limiting conditions are obtained. The propose of cropping pattern planning is to determine the type of crops to be grown, cultivated area and level of water application so that the available resources can be efficiently used as the desired objectives.

5.1 Linear Programming model

The main objective of water allocation planning in irrigation system is to obtain optimum crop productivity and irrigated area. Mathematically equation, linear objective functions and linear equation (as constraints of the irrigation system) can be described as follows;

5.1.1 The main objectives of an irrigation system are to obtain optimum crop productivity and irrigated area. Although two objectives seem to be oppose each other and can not be maximize at the same time. In this study, both objectives have been considered and simulated as the number of times to get the sensibility and complexities in different aspects of operation planning for the decision maker. We can define the objective function equations to get the maximum of crop area and crop productivity as shown in the equation (35) and (36) respectively below;

$$\text{Maximization of crop area: Max A} = \sum_{i=1}^{l}\sum_{j=1}^{m}\sum_{k=1}^{n} A_{ijkr} \qquad (35)$$

Maximum of crop productivity: $\text{Max } P = \sum_{i=1}^{l}\sum_{j=1}^{m}\sum_{k=1}^{n}[(EY_{ijk}P)_i A_{ijkr}]$ (36)

5.1.2 The model is subjective to follow constrain as water allocation, land and crop area bounds which can be described as follow;

- Water allocation constrain is that the irrigation water requirement for all crops at any level of water application can not be higher than the defined allocation water availability at the source.

Water allocation constrain: $\sum_{i=1}^{l}\sum_{j=1}^{m}\sum_{k=1}^{n} W_{ijkr} A_{ijkr} \leq SW$ (37)

- Land constrain are that the sum of the crop area in land j cannot be greater than the total available crop area as shown in equation (38); and sum of crop area in all types of lands should be less than total command area of the project as shown in equation (39)

$$\sum_{i=1}^{l}\sum_{k=1}^{n} C_{ijk} A_{ijkr} \leq TA_j \quad (38)$$

$$\sum_{i=1}^{l}\sum_{j=1}^{m}\sum_{k=1}^{n} C_{ijk} A_{ijkr} \leq TC \quad \text{……...(39)}$$

- Crop area bounds constrain is that lower and upper bounds of some crops are based on the social need, economic viability, physical constraints etc. Crop area bounds constrain as shown in equation (40) and (41)

$$\sum_{i=1}^{l}\sum_{k=1}^{n} A_{ijk} \leq A_{j\,max} \quad (40)$$

$$\sum_{i=1}^{l}\sum_{k=1}^{n} A_{ijk} \geq A_{j\,min} \quad (41)$$

where;

i = index for crop

j = index for area type

k = index for level of water application

l = total number of crops in a year

m = total number of land type

n = total no of water application level

r = percentage(%) of rainfall probability exceedence

EY_{ijk} = expected yield for i crop under j land and k level of irrigation application, kg

P_i = unit price of crop i, USD/kg.

A_{ijkr} = cultivated area of i crop under j land at k level of irrigation application for r% of rainfall probability exceedence, ha

W_{ijkr} = canal water requirement for i crop under j land at k level of irrigation application for r% of rainfall probability exceedence, MCM/ha

SW = Allocated surface water for O&M project, MCM

C_{ijkr} = index equal to 1 if crop i is grown and 0 if i is not grown in sub-area j at k level of irrigation application

TA = total area available for j land, ha

TC = total of command area, ha

$A_{i\ max}$ = maximum area that can be allowed to a crop, ha

$A_{i\ min}$ = minimum area that can be allowed to a crop, ha

5.2 LP Model and Consideration of Alternatives

The total cultivable command area of Plaichumphol O&M project is 34,880 ha. The major water supply is surface water. The water is necessary for crops which were focused on paddy. The comparison of crop water requirement, peanut provides more productivity. So, if the LP model focused on maximum crop productivity, then maximum crop area would be covered by peanut followed by paddy. Whatever, peanut and vegetable provide more productivity, if peanut would be restricted and vegetables cropping areas would be 7,710.52 ha 12,726.30 and 13,819.56 ha at 20%, 50% and 80% rainfall probability exceedence level respectively. Rest area would be covered by paddy. In actual sense, it is not feasible situation because we except soybean and other crops are not suitable in low land. It is true that, the social need and the market price have been considered, the cultivation of upland crop are advocated, so that it is not extent for vegetables crop only. Then, the lower crop boundary to sesame, maize and mungbean has been fixed. The upper crop boundary has been imposed to vegetables, peanut and soybean. According to the statement made by farmers during the field interview; the paddy does not require continuous care through out the growing period which was different with upland crops, and paddy is suitable under low land and clay soil. Moreover, paddy is the staple food. So, The cropping boundary has not been imposed for this crop; the minimum area of non-paddy crops should be 30 % to 40% of total dry season areas. Therefore, lower and upper boundary of different crops has been fixed which were based on the past planning data. Upper boundary of paddy and soybean crop has not been imposed while the notion of total crop area has taken into consideration.

The crop planning scenarios in different level of irrigation application under different cropping area conditions have been considered; there are more options for decision maker as;

1) Single level of irrigation (no deficit)
2) Single level of irrigation (10% deficit)
3) Two level of irrigation (no deficit and 10% deficit)

4) Two level of irrigation (no deficit and 20% deficit)

5) Three level of irrigation (no deficit, 10% deficit and 20% deficit)

6) Three level of irrigation (no deficit, 20% deficit and 30% deficit)

7) Total area under irrigation (at single level, two level and three level irrigation application)

The LP model respect the predefined scenarios and the limitations of O&M project, the LP model is simulated for different alternatives. The cropping patterns are wide range of above discussed, so the cropping pattern conditions are set which are described as follows:

1) No deficit irrigation application with upper and lower crop boundary to upland crops except paddy.

2) No deficit irrigation application covering the whole command area with lower and upper crop boundary conditions to upland crops except soybean.

3) Two levels irrigation application (no deficit irrigation to paddy and 10% deficit irrigation to upland crops) with no lower crop boundary but upper crop boundary to upland crops.

4) Two levels of irrigation application (no deficit irrigation to paddy and 20% deficit irrigation to upland crops) with no lower crop boundary but upper crop boundary to upland crops.

5) Two levels of irrigation application (no deficit irrigation to paddy and 10% deficit irrigation to upland crops) with lower and upper crop boundary condition.

6) Two levels of irrigation application (no deficit irrigation to paddy and 20% deficit irrigation to upland crops) with lower and upper crop boundary condition.

7) Two levels of irrigation application (no deficit irrigation to paddy and 10% deficit irrigation to upland crops) with lower and upper crop boundary to upland crops and covering the total command area.

