AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523
**BIBLIOGRAPHIC INPUT SHEET**

FOR AID USE ONLY

1. SUBJECT CLASSIFICATION
A. PRIMARY
Agriculture
B. SECONDARY
Water Management

2. TITLE AND SUBTITLE
Returns to public investment in water control in Southeast Asia: a case study of the greater Chao Phya project of Thailand

3. AUTHOR(S)
Small, L.E.

| 4. DOCUMENT DATE | 5. NUMBER OF PAGES | 6. ARC NUMBER |
|---|---|---|
| 1972 | 105 p. | ARC |

7. REFERENCE ORGANIZATION NAME AND ADDRESS
Cornell University, Department of Agricultural Economics, New York State College of Agriculture, Ithaca, New York 14850

8. SUPPLEMENTARY NOTES (Sponsoring Organization, Publishers, Availability)
(In New Jersey Agricultural Experiment Station, Cook College Bulletin 842)

9. ABSTRACT

Although the Chao Phya water control project was completed in the early 1960s and is the largest single government project of its kind in Thailand, this study is the first attempt to evaluate the returns from the investment in water control facilities in the project area of 660,000 hectares. The study was limited to an examination of the effects of the system on crop production.

From a national point of view, the water control project has increased exports of milled rice by an average of about 90,000 tons per year. This is roughly 9 percent of Thailand's total exports of rice in recent years. The system has thus contributed both to increasing the average foreign exchange earnings and to reducing the annual fluctuations in these earnings. At the farm level, the risk of complete crop failure has been greatly reduced in the areas that do not flood deeply. Furthermore, the average increase in production made possible by the system has increased the net cash returns earned by the farmers of the area by an estimated 25 percent.

In spite of these benefits, the return to the investment in the original system has not been particularly high. Considering the effects of the system on crop production, the internal rate of return is estimated to be a modest 6 to 9 percent. The basic factor preventing a higher rate of return is the limited potential the system offers for changes in production techniques. The varieties of rice grown are tall varieties that either show little response to fertilizer, or, with large applications of nitrogen, tend to lodge. The short, photoperiod non-sensitive varieties which are responsive to fertilizer cannot be produced successfully without considerably better water control than the system generally affords.


10. CONTROL NUMBER
PN-AAC-667

11. PRICE OF DOCUMENT

12. DESCRIPTORS
Benefit cost analysis
Chao Phya project?
Investments
Southeast Asia
Systems engineering
Thailand

13. PROJECT NUMBER

14. CONTRACT NUMBER
CSD-2823 211(d)

15. TYPE OF DOCUMENT

AID 590-1 (4-74)

RUTGERS
THE STATE UNIVERSITY
OF NEW JERSEY

# Returns to Public Investment in Water Control in Southeast Asia: A Case Study of the Greater Chao Phya Project of Thailand

LESLIE E. SMALL
Department of Agricultural Economics and Marketing
New Jersey Agricultural Experiment Station / Cook College / Bulletin 842

# RETURNS TO PUBLIC INVESTMENT IN WATER CONTROL IN SOUTHEAST ASIA: A CASE STUDY OF THE GREATER CHAO PHYA PROJECT OF THAILAND

by

Leslie E. Small
Assistant Professor of Agricultural Economics
Cook College, Rutgers University

# ACKNOWLEDGMENTS

This publication is based upon research which I conducted in Thailand in 1970 and 1971. The research was undertaken as part of my Ph.D. program at Cornell University. While in Thailand, I was associated with the Department of Agricultural Economics at Kasetsart University. I am deeply indebted to the entire staff of the department for the generous cooperation given to me, and especially to Mr. Chamras Arunpoo, who worked closely with me throughout my stay in Thailand.

There are many individuals and agencies in the Royal Thai Government who gave valuable assistance. I would particularly like to acknowledge the substantial assistance of Mr. Charin Attayodhin, chief of the Operation and Maintenance Division of the Royal Irrigation Department, and of Mr. Paitoon Palayasoot, head of the Irrigation Agronomy Section of the Operation and Maintenance Division.

I am also indebted to Dr. Delane E. Welsch of the Rockefeller Foundation, and Visiting Professor of Agricultural Economics at Kasetsart University, who generously gave of his time to assist my research efforts in Thailand. I am grateful to Professor K. L. Robinson of Cornell University for assistance throughout the planning and implementation of this research, and for the helpful comments and suggestions made on a draft of this publication. Professor William Herr of Southern Illinois University also read and provided helpful comments on a draft of the manuscript.

I wish to acknowledge the financial support of several agencies. The National Science Foundation and the South East Asia Development Advisory Group (SEADAG) of the Asia Society, New York provided financial support during the period of research in Thailand. The Department of Agricultural Economics at Cornell University supported me both before and after my field work in Thailand. The cooperation of the Department of Agricultural Industries and the Center for Vietnamese Studies at Southern Illinois University made it possible for me to write the manuscript. Support for publishing the manuscript came from the New Jersey Agricultural Experiment Station at Cook College of Rutgers University, and from the Department of Agricultural Economics and Marketing at Rutgers. I am grateful to these organizations not only for their financial support, but also for the complete independence given me in both the formulation and implementation of this research project. The interpretations and opinions expressed in this publication are, of course, my own, and do not represent the position of any of these agencies.

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# CHAPTER 1

## THE RIVER DELTAS OF SOUTHEAST ASIA

Rice has long dominated the agriculture of mainland Southeast Asia. Even today, in spite of some efforts to promote agricultural diversification, rice retains its pre-eminent role throughout the area. From 65 to 85 percent of the cropland in Bangladesh, Burma, Thailand, Cambodia, and North and South Vietnam is still planted to rice.

Two distinct methods of rice production can be identified. If production takes place under dryland conditions--i.e., with no surface water standing on the field--the crop is known as upland rice. Rice grown with water standing on the field during at least part of the growing season is known as lowland rice. Most of the rice of mainland Southeast Asia is produced under lowland conditions.

Lowland rice production is possible either where natural conditions lead to water standing on the land for a considerable length of time, or where man is able to exert enough control over the movement of water to cause fields to be covered by standing water. The type of control required may be relatively simple, involving little more than the bunding of fields to prevent surface runoff and the preparation of the soil in a manner designed to limit percolation losses. But in some cases rather complex water control structures, such as diversion weirs and irrigation canals, may also be necessary.

Within mainland Southeast Asia, rice production is concentrated in the river floodplains and delta areas. In some parts of these areas, natural inundation caused either by the annual flooding of the rivers or by surface runoff provides the water conditions necessary for lowland rice production. And in most of the remaining portions of these deltaic areas, the necessary conditions can be created with a minimum amount of water control. These areas have thus become highly specialized in rice production. Of greatest importance, because of their size, are several large deltaic areas located along the coast of mainland Southeast Asia: the Red River delta of North Vietnam; the Mekong delta of South Vietnam and Cambodia; the Chao Phya delta of Thailand; the Irrawaddy delta of Burma; and the Ganges-Brahmaputra delta of Bangladesh and India.

The rivers that form these deltas vary greatly in size. For example, the total area drained by the Ganges and Brahmaputra rivers is nearly twice as large as the basin of the Mekong, and the Mekong drains an area about double that of the Irrawaddy. The Chao Phya and Red river basins are still smaller. The size of each delta is roughly proportional to the drainage area of the major river valley which created it. But the volume of water discharged from each of the major rivers is not proportional to the size of the drainage area. Differences in rainfall account for part of the differences in discharge rates. Although the Chao Phya and the Red rivers drain areas of approximately the same size, the total volume of water carried by the Chao Phya is much less than that of the Red River. This results from a combination of a lower average rainfall in the upstream area of the Chao Phya basin, with an unusually low rate of precipitation in the delta.

In spite of differences in geographic size, river discharge, and rainfall, the five deltaic areas have many characteristics in common. Perhaps the most obvious physical characteristic which these regions share is that of relatively flat topography. The casual observer is likely to be impressed by the vast areas of land that appear to be virtually flat. The land, of course, does slope toward the ocean, but the slope is much too gradual to be detected by the unaided eye. In the Chao Phya delta the slope is on the order of one meter per 10 kilometers in the upper portion, and only one meter per 25 kilometers in the lower part.[1*] The lower portion of the Ganges-Brahmaputra delta is reported to have a slope of only one meter in 38 kilometers.[2]

But this apparent uniformity in topography is somewhat misleading. Within any one deltaic area there are small differences in topography which are directly related to important differences in land utilization. The highest areas, which are least subject to flooding, are generally used for human habitation. Houses, animal shelters, fruit trees and small gardens are commonly found in these areas. Although rice production takes place throughout the lower areas, differences in production techniques are often related to slight differences in topography. In the lowest areas, which flood to the greatest depth and for the longest period of time, rice is often planted by broadcasting the seed directly on the fields. Late maturing varieties are planted in order to reduce the likelihood that the crop will be ready for harvest before the flood waters have drained from the fields. In slightly higher areas, rice is frequently planted by transplanting, and earlier maturing varieties are grown, since the land drains at an earlier date.

These small differences in topography in the deltaic areas follow a reasonably systematic pattern which can be called the levee-basin pattern. Flooding of the rivers leads to the deposition of sediments carried in the water, causing the formation of natural levees along the banks of the main streams and rivers. Areas further from the rivers, known as basin or backswamp areas, receive less of this sedimentation, and are, therefore, lower in elevation. The levee-basin pattern is well illustrated in the cross sections of the Chao Phya floodplain and delta, shown in Figure 1. The

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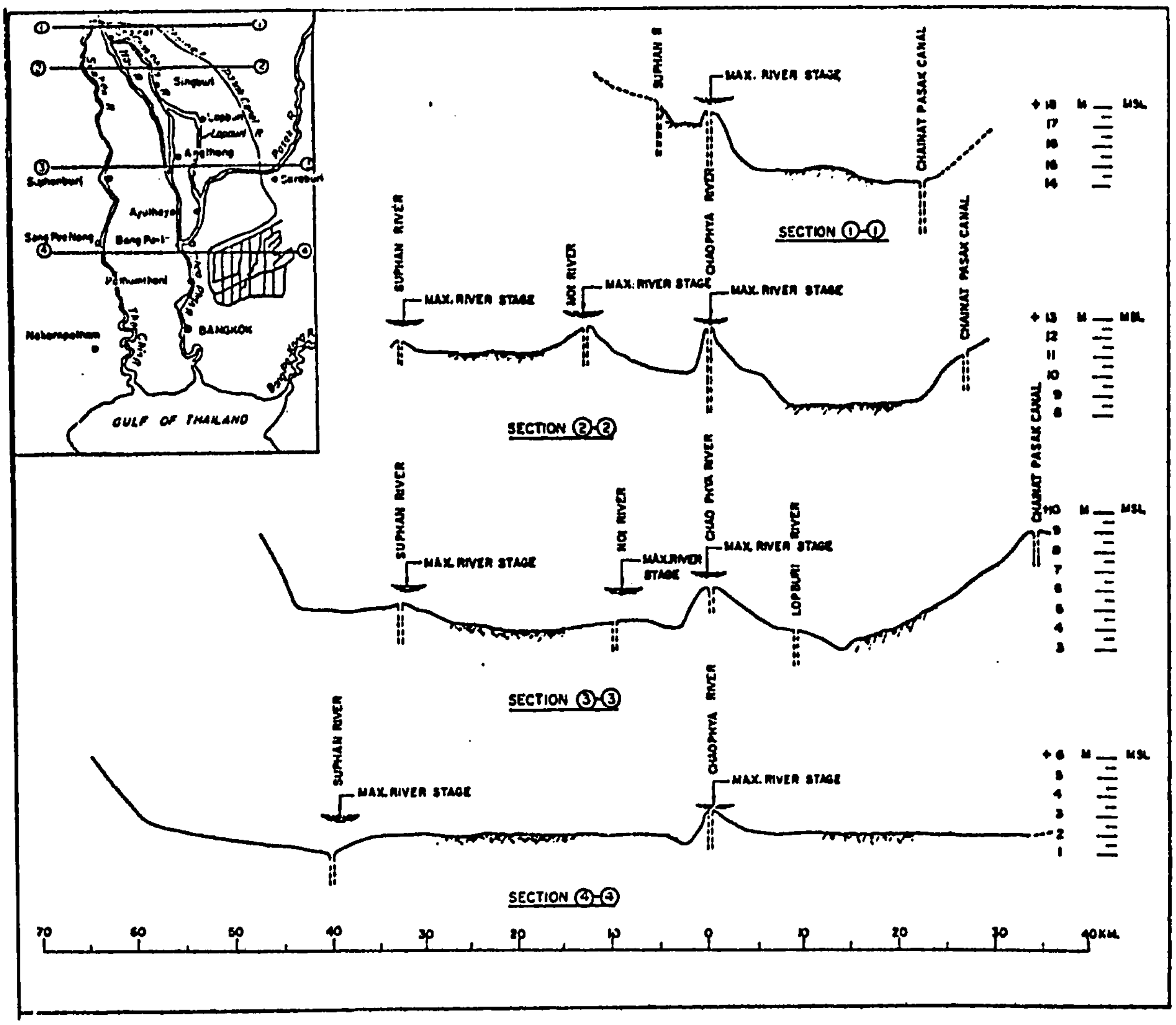
*Footnotes begin on page 86.

Figure 1. Cross Sections of the Chao Phya Deltaic Area




Source: United Nations Economic Commission for Asia and the Far East, Proceedings of the Regional Symposium on Flood Control, Reclamation, Utilization and Development of Deltaic Areas (Held at Bangkok, Thailand, 2 to 9 July 1963) (New York: Water Resources Series No. 25, 1963), p. 27.

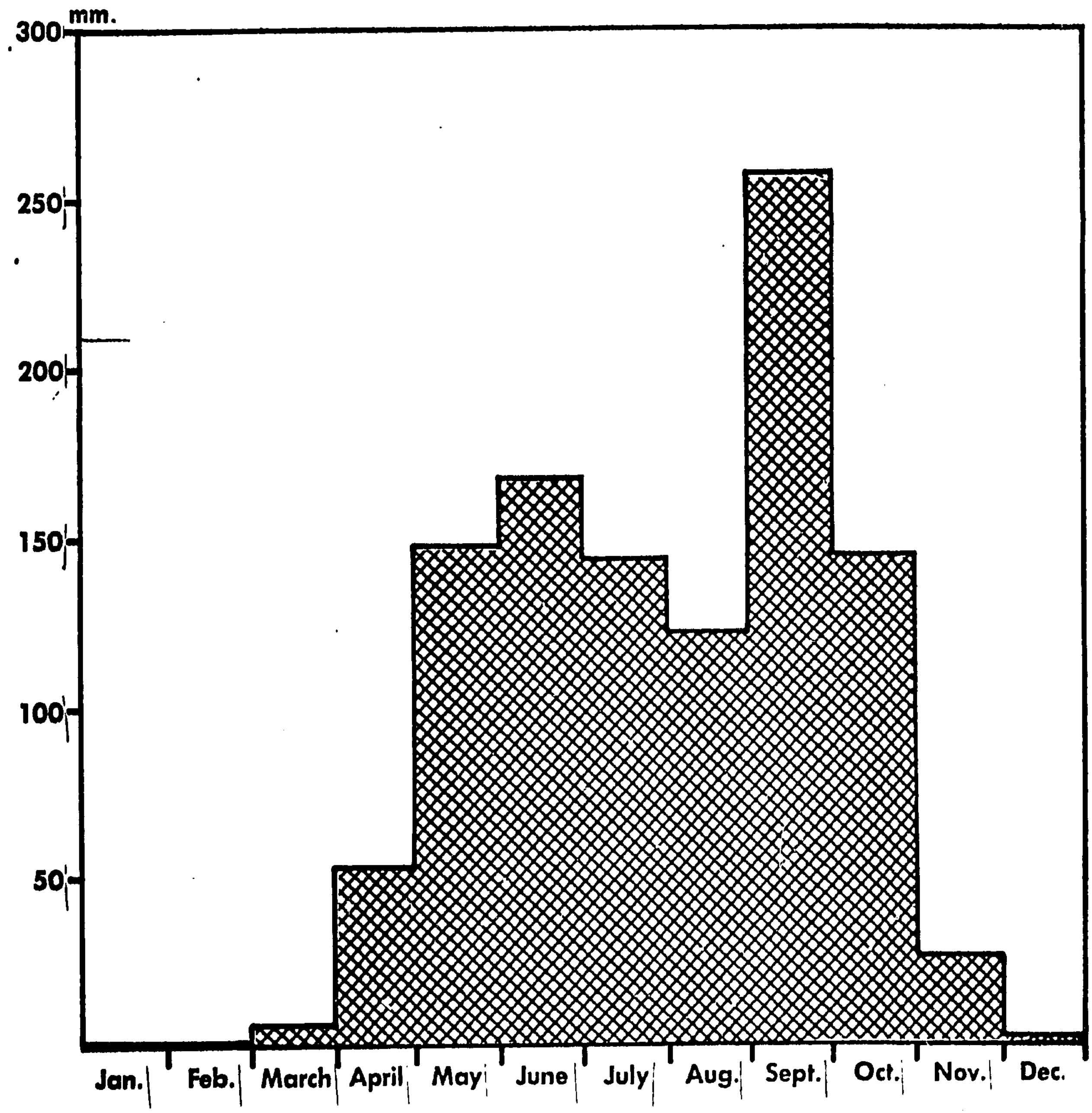
pronounced natural levees of the Chao Phya river, and the smaller levees of its two distributaries, the Suphan and the Noi rivers, are especially clear in cross section 2-2 of Figure 1. But while this general pattern can be identified, the actual micro-relief is considerably more complex than is suggested by Figure 1. In addition to the main river and its distributaries, deltaic areas are covered by a complex network of meandering streams and abandonded river channels. Many of these waterways have their own system of small levees and backswamps. The result is an extremely comples pattern of micro-relief leading to equally complex patterns of differences in water conditions and in agricultural practices.

Deltaic areas also exhibit certain similarities in soil types. The soils can generally be classed as alluvial, since they were formed from parent materials which were deposited as a result of the action of a river. They tend to be heavy in texture, although the texture varies according to the position of the soil with respect to the levees and basins. The lightest textured soils are on the levees, while the heaviest clay soils are to be found in the lowest portions of the basins. Because of the relatively heavy texture of these soils, the rate of percolation of surface water into the ground tends to be low, which facilitates the retention of surface water for the production of lowland rice.

A distinctive feature of the climate in all five deltaic areas is the highly seasonal nature of the rainfall. Precipitation is generally concentrated in the months of May to November. For example. at Ayutthaya, in the Chao Phya delta, slightly over 90 percent of the average annual rainfall occurs during the six months of May through October (Figure 2). By contrast, less than 0.5 percent of the total occurs during the months of December through February. Similar patterns prevail in the other four regions. This rainfall pattern exists not only in the deltaic areas themselves, but also in the catchment basins of their rivers. The flow of each of these rivers is thus highly seasonal in nature. From 83 to 88 percent of the annual discharge of the rivers occurs during the six months of peak flow, and from 37 to 54 percent of the annual flow takes place during the peak two months.

Although the periods of peak river discharge and peak rainfall do not exactly coincide, they generally do occur within a short interval. This leads to one of the most important characteristics of the deltaic areas of mainland Southeast Asia--the huge volume of water which arrives in the deltas in a short period of time. The river systems are generally unable to handle the large volume of water within their banks, so that vast tracts of land flood every year. This, of course, is one of the major reasons why these areas are devoted to lowland rice production. In some areas the natural flooding is such that lowland rice can be successfully produced without any efforts on the part of man to control the water. And in other areas the volume of water available, coupled with the relatively flat topography, make it possible to produce lowland rice with little more effort at water control than the puddling of the soil, the bunding of the fields, and perhaps the digging of some canals to facilitate the flow of water into an area.

Figure 2. Average Monthly Rainfall, Ayutthaya, Thailand




Source: Unpublished data for 1955-1969, furnished by the Royal Irrigation Department, Bangkok, Thailand.

But these natural conditions are not entirely favorable for intensive agricultural production. First, the large volume of water makes it extremely difficult to drain the fields during the wet months. And very few commercial crops other than rice can be produced with water standing on the fields. Second, the natural flooding is not completely beneficial even for the production of rice because the flow varies from year to year. In some years the rice crop may suffer serious damage as a result of heavy flooding, while in other years there may be insufficient water to mature a good crop. A third problem encountered in these deltaic areas is that of salt water intrusion in the coastal reaches. This problem is aggravated in the dry season because the very low volume of flow of fresh water in the river system permits the intrusion of salt water for considerable distances from the coast. Finally, the successful application of many elements of modern agricultural technology requires better water control--and in particular, better drainage. Traditional techniques are well adapted to the conditions that naturally prevail in these delta areas, but there is a limit to the yields that can be obtained with these techniques. The conditions which led to the production of rice on most of the deltaic areas now constitute a barrier to the adoption of improved methods of production, such as high rates of fertilization and the use of high yielding varieties.

The need for improvements in water control has been widely recognized by governments in the areas involved. In general, primary emphasis has been given to the construction of embankments or levees to control flooding, mainly to provide protection against abnormally high water. For example, in the Red river delta, where floods tend to be much more severe than in the other deltas, an extensive system of dikes has been built over a long period of time.[3] Flood control dikes are also of considerable importance in the Irrawaddy delta.[4]

In the Chao Phya delta some flood control structures have been built, but largely in conjunction with the construction of facilities designed to provide additional water to the fields in periods when rainfall and natural flooding are inadequate. This type of water control, with its emphasis on supplemental irrigation, has probably been developed further in the Chao Phya floodplain and delta than in any of the other major deltaic areas of mainland Southeast Asia. In part this is because the Chao Phya delta receives considerably less rainfall than the other deltaic regions so that there is a greater need to supplement the natural supply of water. Furthermore, in the Chao Phya delta there is typically a period of a few weeks in the middle of the wet season when rainfall is very light. This dry period usually occurs in July and August, thus creating an additional need for supplemental water, especially since the period of light rain occurs when the river has not yet risen enough to provide much water from natural flooding (see Figure 2).