8) Three levels of irrigation application (no deficit irrigation to paddy, 20% deficit irrigation to maize, sesame, peanut, and mungbean and 30% deficit irrigation to vegetable and soybean) with no lower crop boundary but with upper crop boundary.

9) Three level of irrigation application(no deficit irrigation to paddy, 10% deficit irrigation to maize, sesame, peanut, and mungbean and 20% deficit irrigation to vegetable and soybean) with lower and upper crop boundary condition.

10) Three levels of irrigation application (no deficit irrigation to paddy, 10% deficit irrigation to maize, sesame, peanut, and mungbean and 20% deficit irrigation to vegetable and soybean) with no lower crop boundary condition, but upper crop boundary condition to upland crops except soybean and covering the total command area.

11) Three levels of irrigation application (no deficit irrigation to paddy, 20% deficit irrigation to maize, sesame, peanut, and mungbean and 30% deficit irrigation to vegetable and soybean) with no lower crop boundary condition, but upper crop boundary condition to upland crop except soybean and covering the total command area.

12) Single level of irrigation application (10% deficit irrigation) to all crops including paddy with lower and upper crop boundary conditions except paddy.

The above cropping patterns are simulated for three level of rainfall reliability level as 20%, 50% and 80%. The 36 alternatives will be obtained for multi-objective analysis. The 36 alternative which were presented in table 11

Table 11 The 36 alternatives of water allocation plan of Plaichumpol O&M project

Solution	Objective	Alternative	Benefit	Irrigated area (ha)				
No			Million USD.	No deficit	10%deficit	20%deficit	30%deficit	Total
1	Max benefit	NDIW1	13.686	34,104				34,104
2	Max area	NDIWW2	13.564	34,800				34,800
3	Max benefit	NDIN1	12.275	31,008				31,008
4	Max area	NDINW2	11.775	34,880				34,880
5	Max benefit	NDID1	11.938	30,267				30,267
6	Max area	NDIDW2	11.426	34,880				34,880
7	Max benefit	2LIW1	13.715	32,134	1,515			33,649
8	Max benefit	2LIW2	13.689	32,753		0		32,753
9	Max benefit	2LIW3	13.617	31,225	3,035			34,260
10		2LIW4	13.551	31,390		3,030		34,420
11		2LIW5	11.891	2,967	31,913			34,880
12	Max area	2LIWW6	13.522	30,295	4,585			34,880
13	Max benefit	2LIN1	12.291	29,011	1,515			30,526
14	Max benefit	2LIN2	12.236	29,076		1,500		30,576
15	Max benefit	2LIN3	12.199	28,126	3,035			31,161
16		2LIN4	12.123	28,281		3,030		31,311
17		2LIN5	10.403	3,867	29,443			33,310
18	Max area	2LINW6	11.673	22,836	12,044			34,880
19	Max benefit	2LID1	11.946	28,251	1,515			29,766
20	Max benefit	2LID2	11.889	28,314		1,500		29,814
21	Max benefit	2LID3	11.86	27,381	3,035			30,416
22		2LID4	11.764	27,496		3,030		30,526
23		2LID5	10.004	3,867	28,649			32,516
24	Max area	2LIDW6	11.288	21,292	13,588			34,880
25	Max benefit	3LIW1	13.689	31,067			0	31,067
26		3LIW2	13.553	31,375	45	3,000		34,420
27	Max area	3LIWW3	13.426	30,638	30	4,212		34,880
28	Max area	3LIWW4	13.442	31,279		45	3,556	34,880
29	Max benefit	3LIN1	12.235	29,563			0	29,563
30		3LIN2	12.124	28,266	45	3,000		31,311
31	Max area	3LINW3	11.594	24,338	30	10,512		34,880
32	Max area	3LINW4	11.513	25,492		50	9,338	34,880
33	Max benefit	3LID1	11.882	28,786			0	28,786
34		3LID2	11.782	27,518	45	3,000		30,563
35	Max area	3LIDW3	11.178	22,937	30	11,913		34,880
36	Max area	3LIDW4	11.083	24,231		50	10,599	34,880

RESULTS AND DISCUSSION

1. Knowledge for Water Allocation Using Rapid Appraisal Process

The conclusion of RAP evaluation results by 12 pilot projects were shown in appendix A. The results of evaluation can be guided for setting modernization plan. In addition, this study can conclude the key performance indicators depended on knowledge for water allocation using RAP.

1.1 Water delivery service evaluations

The evaluation of water delivery service consisted of three sub-indicators: (1) from the main canals to the secondary canals; (2) to the furthest downstream point controlled by system operators; and, (3) to individual ownership units. In each sub-indicator, the assessments were separated in two conditions as report and actual. The reported condition is the operational target or irrigation performance of the project based on the water management expectations of project employees; otherwise, the actual condition is the water management practice which the evaluator actually observes in the field. The results of water delivery service evaluation are summarized in table 12.

It is found that the expected operation is higher than the actual operation in the field. In particular, water delivery service at the furthest downstream point in system, and at individual ownership units, have low average actual index values (1.0 and 1.2, respectively). Observations in the field indicate that there is no capability to measure flows to the fields, some points along the canal do not enjoy the same level of delivery service, and water supply to the farms was not in accordance with demands.

Table 12 Status of water delivery service in the irrigation projects.

Irrigation projects		Naraysuan dam	Plaichumpol	Dong Setthi	Tha Bua	Manorom	Chong Khae	Khok Krathiam	Roeng Rang	Phonlathep	Tha Bot	Samchuk	Pho Phraya	**Average**
Delivery Services indicaters														
Water Delivery Service by the Main Canals to the Second Level Canals	Reported	2.8	3.0	3.2	3.0	3.4	2.4	2.3	2.9	2.7	1.2	2.7	2.7	**2.7**
	Actual	2.2	2.4	1.8	2.4	1.8	2.0	2.6	2.0	1.4	1.2	2.2	1.4	**2.0**
Water Delivery Service at the most downstream point in the system operated by a paid employee	Reported	1.2	1.8	1.6	1.8	1.2	2.1	2.6	1.8	1.4	1.2	1.2	1.4	**1.6**
	Actual	1.4	0.7	1.2	0.9	0.7	1.6	0.8	0.8	1.2	0.7	1.2	1.3	**1.0**
Water Delivery Service to Individual Ownership Units (e.g., field or farm)	Reported	1.8	2.0	2.3	2.0	1.3	1.8	1.8	1.9	1.7	1.8	1.7	1.7	**1.8**
	Actual	1.8	0.7	1.2	0.7	0.9	1.5	0.9	1.3	0.9	1.1	1.6	1.8	**1.2**

Note: the range of values was 0 to 4

1.2 Project employees and water user association evaluations

The assessment of organizations and participations in irrigation projects consists of project employees and Water User Associations (WUAs). In addition, the budgets evaluation has more important for the operation and maintenance in each project. WUAs are voluntary and self-governed groups of water users who jointly manage their water resources and infrastructure irrigation systems. The level of participation by both project employees and WUAs in water management is manifested by the strength of the organizations. The strength of organizations and budget of irrigation projects can be evaluated and shown by indicators values as illustrated in table 13.

Table 13 The evaluations of project employees and water user associations.

Irrigation projects	Naraysuan dam	Plaichumpol	Dong Setthi	Tha Bua	Manorom	Chong Khae	Khok Krathiam	Roeng Rang	Phonlathep	Tha Bot	Samchuk	Pho Phraya	**Average**
Sub-indicators													
Budgets	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Project Employees	2.4	1.4	1.2	1.4	1.9	1.8	2.3	1.3	2.4	2.1	2.0	1.9	1.8
Water User Associations	0.5	0.2	0.2	0.2	0.5	0.2	1.9	0.9	0.3	0.3	0.3	1.8	0.6
Average	1.5	1.1	1.0	1.1	1.3	1.2	2.0	1.3	1.4	1.3	1.3	1.8	**1.3**

Note: the range of values was 0 to 4

Following the evaluations of project employees and water user associations, it was found that the WUA index has the lowest average value of 0.6, and the budget and project employee average index values were 1.6 and 1.8, respectively. These index value results can be explained as follows: even the project users who have a functional, formal unit which participates in water distribution are unable to operate and maintain the irrigation system without external assistance. The WUAs have been set up and supported only by the government. The government officially recognizes the WUAs, but in reality they have not been empowered related to water. The funds to replace and maintain key structures are insufficient because a water fee has not been assessed nor collected. The employees are not permitted to perform any significant tasks without governmental authorization. Training exists at all levels as needed, but evidently training is not enough, because employees at all levels seem to have missed some important ideas. In fact, after numerous field interviews, it has become apparent that many employees have never had adequate training, nor did they have sufficient experience prior to taking the job.

1.3 Main canal evaluations

The assessment of water distribution at the main canal level consists of cross-regulators, turnout, regulating reservoirs, communication, general conditions and operations. The modernization objective for main canal management is control water level dependence on supply and demand. The water level in the main canal has a greater influence to water distribution than the next level, so the evaluations emphasize water control in the main canal. The results of main canal assessment are shown in table 14.

Table 14. Water delivery service evaluation in the main canal

Irrigation projects	Naraysuan dam	Plaichumpol	Dong Setthi	Tha Bua	Manorom	Chong Khae	Khok Krathiam	Roeng Rang	Phonlathep	Tha Bot	Samchuk	Pho Phraya	**Average**
Sub-indicators													
Cross regulator hardware (main canal)	1.6	1.0	2.0	1.0	0.8	2.3	2.3	2.0	0.9	0.6	0.9	0.9	1.3
Turnouts from the main canal	2.3	2.3	2.0	1.7	2.8	2.2	2.2	2.2	2.0	2.3	2.2	2.0	2.2
Regulating reservoirs in the main canal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Communications for the main canal	2.0	2.7	2.7	2.2	2.5	3.0	2.2	2.7	3.4	2.4	3.4	3.6	2.7
Generalconditions for the main canal	2.0	2.4	3.0	1.8	3.0	2.8	2.9	1.6	2.2	1.6	2.2	2.2	2.3
Operation of themain canal	2.3	2.5	2.3	2.0	2.5	2.2	2.5	2.7	2.8	1.9	2.8	2.8	2.4
Average	1.7	1.8	2.0	1.4	1.9	2.1	2.0	1.9	1.9	1.5	1.9	1.9	**1.8**

Note: the range of values was 0 to 4

The average index value as shown in table 14 for the twelve projects is 1.8. The regulating reservoirs were not present in any of 12 projects, so the index value is 0.0. Thus, not considering regulating reservoirs, the cross regulator hardware has the lowest average index value of 1.3. The main problem is the water level control which it based on existing infrastructure and operations. So, the ease of cross-regulator operation under the target operation (water level) is necessary to control water. That means that this rating indicates how easy or difficult it would be to operate the cross-regulators to meet the water delivery targets. Nevertheless, water use along the canal, general conditions and operation of main canal are also factors.

1.4 Secondary and tertiary canals evaluations

The water operation in secondary and tertiary canal has the same objectives as supplying water based on demands. Each evaluation items is the same as that for the main canal. The items and results of the evaluation are shown in tables 15 and 16.

The data collection and survey in secondary and tertiary systems found that the total average index values are 1.7 and 1.6, respectively. The index values which are shown in Tables 8 and 9 can be used for diagnosis of both systems because regulating reservoirs were not present in either system (index value is 0). There are many problems of water control and operation at cross-regulators and turnouts as the canal operator does not have good mobility and is not responsible for the operation of structures. The operators who are in control of flows to farmers of the next lower level do not know the discharge, and the whole length of this canal was checked for problems and reported to the office, and routine maintenance is inadequate in terms of preventing a decrease in canal performance. These problems are the direct effects of water ordering and delivery procedures which are implemented to match actual demands.

Table 15 Water delivery service evaluation in secondary canals.

Irrigation projects / Sub-indicators	Naraysuan dam	Plaichumpol	Dong Setthi	Tha Bua	Manorom	Chong Khae	Khok Krathiam	Roeng Rang	Phonlathep	Tha Bot	Samchuk	Pho Phraya	**Average**
Cross regulator hardware (second level canals)	2.3	3.4	1.9	0.9	1.4	1.1	0.6	3.1	1.7	3.4	2.1	1.7	2.0
Turnouts from the second Level canals	2.2	2.0	2.0	2.0	1.0	1.8	1.7	2.7	2.0	1.5	1.8	2.0	1.9
Regulating reservoirs in the second Level canals	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Communications for the second Level canals	2.1	2.4	2.8	2.4	1.8	2.2	2.1	3.5	3.4	2.0	3.0	3.0	2.6
General conditions for the second level canals	1.7	2.7	1.9	2.7	1.6	2.2	2.0	1.6	2.2	1.5	1.6	1.5	1.9
Operation of the second level canals	2.1	2.1	2.3	2.1	1.0	2.1	1.2	1.9	2.1	1.2	2.1	2.4	1.9
Average	1.7	2.1	1.8	1.7	1.1	1.6	1.3	2.1	1.9	1.6	1.8	1.8	**1.7**

Note: the range of values was 0 to 4

Table 16 Water delivery service evaluation in tertiary canals.