While governments in Southeast Asia have devoted considerable resources to the construction of water control facilities, very little has been done to appraise, ex post, the costs and benefits of these projects. To learn more about the achievements and limitations of such projects, I went to Thailand in 1970 to study the results of efforts by the Thai government to improve water control in the Chao Phya river basin. The findings of this study are reported in the pages which follow. While differences in the river basins in Southeast Asia cannot be ignored, I am convinced that there are enough similarities to make the information obtained from this study useful to those concerned with the construction or improvement of water control facilities in river basins other than the Chao Phya. Among the objectives of the study was to provide a framework that could be used in evaluating similar water control projects. It is hoped that this framework will be useful to those involved in attempting to appraise future investments in water control facilities.

## Characteristics of the Chao Phya Deltaic Region

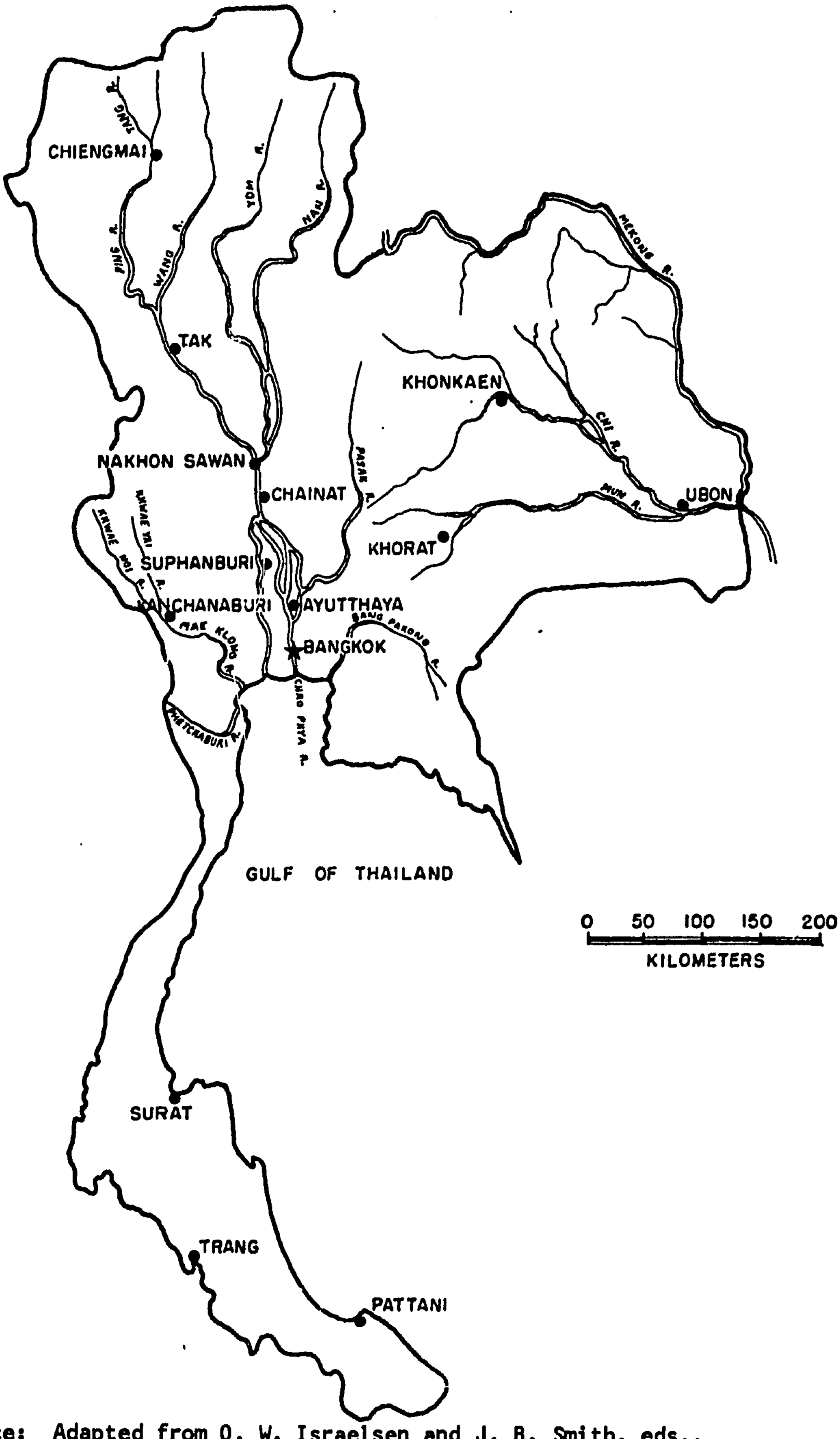
The floodplain and delta of the Chao Phya river form the bulk of a larger deltaic area known as the Central Plain of Thailand. In addition to the Chao Phya river, the Central Plain includes the deltaic areas of the Mae Klong river to the west, and of the Bang Pakong river to the east (Figure 3). The entire Central Plain comprises one portion of the Central Region of Thailand, which in turn is one of the four major geographic regions into which the country is traditionally divided.[5]

The economy of Thailand has traditionally been dominated by rice. For over a century the country has been able to produce more rice than needed for domestic consumption, and has therefore earned considerable amounts of foreign exchange from rice exports. Today Thailand is one of the world's leading rice exporters. During the decade of the 1960's, exports averaged nearly 25 percent of domestic production. In recent years exports have dropped somewhat, but have still been from 15 to 20 percent of total production.[6] It is in the Central Plain, which is sometimes known as the "rice bowl" of Thailand, that a substantial portion of the surplus rice available for export originates.

Considering the importance of the Central Plain in the economy of Thailand, and given the predominant position of the Chao Phya river within the Central Plain, it is not surprising that some of the first investments in water control made by the Thai government were in the Chao Phya deltaic region. Most of the water control facilities resulting from these and subsequent investments have come to be known as the Greater Chao Phya water control project.[7] This project, covering a total of 910,000 hectares, is commonly divided into a northern or upper portion of 660,000 hectares, and a southern portion of 250,000 hectares. The northern portion, which is often called the northern Chao Phya region (see Figure 4), is further divided into 16 subprojects.[8] A diversion dam near Chainat at the northernmost tip of the project diverts water from the Chao Phya river into a network of distribution canals which carry it throughout the 16 subprojects. From the main canals and laterals of this system, the water is released through turnouts to flow into small ditches and onto the rice fields. The diversion dam (known as the Chao Phya or Chainat dam) was built in the mid-1950's, and the distribution network was completed in the early 1960's.

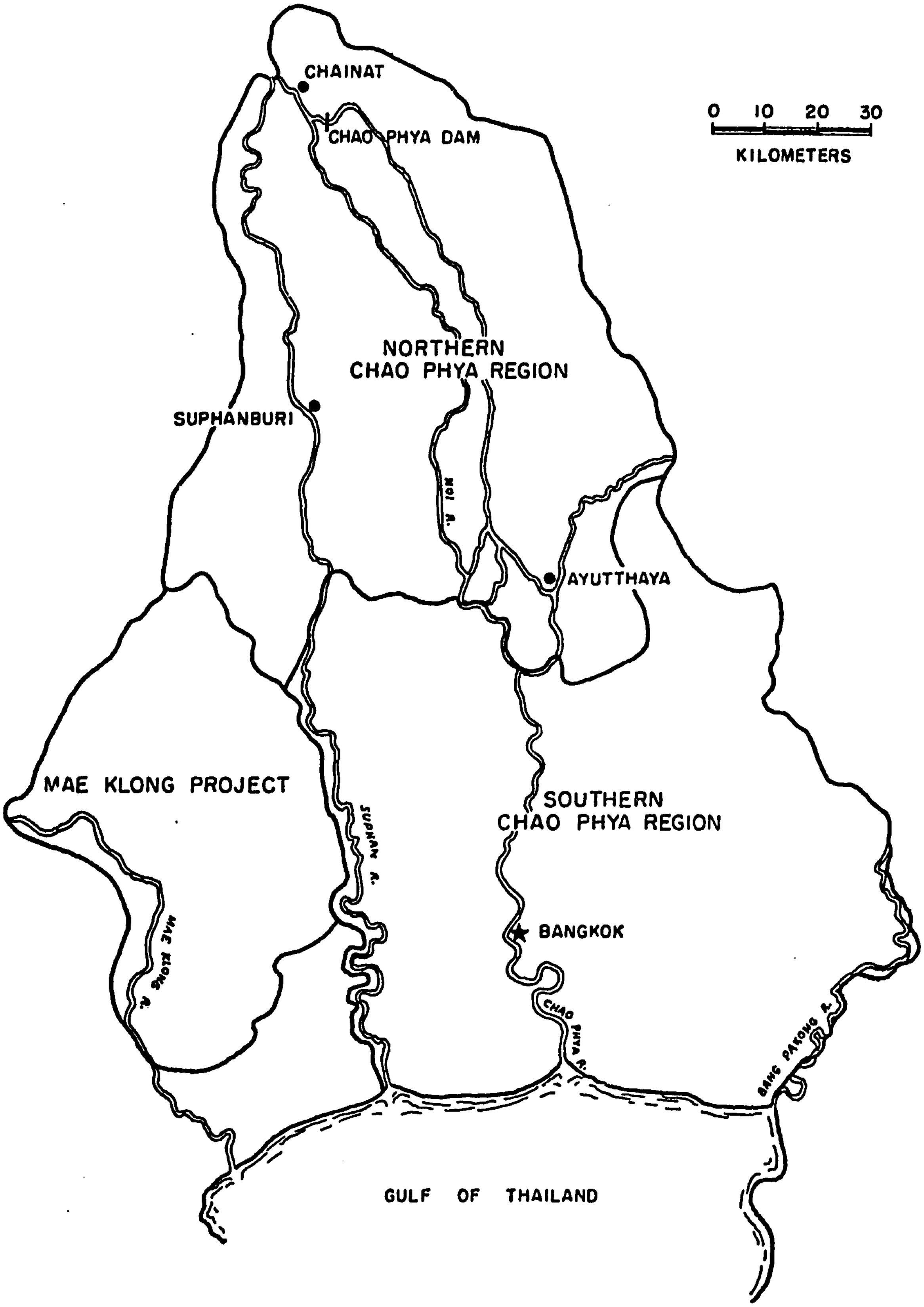
The southern portion of the Greater Chao Phya project is not served by distribution canals from the Chao Phya dam, since the area is too flat for such canals to function properly. Water control features in this area consist of canals which have been dug for communication and

Figure 3. Major River Systems of Thailand




Source: Adapted from O. W. Israelsen and J. B. Smith, eds., Irrigation and Drainage Practices, Progress, and Problems in the Philippines, Thailand, and West Pakistan (Bangkok: SEATO Graduate School of Engineering, 1965), p. 67.

Figure 4. Major Water Control Projects in the Central Plain of Thailand




Source: Adapted from Thailand, Ministry of Agriculture, Agriculture in Thailand (Bangkok, 1961), opposite p. 140.

drainage, and of the control structures which have been built on these canals so that water may be retained when it is still needed for rice production. Construction in the southern section began early in the 20th century, and was completed by 1950. Administratively, this portion of the Greater Chao Phya project is divided into two tracts, covering 250,000 hectares.[9] An additional 330,000 hectares adjacent to this southern section of the Greater Chao Phya project are served by similar water control facilities, although the area is officially divided into separate projects. Since these projects are within the Chao Phya basin, they are included in the southern Chao Phya region shown in Figure 4.

This study of water control in the Chao Phya deltaic region is limited to the 16 subprojects comprising the northern section of the Greater Chao Phya project. All of the projects in the southern Chao Phya region have been excluded from the study. In part this is because the southern area is not directly served by the distribution canals of the Chao Phya dam. Furthermore, the water control facilities were constructed so long ago that it does not appear to be possible to quantify their effect on production. Finally, most of the current debate concerning the effectiveness of the present system, and concerning the type of additional investment that might be made in the future involves the northern region. Throughout this publication, the study area consisting of the 660,000 hectares of the northern Chao Phya region is referred to as the project area.

The project area is the largest single water control project in Thailand, accounting for about one-fourth of the entire area of all of the water control projects in Thailand which are run by the government, and about 40 percent of the area of such projects in the Central Plain. Outside of the Chao Phya region, the next largest project is the still unfinished Mae Klong project, which will cover about 160,000 hectares in the southwestern portion of the Central Plain (Figure 4).

Agriculture in the project area is limited almost exclusively to a single crop of rice grown during the wet season. The planted area is about 600,000 hectares, which is over one-fourth of the area planted to rice in the entire Central region of Thailand. The average annual production of paddy in the project area is approximately 1.1 million metric tons. In one portion of the project area sugarcane production attains some importance, but the total area planted is less than 3,000 hectares. Scattered areas of "upland" crops[10] are grown in the dry season, and in one area there has recently been a significant increase in dry season rice production. But the total area planted to all crops grown in the dry season is less than five percent of the area planted to wet season rice.

The Greater Chao Phya project has been in full operation since the early 1960's. But in recent years there has been considerable dissatisfaction expressed with its performance.[11] Although the project was originally designed to increase production in the wet season, much of the disappointment has been due to the slow increase in dry season production. In spite of the criticisms, however, no systematic study of the actual effects of the project has previously been undertaken. A major objective of this study was, therefore, to evaluate the returns to the investment in water control facilities in the project area.

Since the system is designed primarily to improve agricultural conditions, this evaluation has been limited to an examination of the effects of the system on crop production. Any other effects of the system have been ignored. The results of this part of the study are presented in Chapter 3.

As a result of the dissatisfaction with the performance of the project, there have been a number of recent proposals for additional investment to overcome various deficiencies of the present system. Since adoption of some of these proposals would involve substantial new investments, major policy decisions concerning the future strategy for the development of the area are required. These alternatives are examined in Chapter 4.

Before proceeding with the analysis of the effects of the system it is useful to consider some aspects of the historical development of the project. It is to these matters that we now turn in Chapter 2.

## CHAPTER 2

## THE HISTORICAL BACKGROUND

One of the important by-products of the Bowring Treaty of 1856 was to expand the area devoted to rice for export. This necessitated the spread of rice production to areas where natural water conditions were less favorable than in the areas previously cultivated, which, in turn led to an increase in the frequency of serious crop failures. Interest in developing improved water control facilities grew out of this experience.

In 1889 the Siam Canals, Land and Irrigation Company, operating under a government concession, began digging canals in the largely unpopulated Rangsit area of the lower Chao Phya delta. By making the area accessible, and by permitting the drainage of flood waters, these canals opened an area of about 142,000 hectares of land to cultivation.[1] The government had hoped that this type of "irrigation scheme" would prove to be a solution to the problems of unfavorable water conditions, and could eventually be extended to the rest of the Central Plain.[2] Difficulties with the Rangsit scheme soon demonstrated that such expectations were unrealistic. Although certain control structures had been built on the canals to regulate the drainage of water from the area, the system was unable to bring any additional water into the area in times of drought. It thus was unable to deal with one of the major causes of crop failure. Furthermore, within a short time the canals began to silt up, making parts of the area inaccessible once again. By the turn of the century, less than 40 percent of the entire area opened up by the project had ever been cultivated.[3] As a result of these problems it was decided to obtain the services of a hydraulics engineer to advise the Ministry of Agriculture (also known as the Ministry of Lands and Agriculture). The man selected, Mr. J. Homan van der Heide, arrived from the Netherlands East Indies in 1902.

In January of 1903 van der Heide submitted to the Minster of Agriculture a comprehensive report in which he proposed an irrigation scheme based on a diversion dam across the Chao Phya river near Chainat, and on a network of distribution canals which would carry the diverted water throughout the flood plain and delta of the Chao Phya river.[4] In the lower delta region he also recommended the improvement of various canals by further excavation and by the construction of control gates to permit the retention of water and to reduce the influence of the tides on the water supply. If effect, van der Heide thus proposed the construction of what is today known as the Greater Chao Phya project.

Approval was given to proceed with some of the improvements of the canals in the lower delta, as proposed by van der Heide. A Royal Irrigation Department (RID) was established within the Ministry of Lands and Agriculture, with van der Heide as Director-General. The main scheme, however, was postponed indefinitely, although it was suggested that all hydraulic works built in the future should be constructed in such a manner that they could eventually be combined into the master scheme proposed by van der Heide.[5]

van der Heide then developed plans for a less expensive project, known as "irrigation at reduced capacity." The Siam Canals, Land and Irrigation Company apparently took an interest in one part of this plan, and petitioned the government for a decision. Thus in 1906 the government reviewed the entire question of irrigation. The decision was to postpone all of the prosals for at least two years.[6]

In 1908 the worst flood in 30 years occurred, causing serious damage to many of the canal control structures which had been constructed by RID in the years since 1903.[7] Although there is no record of the effect of these events on the attitudes of the government ministers and advisers, it seems probable that they strengthened the position of those who opposed the irrigation proposals. In any case, early in 1909 the government decided to postpone indefinitely the construction of all irrigation works, whereupon van der Heide left the country.[8]

The issue of irrigation was soon revived, however. In both 1911 and 1912 there were serious losses from drought, as the Chao Phya river failed to reach the level necessary for normal inundation. This led King Rama VI to order the establishment of a commission, headed by Prince Rabi, Minister of Lands and Agriculture, to consider measures to avoid such problems in the future. "The commission reported that to concentrate upon rice production, and to supplement by scientific irrigation, the natural but capricious supply of water obtained from rainfall and river inundation, was the best means to secure agricultural results necessary for the regular provision of that public and private wealth, without which the welfare of the state and its inhabitants could not be assured."[9] Arrangements were made for another irrigation engineer, Mr. Thomas Ward, to come to Thailand to develop proposals for the projects to be undertaken. Although Ward confirmed the soundness of the basic outline of van der Heide's proposal, he differed with van der Heide regarding the strategy to beused in the development of the water control facilities. Ward suggested that the construction of a diversion dam on the Chao Phya river near Chainat should be postponed since the dam would be able to serve a much larger area than could be cultivated by the existing population.[10] He thus recommended the gradual construction of a series of smaller "inundation projects" which could function even without the dam at Chainat, but which could later be linked together and converted into "irrigation projects" by the construction of such a dam.[11] It was proposed that the area along the Suphan river (which is the area of the Sam Chuk and Pho Phraya subprojects of the present system) be developed first. Ward also proposed the construction of projects in the Pasak and Phetchaburi basins, based on diversion dams across each of these rivers (see Figure 3).

Ward's report was submitted in February of 1915, and later that year the government decided to proceed first with the South Pasak project.

This project, which required the construction of a diversion dam across the Pasak River, was designed to benefit the area of the old Rangsit scheme (the concession for which had lapsed to the government in 1914). The Suphan river project, upon which Ward had placed top priority, was postponed, and preliminary work in the Suphan area, undertaken in anticiaption that this project would be approved, was terminated.[12] It was reported that the decision to proceed first with the South Pasak scheme was taken "probably because it was considered inadvisable to disturb existing arrangements of landlord and tenant in the Rangsit area and elsewhere, which the opening up of big areas of land in Suphan, free to all, must have done."[13] Whether or not this is true, it is clear from a note of the Financial Adviser that the fact that the South Pasak project would improve conditions in an already populated area (in contrast to the Suphan scheme, which involved a largely unpopulated area) was a major factor in the decision.[14]

Although the decision had thus finally been made for the government to undertake a major water control project, the effects of World War I resulted in slow progress in the actual construction. Funds were scarce; prices rose; and the import of equipment was difficult. As a result, the South Pasak project was not completed until 1922.[15] Work was then begun on the Suphan project, the first of the projects to be undertaken in the northern Chao Phya region. The first item constructed was the regulator on the Suphan river at Pho Phraya, which was completed in 1925. This was followed by the construction of the main distribution canals to carry the water diverted by the regulator.[16] Work continued to proceed slowly, however, and it must be assumed that the depression of the 1930's, during which rice prices fell drastically, further slowed the work. The entire Pho Phraya section of the Suphan project was not completed until 1933.[17] During the 1930's the Suphan project was extended north to include the area of the present Sam Chuk subproject. Construction of a head regulator on the Suphan river near the town of Sam Chuk began in 1935, but the entire project was not completed until 1950.[18]

World War II again put a temporary restraint on the construction of water control facilities. Shortly after the end of the war, the Director-General of the Royal Irrigation Department, M. L. Xujati Kambhu submitted a proposal to the Ministry of Agriculture for the construction of a diversion dam at Chainat, and of the headworks and canals required to carry the diverted water throughout the area of the northern section of the Greater Chao Phya project.[19] The proposal was submitted to the International Bank for Reconstruction and Development (IBRD), and in October 1950 a loan of $18 million was granted to Thailand for the construction of the project.[20] Construction on the dam began in 1952, and was completed in 1956. Work on the distribution canals lagged, however, and was not completed until early in the 1960's.

Thus the system which van der Heide, in 1903, had suggested could be completed in 12 years was finally finished in the early 1960's. Even before completion of the system, however, plans were made for the construction of upstream storage dams on two of the tributaries of the Chao Phya river. These projects were mentioned in the 1949 feasibility report for the Chao Phya project,[21] and in 1955 the U.S. Bureau of Reclamation completed the feasibility study for the first dam, known as the Yanhee or Bhumiphol project.[22] The project was designed primarily for the production of hydro-electric power, although some flood control, navigation, and irrigation benefits were also expected.[23] In 1957 a loan for $66 million was obtained from the IBRD for the construction of the Bhumiphol dam,[24] and construction began in the following year.[25] Although the dam was completed in 1964, unusually dry conditions in the years 1965 to 1967 resulted in the failure of the reservoir to fill to the expected level.[26] As a result, the quantity of water available for irrigation was severely limited. Even in more recent years, the volume of water released in the dry season has been well below that originally estimated.[27]

In 1962 another loan (for $5.6 million) was obtained from the IBRD for the Ditches and Dikes program. This program was designed to improve the distribution of water in the northern Chao Phya region. This was to be achieved by adding to the existing network of distribution canals and laterals a partial network of small ditches that would convey the water closer to the individual farms. Most of the construction of these ditches took place from 1963 to 1968, although in some cases work has continued into the 1970's. Another improvement within the project area involves the provision of drainage facilities. Work on a system of drainage canals began in 1965, and is scheduled to continue until 1980.