Irrigation projects / Sub-indicators	Naraysuan dam	Plaichumpol	Dong Setthi	Tha Bua	Manorom	Chong Khae	Khok Krathiam	Roeng Rang	Phonlathep	Tha Bot	Samchuk	Pho Phraya	**Average**
Cross regulator hardware (third level canals)	2.1	2.0	2.1	2.0	0.5	1.4	0.4	1.1	1.7	1.3	1.4	1.9	1.5
Turnouts from the third level canals	1.7	1.6	2.0	2.0	1.0	2.2	1.3	2.5	1.8	1.3	1.8	2.3	1.8
Regulating reservoirs in the third level canals	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Communications for the third level canals	2.4	2.2	2.8	2.2	1.5	1.3	1.9	2.6	2.5	1.0	2.1	1.8	2.0
General conditions for the third level canals	2.1	2.2	2.2	2.2	1.1	2.1	1.4	2.4	1.9	1.2	2.3	2.0	1.9
Operation of the third level canals	2.0	2.7	2.0	2.7	1.0	2.4	1.5	2.9	2.1	0.9	2.4	2.7	2.1
Average	1.7	1.8	1.9	1.8	0.9	1.6	1.1	1.9	1.7	0.9	1.7	1.8	**1.6**

Note: the range of values was 0 to 4

1.5 The guided line for setting modernization plan for large irrigation system

The evaluation of irrigation practices in the pilot irrigation projects found a need for both management and hardware improvements in each project. Some management issues are closely tied to culture and governmental policies – such influences are difficult to change quickly at the irrigation project level. Nevertheless, operation and management changes could be immediately implemented and have beneficial impacts on irrigation performance, and the costs of irrigation improvement projects will depend on their physical and operational conditions. An example of modernization activities is given in table 17, which separates the planning into three phases: short term, medium term, and long term. In the short term, activities are limited to low-cost water management improvements, deferring the relatively high costs of rehabilitation and infrastructure improvements to the medium and long term.

1.6 The RAP result in different weighted factor

The result can be guided for water allocation improvement during the season on pre-season. The main objective of project assessment for large irrigation system should be considered for the operation and maintenance in main canal. According to field visit and using RAP, there are several ideas of decision maker on the methodology of water allocation, its evaluation base on the relative important of indicators which was identified by FAO. In each project, there are many conditions for assessment depended on spatial and temporal. The water allocation activity will be plan by the decision maker, so the area for interest and priority set of indicator will be specified by decision maker or operator. The different of weighted factors of indicator are resulted to the guide for water allocation improvement which have been shown by sub-indicator values. The comparisons between FAO's weighted factor and modified weighted factor were applied at Plaichumpol O&M project. The result have been shown in table 18.

Table 17 An example of possible modernization activities for a large irrigation system.

Planning	Items	Activities
Short-term (1-2 years)	Maintenance	- Maintenance and calibration of head regulators and check structures in main canals - Main canal, farm turnout, and ditch maintenance
	Operation	- Operational training on water control, cropping patterns, and other topics - Reorganize O&M staff, as necessary - Set up operation control room and database program in each project - Using mathematical modeling for estimating water demand and supply - Establishment and training of WUAs
	Construction and infrastructure improvements	- None
Medium-term (5 years)	Maintenance and rehabilitation	- Maintenance and calibration of regulators and checks in secondary canals - Rehabilitation secondary canal, farm turnouts and ditches
	Operation	- Improved monitoring and control system - Institutional strengthening of WUA - Irrigation transfer training for operators and WUAs
	Construction and infrastructure improvements	- Operation room and database center in RID regional offices - Install automatic gates at head regulators and checks in the main canal, where appropriate - Regulating reservoir in main canal
Long-term (10 years)	Maintenance and rehabilitation	- Maintenance and calibration of regulators and checks in tertiary canals - Rehabilitation of tertiary canals, farm turnouts and ditches
	Operation	- Real time monitoring system - Strengthen and institutional of WUA - Irrigation transfer to WUAs (tertiary canal and ditch)
	Construction and infrastructure improvements	- Operation room and database center at RID center - Install automatic gates, where appropriate, at regulators in secondary canals

Table 18 The comparisons between FAO and modified weighted factor applied at Plaichumpol project

Index	MAIN CANAL		Weighted factors by FAO	Interaction matrix	Modifile	Evaluation Praychumpol [Value (0-4)]
I3	**Operation of the Main Canal**					**2.52**
I3.1		How frequently does the headworks respond to realistic real time feedback from the operators/observers of this canal level? This question deals with a mismatch of orders, and problems associated with wedge storage variations and wave travel times.	2.0	0.400	2.0	1.3
I3.2		Existence and effectiveness of water ordering/delivery procedures to match actual demands. This is different than the previous question, because the previous question dealt with problems that occur AFTER a change has been made.	1.0	0.300	1.5	3.0
I3.3		Clarity and correctness of instructions to operators.	1.0	0.100	0.5	3.0
I3.4		How frequently is the whole length of this canal checked for problems and reported to the office? This means one or more persons physically drive all the sections of the canal.	1.0	0.200	1.0	4.0
I4	**General Conditions for the Main Canal**					**2.75**
I4.1		General level of maintenance of the canal floor and canal banks	1.0	0.357	1.43	3.0
I4.2		General lack of undesired seepage (note: if deliberate conjunctive use is practiced, some seepage may be desired).	1.0	0.357	1.43	2.0
I4.3		Availability of proper equipment and staff to adequately maintain this canal	2.0	0.286	1.14	3.0
I5	**Cross regulator hardware**					**1.00**
I5.1		Ease of cross regulator operation under the current target operation. This does not mean that the current targets are being met; rather this rating indicates how easy or difficult it would be to move the cross regulators to meet the targets.	1.0	0.250	1.25	3.0
I5.2		Level of maintenance of the cross regulators.	1.0	0.250	1.25	2.0
I5.3		Water level fluctuation	3.0	0.500	2.5	0.0
I6	**Turnouts from Main Canal**					**2.33**
I6.1		Ease of turnout operation under the current target operation. This does not mean that the current targets are being met; rather this rating indicates how easy or difficult it would be to move the turnouts and measure flows to meet the targets.	1.0	0.500	1.50	3.0
I6.2		Level of maintenance	1.0	0.333	1.00	2.0
I6.3		Flow rate capacities	1.0	0.167	0.50	2.0

3. LP Model Results of the Alternatives on Maximum of Crop Area and Productivity

The crop productivity and crop area for the planned were actually cultivated and proposed cropping patterns for 2004. The results of each alternative have been presented in table 19 to 20; and figure 18 and 19 were shown the comparison of the crop productivity and crop area in different cropping pattern. Moreover, the comparison of proposed, planed and cultivate pattern under different resource reliability (dry, normal and wet year) were shown figure 20.