The initial feasibility study for the second of the two upstream storage dams was completed in 1964.[28] Compared with the Bhumiphol project, much greater emphasis was placed on the use of the water for irrigation in the dry season, although production of electric power is one of the purposes of the project. This project was also submitted to the IBRD, and after additional investigation,[29] a loan of $26 million was granted in 1967.[30] The dam, known as the Phasom or Sirikit dam, was scheduled for completion in 1972.[31] In accepting the loan for this project, the Thai government agreed to conduct a number of studies relating to the agricultural, institutional, and engineering requirements for the successful use of the irrigation water that would be made available as a result of the project.

## Objectives in the Development of Water Control

The major objective underlying the original development of water control in the project area was to avoid the serious crop failures which had occurred frequently in the late 19th and early 20th centuries. This was generally referred to as the stabilization of production. It was this single objective that dominated the discussion of the merits of water control throughout the first half of the 20th century.

In justifying the need for stabilization, emphasis was placed on the importance of foreign exchange. van der Heide noted that "Progress is going on rapidly and, in connection herewith, the wants of the Government and the people and the imports will continue to increase steadily. . . .Rapid increase of production and of export, to meet the increase of wants, is therefore incontestably necessary for Siam."[32] In this respect, international competition was a factor. Thus in the introduction to Ward's report, the Minister of Agriculture stated that the objective of the government in investigating and undertaking water control projects was "to enable the farmers of Siam to maintain against the increasing competition of neighbouring rice-growing states fostered by energetic governments, the position hitherto held by Siam in the rice markets of the world."[33]

Given the potential of the water control projects to open new land for cultivation, it might be thought that the expansion of the area under rice production was another major objective of the government in investing in water control. This was not the case, and one reason for the long delay in the development of water control appears to have been the concern that the construction of the proposed projects would permit land to be opened up too rapidly, with undesirable political, social, and economic consequences. One of the major questions raised when van der Heide's proposals were under consideration in 1906 was how to populate the area that would be under the command of the projects.[34] And as previously mentioned, the choice of the South Pasak project over the Suphan project was based in part on the lack of population in the latter area, coupled with concern that the tenants in the Rangsit area would move to obtain the free land which would have become available in the Suphan area. Such a migration would have resulted not only in losses to the landlords, but also in the probable abandonment of much of the land which had been recently developed in the Rangsit area. There was also concern that the development of water control projects would allow foreigners to gain control of the land, and that further immigration of Chinese might be stimulated.[35] It can thus be seen that the major interest of the government was to stabilize production in areas that were already largely cultivated. Projects which provided a potential for the opening up of large new areas were generally postponed.

Dry season production was not a major objective of those involved in the original development of the system. van der Heide suggested that a considerable amount of dry season production would be possible if the entire dry season flow of the Chao Phya river were diverted. He recommended the production of upland crops such as maize, beans, peas, cotton, peanuts, etc. He did not feel that a second rice crop would be appropriate, partly because of its greater water requirement, and partly because he felt it would result in soil and disease problems.[36]

With the rejection of his proposal, virtually all consideration of dry season irrigation ceased for over 40 years. The Ward proposals for the project area were for "inundation" projects, which could not provide any water in the dry season. Although Ward and officials of the Royal Irrigation Department anticipated the eventual construction of a diversion dam near Chainat, they made no mention of the possibilities which this might entail for the production of crops in the dry season. The only reference in this period to dry season production was made in a proposal for the dredging of the head of the Suphan river to permit water to flow in the distributary throughout the year. A brief comment was made that the dredging might permit farmers in the Pho Phraya area to raise two crops per year.[37]

The possibility of dry season crop production was again mentioned in the 1949 report in which RID preposed the construction of the Chao Phya dam. The main emphasis in this report, however, was on the system requirements for wet season production. Dry season cropping was dealt with almost as an afterthought. It was simply suggested that there would be enough water and good land to grow 160,000 hectares of soybeans in the dry season, half of which would be plowed under as green manure.[38] No consideration was given to the different requirements that such production would place on the water control system.

Thus it can be seen that prior to 1960, the primary object of the Thai government in the development of the Greater Chao Phya project was to create conditions more favorable for wet season rice production. Since 1960, however, the goals of the government have gradually shifted toward the development of the conditions necessary for dry season production.

Although the construction of the Bhumiphol dam proveded some potential for irrigation, the main purpose of the dam was to generate electric power. Furthermore, in the 1955 feasibility report, the brief discussion of irrigation emphasized the benefits that would result from the increase in water early in the wet season, when there is often a shortage of water for land preparation and transplanting. In the single paragraph devoted to a discussion of dry season irrigation, it was simply stated that the average dry season flow of the river at Chainat would be increased by 204 cubic meters per second, and that this quantity of water would be sufficient for the production of 368,000 hectares of upland crops.[39] No consideration was given to other uses for the water (such as improved navigation below Chainat and salt water intrusion control), or to the problems involved in getting the water on the fields.

It was the recognition of the fact that additional facilities were required to bring dry season irrigation water to the farm fields that led to the proposal for the Ditches and Dikes program in the early 1960's.[40] The ditches, of course, were also designed to increase the effectiveness of the distribution of water in the wet season. It will be recalled that Ward had proposed an even more complete system of ditches, even though dry season irrigation was not an element of his proposal. In any case, the Ditches and Dikes program was the first concrete step taken in the direction of modifying the original water control system to permit the effective use of water for dry season production.

Finally, as previously noted, the Sirikit dam project has been developed with the provision of water for dry season irrigation as a major objective. It is the potentially large volume of water which will be available upon the completion of this dam that has led to the various studies and proposals for further modifications and developments of the original system to enable it to support dry season irrigated agriculture.

## Issues in the Development of Water Control

### Extensive Versus Intensive Development

One issue which has arisen several times in the history of the development of water control in the Greater Chao Phya project relates to the strategy to be followed for the ultimate development of a system in which the application of irrigation water and the drainage of excess water can be controlled on each individual farm plot. Conceptually, the various approaches can be placed on an "extensive-intensive" continuum. At one extreme is the extensive approach, under which a skeleton system of diversion structures and canals provides a supply of water to a large area, but on the basis of relatively uncontrolled field to field flooding. This network is gradually improved through the addition of a drainage system, and of canals and ditches for the control of irrigation and drainage water on the individual farms throughout the area. At the other extreme is the intensive approach, under which an initially small area is provided with all the facilities necessary to control the flow of irrigation water to, and drainage water from, each individual field. The expansion of the system over time would thus involve a series of geographic steps, in contrast to the functional steps by which the system would be improved under the extensive approach.

Although van der Heide explicitly recognized the desirability of a system that provided the ability to apply water to and remove it from any farmer's field at will, he argued against immediate efforts to construct such a "thoroughly perfectionated irrigation and drainage system."[41] His argument was based on the grounds (1) that financial considerations made it necessary to use natural channels as much as possible, even though such channels were somewhat less than ideal for the purposes of the system, and (2) that farmers would not yet have the skills to fully utilize a more complete system. He therefore suggested that the construction of a drainage system be postponed, and that the construction of the small distribution ditches be left to "the local communities [which] will make them in the way of cooperation, customary to the country."[42] Even if the people did not construct these ditches immediately, he felt that a system of field to field flooding would be satisfactory.[43] van der Heide thus opted for a fairly extensive approach, whereby a large area would, within a short period of time, be served by a system which would function "fairly well" and which could gradually be improved as farmers learned to make use of the system, and as financial resources became available.

Ward recommended a much more intensive approach to the development of water control. He rejected the idea of the immediate construction of the dam at Chainat, not only because of its expense, but also because it could serve a much larger area than could readily be cultivated by the population. Furthermore, he disagreed explicitly with van der Heide's suggestion that distribution on a field to field basis would be satisfactory.[44] He therefore urged the construction of smaller projects which, in the words of the Minister of Lands and Agriculture, would be "thoroughly carried out to the last detail of the field embankments and ditches."[45] Ward argued that it was particularly important for the first project to be constructed in this manner so that the project could be "a shining example to the farmers throughout the country" of the benefits of "scientific irrigation."[46] He felt that this would be important in gaining the support and cooperation of the farmers in the development of other projects. While recognizing that financial considerations would militate against this intensive approach, he pointed out that farmers were not likely to have either the technical expertise or the capital necessary to carry out the construction of the small ditches, drains, and other works required "inside the village." He therefore suggested that the government design and construct these works, but that the farmers be required to pay for them under long term credit arrangements.[47]

Although the government accepted some of the projects proposed by Ward, the above recommendations were not implemented. Thus neither the

South Pasak project, which was the first to be built, nor the Suphan project, which was to have been the "shining example," was constructed in the "thorough" manner recommended by Ward.

The issue of alternative approaches to the development of the water control system was not explicitly raised in the 1949 feasibility report for the Chao Phya dam. In effect, however, the proposal was a revival of van der Heide's extensive approach. Although van der Heide had recognized the ultimate need for a network of drainage canals and of small distribution and drainage ditches, these features were not mentioned in the 1949 report. It was claimed that the construction of the facilities proposed (i.e., the dam at Chainat and the network of distribution canals) would bring about "perfect water control."[48]

In the early 1960's, with the basic framework of the water control system complete throughout the project area, attention shifted to improvements which would make that framework more effective. Thus the Ditches and Dikes program was initiated. This program also represented an extensive approach to the further development of water control, with a skeleton network of ditches constructed throughout the project area. The drainage system, begun in 1965, follows a similar pattern.

From this discussion it can be seen that the government has consistently followed a relatively extensive policy in the development of water control in the Greater Chao Phya area. The extensive-intensive issue has thus far largely been settled in favor of the extensive approach. But the issue has re-emerged recently in conjunction with proposals for the further development of the area. The creation of several pilot projects demonstrating quite intensive approaches to further development reflect renewed interest in this approach.

## Mobilization of the Farmers' Resources

Closely related to the extensive-intensive issue is the question of the role of farmers in the development of the water control system. In order to reduce the cost to the government, proposals have been made to have the farmers construct the small ditches required to carry the water to each plot of land. van der Heide recommended such an approach, and it appears to have been the policy officially adopted by the government. In the mid 1920's landowners and cultivators were assigned the responsibility of constructing small ditches, but the historical record indicates that they failed to fulfill this obligation.

In 1941 the concept that the farmers should provide for these facilities was incorporated into law.[49] In spite of the law, little construction took place. As a result, RID finally undertook the Ditches and Dikes program in the 1960's. This program does not, however, appear to have stimulated additional construction by farmers. Furthermore, the maintenance of the ditches dug by RID (which is also a responsibility of the farmers) has been relatively poor. Efforts to mobilize the labor of farmers for the construction and maintenance of the system have thus not been very successful.

A second approach to obtaining the resources of the farmers is to collect cash payments from them. This could be done in a number of ways, such as by imposing an irrigation tax or by raising land taxes. Such procedures have long been recommended. van der Heide, for example, proposed that farmers pay a water tax of 6.25 baht per hectare.[50] Ward also favored such a tax, and in addition suggested that the small ditches be constructed by RID, with the farmers being charged (under a long term credit arrangement) for the expense.[51] Although the Ministry of Lands and Agriculture apparently accepted Ward's tax proposals, considerable opposition was encountered in other parts of the government. The tax proposals were not accepted, and no charges were levied on the farmers to recover either the capital cost or the operation and maintenance costs of the water control facilities. Although the issue of a water tax has been raised a number of times in more recent years, governmental policy has remained unchanged.

The government has thus not succeeded in mobilizing in any direct fashion either the labor or the financial resources of the farmers for the construction and the maintenance of the water control system. Viewed in historical perspective, it seems that the failure of the government to mobilize these resources has been one constraint on the development of the water control system.

## Effectiveness of the Project

Throughout the history of the Chao Phya project, there has been some disappointment expressed with the results that it has achieved. From the historical record it appears that one of the reasons for this is that the development of the system has, to a considerable extent, proceeded on a trial and error basis. Thus in 1908 it was found that the structures which had been built to retain water in the Rangsit area hindered the rapid removal of excess water which had entered the area as a result of the disastrous flood of that year. Fearing heavy crop losses if the water level could not be lowered quickly, RID ordered that the earthen dams be cut, and that the locks be opened. The locks, which had not been built for the release of water, were severely damaged. Several years were spent repairing the damage and building additional structures to prevent a recurrence of the problem.[52]

Other examples of the trial and error nature of early developments can be taken from the Suphan project (Pho Phraya) in the northern Chao Phya area. Construction of the head regulator on the Suphan river at Pho Phraya was completed in October of 1925, at a time when crops both upstream and downstream from the regulator were suffering from a serious water shortage. Since the downstream area was larger, the provincial Governor ordered that the gates of the regulator be opened. This was done, but the water level in the river was too low to enter any of the downstream canals. When this was observed, orders were given to close the gates. But by that time the supply in the river was so low that the water could be headed up enough to serve only a few canals. RID officials estimated that a much larger area could have been served if the gate had not first been opened.[53] Two years later it was discovered that the regulator was unable to function as anticipated because of the very small amount of water coming into the Suphan river, which is a distributary of the Chao Phya (see Figure 4). The problem was silting at the head of the Suphan river, where one to two meters of additional silt had apparently been deposited in the 14 years that had elapsed since Ward made his proposals.[54] Simply dredging the head of the river was regarded as dangerous because of the possibility that such action might result in the main river shifting its course into the Suphan channel. To prevent this, an additional regulator at the head of the river was recommended.[55]

Development in this trial and error fashion was in part due to the large and hydrologically complex nature of the project area, and the resulting lack of knowledge of the exact effect that a given change would have. Financial constraints certainly also contributed to the difficulties. Important elements of projects were often modified or temporarily ignored in order to obtain financial approval. As certain aspects of the system were later found to be deficient, efforts were then made to obtain the additional resources necessary to bring about the desired improvements. In terms of the previous discussion, the extensive approach to the development of water control was to a considerable degree imposed by financial constraints, which were exacerbated by the inability to mobilize the resources of the farmers in the development of the system. Under such conditions, expectations concerning the effect of the system were probably often unrealistic. The next chapter is devoted to a detailed examination of the nature and magnitude of these effects.

# CHAPTER 3

# THE RETURNS TO INVESTMENT IN WATER CONTROL

A common misconception regarding deltaic areas in mainland Southeast Asia is that they have generally uniform agricultural conditions. In fact, as mentioned in Chapter 1, there are differences in water conditions within a given deltaic area which result in significant differences both in agricultural practices, and in the effects of a water control system. To investigate the nature and magnitude of the returns to the investment in the Greater Chao Phya project, it is first necessary to deal with the problems posed by this diversity in agricultural conditions.

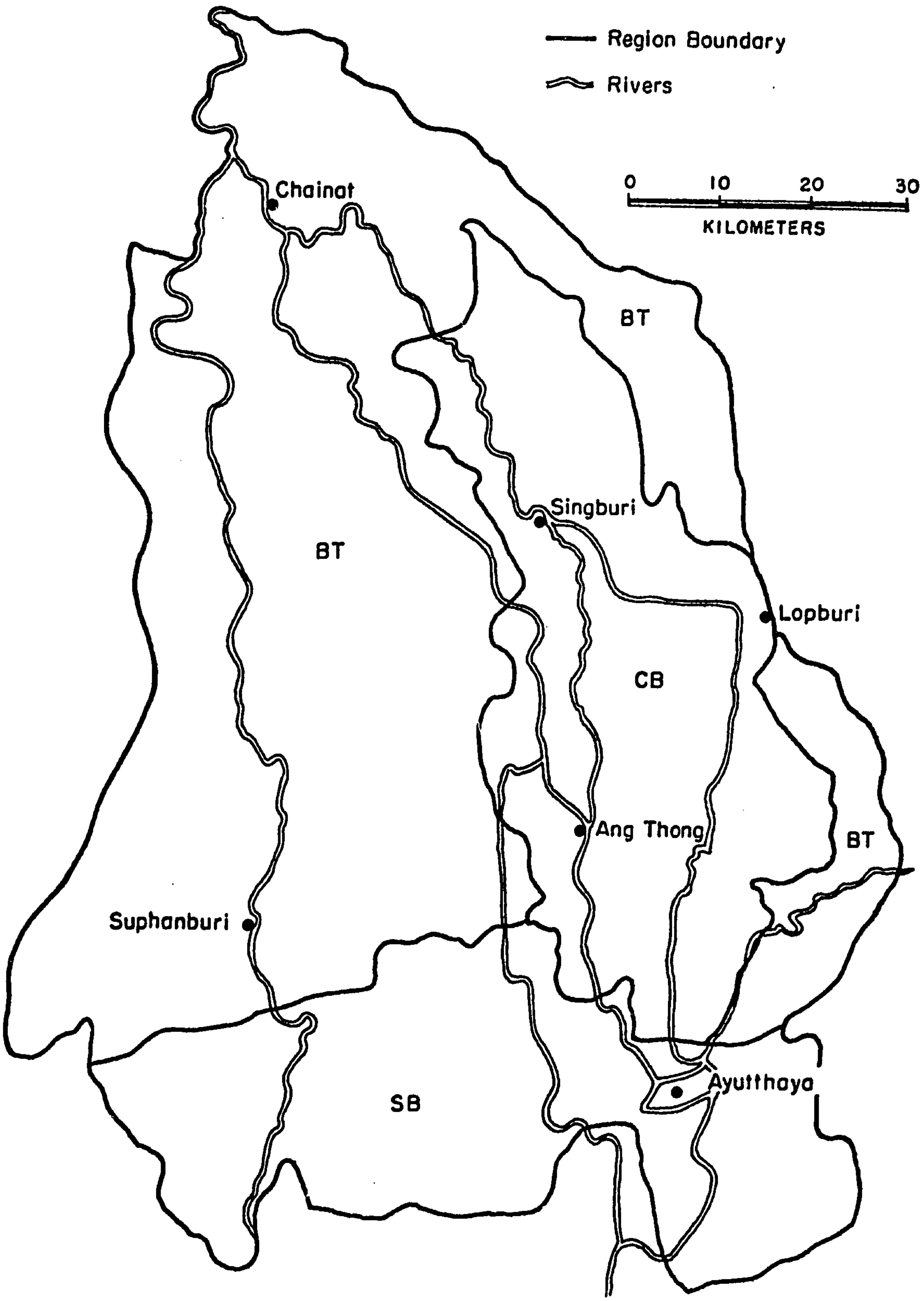
## Agricultural Regions of the Project Area

Major differences in agricultural practices in the Greater Chao Phya project appear to be related most directly to differences in the amount and source of water received. In areas which receive water mainly from rainfall, rice is generally planted by transplanting the seedlings from a seedbed. In areas which flood from the runoff from higher areas, rice may be planted either by broadcasting the seed directly on the field, or by transplanting. And in those areas which are annually inundated to depths of from one to three meters by the flooding of the river, floating varieties of rice, which are planted by broadcasting, are generally grown.[1]

Based on these differences in water conditions and agricultural practices, the project area was divided into three agricultural regions (Figure 5).[2] The largest region, covering approximately one-half of the project, consists of areas which generally either do not flood at all, or which flood only to a relatively shallow depth, usually as a result of runoff from surrounding fields. Rice is generally transplanted in the higher portions of this region, while in the lower areas, which have poorer drainage and are thus subjected to greater depths of standing water, the rice is planted by broadcasting. The water control system has had a considerable effect on this Broadcast-Transplant (BT) region.

The remaining two agricultural regions consist primarily of areas which flood deeply every year. The Central Broadcast (CB) region consists of the low areas lying on either side of the Chao Phya river (see Figure 5 and cross sections 2-2 and 3-3 of Figure 1). Parts of this region are the most deeply flooded areas to be found in the entire

Figure 5. Major Agricultural Regions of the Project Area



Greater Chao Phya project. The CB region, which covers roughly 25 percent of the project area, has been affected only moderately by the water control project. The final 25 percent of the project area is located in the Southern Broadcast (SB) region. Depths of flooding in this region are somewhat less than in the CB region; however, the SB region does not appear to have been affected by the water control system.

## Production Data

### Rice

Because the results of a quantitative examination of the effects of the water control system depend on the production data used, it is necessary to critically examine the nature and quality of the data available.

Historically the collection of data on rice production has been a function of the Ministry of Agriculture. Although provincial (changwat)[3] estimates of planted area, harvested area, and production are available since 1937,[4] little information is available concerning the methods of data collection used prior to 1955.[5] In 1955 the Rice Department established a new system for the collection and reporting of these data. This reporting system is based on a series of three report forms. Information on the areas planted by broadcasting and by transplanting is reported at the end of the planting period; information on crop damage is reported periodically throughout the growing season; and information on the area harvested and on total production is reported at the end of the crop year. These reports are to be filled out by each village major (phuyaiban), who should report the required information separately for each individual farmer. These reports are then sent, generally via the tambon leader (the kamnan, who is also the phuyaiban of his own village), to the amphoe officer of the Rice Department. This officer is responsible for tabulating the data, and for reporting the totals for each tambon to both the provincial officer of the Rice Department and to the Department itself in Bangkok. The provincial rice officer's duties are mainly those of supervision, particularly in seeing that the reports are completed by all of the amphoe officers. The Rice Department in Bangkok is responsible for checking the reports as they are received, and for compiling and publishing provincial, regional, and national totals.

Thus the system, as it is theoretically designed to operate, provides for a complete enumeration each year. The burdens of this enumeration fall mainly on the phuyaiban, who must report on anywhere from 30 to 120 individual farmers, and on the amphoe rice officers, who must tabulate the reports of from 45 to 125 phuyaiban. Not surprisingly, it is at these two points in the reporting system that the greatest deviation from the design occurs.

While some phuyaiban attempt to follow the system described above, many others follow procedures which simplify their work. In areas where there is little change in the area planted from year to year, the figures for the area planted in a given year may be taken directly from the report of the previous year. Even in such a situation, however, any large changes such as sometimes occur due to early flooding, would probably be reported. Similarly, in the reporting of damaged areas, scattered areas left unharvested are less likely to be systematically reported than are large areas in which the crop is totally destroyed by flood or drought. The phuyaiban may also simplify the reporting of production by making an estimate of the average yield per unit area and then converting this into a figure for total production. These yield estimates may be made partly on the basis of casual conversations with some of the farmers in the village, and partly on the basis of rules of thumb. In addition to these procedures for simplifying the job, some phuyaiban simply fail to complete the reports. When this happens, the kamnan may make the production estimates for villages for which the phuyaiban fail to submit reports. Although all of these practices reduce the role of the individual farmer in the reporting process, the data still appear to represent the "best estimates" (allowing for certain biases to be discussed below) of a fairly large number of individuals with intimate knowledge of local agricultural conditions.

A more serious problem, in terms of the usefulness of the data, arises at the amphoe level. The burden of tabulating all the reports received from the phuyaiban and kamnan is great, especially when the data are listed by individual farmer (as may be done even when average yield estimates for a whole village have been made). The problem may be further complicated by the failure of some phuyaiban or kamnan to submit their reports, and by gross inconsistencies in some of the reports. While some amphoe officers tabulate and report the data as they are received, others have developed various procedures which eliminate the necessity of tabulating all of the data received from the villages. The actual methods used vary from amphoe to amphoe. In some cases, an average yield is estimated for the entire amphoe, while in other cases estimates may be made separately for some or all of the tambon. Except to the extent that such procedures are used to correct obvious mistakes in the original reports, their use can generally be expected to lower the quality of the final data, since the new estimates are made by a smaller number of individuals having less knowledge of local conditions.

Once the reports are submitted by the amphoe rice officers, the system functions largely according to its design. Reports received in Bangkok are checked and edited for obvious errors and inconsistencies, but there is no evidence that any adjustments or new estimates are made. Whatever the truth of the suggestion that pressures have at times been brought on the Rice Department to underestimate production in order to help maintain a high export price of rice, there is no evidence that such pressures have had any influence on the production statistics used in this study.[6]

This discussion leads to the conclusion that the geographic and temporal differences encountered in the quality of the data are most likely to be due to differences in the procedures used by the amphoe officers. While the generation of estimates by these officers may introduce certain biases, it does not seem possible to generalize about either their magnitude or their direction. It is, however, widely believed that the Rice Department data systematically underestimate production. The cause of this presumed bias is the alleged tendency of farmers, and of phuyaiban (who are commonly also farmers), to under-estimate or under-report their production. It is frequently suggested that this is due partly to fears of possible taxation, and partly to the feeling that it is not wise, particularly if one is fairly well off, to show or make known to others in the village the extent of one's wealth. Furthermore, it has been observed in many countries that regardless of the reasons, "eye" estimates of production tend to underestimate actual production.[7]

To investigate the possibility of such a downward bias, comparisions were made between the data of the Rice Department and data gathered since 1966 from crop cutting surveys conducted by the National Statistics Office (NSO). Because the sampling procedures used by the NSO generally permit estimation only for the four major geographic regions of the country, it is necessary to compare the two sources of data for the entire Central Region of Thailand. For the four years for which the data are available (1966-1969), differences in total production were small, with the NSO estimates generally ranging from five percent below to five percent above the estimates of the Rice Department. The estimates of the Rice Department concerning the planted area were generally higher than the corresponding estimates of the NSO. As expected, the yield estimates of the NSO were higher than those of the Rice Department; however, with the exception of 1968 (when the NSO estimates was 13 percent higher) the differences have been small, with the NSO estimates only one to four percent higher than the Rice Department estimates. If it is assumed that the NSO data are correct, and that the differences for Central Thailand accurately reflect the differences for the project area, then the implication is that the Rice Department data on total production for the project area are probably reasonably accurate, but that the yield data slightly underestimate actual yields. It seems reasonable to assume that this slight bias has changed little over time, so that it may be ignored in the analysis of trends in the data.

A different problem arises in conjunction with the data on the area planted. It appears that new land was commonly brought into production by clearing some trees, especially around the outside of a plot, and then planting rice on the cleared area. As more trees were gradually cleared, the actual area under cultivation expanded, although the perimeter of the cultivated area might remain about the same. Under such conditions it would have been very difficult even for the farmer to determine the exact size of the area which he planted each year. Real changes in planted area may, therefore, have gone unreported. On the other hand, an improvement in the farmers' knowledge about the size of the area they cultivate might result in a reported change unrelated to any real change. Such a situation may have occurred in parts of the project where plowing by tractor is now common. Thus, one must be very cautious about drawing conclusions from trends in the data on planted area.

Another factor which must be considered in an evaluation of the Rice Department data is the effect of the 1963 agricultural census, conducted by the NSO for the 1962 crop year. Due to a lack of personnel, many of the field officers of the Rice Department worked on the census.[8] This presumably often made it possible for the Rice Department officers to base their 1962 production reports on the same data that were being collected for the census. Close agreement between the two sources of production data for 1962 would, therefore, be expected. An examination of the national totals confirms this expectation, with the two sources differing by less than one percent in their estimates of total production. But because the 1962 figures for total production are over 10 percent higher than any of the previous production estimates of the Rice Department, it appears that the census procedures resulted in higher estimates of production than did the methods previously used by the Rice Department, and that this caused a discontinuity in the time series production data. There is not, however, any evidence that these conclusions apply to the area of the Greater Chao Phya project. Although the two sources provide nearly identical estimates of total production within the project area, differences between the sources of up to 15 percent exist for the individual agricultural regions of the area. Furthermore, a comparison with previous years shows that for the project area, the 1962 production data were not higher than the data gathered in earlier years. The evidence thus suggests that for the project area, there were no significant differences in the production data generated by the two methods.

Following the completion of the census, a Post-Enumeration Survey was conducted in order to estimate the degree of error in the census.[9] The survey indicated that national rice production was underestimated in the census by approximately 6.1 percent. This figure has attained importance, as it is used in adjusting the Rice Department data in the development of production estimates for use in the National Income Accounts.[10] The figure is, however, a national average, and there is no indication of the geographic distribution of this underestimation. It has already been noted that while the census appears to have estimated national production to be about 10 percent higher than had previously been estimated by the Rice Department, no discrepancy was observed in the project area. There would thus seem to be some question concerning the validity of using these survey results to conclude that the Rice Department data for the project area are 6 percent too low. Furthermore, this underestimation of production was due to a 7.2 percent underestimation of the area planted, combined with a slight overestimation of yields. Thus even if the 6 percent figure is applicable to the project area, it does not imply any underestimation of yields.

The discussion thus far indicates that the yield data of the Rice Department are reasonable satisfactory for use in the examination of the effects of the water control system. There is, however, an alternative source of time series data on rice production which must be considered. Since 1958 the Royal Irrigation Department has collected and published statistics on rice production for each of the 16 water control subprojects in the project area. A detailed comparison of these data with the data of the Rice Department, combined with information obtained from interviews with the officials responsible for gathering these data led to the conclusion that the analysis of the effects of the water control system could best be conducted by using the Rice Department data.

There were several factors leading to this decision. The Rice Department series is 3 years longer than the RID series, facilitating the analysis of conditions prior to the completion of the water control system. Second, it appears that in general there are a larger number of people involved in the generation of the estimates upon which the Rice Department data are based than is the case with the RID data. This reduces the effect of the bias that any one individual may have, giving greater consistency to the time series. A third factor is that there have been a number of methodological changes over time in the collection of the RID data, thus reducing their usefulness for time series analysis. Furthermore, although the RID yield data are now based on crop cutting surveys, there are some serious problems with the techniques used. Although the villages to be sampled appear to be chosen in a reasonably random fashion, considerable subjective judgement regarding the fields to be sampled is commonly exercised by those taking the sample. This not only reduces the likelihood of sampling fields with very low yields, but also appears to lead to a fairly heavy concentration of samples in the areas of easiest access by road. Because the roads generally run beside the irrigation canals, this results in high proportion of samples coming from fields which, being close to the canals, are most likely to have the best water control. For these reasons I believe that there has been a fairly strong upward bias in the RID yield data. This presumption is strengthened by a detailed comparison which I made between the RID data and the data of the Rice Department for each of the 16 subprojects. The comparison demonstrated that yields as reported by RID averaged 50 percent higher than the yields reported by the Rice Department.[11] Because this upward bias in the yield data has varied over time and among the subprojects, it does not seem appropriate to use the RID time series data for the analysis of the effects of the water control system. A final reason for the decision to use the Rice Department data involves differences in the geographic coverage of the data. Although RID data are available for each of the subprojects, it is not possible to disaggregate the data in order to make them correspond to the agricultural regions into which the project was divided. Furthermore, data are generally not available from areas outside the water control project. Only by using the Rice Department data is it possible to make valid comparisons between the project area and similar but nonirrigated areas outside the project boundary.

## Upland Crops

Given the dominant role which rice has traditionally had in the agricultural economy of Thailand, it is not surprising that more emphasis has been placed on the reporting of rice production than on the reporting of upland crop production. For this reason, data on upland crops appear to be less reliable than data on rice production.

Primary responsibility for the collection of data on upland crops has been with the Department of Agriculture of the Ministry of Agriculture. While the reporting system is outwardly similar to that used for rice, estimates made at the amphoe level or even at the provincial level are much more common.[12] These data are published by province, and except for 1970, it was not possible to obtain data for any smaller administrative units. Since the provincial totals for upland crop production are dominated by the large areas of wet season production in the upland areas outside of the Greater Chao Phya project, it is not possible to use these data to examine the dry season changes taking place within the project area.

The only other data on dry season crop production are those collected by RID within the project area. Although there are difficulties with these data, the problems appear to be less serious than in the case of the RID rice data. Dry season production data are not collected by crop cutting techniques, and so there has been much less change in the methods of data collection than in the case with rice. Furthermore, given the relative unimportance of dry season crop production in the project area, any errors in the dry season data would have a much smaller impact on the overall analysis than would be the case for the rice data. The analysis of the changes in dry season production is therefore based on the RID data. These data are available for some crops since 1964, and for all crops since 1966.[13]

## The Effects of Water Control

### Method of Analysis

There are several possible approaches to the quantification of the effects of a water control project. Some studies attempt to determine a functional relationship between water and production.[14] In these studies, through a knowledge of rainfall probabilities; of the effect of rainfall on the deliveries of the irrigation system; and of the relationship between water and yield, attempts are made to estimate yields that would exist with and without the system. For the present study, however, such an approach is not feasible. There are no data which would permit the estimation of the relationships between water and yield. The fact that the project area may suffer both from too little and too much water suggests that there is no simple relationship between water and yield. Furthermore, the size of the area is much too large to expect that any single relationship exists throughout the area.

A more common approach to the quantification of the effects of water control projects is based on comparisons between irrigated and nonirrigated areas.[15] This approach may provide reasonable results in cases where the projects are relatively small and well defined, or where they are located in arid or semi-arid areas. In the case of the Chao Phya project, however, it was not felt appropriate to place primary emphasis on such an approach because the size of the project area and the variety of water conditions found within it make comparisons with any other area of limited validity. While a nonirrigated area outside the project has been identified for the purpose of making certain comparisons, primary emphasis has been placed on the examination of time series data from the project area itself.

Two approaches to the analysis of the time series data are vailable. One approach is to use the date of the completion of the project to divide the data into "before" and "after" periods, and to examine the differences between the two periods. The other approach is to treat time as a continuous variable, and to examine the trends which have taken place. Neither approach is entirely satisfactory. Dividing the data into two periods ignores the fact that the "completion" of a water control system does not take place at a given moment in time. Initial completion of the dam and major canals may provide only a limited change in water conditions, while the extension of the entire network of canals and small channels may continue to make further improvements in water conditions over a considerable period of time. Furthermore, even if there is a rather definite discontinuity in water conditions, observable human response is likely to lag behind, and to occur more gradually. On the other hand, certain results of the system--especially those which can occur with a minimum of farmer response--are likely to become apparent within the course of a few years after a project reaches some relatively advanced stage of construction. For such effects, the "before-after" approach would be more appropriate.

Although both approaches are used in this study, greater emphasis is placed on the "before-after" approach. It is somewhat difficult to determine the appropriate date to use to separate the two periods. Although the Chao Phya dam was completed by 1957, the construction of many of the delivery canals lagged several years. The Royal Irrigation Department reports the completion dates of the subprojects in the project area as ranging from 1962 to 1964.[16] It appears however, that for any given subproject, most of the canals were in operation prior to the formal completion date. While it had been hoped to obtain enough information on the completion dates of various parts of the system to be able to determine the cutoff date separately for each agricultural region, the lack of detailed records made this impossible. It was, therefore, decided that for all projects 1961 would be considered to be the last year prior to the operation of the system. While this date may be a bit later than would be most appropriate for certain parts of the system, and a bit too early for other parts, it is believed to be a reasonable reflection of the point in time at which the system brought about major changes in water conditions in the project area. Thus in quantifying the wet season effects of the water control system, data from 1955 to 1961 were used for the "before" period, and data from 1962 to 1969 were used for the "after" period. Since the system had little effect on dry season production until after the completion of the first upstream storage dam in 1964, data for the period from 1964 to 1971 were considered to represent the "after" period in the analysis of the dry season effects.

## Wet Season Effects

In Chapter 2 it was noted that a major objective of those who planned for the development of the water control system was the "stabilization" of production, meaning a reduction in the losses which frequently occurred due to flood and drought. Given the nature of the data available, the achievement of this goal is reflected in two ways: (1) a decline in the average percentage of the planted area which is damaged so severely that it cannot be harvested,[17] and (2) an increase in yields on areas which would have suffered reduced production without the water control system. Although both of these effects presumably occur together, the reduction in damaged area is easier to identify.

Throughout the BT region, agricultural officials are in general agreement that there is less damage now than in the past. In the areas of deep water rice there is greater diversity of opinion. Many officials in the SB region do not feel there had been much change in the amount of damaged area. And in parts of the CB region some officials and farmers feel that the operation of the system has resulted in increased damage. Their claim is that the flood waters, which are now channelled through the system of canals, arrive later but rise more rapidly than had been the case prior to the existence of the system, and that this results in a greater risk of damage to the crop, both from lack of water very early in the season, and from too much water somewhat later on. As is discussed more fully later in this chapter, the analysis conducted in this study does not provide any evidence to support this claim.[18]

In addition to the two effects of water control which are related to the stabilization of production, the construction of the system has made it possible for many farmers to change their method of planting from broadcating to transplanting. This third effect of the water control system has been limited mainly to the BT region. Although transplanting requires considerably more labor than broadcasting, it appears to be generally preferred by farmers wherever water conditions make it feasible.[19] While there is some controversy regarding the effect of the method of planting on production, it seems that under the water management conditions faced by farmers in the project area, transplanting is generally associated with higher yields.[20]

Other effects which are commonly associated with irrigation systems have been of much less importance in the Chao Phya project area. There has been almost no change in the wet season cropping pattern, with rice continuing to be the only wet season crop of major importance. While the cultivated area has expanded since the construction of the system, one can only speculate regarding the effect of the system itself on this expansion. Certainly the expansion of cultivation in Thailand has not been limited to areas with water control systems. One might speculate that without the system the land would have been cultivated, but not to rice. But while the system did increase the comparative advantage of rice, it seems probable, given the natural hydrologic and soil characteristics of the area, plus the skills, knowledge and preferences of the Thai farmers, that the project area would have been cultivated to rice even without a water control system. It is, therefore, concluded that the major impact of the system on wet season production has been through the increased productivity of rice per unit of land planted.

1. Decrease in broadcasting. The difficulty of interpreting the reported changes in planted area makes it necessary for the quantification of this effect to be based on data for the percentage of the planted area which is broadcast. For the entire project area, this figure declined from 78 percent prior to the construction of the system to 62 percent in 1969, which represents a shift in the method of planting on about 96,000 hectares. Of this total, 82,000 hectares are located in the BT region, where the percent broadcast dropped from 56 to 29. The remaining 14,000 hectares are in the CB region, where 90 percent of the land was broadcast in 1969, in contrast to nearly 100 percent during the "before" period. Virtually all of the land in the SB region continues to be planted by broadcasting. Before concluding that these changes have been brought

about as a result of the water control system, other factors which may have caused at least part of the decline in broadcasting must be considered. The two other factors most likely to be causal y linked to this change are weather and labor.

In those parts of the project where farmers are faced with the possibility of choosing between the two methods of planting, weather conditions may play an important role in their decisions. Discussions with both government officials and farmers suggested that ample rain early in the wet season would tend to cause a decrease in broadcasting by providing the water necessary to prepare the land for transplanting. To examine this possibility, the technique of ordinary least squares was used with data from each of the agricultural regions into which the project had been divided. The percentage broadcast was the dependent variable, and in addition to a time trend, several independent variables reflecting water and rainfall conditions were examined. In general only the trend variable proved significant, indicating either that the weather variables were unimportant or else that their effects were so small relative to the large changes which took place in the percentage broadcast that these effects could not be detected.

Because transplanting requires much more labor than broadcasting, it is possible that the increase in transplanting reflects an increased availability of labor caused by the growth of population in the project area. Lack of time series population data made it impossible to use regression analysis to examine this factor. Amphoe population figures, as reported by the Ministry of Interior, were examined in an effort to determine if any significant relationship between population density and percent broadcast could be found.[21] A simple correlation coefficient between the population per hectare planted to rice and the percentage of the planted area which is broadcast was calculated for 1969. In order to reduce the error resulting from the fact that the population data did not distinguish between the rural and urban populations, the amphoe containing the provincial capitals were excluded from the analysis. Furthermore, since water conditions in the SB and CB regions almost completely eliminate the possibility of transplanting rice, the amphoe located in these regions were also excluded. The resulting correlation coefficient, based on 12 amphoe, was -.098, which is not significantly different from zero. Thus these data do not support the hypothesis that transplanting is more prevalent where labor is more abundant.

An alternative approach to the investigation of the labor question is to compare the time series data on percentage broadcast in the project area with data for a similar geographic area which does not have a completed water control system. Although the project area is a unique physical entity which is not exactly duplicated anywhere in Thailand, there is an area southwest of the project which shows many similarities to the Chao Phya region. This is the portion of the Central Plain which lies in the basin of the Mae Klong river (see Figure 4). Although some water control facilities have been built in part of this area, much of it (the "stage II area") will not be substantially affected until the completion of the Mae Klong stage II project. This stage II area is, therefore, considered to be a "control" area which can be compared with the Chao Phya region.

Under the assumption that population growth in the Mae Klong stage II area has followed a pattern similar to that of the Greater Chao Phya area, the hypothesis that the decrease in broadcasting in the latter area is due to the increased availability of labor would lead one to expect a similar decline in the Mae Klong area. In fact, the data show no such trend, with the percentage broadcast fluctuating between 50 and 60 percent throughout the period. The use of regression analysis to attempt to hold constant the effect of weather also confirmed the lack of a time trend. The data from the Mae Klong area thus provide some additional support for the proposition that the decrease in the percent broadcast in the Chao Phya region is not due to an increase in the amount of labor available. To the extent that the only important differences in conditions impinging on the two areas are those resulting from the construction of the water control system in the Chao Phya region, the data also suggest that the entire shift in the method of planting can be attributed to the water control project.

No completely satisfactory method exists for estimating the change in production resulting from this change in the method of planting. The only sources of comprehensive data which distinguish between the two methods of planting are the agricultural census of 1963 and some unpublished tambon data gathered in 1968 and 1969 by the Division of Agricultural Economics. Summary data are also available from three surveys, each of which covered a very small geographic area.[22] Based on these data, an estimate of the average yield differential between broadcast and transplanted rice was made for the BT and CB regions. Although there were a few instances in which the yield of broadcast rice was reported to be higher than the yield of transplanted rice, the average yield of transplanted rice was higher in both of the regions. The estimated average differentials of 240 kilograms per hectare for the BT region and 275 kilograms per hectare for the CB region were then used to estimate the total production effect of the shift in the method of planting.

One objection to this procedure is that the yield differentials on the marginal land (i.e., the land on which the method of planting has changed) may not be the same as the average differentials. On the one hand it could be argued that the average yields of transplanted rice are lower than the yields obtained on the marginal land because the averages include the low yields of the transplanted rice grown on the high levee soils, which tend to be droughty. On the other hand, it could be argued that the average yields of broadcast rice are lower than the marginal, since the land on which the method of planting shifted may have had, even before the construction of the water control system, water conditions which were better than average for broadcast areas. The former line of reasoning would lead to the conclusion that the use of the average data underestimates the true differentials, while the latter argument would suggest just the opposite. Admitting the possibility that both arguments have some validity leaves the direction of the bias indeterminate.

In the absence of any better information, the average differentials were used to estimate that the shift in the method of planting has resulted in an increase in average annual production of 23,200 metric tons of paddy. Of this total, 19,300 tons came from the BT region, and the remainder from the CB region (Table 1, line 3.1).

TABLE 1

COMPONENTS OF THE INCREASE IN WET SEASON PADDY PRODUCTION

| Component | Increase in Average Annual Production (thousand metric tons) | | | |
|---|---|---|---|---|
| | BT Region | CB Region | SB Region | Total |
| 1.0 Total | 172.6 | 58.7 | 14.8 | 246.1 |
| 2.0 Factors unrelated to water control | 42.6 | 21.2 | 14.8 | 78.6 |
| 2.1 Weather | 0.5 | 16.8 | 8.4 | 25.7 |
| 2.2 Fertilizer | 15.0 | 0.4 | 1.4 | 16.8 |
| 2.3 Pesticides | 3.3 | 1.5 | 1.4 | 6.2 |
| 2.4 Improved Management | 23.8 | 2.5 | 3.6 | 29.9 |
| 3.0 Factors related to water control | 130.0 | 37.5 | 0.0 | 167.5 |
| 3.1 Method of planting | 19.3 | 3.9 | 0.0 | 23.2 |
| 3.2 Reduction in damage | 37.6 | 0.0 | 0.0 | 37.6 |
| 3.3 Other increase in yield (residual) | 73.1 | 33.6 | 0.0 | 106.7 |

2. Decrease in damaged area. To consider the effect of the water control system on the amount of damaged area, data on the mean values for the percentage damaged in the "before" and "after" periods were examined for each of the agricultural regions. Because the distribution of the data on percentage damaged is distinctly non-normal, a nonparametric statistical technique, the rank-sum test, was used to evaluate the significance of the observed differences. The analysis indicated that there has been a significant decline in the percentage of the planted area which is damaged in the BT region, but that there have been no significant changes in the two regions comprising the deeply flooded portion of the project area. The observed but non-significant differences in the CB and SB regions were presumably caused by random differences in weather (see line 2.1 of Table 1). For the BT region, there was a decline from an average of 9 percent of the area damaged in the "before" period to 3 percent in the "after" period, resulting in an increase in the average annual area harvested of approximately 18,000 hectares.