Judgment can be made well from cropping pattern 1 and 12 for over all project which crops should be put under deficit irrigation. Although, in case of no deficit irrigation, the crop are increasing 1,670.12 ha (5.23%), 2,302 ha (7.82%) and 2,249.33 ha (7.85%) over 10% deficit irrigation under lower and upper crop boundary condition for 20%, 50% and 80% rainfall reliability level respectively otherwise the income reduces 1.764 million USD (15.51%), 1.872 million USD (19.0%) and 1.933 million USD (20.45%) correspondingly. These results shown that the net income from paddy production declines faster under deficit supply; in addition, paddy is dominant crop of Plaichumpol O&M project. Whereas, in case of no deficit irrigation, the paddy is the main crop; the results found that the productivity could be maximized otherwise crop area could not be maximized because paddy crop requires high water demand. In case of cropping pattern no.1 (no deficit with upper and lower crop boundary), the income reduces 0.028 million USD, 0.016 million USD and 0.008 million USD where as crop area increases 455.08 ha, 481.49 ha and 500.27 ha over in case of two levels irrigation (no deficit to paddy and 10% deficit irrigation to upland crops) with no lower crop boundary but upper crop boundary to upland crops.

Table 19 Optimal alternative of water allocation plan of Plaichumpol O&M project

Solution No	Objective	Alternative	Benefit Million USD.	Irrigated area (ha)				
				No deficit	10%deficit	20%deficit	30%deficit	Total
1	Max benefit	NDIW1	13.686	34,104				34,104
2	Max area	NDIWW2	13.564	34,800				34,800
3	Max benefit	NDIN1	12.275	31,008				31,008
4	Max area	NDINW2	11.775	34,880				34,880
5	Max benefit	NDID1	11.938	30,267				30,267
6	Max area	NDIDW2	11.426	34,880				34,880
7	Max benefit	2LIW1	13.715	32,134	1,515			33,649
8	Max benefit	2LIW2	13.689	32,753		0		32,753
9	Max benefit	2LIW3	13.617	31,225	3,035			34,260
10		2LIW4	13.551	31,390		3,030		34,420
11		2LIW5	11.891	2,967	31,913			34,880
12	Max area	2LIWW6	13.522	30,295	4,585			34,880
13	Max benefit	2LIN1	12.291	29,011	1,515			30,526
14	Max benefit	2LIN2	12.236	29,076		1,500		30,576
15	Max benefit	2LIN3	12.199	28,126	3,035			31,161
16		2LIN4	12.123	28,281		3,030		31,311
17		2LIN5	10.403	3,867	29,443			33,310
18	Max area	2LINW6	11.673	22,836	12,044			34,880
19	Max benefit	2LID1	11.946	28,251	1,515			29,766
20	Max benefit	2LID2	11.889	28,314		1,500		29,814
21	Max benefit	2LID3	11.86	27,381	3,035			30,416
22		2LID4	11.764	27,496		3,030		30,526
23		2LID5	10.004	3,867	28,649			32,516
24	Max area	2LIDW6	11.288	21,292	13,588			34,880
25	Max benefit	3LIW1	13.689	31,067			0	31,067
26		3LIW2	13.553	31,375	45	3,000		34,420
27	Max area	3LIWW3	13.426	30,638	30	4,212		34,880
28	Max area	3LIWW4	13.442	31,279		45	3,556	34,880
29	Max benefit	3LIN1	12.235	29,563			0	29,563
30		3LIN2	12.124	28,266	45	3,000		31,311
31	Max area	3LINW3	11.594	24,338	30	10,512		34,880
32	Max area	3LINW4	11.513	25,492		50	9,338	34,880
33	Max benefit	3LID1	11.882	28,786			0	28,786
34		3LID2	11.782	27,518	45	3,000		30,563
35	Max area	3LIDW3	11.178	22,937	30	11,913		34,880
36	Max area	3LIDW4	11.083	24,231		50	10,599	34,880

Table 20 Crop area distribution in different cropping patterns

Cropping patterns	Wet year (ha)			Normal year (ha)			Dry year (ha)		
	Paddy	Other crop	Total	Paddy	Other crop	Total	Paddy	Other crop	Total
1	27,197.7	6,906.3	34,104.0	24,095.9	6,911.7	31,007.6	23,354.9	6,911.7	30,266.6
2	25,665.5	9,214.5	34,880.0	16,923.8	17,956.2	34,880.0	15,216.0	19,664.1	34,880.0
3	28,272.6	5,376.3	33,648.9	25,144.4	5,381.7	30,526.1	24,384.6	5,381.7	29,766.3
4	28,891.8	3,861.3	32,753.1	25,209.0	5,366.7	30,575.7	24,447.4	5,366.7	29,814.1
5	27,354.0	6,906.3	34,260.3	24,248.9	6,911.7	31,160.6	23,504.5	6,911.7	30,416.2
6	27,518.6	6,901.3	34,419.9	24,404.2	6,906.7	31,310.8	23,619.3	3,606.7	27,226.0
7	26,428.7	8,451.3	34,880.0	18,969.2	15,910.8	34,880.0	17,424.9	17,455.1	34,880.0
8	28,891.8	3,861.3	32,753.1	25,695.9	3,866.7	29,562.5	24,919.5	3,866.7	28,786.2
9	27,513.5	6,906.3	34,419.8	24,399.2	6,911.7	31,310.9	23,651.6	6,911.7	30,563.3
10	26,771.6	8,108.4	34,880.0	20,471.7	14,408.3	34,880.0	19,070.4	15,809.6	34,880.0
11	27,411.9	7,468.2	34,880.0	21,625.6	13,254.4	34,880.0	20,364.2	14,515.8	34,880.0
12	31,000.6	3,879.3	34,880.0	26,397.9	6,911.7	33,309.6	25,604.2	6,911.7	32,515.9
Planned	21,768.0	0.0	21,768.0	21,768.0	0.0	21,768.0	21,768.0	0.0	21,768.0
Cultivated	28,984.6	16.0	29,000.6	28,984.5	16.0	29,000.5	28,984.6	16.0	29,000.6