As in the case with the analysis of the change in the method of planting, it is necessary to consider various factors which might have caused the observed changes in the amount of damaged area. Given the substantial year-to-year fluctuations in weather conditions, it might be argued that much or all of the decrease in damaged area in the BT region was caused not by the operation of the water control system, but by relatively better weather conditions during the "after" period. To examine this possibility a multiple regression model was developed. Initially the model included both trend and dummy variables, as well as several variables reflecting weather conditions. The lack of significance of the trend variable caused it to be dropped from the model. Because the non-normality of the distribution of the dependent variable results in the violation of the assumptions of the classical least squares model, a square root transformation was applied to the data on the percent damaged in order to achieve a variable with a more nearly normal distribution.[23]

In spite of the complexity of the effects of weather on production, it was found that significant relationships could be established between the variable representing the percent of the area damaged and a small number of weather variables.[24] The analysis suggests that in the BT region there has been a reduction of 17,000 hectares in the average annual amount of damaged area, even after accounting for differences in weather between the "before" and "after" periods. This analysis thus modifies only slightly the original estimates based on the observed means.

Although this is one more bit of evidence in favor of the hypothesis that the water control system is the major cause of the reduction in damage, it might still be argued that this reduction is due to other non-weather factors which have not been included in the analysis. To examine this possibility a comparison was made with the Mae Klong state II area. No significant difference in the amount of damaged aread between the two periods could be detected for this region. It thus appears that the factors causing the decline in the percent damaged in the Chao Phya project area were not operative in the Mae Klong area, from which I conclude that the water control system is the probable cause of this decline. From the production data I estimate that the increase in average annual production resulting from this reduction in damaged area is approximately 37,600 metric tons of paddy (Table 1).

3. Increase in yield per unit area harvested. It was previously noted that any decline in the area which is left unharvested due to damage would presumably be accompanied by an increase in production in areas that, in the absence of the system, would have suffered reduced yields from unfavorable water conditions. Because there is no direct way to measure the magnitude of this effect, it is necessary to estimate it as a residual after attempting to account for all other sources of increased production.

To consider the effect of weather, multiple regression was again used. Although significant coefficients for weather variables were obtained in the BT and CB regions, the results indicate that the systematic differences in weather accounted for only minor differences in production between the two periods. In the SB region a non-significant increase in production was assumed to be related mainly to random differences in weather.

A second source of increased production between the "before" and "after" periods is fertilizer. Estimation of the production effect of this factor is based on data from two farm surveys conducted by agencies of the Thai government.[25] These surveys demonstrate that the total amount of fertilizer used in the project area is small. Furthermore, rates of application are quite low. A mixed fertilizer, such as 16-20-0, is commonly used, with application rates generally on the order of from 25 to 150 kilograms of fertilizer per hectare. From the DAE survey data I estimated the total amount of fertilizer used on rice in the project area in 1970 to have been approximately 10,500 tons. Of this amount, 9,400 tons were applied in the BT region, while only 1,100 tons were used in the CB and SB regions.

Prior to the completion of the water control project, a negligible amount of fertilizer was used on rice in the project area. Total imports of fertilizer into Thailand during the "before" period averaged only 34,000 tons per year.[26] A large proportion of this was probably used on high value crops such as vegetables, with virtually none being used on rice.[27] By contrast, imports of fertilizer by the end of the 1960's were approximately 250,000 tons, to which must be added 35,000 tons of domestic production.[28] It has been estimated that about half this amount was used on rice.[29] For the purpose of this study it is assumed that no fertilizer was used during the "before" period, and that use expanded at a linear rate during the "after" period. These assumptions imply that the increase in the average amount of fertilizer used was equal to one-half of the total 1970 use, or an estimated 5,250 tons.

In order to estimate the effect of this fertilizer on production, I analyzed the individual farm data from the Sam Chuk survey, (see footnote 15). The analysis suggested that there is a generally linear response to fertilizer at the low levels of application which prevail, with one kilogram of fertilizer increasing production by approximately 3.2 kilograms of paddy.[30] These results are consistent with the findings of other researchers who have worked in the Central Plain of Thailand.[31] I therefore estimate that the use of fertilizer accounts for approximately 16,800 tons of the increase in paddy production between the "before" and "after" periods.

If the existence of the water control system has stimulated the use of fertilizers, then it could be argued that the resulting increase in production should be considered to be another effect of improved water control. Examination of data from the Mae Klong stage II area, however, reveals that the use of fertilizer is as great or greater in that area, which lacks water control facilities, as it is in the Chao Phya project area. The increase in production caused by fertilizer is therefore considered to be unrelated to the water control system (Table 1).

Another factor which has resulted in a small increase in production is the use of pesticides and herbicides. Based on data from the DAE and the Sam Chuk surveys, I estimate the 1970 production effect of these chemicals to be about 6,200 tons of paddy. Because these chemicals have been used longer than fertilizer, I have assumed that their effect on the average amount of production in the "after" period is equal to the estimated production effect for 1970. As in the case with fertilizer, there is no evidence that the use of these chemicals is related to the water control system.

Weather, fertilizers and pesticides have thus been identified as factors which, while unrelated to water control, have caused part of the observed increase in yields in the Chao Phya project. It is now necessary to determine whether or not there are any other sources of increased production unrelated to the water control system. To do this, the production effects of weather, fertilizer, and pesticides were estimated for the Mae Klong region, using the same procedures used in the Chao Phya region. It was found that these three factors accounted for only part of the increase in production, leaving an unexplained residual of about 150 kilograms per hectare. Since there has been no significant improvement in water control in the Mae Klong area, there must be other factors not yet considered which have caused this residual. Presumably these other factors have also been operative in the Chao Phya area, and, therefore, must be considered before the effect of the water control system can be estimated.

One possible factor is the increased use of better rice varieties. For many years the Rice Department has encouraged the production of selected local rice varieties which appear to give somewhat higher yields than other local varieties. No data are available on the use of these varieties, and interviews with local extension officials revealed that very little is known about the extent to which they are being grown by farmers. Another possibility is that there has been a gradual improvement in the management procedures of the farmers. The increased use of chemicals indicates that farmers have become aware of new techniques of farming. Since these chemicals are generally most effective when combined with other practices such as more careful land preparation, better timing of transplanting, and more weeding, it seems reasonable to assume that farmers who have learned to use the chemical inputs have also gradually learned some of the complementary management techniques. It is also possible that there has been an improvement in production techniques resulting from population growth. As the amount of labor has increased relative to the amount of land available for cultivation, the farmers presumably have had an incentive to adopt more labor-intensive methods of cultivation, leading to higher yields per unit area.

Although it is not possible to obtain independent estimates of the importance of any of these factors, their total effect in the Mae Klong area can be estimated from the unexplained residual increase in production. If these same factors operate with equal strength in the Chao Phya area, the estimate from the Mae Klong region can then be used as the basis for estimating the importance of these factors in the Chao Phya area. Assuming that most of this increase in production is due to improved management practices associated with the use of chemicals, then it is reasonable to assume that the ratio between the increase caused by improved management and the increase caused by the use of chemicals will be the same in both the Mae Klong and Chao Phya regions. This leads to an estimate that improved management has resulted in an increase in production equal to 1.3 times the increase due to the use of the chemical inputs. For the Chao Phya region this implies an increase in production of nearly 30,000 tons of paddy (Table 1).

Having estimated the importance of the four factors which are unrelated to the water control system, and of two of the effects of the system, it is now possible to estimate the third effect of improved water control as a final residual. As is shown in line 3.3 of Table 1, this third effect is estimated to account for 107,000 tons of the average annual production of the "after" period, which is nearly 65 percent of the total increase in production due to the water control system.

4. Appraisal of the Estimates. The water control system is thus estimated to have increased the average annual wet season production of paddy by nearly 170,000 tons, which is approximately 15 percent of the average production of the project area. Over three-fourths of this increase is in the BT region, where the increase is equal to 20 percent of the average production. In the CB region the increase is equal to about 15 percent of the average production. Only in the SB region has the water control project had no discernible effect on production.

Contrary to the claims already noted (see footnote 18), the analysis does not support the contention that conditions in the CB region have deteriorated becuase of the water control system. It is, of course, possible that conditions in relatively small areas have been made worse, but that reduced production in these areas has been more than offset by increased production in the rest of the region. A second possibility is that a deterioration in production conditions took place with the completion of theChao Phya dam in 1956. The dam might have altered the natural flooding patterns enough to cause agricultural production, which had been adjusted to the natural flooding conditions, to become less stable. Since time series data for the CB region are not available prior to 1955, such a change would not have been detected by the above anaylsis.[32] Still a third possibility is that the perceptions of the farmers regarding the effect of the system are wrong. The production data show that rice production in the CB region is still much less stable than in any of the other agricultural regions. Damage in 1964 (a year of a major flood) was 54 percent of the planted area, and damage since that year has averaged 10 percent. In the context of such fluctuation, the concept of average conditions is not a very useful one at the individual farm level, and it would not be surprising to find that farmers were unable to identify a 15 percent increase in average production. But it is easy for the farmers to identify one change that has occured: the diversion of the river water into man-made channels. Before the system had been built the farmer could only blame nature for the disasters that destroyed his rice crop; now he can always suspect (perhaps with some justification) that the disaster which came through the canals of the Royal Irrigation Department could have been avoided if the system had been managed in a different way. The farmer's lack of understanding of the engineering and hydraulic limitations of the system would only serve to reinforce his belief that human mismanagement was responsible for his crop loss. Under these conditions, it would be very easy for farmers to feel that production conditions have been made worse by the water control system.

In attempting to evaluate the validity of my analysis of the wet season effects of the water control system, a comparison with one other source of farmer estimates is of interest. In the Sam Chuk survey, each farmer was asked to estimate both his "normal" five-year average yield and the yield he obtained prior to irrigation. The average increase in production implied by the answers of the 50 farmers who responded was about 1,060 kilograms per hectare. While this is a total figure, and as such cannot be entirely attributed to improved water control, it is substantially larger than the total differences observed in the Rice Department data for the area covered by the Sam Chuk survey. It therefore raised the possibility that my analysis, which treated much of the effect of the water control system as a residual, underestimated the impact of the system because the production data did not fully reflect the change in yields that had taken place. Several alternative explanations are, however, possible.

First, the Sam Chuk survey was conducted in one of the two subprojects which had been constructed prior to 1950. It is thus not clear that the time period which a farmer had in mind when he estimated his yield "prior to irrigation" corresponds at all closely to the "before" period used in this analysis. Second, it may be that the farmers, knowing that the people who were questioning them were connected with the Royal Irrigation Department, deliberately lowered their estimates of the yields obtained prior to irrigation in order to please the officials. A third possibility is that the farmers may unintentionally tend to overstate the increase in yields. The concept of an average yield (in the sense of an arithmetic mean) may have little meaning to farmers who, with little formal education, face large fluctuations in annual yields. If it is further assumed that the farmers' perceptions of the effect of the irrigation system were that it had greatly reduced the frequency of the very disastrous years, it seems reasonable to suggest that an interview which caused them to focus their thought on the effects of the irrigation system would also tend to focus their thoughts on the very disastrous years of the past. Thus, the response to the question of yields prior to irrigation may reflect yields in the bad years better than average yields. Considering the Rice Department data for the area of the Sam Chuk survey, it was found that the differences between the average yields in the "after" period and the yields in the three worst years of the seven-year "before" period were 1,100, 931, and 769 kilograms per hectare. As noted above, the average differences reported by the farmers was 1,060 kilograms per hectare.

While it is thus possible that the farmers' responses in the Sam Chuk survey are consistent with the aggregate data on which the analysis in this study is based, it is not possible to rule out any of the other alternative explanations. Only with additional research at the micro level to ascertain the response of rice to water will it become possible to better evaluate these alternative explanations, and to state with greater confidence the effects of the system on wet season rice production in the project area.

## Dry Season Effects

As noted in Chapter 2, until the mid 1960's very little emphasis was placed on the use of the water control system to support dry season production. Because the dam at Chainat could only divert water flowing in the river, the very low volume of flow during the dry season made it impossible to provide much of any water for irrigation. Since 1964, the operation of the Bhumiphol storage dam has resulted in some additional flow during the dry season, thus increasing the possibilities of dry season irrigation. In this section the changes in dry season production which have occurred since 1964 are examined.

Data for 1964, 1970 and 1971 on the area planted to various categories of dry season crops are presented in the first three columns of Table 2. Considering that in the wet season, 600,000 hectares of rice are grown in the project area, these figures demonstrate the relative unimportance of dry season production in the Greater Chao Phya project. Even in 1971, dry season crops occupied less than 5 percent of the area planted in the wet season. To investigate the effect of the water control system on this dry season production, it is necessary to consider each of the crops listed in Table 2.

There has been little change since 1964 in the total area planted either to vegetables or to perennial crops. This suggests that the production of these crops has not been greatly affected by the water control system. Consideration of the methods of production supports this conclusion. Perennials are usually grown around farmers' houses, on the high levee soils along the banks of rivers and natural canals. It is very unlikely that any substantial portion of the 7,400 hectares reported in 1966 had been planted because of the increased supply of water available from the irrigation canals. While data on the area of these perennial crops are notoriously unreliable, the complete absence of a trend since 1966 suggests that any changes that have taken place have been so small and scattered that they have failed to attract the attention of local officials. Vegetable production also tends to be in small plots near the homes of farmers. These plots are generally irrigated with water carried or pumped from a nearby stream or river. Given this pattern of production, it is reasonable to assume that virtually none of the 1964 vegetable production was dependent on the irrigation system. While the availability of irrigation water may have made increased production technically possible, the failure of vegetable production to show much expansion suggests that it is limited by other factors such as effective demand.

Unlike perennial crops and vegetables, sugarcane is highly concentrated in one portion of the BT region. The area is served by the

TABLE 2

DRY SEASON CROP PRODUCTION IN THE PROJECT AREA

| | Total Production (thousand hectares) | | | Area Dependent on the Water Control System (thousand hectares) | |
|---|---|---|---|---|---|
| | 1964 | 1970 | 1971 | 1970 | 1971 |
| 1. All dry season crops | 4.7 | 14.5 | 16.5 | 7.7 | 10.6 |
| a. Vegetables | 0.9 | 1.2 | 0.9 | 0.0 | 0.0 |
| b. Watermelons | NA[a] | 4.8 | 1.1 | 4.5 | 0.8 |
| c. Rice | 1.7 | 4.7 | 11.5 | 3.2 | 9.8 |
| d. Other field crops | 2.1[a] | 3.8 | 3.0 | 0.0 | 0.0 |
| 2. Sugarcane | 4.4[b] | 2.8 | 2.5 | 2.7 | 2.5 |
| 3. Perennial crops | 7.4[c] | 7.5 | 7.5 | 0.0 | 0.0 |
| 4. Total | 16.5 | 24.8 | 26.5 | 10.4 | 13.1 |

[a]Watermelon production in 1964 is included in the category "other field crops". In 1966, the first year for which complete data on watermelon production are available, the total area planted to watermelons was 800 hectares.

[b]1965 figure, as complete data for 1964 area unavailable.

[c]1966 figure, as complete data for 1964 and 1965 are unavailable.

Sam Chuk water control subproject, which was mostly built prior to World War II. Since the construction of the Chao Phya Dam, the area has received priority for water in the dry season, making possible the production of sugarcane. In recent years there has been a considerable decline in the area planted, which local officials feel has been caused by a decline in the price of sugarcane. Inadequate price data and a lack of information on marketing arrangements made it impossible to investigate this proposition. In any case, it appears that virtually all of the sugarcane production is dependent on the water control system (Table 2). At an average yield of 37.5 tons per hectare, the production in 1971 of nearly 94,000 tons of sugarcane can thus be attributed to the water control system.

Watermelons are listed separately in Table 2 because of their nature as a specialty crop. Two separate areas of production can be identified. In parts of the CB region, farmers have produced watermelons for many years. Data for 1966 (the first year for which separate data on watermelon production are available) indicate some 770 hectares produced in this area. Production declined to about 230 hectares in 1968, and has remained at about that level. Most of these watermelons are probably grown as a vegetable, with the fruit being harvested while still very immature. It is unlikely that production in this area is dependent on water from the irrigation system. Watermelons are also grown in a portion of the BT region. There were virtually no melons grown in this area in 1966, but in the following years production (for ripe melons) increased very rapidly, reaching a peak of about 4,500 hectares in 1970. The fact that irrigation water has been quite readily available in this area (due in part to the priority which the area has received because of the production of sugarcane) has been important in stimulating this growth.[33] Although most of the watermelons are marketed outside the area, the high production of 1970 glutted the market, resulting in very low farm prices. This in turn led to a major decline in production, with only about 800 hectares planted in 1971. Based on the average yield of 9.4 tons per hectare, the water control system thus accounted for approximately 42,000 tons of watermelons in 1970, and 7,500 tons in 1971.

Production of dry season rice has also been stimulated by the availability of irrigation water. Prior to the completion of the Bhumiphol Dam, the Thai government embarked upon a program to encourage the production of a second crop of rice. Large pumps supplied and operated by the Ministry of Interior were used to provide the necessary water. It is probable that much of the 1,700 hectares of the rice grown in the project area in 1964 was under this program (Table 2). But the program was costly to the government and over time it declined in importance, so that by 1966, dry season rice production in the project area had dropped to less than 1,000 hectares. Since 1966, however, production has expanded. Part of the reported growth represents a shift in the timing of the production of the annual rice crop. Thus some farmers in the SB region no longer plant rice before the annual flood. Instead varieties which mature in a short time are planted when the flood waters recede. While such an "off-season" crop may depend to some extent on water which is retained on the land by control structures located south of the project area, it is not irrigated in the usual sense. Thus it does not appear that the crop is dependent upon the water control system of the project area.

The most striking feature about the growth in rice production since 1966, however, is the recent increase in the amount of production which is dependent on the water control system. From an estimated 3,200 hectares in 1970, the area dependent on the irrigation system increased to 9,800 hectares in 1971. One might be tempted to assume that this is a temporary phenomenon related to the fact that in some areas many farmers lost their entire wet season crop due to the 1970 flood. Examination of the data, however, reveals that over three-fourths of the entire increase in production occurred in the same area where sugarcane and watermelon production is concentrated. As there was no serious flood damage in this area, other explanations for the increase in production must be sought. One factor may have been the reduction in watermelon production, with farmers who had previously produced watermelons switching to rice in 1971. But probably the most important factor was the increased availability of seed of two high-yielding rice varieties which had been released for general production in 1969.[34] Because they produce a high yield in a short period of time, these varieties are especially well suited for dry season production. It is important to note, however, that the expansion of production occurred only in an area where there was a relatively assured supply of dry season irrigation water as well as a supply of seed of the new varieties. Both inputs thus appear to be critical to the expansion of dry season rice production.

The remaining item in Table 2 is that of "other field crops". The chief component is mungbeans with smaller amounts of peanuts, maize, soybeans, and sesame. Over half of the production of these crops is in the CB region. Interviews with local agricultural officials and with farmers indicated that substantial areas of these crops receive little or no irrigation, with production dependent on residual moisture and on the light rainfall that occurs during the dry season. It appears from the large year-to-year fluctuations that the area planted to these crops may depend on the amount of rain which falls early in the dry season. To examine this possibility, regression analysis was used, with the area planted to "other field crops" as the dependent variable. Both a time trend and variables reflecting dry season rainfall were examined as independent variable. Although the analysis was limited by the fact that data are available for only seven years, the results tend to confirm the importance of rainfall in December and January. Efforts to include a trend variable either with or without the rainfall variable proved unsuccessful. Equations estimated for the other regions with much smaller areas planted were less significant, but also suggested the importance of rainfall. On the basis of these results, I conclude that the water control system has had very little effect on the production of these field crops.

The dry season production effects of the water control system have thus been limited to three crops: sugarcane, watermelons, and rice. Geographically, these effects have been limited almost exclusively to the BT region. Of the 13,100 hectares of dry season crops dependent on the water control system in 1971 (Table 2), all were in the BT region except for 300 hectares of rice grown in the CB region.

## The Value of the Returns to Water Control

### Gross Value

Having estimated the effects of the water control system on production in both the wet and the dry seasons, the gross value of these effects can be determined once the value per unit of production of each of the three crops is known. For sugarcane and watermelons, the appropriate values to use are the average farm prices, which are estimated to be $6.25 per ton of sugarcane and $.10 per kilogram of watermelons. For paddy, however, the farm price does not reflect the true value of the crop to Thailand, because a heavy export tax on rice (generally called the rice premium) has held domestic prices considerably below the prices prevailing in international markets.[35] Since Thailand exports its surplus rice, it is appropriate to assume that all of the increase in paddy production resulting from the water control system is exported. A price reflecting the true value to Thailand of this paddy must take into account the increase in government revenues from the taxes on these exports.

While there has been considerable controversy over the exact effect of the rice premium on the farm price of paddy, some calculations by Usher resulting from his investigation of rice marketing in Thailand provide a basis for adjusting the farm price of paddy to more nearly reflect its true value to the nation.[36] Usher estimated the marketing costs and the rice price at each stage in the marketing process from the purchase of paddy at the farm to the ultimate export of the milled rice. The total marketing costs, including profits, amounted to about 20 percent of the export proceeds after the government taxes had been subtracted. Usher argues that the removal of the rice premium would have little effect on marketing costs in the short run. While these costs might rise some in the long run, because of increased wages stemming from a higher domestic price of rice, he argues that the farmers would, at the very least, maintain their share of the rice price.

Based on the above line of reasoning, it is assumed that a minimum of 80 percent of the export price of rice is the farm share that would prevail if there were no tax. With an average milling yield of 670 kilograms of rice from one ton of paddy, the minimum farm price of paddy which would exist without the rice export taxes can be calculated as equal to 54 percent of the export price of milled rice. This adjusted farm price was calculated for each year from 1962 to 1970 based on the average export price of rice, as determined from data on the total volume and value of rice exports. The average adjusted farm paddy price for this period is approximately $.07 per kilogram. This price is used in the calculation of the average annual benefits of the water control system for the period 1962-1970. But paddy prices have declined since 1966, with a very sharp drop in 1971, so that prices in future years are likely to be lower than in the past decade. To calculate the gross value of the estimated benefits of the water control system for future years, two alternative assumptions have been made. The first assumption is that paddy prices will remain at the estimated 1971 level of $.05 per kilogram. The second is based on the judgement that prices in 1971 were unusually depressed, and that the 1970 price of $.06 per kilogram is a better estimate of the level that will prevail in the future.

The calculated gross values of the production benefits of the water control system are presented in Table 3. The wet season figures are on an average annual basis, while the figures for the dry season represent the benefits for 1971 only. Dry season benefits for years prior to 1969 were virtually nonexistent.

## Net Value

The additional production resulting from the water control system entails certain increases in costs. For wet season rice production, the major change is in the input of labor. More labor is required at the time of transplanting because of the shift in the method of planting, while the reduction in damaged area and the increase in average yield per unit area harvested both increase the requirement for labor at harvest time.

But it is not possible to determine with precision the magnitude of this increase. Because of the difficulties of accurately measuring the amount of labor used for various farm operations, most farm management studies provide only general estimates of labor use. Furthermore, there is considerable variability among farms in the amount of labor used, so that even very accurate measurements made on a few farms are of limited value in determining the effect of the water control system on the input of labor in the entire project area. Based on an examination of data from a number of studies and surveys of farm practices in the project area, I estimate that the total increase in the input of labor made necessary by the water control system is on the order of from 41 to 57 million man-hours.[37]

To estimate the effect of the water control system on the cost of production, a value must be imputed to this family labor. Since the project is analyzed in terms of its production effects on society, the opportunity cost to society of this labor must be evaluated. Considering the fact that rice is virtually the only crop planted in the wet season, and assuming that the existence of the water control system has not affected the total amount of labor available in the project area, then the opportunity cost of this labor must be in the form of foregone rice production. Specifically, it is the additional production of rice which would have occurred if this labor had been available for other tasks such as more timely transplanting. Conceptually, the increase in rice production actually observed in the time series data represents the total increase which would have occurred if labor had been more abundant, minus the opportunity cost of the additional labor made necessary by the water control system. Because the analysis of the effects of the system is based on the observed increases in production, the opportunity cost of this labor is implicitly included. It would be incorrect to include it a second time by inputing some positive monetary value to it. A zero opportunity cost for the additional wet season family labor has therefore been used in calculating the increase in the cost associated with the additional production.

The increase in production also implies some increase in the amount of hired labor used. But insofar as the total supply of hired labor is inelastic during the two periods of peak demand, the increase in the quantity

TABLE 3

VALUE OF THE CROP PRODUCTION BENEFITS OF THE WATER CONTROL SYSTEM

(Million Dollars)

| Item | Gross Value | Net Value |
|---|---|---|
| 1. Wet Season | | |
| a. Average per year, 1962-1970 | 11.73 | 11.64 |
| b. Average per year after 1970 if paddy price is: | | |
| $.050 per kilogram | 8.38 | 8.29 |
| $.060 per kilogram | 10.05 | 9.96 |
| 2. Dry Season (value for 1971) | | |
| a. Sugarcane, if paddy price is: | | |
| $.050 per kilogram | 0.59 | 0.05 |
| $.060 per kilogram | 0.59 | 0.00 |
| b. Watermelon | 0.75 | 0.59 |
| c. Rice, if paddy price is: | | |
| $.050 per kilogram | 1.38 | 0.95 |
| $.060 per kilogram | 1.65 | 1.22 |

used on some farms must be offset by a decrease on other farms, so that the net effect on the social cost of production is zero. And to the extent that the increase represents a net increase in the amount of labor performed by the individuals living in the project area, the opportunity cost to society can again be considered to be zero. Thus no charge has been made for the additional hired labor.

The only other change in the cost of wet season rice production resulting from the water control system is that associated with the increased use of small water pumps. These pumps are frequently used by farmers to pump water onto fields from the canals and ditches of the water control system. I have estimated that in 1970, farmers used pumps on about 52,800 hectares, at an average cost of $1.60 per hectare.[38] It is assumed that without the water control system there would have been no pumping, since there would have been fewer sources of water from which to pump. Under these assumptions, the increased cost of pumping due to the water control system is about $85,000 per year. Subtracting this figure from the figures for the gross value of the benefits for the wet season results in estimates of the net value of the wet season production benefits of the water control system. These figures are shown in the second column of Table 3.

The dry season benefits of the water control system all result from production which would not have taken place in the absence of the system. It is therefore necessary to subtract the entire cost of this production from the gross benefits. For dry season rice, the cost of production, exclusive of family labor, is estimated to be $59.40 per hectare. This figure includes $9.70 for slightly over 90 kilograms of fertilizer, $25.00 for 62.5 hours of pumping, and $15.30 for 200 man-hours of hired labor.[39] In addition, it is estimated that from 490 to 770 man-hours of family labor are required per hectare of dry season rice production. As in the case of wet season production, the opportunity cost of this family labor must be considered. For labor in the dry season, the opportunity cost is largely the farmer's foregone enjoyment of leisure activities. The farmer will be unwilling to engage in production unless he receives returns to his labor which are large enough to cover these subjective costs. But from the point of view of national production, it is appropriate to consider this labor to have an opportunity cost which is close to zero. A similar argument can be made concerning hired labor. While it is definitely a cost of production from the point of view of the farmer, it would seem to have a near zero opportunity cost from a social production point of view. For the purpose of evaluating the water control system, the cost of production of dry season rice is thus estimated to be $44.10 per hectare. Subtracting this cost from the gross value of the benefits resulting from dry season rice production gives an estimated net benefit of $950,000 at paddy price of $.05 per kilogram, or $1,220,000 at a price of $.06 (Table 3).

Net values for the production benefits for sugarcane and watermelons are also shown in Table 3. Since sugarcane competes with wet season rice for land, it is necessary to subtract not only the production costs of sugarcane, but also an amount equal to the net value of the rice which would have been grown if the water control system had not been built. For this reason, the net value of sugarcane is shown at the two alternative paddy prices. These estimates suggest that the net benefits resulting from the production of sugarcane are practically zero.

In the final section of this chapter the net benefits discussed in this section are compared with the costs of the water control project in order to evaluate the return on the investment. But it is also useful to compare these benefits with the total net cash returns from crop production earned by farmers. Such a comparison suggests that as a result of the water control system, there has been a 25 percent increase in the aggregate net cash income which the farmers of the project area receive from crop production.[40]

## The Cost of the Water Control System

The bulk of the construction of the Greater Chao Phya project took place in the ten-year period beginning in 1952. The construction of the Chao Phya dam itself, and of some of the headworks on the main canals of the system took place from 1952 to about 1956. Much of the construction of the canals and laterals took place between 1956 and the early 1960's. But construction did not end with the "completion" of the project. The Ditches and Dikes program, which began about 1963, added many ditches to the original network of distribution canals. Under a drainage program, begun in 1965 and currently projected to continue until 1980, an entire network of drainage canals within the project area is being constructed. The Bhumiphol multipurpose dam, constructed in the early 1960's has also affected water conditions in the project area. Likewise, the Sirikit dam, which is currently under construction on another of the tributaries of the Chao Phya will provide additional water for future dry season irrigation. Finally, it must be recalled that two of the subprojects were in partial operation during the wet season many years prior to the construction of the Chao Phya dam.

An economic evaluation of the costs requires information on expenditures at different points in time. Ideally, the cost data would permit the calculation of expenditures for each year. Such detailed information is available only for expenditures for the drainage canals and for the ditches and dikes. For the remaing costs, the only estimates available are for the total amount spent for each major segment of the project (such as the Chao Phya dam). The costs of the system as estimated by RID are presented in the first column of Table 4. The figure of $27.5 million for the Bhumiphol dam is 25 percent of the total construction cost of the dam. This is an arbitrary allocation of the cost of this multipurpose dam, based on the procedures of the Bureau of Reclamation. Since the dam is operated primarily for power production, it may be unrealistic to allocate such a large percentage of the cost to the Chao Phya project.

In order to evaluate these costs it is necessary to adjust them to reflect their value at a common point in time. The year 1961 was chosen for this, since it is the last year of the "before" period. Using an annual interest rate of 5 percent, costs incurred prior to 1961 were adjusted upward, while costs incurred after 1961 were discounted (also at 5 percent) to relfect their 1961 value. These adjusted costs are shown in the last two columns of Table 4. Since exact information on the timing of the expenditures was not available, certain working assumptions have been made, all of which involve assuming that the entire cost of a given item was incurred in a single year, generally near the mid-point of the construction period for that item. Thus it is assumed that the entire

TABLE 4

CONSTRUCTION COSTS OF THE WATER CONTROL SYSTEM

| Item | Reported costs (million dollars) | Reported Costs Adjusted to 1961 Value (million dollars) | Adjusted Costs per hectare[a] (dollars) |
|---|---|---|---|
| 1. Chao Phya Dam | 19.3 | 27.1 | 45.50 |
| 2. Canals and laterals | 51.3 | 59.5 | 99.80 |
| 3. Ditches and dikes | 4.0 | 3.3 | 5.50 |
| 4. Drainage canals | 5.2 | 3.8 | 6.40 |
| 5. Initial structures and canals in Sam Chuk and Pho Phraya | 1.2 | 2.1 | 3.50 |
| 6. Subtotal | 81.2 | 95.8 | 160.70 |
| 7. Bhumiphol Dam | 27.5 | 26.2 | 44.00 |
| 8. Total | 108.5 | 122.0 | 204.70 |

[a]Based on the total area planted within the project area, estimated to be 596,000 hectares.

Source:

Food and Agriculture Organization, United Nations Development Program Survey Mission for the Chao Phya Delta, Thailand, Report to the United Nations Development Programme, 4 February to 30 April, 1968 (Rome: EA:SF/THA/68, April 30, 1968), Appendix 1; Thailand, Royal Irrigation Department, Thi Raluk nay Kan Poet Khuan Chao Phya (in Thai) [Memorial on the Occasion of the Opening of the Chao Phya Dam] (Bangkok, February 7, 1957); and unpublished data furnished by the Royal Irrigation Department.

expenditure for the Chao Phya dam occurred in 1954; for the canals and laterals in 1958; for the Bhumiphol dam in 1962; and for the Sam Chuk and Pho Phraya projects in 1950.

In the economic analysis of public investment in low income countries it is often assumed that some of the money costs of the construction of the project are greater than the social costs. The most important item in this respect is unskilled labor. To the extent to which the money wages paid for labor are greater than the opportunity cost of that labor, the money costs of the project overstate the true social costs. Unfortunately, it has not been possible to obtain the disaggregation of the cost figures necessary to permit any adjustments to be made for the opportunity cost of labor. It could thus be argued that the costs presented in Table 4 overestimate the actual social costs. However, the construction techniques used were relatively capital intensive, with machinery being used for most of the earthmoving. Thus it is not likely that an adjustment of the cost data to reflect the opportunity cost of unskilled labor would have a major effect on the analysis.

Upon the official completion of the construction of the project, responsibility was transferred from the Construction Division of RID to the Operation and Maintenance Division. Data on the operation and maintenance costs incurred for each of the subprojects for each year were obtained from the Operation and Maintenance Division of RID. There has been a steady increase in the average operation and maintenance costs from about $1.90 per hectare in 1964 to $4.90 in 1970. This increase does not reflect an increase in the problems encountered in maintaining the system. The expenditure levels of the early years were generally regarded as insufficient to provide adequate, long-term maintenance of the project.[41] Thus the increase in costs represents gradual improvement in the quality of the maintenance.

## Measures of the Returns to Investment in Water Control

Having estimated both the net crop production benefits and the costs of the water control system, it is possible to calculate various measures of the returns to the investment. Two of the commonly used measures are the benefit-cost ratio and the internal rate of return. Both of these measures involve discounting to permit the comparison of the costs and benefits at a common point in time. For the benefit-cost analysis, the analyst must select the discount rate to be used. The measure then shows the ratio of the discounted annual benefits to the sum of the construction costs plus the discounted annual operation and maintenance costs. The higher the discount rate selected, the lower will be the benefit-cost ratio. Since it is often difficult to determine the appropriate discount rate to use, an alternative approach is to calculate the discount rate at which the benefit-cost ratio would have a value of 1.0. This rate is called the internal rate of return.[42] The use of either measure requires that the length of time for which the project is to be evaluated be specified.

In this section internal rates of return are presented for a variety of alternative assumptions. In all cases, however, the analysis assumes that the construction costs were incurred in 1961; that the wet season benefits began in 1962 and continued throughout the period of analysis at the level shown in Table 3; and that the operation and maintenance costs were at the levels reported by RID for the years 1964 to 1970, and at the 1970 level for all subsequent years.

In the first line of Table 5, three rates of return are presented based on a paddy price of $0.07 per kilogram for the period 1962-1970, and on a price of $0.06 per kilogram for the remainder of the 25 year period of analysis. If only wet season benefits are considered, the internal rate of return is estimated to be 8.0 percent. Since dry season benefits were ignored, the cost of the Bhumiphol dam was not included in this calculation. Alternative estimates of the internal rate of return when dry season benefits are included are presented in the last two columns of Table 5. For these calculations it was assumed that the dry season benefits shown in Table 3 began in 1969, and continued at the same level to the end of the period of analysis. The two estimates represent two extreme possibilities concerning the allocation of the cost of the Bhumiphol dam. In the second column the cost of the dam was ignored, while in the last column the full 25 percent of the total construction cost was used. Comparing the figures in the first two columns of the first line, it can be seen that including the dry season benefits while holding the assumed system costs constant raises the estimated rate of return by 1.3 percentage points. A comparison of the first and last columns shows that the addition of both the dry season benefits and the full 25 percent of the cost of the Bhumiphol dam results in a decrease in the rate of return by 1.7 percentage points. These figures thus emphasize once again the relative unimportance of dry season benefits in the overall returns to the water control system.

Because the 1971 adjusted paddy price was approximately $0.05 per kilogram, it might be argued that it would be more appropriate to estimate the rate of return on the assumption that the future price of paddy will be at this level. This results in a rate of return of about 7 percent if only wet season benefits are included. If dry season benefits are included, the rate of return ranges from 5 to 8 percent, depending on the portion of the cost of the Bhumiphol dam which is allocated to the water control system.

While I regard it somewhat tenous to carry the analysis beyond a 25-year period, rates of return were calculated for periods of 35 and 45 years to observe the extent to which the estimated rate of return would rise. These results are shown in lines 2 and 3 of Table 5. It will be observed that the effect of lengthening the period of analysis is modest, with the rates of return for the 45-year period about 1 percentage point higher than in the case of the 25-year period.

One final calculation was made to investigate the effect of assuming that the benefits from dry season cropping will expand in the future. While there are various plans for the expansion of dry season cropping which involve additional investment in the water control system, it seems likely, based on experience in 1970 and 1971, that there could be some increase in dry season production even without any further investment, and even without the additional water which will soon become available as a result of the completion of the Sirikit dam. Under the assumption that dry season benefits would double in 1974 and then double again in 1979, the internal rate of return was estimated to be only about 1.2 percentage points higher than the rate of return calculated on the assumption that dry season

TABLE 5

ESTIMATED INTERNAL RATES OF RETURN UNDER ALTERNATIVE ASSUMPTIONS[a]

| Length of Period of Analysis | Wet Season Benefits Only | Wet Season plus Dry Season Benefits: Cost of Bhumiphol Dam excluded | Wet Season plus Dry Season Benefits: Cost of Bhumiphol Dam included |
|---|---|---|---|
| 1. 25 years | 8.0% | 9.3% | 6.3% |
| 2. 35 years | 8.8% | 10.0% | 7.4% |
| 3. 45 years | 9.1% | 10.3% | 7.7% |

[a]Benefits are calculated using a paddy price of $.070 per kilogram for the period 1962-1970, and a price of $.060 for the remainder of the period of analysis.

benefits would remain constant at the 1971 level. It can thus be seen that even substantial increases in the amount of dry season cropping would have only a modest impact on the estimated rate of return.

Of the various rates of return which have been calculated, I believe the most realistic are those based on a 25 year period of analysis, using a paddy price of $.06 per kilogram for the years subsequent to 1970, and assuming constant dry season benefits beginning in 1969 at their 1971 level. This leads to the conclusion that the rate of return to the investment in the system, based on the benefits from crop production, is on the order of 6 to 9 percent. The analysis has shown, however, that neither a moderate decrease in the assumed future price of paddy, nor substantial increases in either the length of the period of analysis or the amount of dry season benefits results in an estimated rate of return much lower than 5 percent or higher than 10 percent. These figures demonstrate that there have been only moderate returns to the investment in water control, in spite of the fact that the incomes of farmers in the project area are significantly higher as a result of the investment.

# CHAPTER 4

# ALTERNATIVE APPROACHES TO IMPROVEMENT IN WATER CONTROL

Because of their size, deltaic water control projects are generally developed over a long period of time. During the period of development, the purposes of a given project may change rather drastically. Such is definitely the case with the Greater Chao Phya project. Discussion in the previous two chapters has emphasized that the project was originally undertaken to improve the conditions under which traditional wet season agricultural production took place. In recent years, however, as construction of upstream storage dams increased the potential availability of water in the dry season, emphasis shifted to consideration of the requirements for the support of irrigated dry season agriculture. Several proposals for further development of the water control system have been made in recent years, and a number of pilot projects have been started.[1] In this chapter some general policy alternatives available to the government with respect to the improvement of water control in the Greater Chao Phya project are examined and evaluated.

## The Need for Improvement in Water Control

As noted in Chapter 2, the past development of the water control system has been on an "extensive" basis. Effort was directed first to the construction of the headworks and the skeleton system of main canals and laterals which would permit the distribution, on the basis of field to field flooding, of supplemental water in the wet season. At a somewhat later date a skeleton system of ditches was added to make some improvement in the distribution. While such a system provides a low-cost method of delivering supplemental water in the wet season, it has a number of limitations with respect to dry season irrigation.

First, with a lower volume of flow in the main rivers during the dry season, the system is unable to deliver water by gravity to much of the area. A recent investigation by RID indicated that water can be delivered by gravity in the dry season to only about 11 percent of the planted area of the project.[2] Gravity delivery appears to be possible in about 15 percent of the BT region and 10 percent of the CB region, while none of the SB region can receive water by gravity during the dry season. Although some farmers may find it possible to pump water from the canals of the system, these figures indicate that at the present time farmers in large parts of the project are likely to find that it is either difficult or impossible to obtain water for irrigation in the dry season.

A second limitation is the inability of the existing system to control the distribution of water to the individual farms. Once the water is released from the laterals of the system, it flows in ditches and over fields with little control except that provided by small temporary earthen embankments built by the farmers to channel the water in desired directions. Since many fields are not cropped in the dry season, this situation may make it very difficult for an individual farmer to obtain water on his field, even if it is available at the turnout of the distribution canal. Furthermore, a farmer who is growing upland crops will not be willing to flood his field in order to permit water to flow to another farmer.

A third difficulty relates to the drainage of excees water from the land. Lack of drainage facilities at the individual farm level may result in excess water from one farm draining onto fields of other farms, where it is not desired. And the lack of a main drainage system implies that the excess water from relatively large areas may drain onto low areas from which it cannot be removed. This waterlogging of the low areas may cause salinity problems, stimulate weed growth, and interfere with the preparation of the land for the following wet season crop.

Still another problem is that the land is too uneven for satisfactory irrigation in the dry season. Farmers do some levelling of the paddy fields in the process of preparing the land for the wet season rice crop. But the degree of levelling necessary for the production of rice in the wet season, when water is abundant, is not adequate for the production of irrigated dry season crops. If dry season rice is grown, inadequate levelling means that large volumes of water are required to flood the higher parts of the fields. And if irrigated upland crops are produced, more serious problems are encountered. Because of the very impervious nature of most of the soils in the project area, it is difficult to obtain uniform penetration of irrigation water into the soil. Unless the land is carefully levelled and graded, the water tends to run off the higher parts of the fields, resulting in inadequate water for crop production. The runoff then collects in the lower areas, which become waterlogged and therefore unsuitable for the production of upland crops.

The above limitations suggest the likelihood of conflicts between the farmers and the irrigation officials regarding the management of the existing system. Farmers attempting to grow dry season crops want the system to be managed in such a way that it is as easy as possible for them to receive abundant water to produce a good crop. But given the lack of control over the water as it leaves the canals, such an abundance is likely to result in large quantities of water in areas where it is neither needed nor desired. This is particularly true in situations where only a small portion of the total area is cropped. Furthermore, given the limited amount of water available for dry season irrigation, such extravagent use in one area may lead to shortages in other areas. Irrigation officials are therefore likely to attempt to limit as much as possible the quantity of water which is made available in a given canal.

A number of observers have noted the apparent paradox that while irrigation officials commonly complain that full utilization of the available supply of water for dry season irrigation has not been achieved due to the small number of farmers who grow dry season crops, a common complaint on the part of the farmers -- and a reason often given by them for not growing dry season crops -- is the lack of adequate water. The above discussion suggests that part of the explanation of this paradox lies in the fact that the physical limitations of the existing water control system result in conflicting views regarding both the management of the system and the amount of water which is "adequate". The existence of this conflict again emphasizes that the inadequacies of the water control system have inhibited the growth of dry season production.

## The Framework of Analysis

Three broad categories of alternative approaches to the improvement of the water control system have been identified: (1) investment for the improvement of wet season production; (2) investment to promote dry season rice production; and (3) investment to promote dry season upland crop production. Although any one of these approaches might be undertaken singly, the three alternatives could be implemented sequentially. Thus it would be possible to undertake first the developments necessary to improve wet season conditions, followed at some later time by the investment needed to promote the production of dry season rice. Finally, the additional developments required for the promotion of upland crops could be undertaken. This type of sequential development--which represents an "extensive" approach to the further development of water control--is not necessarily more costly than an intensive approach. This is because in general the physical requirements for the development of a given alternative include all of the requirements for the preceding alternative, so that the total cost of full development on a sequential basis is roughly the same as the cost of directly implementing the final alternative.