Table 21 The distributions income and crop area in different cropping pattern

Cropping patterns	Income at different rainfall reliability (million USD)			Area at different rainfall reliability (ha)		
	Wet year	Normal year	Dry year	Wet year	Normal year	Dry year
1	13.686	12.275	11.938	34,104.0	31,007.6	30,266.6
2	13.564	11.775	11.426	34,880.0	34,880.0	34,880.0
3	13.715	12.292	11.946	33,648.9	30,526.1	29,766.3
4	13.689	12.236	11.889	32,753.1	30,575.7	29,814.1
5	13.617	12.199	11.860	34,260.3	31,160.6	30,416.2
6	13.551	12.123	11.764	34,419.9	31,310.8	27,226.0
7	13.522	11.673	11.288	34,880.0	34,880.0	34,880.0
8	13.689	12.235	11.882	32,753.1	29,562.5	28,786.2
9	13.553	12.124	11.782	34,419.8	31,310.9	30,563.3
10	13.426	11.594	11.178	34,880.0	34,880.0	34,880.0
11	13.442	11.513	11.083	34,880.0	34,880.0	34,880.0
12	11.819	10.403	10.005	34,880.0	33,309.6	32,515.9
Planned	9.899	9.899	9.899	21,768.0	21,768.0	21,768.0
Cultivated	11.387	11.387	11.387	29,000.6	29,000.6	29,000.6

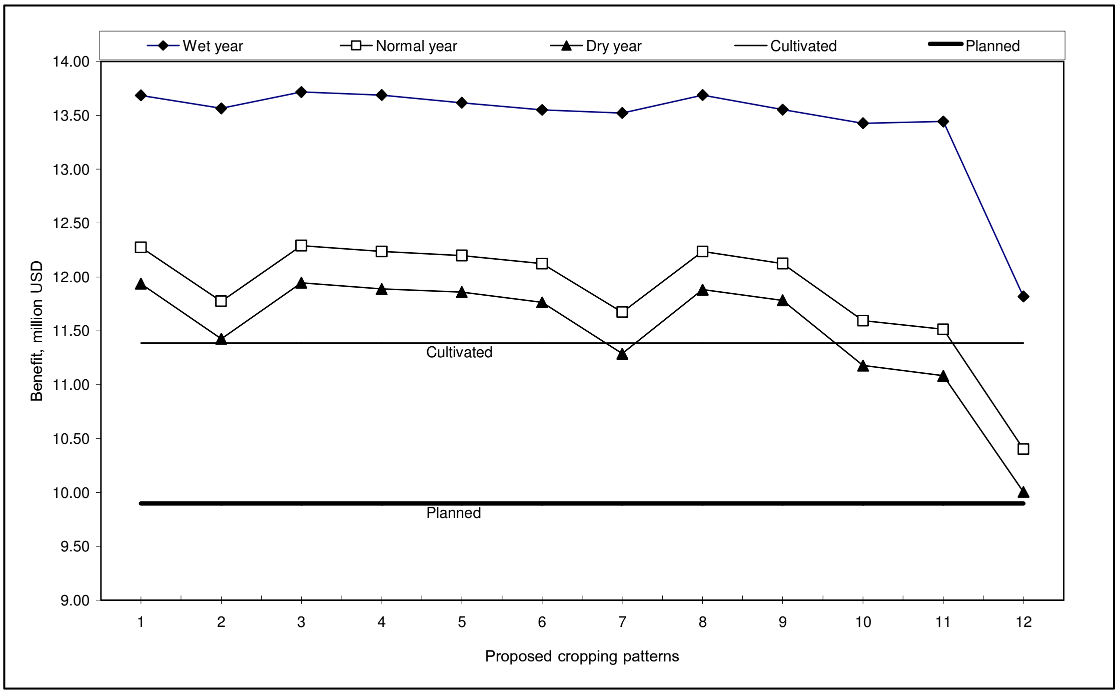


Figure 18 Comparison of crop productivity in different cropping pattern

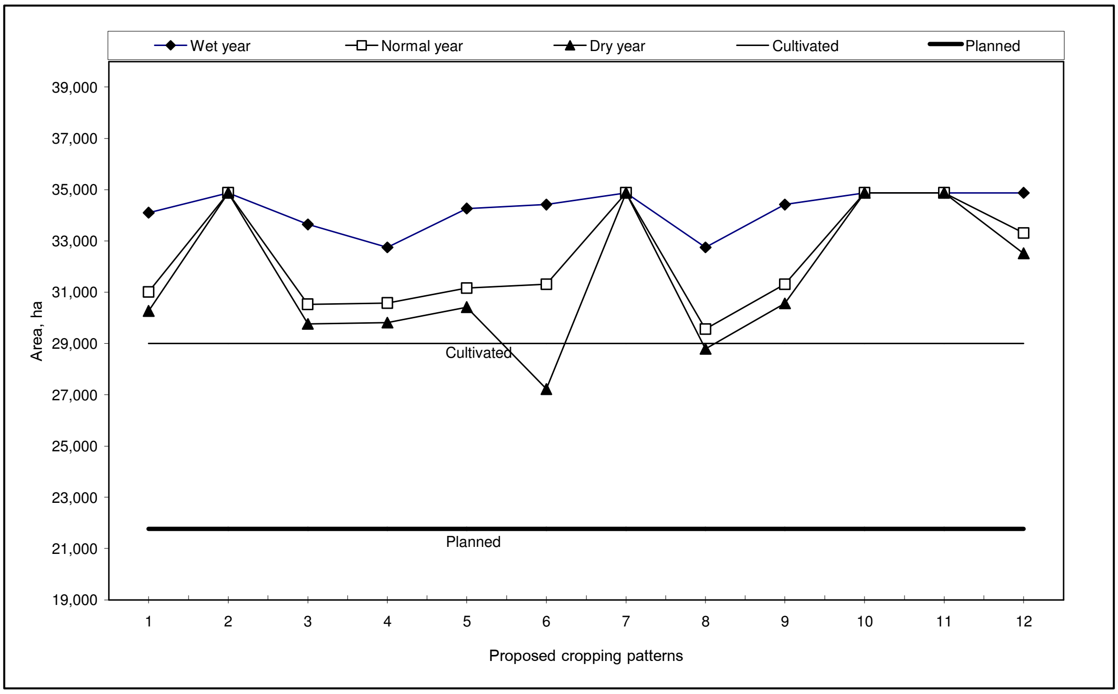
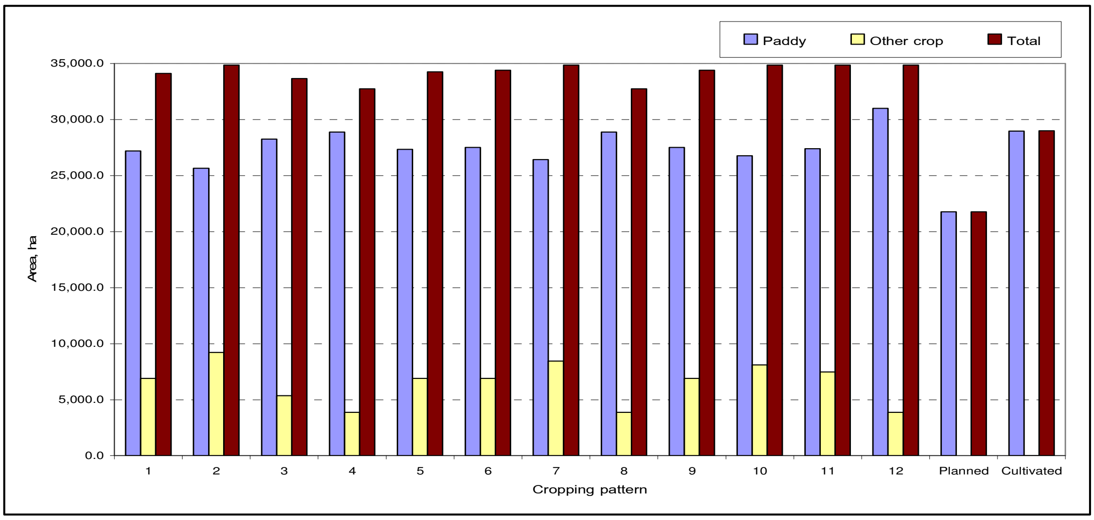
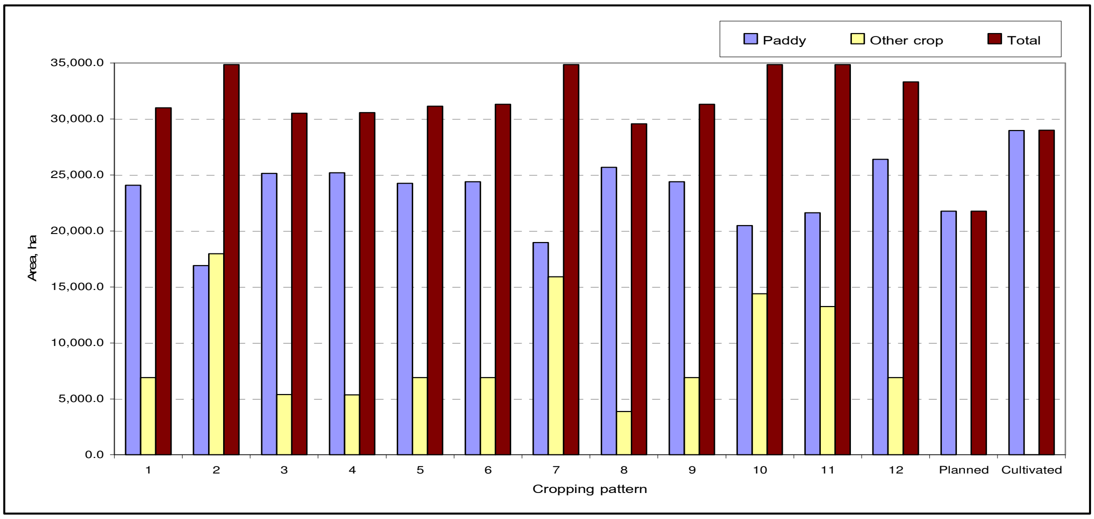