Because of this potential for sequential development, it is possible to use a marginal approach to the analysis of the three alternatives. In this chapter the analysis is thus based on an examination of the increases which would result in both the costs and the benefits if a given alternative were undertaken following the implementation of the previous alternative. For the first alternative, the comparison must be made with the situation that would exist if there were no further government investment to improve water control. This situation--the "without" case with respect to further government investment-- is not the same as the present situation, since some increase in production can be expected even without any further improvements in water control.

Before proceeding with the analysis of the three alternatives, it is thus necessary to estimate the conditions that would exist in the "without" situation. These estimates are made for the BT region only, since, as is explained more fully in the discussion of the alternatives, virtually no improvement in water conditions can be expected in the CB and SB regions.

The major potential for future increases in wet season production under the present water control system involves the use of the high yielding varieties of rice which were released for production in 1969. Although see has been somewhat limited, production of these varieties has expanded rapidly in parts of the BT region. Being much shorter than the traditional varieties, they can be grown only under conditions of relatively good water control. Drainage is of special importance, as best results are obtained under conditions where the depth of water on the rice paddy is not more than 10 centimeters.[3] While it is clear that water control is an important factor determining the areas which can be planted to these varieties, it is difficult to estimate the proportion of the area having suitable water conditions. Reliable estimates of the total area of high yielding varieties planted in the 1970 and 1971 wet seasons do not exist. In 1971, however, Burton began a study of farmers in four villages in which the new varieties were being grown.[4] Using some of the preliminary survey data from this study, it is possible to make some rough estimates of the potential of these varieties for increasing production under the present water conditions.

In the four villages included in the Burton study, all of which are in the BT region, the average area planted to high yielding varieties in the 1971 wet season ranged from slightly more than one percent to about 26 percent of the total planted area. The average for the four villages was 14 percent. Many farmers grew both local varieties and high yielding varieties, planting the former in areas which they considered to have too much water for the short varieties. These data thus suggest that on about 15 percent of the planted area in these villages water conditions are suitable for the production of high yielding varieties of rice. Considering that all of the rice grown in these villages is transplanted, it is crudely estimated that the high yielding varieties of rice could be grown on about 15 percent of the transplanted area of the BT region. I therefore estimate that without any further improvement in water control, approximately 31,500 hectares could be planted to the high yielding varieties of rice. In terms of cultivated area, this is about 10 percent of the BT region, or 5 percent of the entire project area.

Data from the Burton study show that in 1971 the average yield of the new varieties was about 30 percent above the average for the local varieties.[5] It is therefore estimated that without any additional government investment to improve water conditions, the total increase in wet season production resulting from the spread of the new varieties would be about 21,000 tons of paddy per year, or an average increase in production of nearly 650 kilograms per hectare planted to the new varieties.

Considering the preliminary information from the Burton study, it is assumed that the only additional costs of production associated with the new varieties are those due to the use of 16-20-0 fertilizer at the rate of 100 kilograms per hectare, and of pesticide worth $1.25 per hectare. After allowance is made for the estimated amounts of fertilizer and pesticide currently being used on transplanted rice,[6] the increase in cost due to the use of the new varieties is estimated to average $6.50 per hectare. No additional cash or labor costs for harvesting are included, since it appears that the higher labor requirements resulting from the increased quantity of paddy are offset by lower requirements resulting from the greater ease of harvesting the shorter varieties. It is, for example, a common practice for farmers growing the taller varieties to go through the field just prior to harvest with a device which lodges the plants in one direction. This operation, which is designed to facilitate the actual harvesting, is not necessary with the high yielding varieties.

These yield and cost estimates suggest that there are relatively high returns to the use of these new varieties in the wet season. Even at a low paddy price of $.04 per kilogram, the marginal revenue resulting from a shift to the new varieties is estimated to be roughly four times the marginal cost. Barring unforeseen problems, this high profitability is likely to lead to a rapid adoption of these varieties in the limited areas having satisfactory water conditions.

Compared with the potential for increased production resulting from the use of the high yielding varieties, other possible sources of increased wet season production appear to be relatively unimportant. Most of the increase in the use of fertilizers and other chemicals would be in conjunction with the production of the new varieties. These effects have already been included in the above estimates. Similar conclusions can be drawn for factors such as improved management. Likewise, little additional wet season production could be expected from any of the three major effects of the water control system which were identified in Chapter 3. Considering the first effect, it is possible that some further shift in the method of planting may take place in parts of the BT region. But data on past trends indicate that any further change is likely to take place in those parts of the region where the apparent yield differential between broadcast and transplanted rice is so small that the total effect on production would be negligible. As for the second effect, the amount of damaged area in the BT region has already reached very low levels, so that there is little potential for increased production from any further decline. And finally, while there is still considerable potential for additional yield increases resulting from better water conditions, little increase in total production could be expected from this effect because there would be very little improvement in water control in the absence of additional government investment.

Past experience suggests that with no further government investment to improve the water control system, most of the increase in dry season production would be due to rice, although a small increase in upland crop production could also be expected. As noted in Chapter 3, the availability of the seed of high yielding rice varieties has increased the incentive to produce dry season rice. Seed of these varieties will be even more readily available in the future. Production should also be stimulated by the completion of the Sirikit dam in 1972 or 1973, since the operation of this dam should make water more readily and reliable available in the dry season.

While the above factors are easily identifiable, it is not possible to accurately quantify their impact on dry season production. More information is needed on other factors which contribute to the decisions of the farmer regarding dry season production. For example, individual farm data are needed on the areas planted in the dry season compared to the areas planted in the wet season. Information on the extent to which current production is limited to areas that can receive water by gravity from the irrigation system would also be valuable.

Lacking this kind of information, only a very crude estimate of the possibilities for the expansion of dry season rice production can be made. In the Sam Chuk and Sam Chuk Extension subprojects, where much of the existing production is concentrated, the area planted to rice in the 1971 dry season was approximately equivalent to 62 percent of the area of the two subprojects for which gravity delivery of water was possible. If it is assumed that throughout the area of the BT region the production of dry season rice would expand to roughly two-thirds of the area which can be served by gravity, then the total area planted would be approximately 32,000 hectares, which is about three times the area planted in 1971. At an estimated average yield of 2.8 tons per hectare, dry season paddy production would thus increase by about 62,000 tons per year.

I therefore estimate that in the absence of any further government investment in water control after the completion of the Sirikit dam, paddy production in the BT region would increase by about 21,000 tons in the wet season, and by about 62,000 tons in the dry season. The production increase in the dry season is thus anticipated to be considerably larger than in the wet season, which is in sharp contrast to the past increases in production which have been brought about by the water control system.

## Alternative 1: Investment for the Improvement of Wet Season Production

Considering that most of the present concern about the limitations of the water control system centers on the problems involved in the production of dry season crops, it is not surprising that there has been no pilot project designed specifically to investigate the requirements for the improvement of wet season production. Although implementation of proposals designed to promote dry season production would also result in some wet season benefits, the fact that the major effects of the present system have been on wet season production suggests the desirability of examining the costs and effects of improvements designed specifically for the wet season. In the absence of any detailed engineering proposals, the following discussion is rather general in nature.

The most important requirement for the improvement of wet season conditions is better drainage. Given the large volume of water which annually floods the CB and SB regions, improving drainage would require substantially increasing the discharge capacity of the main river system. Because this does not appear to be economically feasible,[7] the implementation of Alternative 1 would be limited to the BT region. Within this region, the major source of increased production would be a further expansion of the area planted to the high yielding rice varieties. Improved drainage should also permit some increase in the yield of the traditional varieties of rice. A modest increase in the proportion of the area which is transplanted could also be expected, but the impact on total production would be so small that this effect can be ignored.

Unfortunately, the technical requirements for a drainage program which would permit these increases in production have not been clearly identified. One unanswered question involves the adequacy of a drainage network composed of main drains and collector drains, but without minor drains for the collection of water from individual farms. A related question concerns the relative effects of two alternative proposals for the construction of the main drainage system. As noted in Chapter 2, RID is currently in the process of constructing a network of drainage canals. In a study by the Netherlands Engineering Consultants (NEDECO) it was concluded that the continuation of the existing RID plan might cause increased flooding, since the drainage system would allow additional water from the higher areas to drain into the lower areas, but would not make possible the removal of this water from these low areas during the periods of peak river flow.[8] Some RID officials suggest, however, that this would not be a serious problem because there is only a relatively short period of time during which the water could not be discharged.

This controversy emphasizes the inadequacy of current knowledge regarding the effects of a main drainage system on the agriculture of the area. Given this lack of knowledge, it is difficult to estimate the returns that can be expected from Alternative 1. However, to illustrate the orders of magnitude involved under assumptions which appear to be reasonable, some estimates have been made (Table 6).

A basic assumption underlying these estimates is that improved drainage would permit the use of high yielding varieties in the wet season on the entire area which was transplanted prior to the construction of the water control system. The rationale for this assumption is that improved drainage is most likely to create the conditions necessary for the production of the new varieties in those areas which already had relatively good drainage prior to the construction of the original water control system. A second assumption is that there would be no increase in the average yield of the traditional rice varieties. The use of this assumption is partly due to the complete absence of information on which to estimate the effect of improved drainage on the yield of these varieties. In part, however, it reflects the uncertainty regarding the net effect which a drainage system would have on production in the areas planted to the traditional varieties. If the system causes more flooding in parts of the BT region, then increases in production in some areas might be offset by decreases in other areas. The third assumption used in making the estimates is that the switch to the new varieties involves increased production costs in the form of additional quantities of pesticides and fertilizer.

Considerable uncertainty also exists regarding the cost of constructing the drainage system. Estimates made by the Royal Irrigation Department place the cost at about $39 per hectare.[9] But the NEDECO study suggests that the RID estimates are too low, in part because of an unrealistically low rate charged for excavation.[10] NEDECO estimates that construction of the drainage canals, based either on the RID approach or on the NEDECO proposal, would cost about $55 per hectare.[11] But the system proposed by NEDECO would increase the amount of water discharged during periods of peak river flow, resulting in greater flooding in downstream areas--most notably in the city of Bangkok. To prevent this, the flood-control dikes which are now planned for the city of Bangkok would have to be built higher than originally proposed. In the absence of the detailed information needed to determine with precision the magnitude of the necessary increase in height, NEDECO roughly estimated the "maximum possible cost" of the flood control structures to be about $63 per hectare.[12] I therefore estimate that the cost of the RID system would be about $55 per hectare, while the entire cost of the NEDECO proposal would be not more than $118 per hectare (Table 6).

## Alternative 2: Investment to Promote Dry Season Rice Production

As in the previous case, discussion is limited by the lack of any pilot project designed specifically to meet the requirements of dry season

TABLE 6

ESTIMATED COSTS AND BENEFITS OF ALTERNATIVE POLICIES FOR IMPROVEMENT IN WATER CONTROL

(DOLLARS PER HECTARE)

| Item | Policy Alternative | | | | |
|---|---|---|---|---|---|
| | Alternative 1: Wet Season Rice | Alternative 2: Dry Season Rice | | Alternative 3: Dry Season Upland Crops | |
| | | Marginal | Average | Marginal | Average |
| 1. Construction cost | 55-118 | 23 | 78-141 | 187.00 | 265-328 |
| 2. Net cash return per hectare at paddy price of .05/kg. | | | | | |
| a. wet season | 8.70 | 0.00 | 8.70 | 13.20 | 21.90 |
| b. dry season | 0.00 | 13.50 | 13.50 | 4.60 | 18.10 |
| c. total | 8.70 | 13.50 | 22.20 | 17.80 | 40.00 |
| d. value of total capitalized at 10% | 87.00 | 135.00 | 222.00 | 178.00 | 400.00 |
| e. value per dollar of construction cost | 1.60-0.74 | 5.90 | 2.80-1.60 | 0.95 | 1.50-1.20 |
| 3. Net cash returns per hectare at paddy price of .06/kg. | | | | | |
| a. wet season | 10.90 | 0.00 | 10.90 | 16.00 | 26.90 |
| b. dry season | 0.00 | 17.50 | 17.50 | 5.90 | 23.40 |
| c. total | 10.90 | 17.50 | 28.40 | 21.90 | 50.30 |
| d. value of total capitalized at 10% | 109.00 | 175.00 | 284.00 | 219.00 | 503.00 |
| e. value per dollar of construction cost | 2.00-0.92 | 7.60 | 3.60-2.00 | 1.20 | 1.90-1.50 |

rice production. Certainly some improvements in drainage would be necessary to avoid the inundation of low areas not planted in the dry season. And to increase the ability to deliver water by gravity, improvements in the distribution system would also be necessary. In the following discussion it is assumed that the required improvements in drainage are identical to those discussed for the previous alternative. It is also assumed that the necessary improvements in the distribution system will have no effect on wet season production. Under these assumptions, the wet season benefits of the two alternatives are identical.

Discussion of the increases in dry season production which could be expected must begin with an examination of some limitations on the implementation of this alternative. First, the development of the SB and CB regions for dry season production does not seem feasible. Any structures built for the delivery of water or for the drainage of excess irrigation water would probably be severely damaged by the annual flood. Another limitation is imposed by the capacity of the main distribution system. This system was designed for supplemental wet season delivery, with an overall capacity of only 7 millimeters per day,[13] which is considerably less than the amount required to support the production of a crop of dry season rice. Data from the RID water use experiment station at Sam Chuk indicate an average evapotranspiration in April of from 8.5 to 9.5 millimeters per day for a typical dry season rice crop.[14] Using the optimistic assumption that the irrigation system has a 60 percent diversion efficiency, the system water requirement for such a crop would be about 15 millimeters per day during the month of April. Although the daily requirement on the system may be reduced somewhat by staggering the time of planting of the dry season crop, it is doubtful that the system could support the production of dry season rice on more than one-half of the BT region. A third factor limiting the size of the area that could be planted to rice is the quantity of water which will be available for dry season irrigation. It has been estimated that after the completion of the Sirikit dam, and with high rainfall and irrigation efficiencies, there would be enough water to cultivate about 25 percent of the project area to dry season rice and 25 percent to other crops having lower water requirements.[15] The study emphasized that the rainfall and irrigation efficiencies used to arrive at these figures are not likely to be achieved for many years.

Given these considerations, I estimate that under Alternative 2 production of dry season rice would occur on 25 percent of the BT region. Compared with the situation under Alternative 1, this represents an increase of 41,600 hectares. Using the cost and yield assumptions presented in Chapter 3, the estimated increases in net cash returns resulting from the sequential implementation of Alternative 2 (i.e., following the implementation of Alternative 1) have been calculated. The resulting figures were divided by the number of hectares in the BT region to give the figures shown in the second column of Table 6. These are the estimated marginal benefits, per hectare, resulting from the sequential implementation of Alternative 2.

The costs associated with the sequential development of Alternative 2 are those incurred for the improvement of the distribution system. The required improvements appear to be approximately the same as those of the first phase of a development program proposed by NEDECO.[16] These costs are estimated by NEDECO to be approximately $23 per hectare.

It should be clear that the sum of the benefits (or costs) which result when Alternative 1 is first undertaken (the first column of Table 6) and the additional benefits (or costs) that result when Alternative 2 is later undertaken (the second column of Table 6) is equal to the benefits (or costs) which would result if Alternative 2 were undertaken directly. To facilitate the discussion of the last section of this chapter, these figures are shown in the third column of Table 6. These are the estimated average costs and returns per hectare resulting from the direct implementation of Alternative 2.

## Alternative 3: Investment to Promote Dry Season Upland Crop Production

Of the three alternative discussed in this chapter, this one has received by far the most attention. In part this is a result of the fact that as the planning and construction of upstream storage dams increased the potential supplv of dry season irrigation water, emphasis shifted toward dry season cropping. Considering both that the production of rice requires more water than is necessary for upland crops, and that for many years the Thai government has attempted to promote agricultural diversification, it is not surprising that with the shift in emphasis to dry season production, attention has been focused on upland crops. In recent years, low export prices for rice and the difficulties encountered by Thailand in maintaining her export markets have further intensified interest in stimulating the production of upland crops.

To examine the feasibility of Alternative 3, the Thai government has established four pilot projects in the BT region. In 1969 NEDECO, working under contract to RID, began construction on the first part of a "land consolidation" pilot project in amphoe Bang Rachan of the province of Singburi.[17] This project, which initially covered about 160 hectares, involved the construction of inter-farm channels for water distribution and drainage; land levelling of farm fields; some realignment of farm boundaries and consolidation of holdings; and, as an incentive to cooperation, the issuance of title deeds. A farm management survey was conducted prior to the implementation of the project. Similar data have been gathered since its construction.[18]

In 1969 the Central Region Agricultural Center at Chainat[19] began work with a group of farmers in Pho Nang Dam, located in amphoe Sanphaya of Chainat province. With the assistance of RID, some 40 hectares of land were developed by levelling the land, clearing away some of the trees, and improving the distribution ditches.[20] A major purpose of the project was to test some of the Center's research results under farm conditions. For this reason an intensive extension effort was undertaken in conjunction with the project. Data on the changes in farm conditions in this pilot project are currently being analyzed.[21]

With assistance from the Chinese Agricultural Technical Mission to Thailand, a multipurpose cooperative project has been established in *amphoe* Sanphaya.[22] The purpose of this project is to improve the production and marketing conditions faced by the farmers of the area. A major aspect in the improvement of production conditions involves land development and improvements in water control to permit dry season production of upland crops. With the assistance of RID, construction was begun in the dry season of 1971 in a pilot area of approximately 125 hectares.[23] Compared with the previous two projects, a more intensive approach was used, with every individual farm plot being connected to both a distribution channel and a drainage channel. At the time of writing, only data on the costs of development for this project were available.

The final project, also constructed during the 1971 dry season, is at Khao Tha Phra, in *amphoe* Muang Chainat. This project, administered by the Ministry of Agriculture, was designed to demonstrate a somewhat less intensive approach to land development than the other three projects. No data from the project were available at the time of writing.

Although the emphasis in these projects has been on upland crops, most of the benefits which have resulted thus far have been in the form of increased rice production. The following discussion of the benefits of Alternative 3 therefore focuses on the changes in rice production.

Data from the NEDECO land consolidation project show that there has been a considerable increase in wet season rice production since 1968.[24] From an average yield of 2.00 tons per hectare in 1968, the yield of the traditional varieties increased to 2.50 tons in 1969 and 1970.[25] The Rice Department data for the entire *amphoe* of Bang Rachan show an average yield of 2.15 tons per hectare for 1968, and 2.31 tons per hectare for 1969. (Date for 1970 were unavailable at the time of writing.) This suggests that approximately 160 kilograms of the 500-kilogram increase which was observed in the pilot project could be attributed to more favorable weather and pest conditions. It is thus estimated that the yields of traditional varieties of rice rose by about 340 kilograms per hectare as a result of the project. There has also been an increase in the use of the high yielding varieties in the pilot project. By the 1970 wet season these varieties were grown on about 10 percent of the area of the pilot project. The 1970 yield of these varieties averaged nearly 3 tons per hectare, which was roughly 20 percent higher than the average yield of the traditional varieties grown during the same year. Estimates of the net value of these wet season benefits are presented in the last two columns of Table 6. The figures in the next to last column show the increase in net benefits which could be expected to result from the implementation of Alternative 3 in a situation in which Alternative 2 has already been undertaken. The figures in the final column show the benefits attributable to Alternative 3 if it is undertaken directly. These figures are, of course, simply the sum of the corresponding figures in the third and fourth columns.

The NEDECO pilot project stimulated a rapid increase in dry season production. Prior to the project there had been no dry season cropping in the area. In the 1969 dry season nearly half of the area was cropped to rice, and in 1970 this increased to two-thirds of the area. The high yielding varieties were grown exclusively, giving an average yield in 1970 of approximately 3.3 tons per hectare. Production of upland crops was very limited in both years, with only 4 hectares (less than three percent of the area planted to rice in the wet season) planted in 1970, and 6 hectares in 1971.[26]

According to a survey of farmers in the pilot area, the average cost of production of the 1970 dry season rice crop, exclusive of family labor, was $53.10 per hectare, which is $6.30 lower than the estimate of the cost of dry season rice production which was presented in Chapter 3.[27] A detailed examination of these estimates reveals two basic differences. The amount of fertilizer applied in the land consolidation area averaged 190 kilograms per hectare, while pesticides and other chemicals were used at an average rate of $4.70 per hectare. These rates are substantially higher than those assumed for the estimates presented in Chapter 3, and reflect the increased use of these inputs under conditions of improved water control. This increase in cost is, however, more than offset by the second difference between the two figures. The figures of Chapter 3 include $25 per hectare to cover the cost of pumping. Since water is delivered by gravity in the pilot area, pumping is not necessary.

Using the cost figures from the pilot project, and assuming that the yield obtained in the 1970 dry season is typical for the yield that can be expected in the future, it is possible to estimate the average net cash returns which can be earned per hectare planted in the dry season. But to determine the benefits that could be expected to accrue if Alternative 3 were implemented throughout the BT region, it is necessary to estimate the proportion of the area which would be planted in the dry season. Although one-half to two-thirds of the pilot area has been planted in recent dry seasons, it has already been noted in the discussion of Alternative 2 that dry season production of rice on such a large proportion of the entire BT region is unlikely. Furthermore, it seems likely that the high proportion of the area of the pilot project which was planted to dry season rice was in part due to the fact that some farmers from outside the pilot project rented or borrowed land within the project in order to take advantage of the possibility of dry season production. Nearly 50 percent of the area planted in the 1970 dry season was cultivated by farmers who had either rented or borrowed the land.[28] But approximately 80 percent of the pilot project is owner-operated in the wet season.[29] It must therefore be concluded either that all of the rented land is cultivated in the dry season (in contrast to only about 30 percent of the owner-operated land) or that some outside farmers obtained access to land in the project area for dry season cropping. The latter conclusion appears to be the more realistic of the two. While substantial production by outside farmers is possible under conditions of a relatively small pilot project surrounded by areas which have not yet been developed, it would be less likely if the entire area of the BT region were developed.[30]

Although it is thus not reasonable to expect that one-half to two-thirds of the BT region would be planted to rice in the dry season, it is not clear what proportion represents a reasonable estimate. Certainly at least as much of the area would be planted as in the case of Alternative 2. In the absence of information on which to make a better judgement, the figure of 25 percent used for Alternative 2 is therefore used as a working assumption. The average dry season benefits per hectare for the entire BT region are thus calculated as equal to one-fourth of the benefits per hectare planted. These figures, minus $2.50 for the estimated increase in operation and maintenance costs associated with Alternative 3, are shown in the last two columns of Table 6.