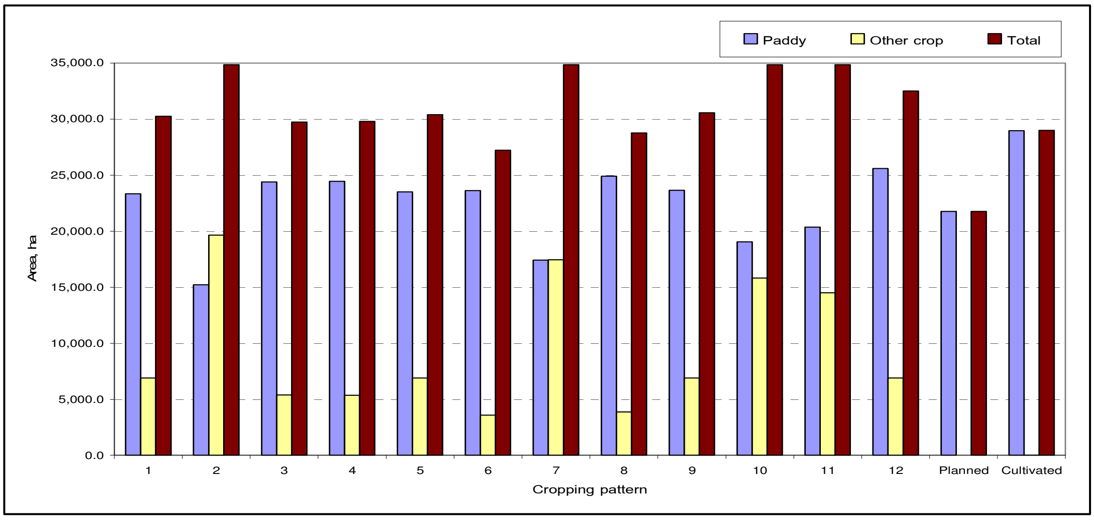
Figure 19 Comparison of crop area in different cropping pattern



(i) 20% Resource Reliability (Wet year)



(ii) 50% Resource Reliability (Normal year)



(iii) 80% Resource Reliability (Dry year)

Figure 20 Crop area comparison of proposed, planned and cultivated pattern

There are many reliability resources which are effected on crop area and productivity. Although rainfall intensity in dry season is less, it results a significant variance in both crop productivity as well as crop area. In case of higher resources reliability which indicates the lower occurrence of rainfall (dry year) produce crop productivity and crop area than the lower reliability (wet year). In case of single level irrigation (cropping pattern no.1), crop productivities are increasing 1.411 million USD (11.50%) and 1.748 million USD (14.64%) in case of wet year over normal and dry year respectively; and 0.337 million USD (2.82%) in case of normal year over dry year. Total crop areas are increasing 3,096.40 ha (9.99%) and 3,837.42 ha (12.70%) in case of wet year over normal year and dry year; and 741.02 ha (2.45%) in case of normal year over dry year. In case of two levels irrigation (Cropping pattern no.3), the crop productivities are increasing 1.423 million USD (11.58%) and 1.769 million USD (14.80%) in case of wet year over normal year and dry year respectively; and 0.346 million USD (2.89%) in case of normal year over dry year. The total crop areas are increasing 3,122.81 ha (10.23%) and 3,882.61 ha (13.04%) in case of wet year over normal year and dry year respectively; and 759.8 ha (2.55%) in case of normal year over dry year. Three levels of irrigation application, which are the same conditions approximately, produces the same difference under difference rainfall reliability level.

From above discussion, it can be concluded that the effect of different rainfall reliability on crop productivity and crop area is different. In case of wet year, the increasing rates of crop productivity and crop area are higher than in case of normal year and dry year. Moreover, in case of normal year, the increasing rates of crop area and crop productivity are more than in case of dry year. These methodologies are uncertainly. In addition, there are significant reflections of its occurrence in both objectives (crop area and crop productivity).

CONCLUSION AND RECOMMENDATION

Conclusion

The Chao Phraya river basin basin has the catchments area occupying about 157,925 km^2 or 30% of the whole country area. The large irrigation projects in the Chao Phraya River Basin serve approximately 1.57 million ha, with 1.24 million ha in the Main Chao Phraya and Tha Chin, or 80% of the large irrigated area in the Chao Phraya River Basin.

The irrigation project assessment using Rapid Appraisal Process (RAP) in the pilot irrigation projects in the Chao Phraya river basin. The specific details which were used for irrigation practice assessment was concluded in questionnaire which was developed by FAO/IPTRID/World Bank. The detailed questionnaire was reviewed and understood by the evaluators to obtain information for evaluation of the water control and management practices. In this study, the implementing pilot irrigation project assessment was done by 2004, which are concluded in three project groups are follow;

1) Phitsanulok irrigation project consisted of Naraysuan dam, Praychumpol, Dong Setthi and Tha Bua O&M project;

2) Upper east bank of lower Chro Phraya river basin consisted of Manorom, Chong Khae ,Khok Krathiam and Roeng Rang O&M project; and

3) Upper east bank of lower Chro Phraya river basin consisted of Phonlathep, Tha Bot, Samchuk and Pho Phraya O&M project.

The result of irrigation project assessment found that these projects need for both management and hardware improvements as presented; the operation and management changes could be immediately implemented and have beneficial impacts on irrigation performance.

Learning the water allocation using RAP has had many problems for evaluation as the time to collect the data is less and much more data to input. The evaluator should have much more both experiencing on irrigation system and applying by RAP's evaluation form, so some indicator doesn't understand to be used and the result of evaluation don't clear to specific for water allocation problems. Nevertheless, the learning process using RAP and the result of evaluation 12 O&M irrigation project can be guided to set the key performance indicators which have been separated in two groups as quantitative indicators and qualitative indicators

Multi-Criteria Decision-Making (MCDM) by AHP was applied for water allocation decision. This methodology can be useful for managers to plan the water allocation of large irrigation system. The decision criteria for water allocation improvement were separated in two groups as qualitative criteria and quantitative criteria which were separated for decision procedure.

Qualitative indicators from RAP will be specified by the Operation criteria and Maintenance criteria, which criteria would be focused on main canal evaluation. In each criteria will be consisted of sub-criteria as;

1) Operation criteria defined on water control in main canal namely I3; and I3 have been defined in 4 sub-criteria.

2) Maintenance criteria defined on characteristics, check structure and Turnout of main canal namely I4, I5 and I6 respectively. Moreover, in each sub-criteria have been defined in sub-criteria.

This research, the interaction matrix form was prepared to collect about pair-wise relative importance among the different criteria and sub-criteria. The discussion and collection the data from 20 RID's officer as Water allocation officer, Chief of O&M branch of O&M project etc. were used for weighted factor evaluation of each sub-criteria which have been applied for project evaluation in Thailand. This procedure can be applied for another irrigation scheme. The qualitative assessment of

Praichumpol O&M project based on the comparisons of on both different weighted factors defined by FAO and this study.

Quantitative indicators will be specified criteria on both the crop area and productivity. The crop area target of irrigation project will focus on water adequacy because among of water supply in early season will be informed for cropping pattern. The productivity will focus on water efficiency or income.

The crop yield analysis for cropping pattern planning using linear programming model was applied for solving maximum of crop area and productivity at different resource reliability level. A procedure has been developed which utilizes the optimization and simulation techniques as well as production function considering the stochastic variability (20%, 50% and 80% rainfall reliability level) associated benefit could be expected. The procedure also approaches the multi-objectives techniques in identifying an optimum diversified mixed cropping pattern. The LP model provides optimum productivity and/or crop area within certain limitation of each cropping patterns. The results of LP analysis found that crops should be put under deficit irrigation because the net income from paddy declines faster under deficit supply. Whereas, if no deficit irrigation will be effected to paddy, the productivity could be maximized otherwise crop area could not be maximized because paddy requires high water demand

Recommendation

The knowledge of water allocation practices in large irrigation system based on qualitative assessment by RAP is a most profit for decision maker. The decision maker should understand for realistic irrigation practices in the project level before water allocation plan in early crop season. The mainly data inputs for this study was resulted by RAP which was implemented in 12 pilot O&M projects in the Chao Phraya river basin in 2004. The main items for project evaluation using RAP consist of 7 irrigation performance criteria as Project office question, Project Employees, Water User Association (WUA), Main canal, Secondary level canal, Third level canal and Final delivery. The RAP results can be concluded as Water delivery service, the participation on water allocation between Project employees and WUAs, Main canal Secondary and tertiary canals evaluations. Some result from RAP should be considered by decision maker to learn, how the RAP index values which depended on irrigation practices in each groups (same system) are not significant relationship between O&M projects at the upstream and downstream of main canal. Because of RAP assessment for this study in 3 groups were implemented by spatial and temporal limits; mean that, there are many several on operation and management practice and different time for irrigation project evaluation. Moreover, the bias of some index values in the evaluation procedure is mainly reason for decision maker to consider and apply for irrigation project improvement. However, the conclusion of irrigation practices evaluation in the pilot irrigation projects found a need for both management and hardware for water allocation improvements in each project. So, we try to conclude the criterions for water allocation assessment based on the easiness and necessary to assess by evaluator. The criteria consisted of 4 sub-criteria which focus on operation and maintenance in main canal. The relative important of criteria was evaluated using interaction matrix; and found that there are different of weighted factor values between FAO guide and this evaluation by interaction matrix because the decision maker in several irrigation systems will mainly focus depended on spatial and temporal conditions. However, the interaction matrix method can be applied in other irrigation schemes evaluation or in different situation.

The quantitative assessment of Plaichumpol O&M project found that some scenario give more productivity but cannot implement; for example, scenario 1 (Single level of irrigation is no deficit with no cropping boundary at 50% rainfall reliability level), result as benefit 12.89 million USD significantly, however it requires grow vegetable in 36.49% which is not practice for plan, because paddy is the most profitable crop but it need high water requirement. Whatever, this methodology of quantitative assessment, which focused on crop yield analysis, is a tool for water allocation planning, but the decision maker should make a decision for plan in early crop season based on farmer's requirement and resources reliability such as water supply, rainfall, land and water allocation planning.

There are many profits on monitoring and evaluation of water allocation in O&M projects. The result of project evaluation can be guided for water allocation improvement. Whatever, the evaluated results and finding optimum on both crop area and productivity should be carefully decided for water allocation improvement plan because we should consider on traditional irrigation practices, local requirement and overall water allocation plan and policy of the government.

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