One possible objection to these estimates is that they are based on the assumption that all of the increase in production will be in the form of rice, while the purpose of Alternative 3 is to promote upland crop production. The presumption of this objection is that by ignoring upland crops, the potential benefits of Alternative 3 have been underestimated. It will now be shown, however, that this is not the case.

Experience at both the NEDECO pilot project and the Pho Nang Dam area demonstrated that family labor is an important constraint on the area of upland crops which can be produced. It has been concluded that under existing conditions, a family consisting of three adult workers can handle only 0.8-0.9 hectares of irrigated upland crops.[31] Although it is difficult to determine the average net cash returns that can be expected from upland crops, some rough estimates can be made from the Pho Nang Dam demonstration area. The 1970 data on returns for various upland crops show that even after two years of development and fairly intensive extension work, all of the crops except string beans yielded average net cash returns of $110 per hectare or less.[32] Returns of $110 per hectare are roughly 1.4 times the net cash returns that could be expected by a farmer who produces rice under the conditions assumed at the NEDECO project, and who obtains a paddy price of only $.04 per kilogram. Thus the net cash returns from the production of about 1.2 hectares of rice would be equal to or greater than the returns that a farmer could earn if he devoted his entire family labor to the production of upland crops. But 1.2 hectares is roughly 25 percent of the average farm size in the BT region. Thus the assumption that 25 percent of the total area would be planted to rice results in an estimate of net cash returns which are at least as large as those that could be earned if the farm families of the area used all of their labor for the production of upland crops.

The development of Alternative 3 involves all of the costs discussed in conjunction with Alternative 2 plus additional costs for on-farm and inter-farm development. These additional costs are for the construction of minor distribution and drainage systems, and for land levelling. Recent estimates obtained from NEDECO place these construction costs at $167 per hectare. Of this amount, no less than $144 is for land levelling.[33] These costs are based on the charge of contractors who in 1971 began the development of additional land adjacent to the original pilot project. In addition to these construction costs, approximately $20 per hectare must be added for the engineering work and for the cadastral survey and the issuance of title deeds to the farmers. Thus the sequential implementation of Alternative 3 is estimated to cost approximately $187 per hectare.

Although this figure is based on the development cost incurred in the NEDECO project, it is quite comparable to the cost of development of the Pho Nang Dam demonstration area. For the Pho Nang Dam area, construction costs were estimated to be $203 per hectare for land prepared for upland crop production, and $169 for land prepared for rice, with an overall average of $184 per hectare.[34] The third project, which is supported by the Chinese Agricultural Technical Mission, is considerably more expensive. In part this is due to the design of the project, which calls for a series of parallel distribution and drainage channels and rectangular plots, each of which is connected to one distribution and one drainage channel. More earth-moving was thus required than was the case with the other projects. In addition, the pilot area had many trees which were removed at considerable expense. The total construction cost, as estimated by RID was approximately $375 per hectare.[35] Since RID accounting methods are often based on unit costs which are lower than could be obtained from a private contractor, it is likely that the true cost was even higher.

Although the improvements in water control undertaken in conjunction with Alternative 3 are designed to promote dry season upland crop production, it has been pointed out that past experience in the pilot projects suggests that in fact these developments will not result in much increase in the production of these crops. Although I have argued that under existing conditions the magnitude of the returns that could be earned under Alternative 3 are at least as great if the increase in production is in the form of rice, this does not imply that it makes no difference if rice or upland crops are produced. To achieve any given level of net cash returns, much larger quantities of water are required for rice production than for upland crops, both because the per hectare water requirements are greater, and because the total number of hectares to be irrigated is larger. Furthermore, declining international rice prices, and difficulties encountered in maintaining rice markets have led the Thai government to place considerable emphasis on further diversification of agricultural production.

Given these considerations, it is appropriate to question why there has been so little increase in upland crop production in the pilot areas. Part of the answer appears to lie in the nature of the soils of the project area. A land classification study conducted by RID indicated that a relatively small proportion of the project area has soil conditions suitable for the production of irrigated upland crops. Only about 11 percent of the BT region is classified as being either most suitable for upland crops or of equal suitability for both rice and upland crops. Another 17 percent of the area is classified as marginally suitable for upland crops, but more suitable for rice.[36] The experience to date in the pilot areas suggests that even on soils classified as suitable for irrigated upland crops, excellent management and water control are required for successful production.[37]

Another part of the answer to the question lies in the returns which farmers are able to obtain from rice compared with the returns from upland crops. This is related to the production problems encountered due to the soil conditions. It has already been noted that at the Pho Nang Dam area, the highest average net cash returns obtained in 1970 for any upland crops, with the exception of string beans, were $110 per hectare. The average returns from one hectare of rice at Pho Nang Dam during that same dry season were $145.[38] In the NEDECO project, where it appears that even at a paddy price of $.04 per kilogram farmers can expect to receive $79 per hectare in net cash returns from dry season rice production, a small demonstration area of 1.6 hectares of upland crops grown in 1970 resulted in net cash returns per hectare of less than $31 for every crop except peanuts, which yielded about $133.[39] While the very low returns to most of the crops can be attributed to numerous problems associated with the fact that neither farmer nor NEDECO had had any prior experience with irrigated upland crop production in the pilot area, the figures do indicate that at least until more experience is gained, the economic incentive to grow many upland crops may be quite low.

There are several other factors which may be important in the slow increase in upland crop production. Experience at Pho Nang Dam and in the NEDECO project has shown that weeds are a major problem. For farmers growing both upland crops and rice, it was observed at Pho Nang Dam that the requirement for weeding the upland crops came during the period of peak demand for labor for transplanting the rice. As the returns to additional transplanting appeared to be greater than the returns from weeding, the upland crops tend to be neglected.[40] Furthermore, weeding is considered to be an onerous chore, especially when compared with alternative activities such as fishing. This is a relevant consideration since the farmer considers not only the net cash returns he will receive, but also the relative amounts (and types) of labor which he will have to expend to receive these returns. Still another factor is the greater experience that the farmers have with rice production. Finally, in contrast to the situation with rice, the marketing channels for upland crops are generally poorly developed in the project area, leaving the farmer with considerably greater uncertainty about his ability to dispose of his crop at a profitable price.

Some of these problems will undoubtedly decline in importance over time. In particular, technological developments should gradually increase the profitability of upland crops. Development of effective chemical weed control could also relieve a major labor constraint on the hectarage that can be planted to upland crops. But while it is thus possible to anticipate some improvement in the prospect for upland crops in the future, the most serious constraint--unfavorable soil conditions --is not likely to be removed by any foreseeable technological developments. Thus the conclusion must be retained that the development of Alternative 3 is likely to lead to substantial increases in rice production, but to only relatively limited increases in the production of upland crops.

## Comparison of the Alternatives

To facilitate a comparison among the alternatives, the estimated annual benefits have been capitalized at an arbitrary interest rate of 10 percent and then divided by the costs of construction (lines 2e and 3e of Table 6). These figures permit some evaluation of the potential returns to the alternative investments to improve water control. The figures should not be interpreted as traditional benefit-cost ratios, since the simple capitalization of the net benefits ignores the problem of the lag between the time that the investment is made and the time that the benefits begin to flow. Since there is no basis on which to make an estimate regarding the nature of this lag, it seems preferable to restrict the analysis to a form where the problem can be temporarily ignored.

The most striking feature about these figures is the very high marginal returns associated with the implementation of Alternative 2. Once a drainage system has been installed, improvement of the distribution system to support dry season rice production appears to be extremely profitable. Returns to the construction of the drainage system itself appear to be much lower, and the magnitude of these returns depends heavily on the extent to which auxiliary costs for flood control in Bangkok must be incurred. If the NEDECO approach to the development of drainage is used, it is doubtful that Alternative 1 would be economically attractive. And while it might be attractive if the RID approach to the drainage system were followed, it is still much less attractive than Alternative 2.

Although the marginal returns to Alternative 2 are high, the average returns are considerably lower because of the low returns to the wet season drainage system. Since all of the marginal benefits of Alternative 2 stem from dry season production, one might consider the possibility of developing this alternative on the basis of a smaller, less expensive drainage system which would be designed specifically for the requirements of dry season production, and which would not cause additional flooding in Bangkok during the wet season. Although a number of engineering questions would have to be investigated to determine the feasibility of such an approach, a few general comments can be made.

First, the development of such a "dry season drainage system" would mean that flooding would continue to be a feature of wet season production in the lower areas of the BT region. In fact, there is some possibility that this type of development would result in increased flooding. The wet season benefits resulting from such a policy would thus be less than the wet season benefits that would have been obtained from Alternative 1. It is therefore not certain that the implementation of Alternative 2 on the basis of a dry season drainage system would increase the average returns to the investment, since both the benefits and the costs would decline from the levels indicated in the third column of Table 6.

Under existing technology, flooding places a relatively low ceiling on the wet season production potential of the land, since adoption of the high yielding varieties is not possible. Over time, as the farmers with better water conditions are able to adjust their management practices to more fully realize the yield potential of the new varieties, the differential in yields between the flooded areas and the rest of the region could be expected to increase.[41] The development of a dry season drainage system therefore probably implies increasing inequality among farmers in terms of wet season production.[42] If, as seems to have been true in the past, farmers in the areas which flood in the wet season are unable to engage in much dry season production, then the implementation of such a program would result in considerable inequality in the distribution of the primary benefits among the farmers. A final point regarding the development of a dry season drainage system is that while this might result in higher returns than could be earned from the implementation of Alternative 2 with a wet season drainage system, this approach is likely to either preclude or else significantly raise the cost of the development of Alternative 3. If the eventual implementation of Alternative 3 is anticipated, the effect of a dry season drainage system on the total costs of final development needs to be considered carefully before a decision is made regarding the type of drainage to be constructed.

The figures in Table 6 suggest that the marginal returns that could be earned from the inplementation of Alternative 3 are much lower than is the case with Alternative 2. In part this is caused by the high cost associated with the development of Alternative 3. Since over three-fourths of the marginal cost of this alternative is for land levelling, the possibility of increasing the returns through lower development costs depends largely on the potential for reducing the costs of land levelling. Unfortunately it appears that a satisfactory job of land levelling cannot easily be accomplished through the use of low opportunity cost farm labor and equipment. Mechanical equipment,operated by trained operators, appears to be necessary to achieve the desired results. On the other hand, there is some evidence from the Pho Nang Dam pilot area that the cost of land development can be reduced by perhaps as much as $34 per hectare if the land is prepared only for rice production, and not for upland crops. Considering the limited increase in upland crop production which has resulted in the pilot projects, this suggests the possibility that the returns to the development of Alternative 3 could be increased somewhat by preparing the land specifically for rice production. This approach might be particularly appropriate in those areas where soil conditions are generally unfavorable for upland crop production.

Another reason for the low marginal returns estimated for Alternative 3 lies in two assumptions used regarding the dry season benefits to be expected from this alternative. The first assumption is that yields are only 500 kilograms per hectare higher than in the case of Alternative 2. This yield differential is based on an assumed average yield for Alternative 3 of 3.3 tons per hectare, which is equal to the average yield actually obtained in the NEDECO project in 1970. But considering the potential yields of the new varieties, it can be expected that after farmers have become familiar with dry season production, yields will be substantially higher. In the Pho Nang Dam pilot area, yields in the 1970 dry season were 1.5 to 2.0 times as high as those of the NEDECO project.[43] Only a small part of the difference can be accounted for by differences in the amount of fertilizer used. It appears that with the intensive extension information available in the Pho Nang Dam area the farmers were able to obtain significantly higher yields through a "package" of improved management practices. The Pho Nang Dam figures were not used in developing the estimates for Table 6 because it does not seem realistic to expect that either the intensity or the quality of the extension work at Pho Nang Dam can be repeated on a large scale. However, as farmers gain experience with dry season production, it is reasonable to expect that they will achieve yields considerably higher than 3.3 tons per hectare.

The second assumption leading to the relatively low estimated returns is that the total area of dry season rice is the same as in the case of Alternative 2, i.e., 25 percent of the planted area. This figure was used only as a working assumption, because while it is not clear what proportion of the area would be planted, it certainly would not be less than in the case of Alternative 2.

Use of these two assumptions has thus caused the marginal returns to Alternative 3 to be underestimated. While the extent of the resulting bias cannot be determined, it is possible to demonstrate that the benefits estimated for Alternative 3 are quite sensitive to changes in either of these assumptions. For example, if the assumed average yield for dry season rice is increased by 21 percent from 3.3 tons per hectare to 4.0 tons, the estimated marginal benefits from Alternative 3 rise 47 percent from $21.90 to $32.20 per hectare. On the other hand, holding the assumed yield constant at 3.3 tons but allowing a 20 percent increase in the assumed area planted in the dry season (i.e., from 25 percent of the planted area to 30 percent), the estimated marginal benefits rise by 36 percent. Given the sensitivity of the benefits to both of these assumptions, there is reason to believe that the marginal returns to Alternative 3 may be substantially larger than estimated in Table 6.

Given the possibility of favorable marginal returns to more than one alternative, a question arises concerning the strategy of development. From a theoretical economic point of view, assuming that there are no constraints on the resources required for development, and that the entire construction occurs at one point in time, followed by the uniform flow of benefits, the greatest efficiency would be achieved by the immediate implementation of Alternative 3 throughout the project area. This statement provides no practical guidance, however, because all of the important elements of the problem are assumed away. In fact there are many constraints on the resources available for development, so that construction must take place over a long period of time, during which benefits will flow in those areas where construction has already taken place. And given these constraints, equity considerations become important. Finally, the constraints also imply that even from the narrower viewpoint of economic efficiency, consideration must be given to the results of alternative investment in other geographic areas, and in other sectors of the economy. While there is no single "best" answer to the question of the strategy of development, a number of points can be made.

Assuming that a decision is made to invest in the project area, it would appear that the most equitable approach to the farmers within the area would be to follow the alternatives sequentially. This would tend to minimize the difference in benefits received by farmers in different parts of the project area at any given point in time. Such a sequential approach is consistent with the past "extensive" approach to the development of the water control system.

Although more equitable, this approach has certain inefficiencies associated with it. First of all, it is possible that the total cost of development will be somewhat higher, especially if a drainage system is constructed which will later have to be substantially modified. Second, the highest marginal returns are to be expected from the development of Alternative 2 following Alternative 1. Development of Alternative 1 would thus be inefficient because average returns can be increased by increasing the variable factor of production per unit of the fixed factor. In this case, the variable factor of production is the investment to improve water control, and the fixed factor is land. It is thus more efficient to concentrate the investment in water control in one area until all the developments necessary for Alternative 2 have been achieved than it is to develop a larger area only to the point of Alternative 1.[44]

Still another reason for inefficiencies in the sequential approach is that the knowledge, skills and personnel required for the different alternatives are not identical. Stated in another way, the resources required for the investment are not fully mobile among the alternatives. For example, a relatively small program for the implementation of Alternative 3 conducted at the same time that major emphasis is placed on Alternative 2 might permit the development of knowledge and skills that could later be used to more rapidly and efficiently implement a program placing major emphasis on Alternative 3. Such knowledge and skills might also help reduce the length of time between the completion of the physical construction and the resulting increase in production. Such a lag, which is common to irrigation projects in most parts of the world, can seriously reduce the returns to the investment in water control. Very high returns could therefore be expected to an approach which permits a significant reduction in this lag.

From the preceding discussion it can be concluded that compared with the direct implementation of Alternative 3, there would be substantial economic inefficiencies in a sequential approach beginning with Alternative 1. For a sequential approach beginning with Alternative 2, however, there would be considerable equity gains, while the loss of efficiency would be much less, especially if the development of pilot areas designed to gain further experience with Alternative 3 is continued. This suggests that a policy for the immediate implementation of Alternative 2, possibly followed at some later date by the implementation of Alternative 3 might have considerable merit from the standpoints of both equity and efficiency.

While the foregoing discussion has focused on the magnitude of the returns to further investment in water control,a final point should be made regarding the form in which these returns can be expected. The preceding analysis suggests that any further investments to improve water control in the project area, including those designed to promote upland crop production, will probably result in a substantial increase in rice production but only a small increase in the production of other crops. Because of the nature of the constraints involved, even substantial government programs aimed at the promotion of upland crops in this area are likely to have only limited success. If it is considered politically undesirable that the returns to the investment should be so heavily in the form of rice, then consideration might be given to the possibility of making no further investment to improve the Greater Chao Phya project. Resources available for investment could then be devoted either to other regions of Thailand where additional production of upland crops is more likely to occur, or to other sectors of the economy. It should be obvious that to the extent that the anticipated returns from the alternative investment are less than those for the Chao Phya project, such a political decision involves, at least in a static sense, a net economic cost to Thailand.

# CHAPTER 5

# CONCLUSIONS

Discussion in the previous chapters has shown that the original water control system and its effects are quite different from the nature and effects of the type of system proposed for the future. In the past, the impact of the system was largely on the traditional wet season agriculture of the project area. Current proposals for development are designed to create the conditions necessary for the application of the technology of "modern" agriculture, i.e., agriculture in which farmers make substantial use of inputs which are developed or produced outside of the agricultural sector of the economy. In summarizing the results of this study and examining their implications, the two types of water control situations are first considered separately. This is followed by a discussion of factors involved in the transformation of the system from one type to the other. The chapter ends with a brief discussion designed to place the economic efficiency analysis of this study in the proper perspective of the overall social evaluation of the water control project.

## Water Control in the Context of Traditional Agriculture

The basic requirements for a water control system which would improve conditions for traditional agriculture in the project area were recognized at the beginning of the 20th century. They consisted of diverting water from the river; channeling it along the higher ridges running in a generally north-south direction throughout the area; and then releasing it to run over the fields, thereby supplementing the natural supply of water received from rainfall, runoff, and flooding. Since the natural supply of water was often inadequate to mature a good crop of rice, it was expected that the system would reduce the frequency and severity of crop losses, thus "stabilizing" production.

In those parts of the area which are not deeply flooded, and which presumably were most subject to inadequate water in the past, a relatively high degree of stabilization has been achieved. On the other hand, the system has been much less successful in stabilizing conditions in the deeply flooded area, where factors such as the timing of the arrival of the flood waters in relation to the beginning of the rains, and the rate of rise of the flood waters are of crucial importance.

Stabilization implied not only a reduction in the annual fluctuations in production but also an increase in the average annual output. From a national point of view, the project has increased exports by an average of about 90 thousand tons of milled rice per year, which represents roughly

9 percent of Thailand's total exports of rice in recent years. The system has thus contributed both to increasing the average foreign exchange earnings of Thailand, and to reducing the annual fluctuations in these earnings. At the farm level, the risk of complete crop failure has been greatly reduced in the areas that do not flood deeply. Furthermore, the average increase in production made possible by the system has increased the net cash returns earned by the farmers of the area by an estimated 25 percent.

In spite of these benefits, the return to the investment in the original system has not been particularly high. Considering the effects of the system on crop porduction in the area of study, the internal rate of return is estimated to be a modest 6 to 9 percent. The basic factor preventing a higher rate of return is the very limited potential created by the system for changes in the techniques of production. The varieties of rice which are grown are tall varieties which either show little response to fertilizer, or else tend to lodge with large applications of nitrogen. The short, photoperiod non-sensitive varieties which are responsive to fertilizer cannot be produced successfully without considerably better water control than generally afforded by the system. Because the system provided only a limited change in the natural water conditions of the area, important management decisions of the farmers continued to be dictated by water conditions beyond the control of man. For example, the selection of the variety of rice to be planted on a particular field often depends on the relationship between the date of maturity of the variety and the expected timing and duration of flooding. The only major change in production techniques made possible by the system was that of the change in the method of planting the rice.

Given this limited potential for changing the techniques of production, the production effects of the system were largely confined to reducing the losses which had previously occurred due to poor water conditions. This permitted average production to rise toward a "ceiling" set at the level of production obtained in years of favorable water conditions prior to the construction of the system. The one production technique that did change (method of planting) raised this ceiling only slightly. Thus the return on the investment was limited (1) by the difference between this ceiling and the average level of production prior to the construction of the system, and (2) by the extent to which the system was able to change the water conditions so that average production could rise toward the ceiling.

Thus if there had been more severe damage prior to the construction of the system, the returns might have been higher. In this context it is interesting to note that the data on damaged area for the years prior to the construction of the system indicate considerably less damage than might be expected from a reading of the reports that were written early in the 20th century. Three explanations seem possible. First, the data of the Rice Department may understate the amount of damage that actually occurred in the years prior to the construction of the system. If this is true, the actual returns to the investment in water control were almost certainly higher than estimated in Chapter 3. Second, it is possible that the early reports presented an inaccurate picture of the magnitude of crop failures. The third possibility is that there was a decrease in the severity of crop failures even prior to the construction of the water control system. It is possible that as farmers began to cultivate new land in the Chao Phya delta in the late 19th and early 20th centuries, they initally encountered very serious crop failures. Gradually, however, they may have learned to adjust their methods of farming (choice of varieties; timing of operations; etc.) to the prevailing water conditions of the area, thus reducing the amount of damage. It seems plausible, therefore, that some stabilization of production was achieved by the farmers themselves. This does not necessarily imply that higher returns could have been obtained by investing in the water control system early in the 20th century. The total area cultivated at that time was much smaller than in 1960, so that larger benefits per hectare might well have been more than offset by the smaller area planted.

It is also clear from this study that there is very limited potential for futher increases in returns under traditional agricultural conditions. Further increases in production from the reduction of damaged area in regions that are not deeply flooded are not possible because such damage has already been largely eliminated. At the same time, limitations of the system make it unlikely that any substantial reduction in the area damaged will take place in the regions that flood deeply. It can thus be concluded that the original system has largely achieved its potential for increasing production. The returns to the investment in this system have probably been as high as could reasonably be expected, considering both the nature of the system and the agricultural conditions prevailing in the project area prior to its construction.

Since the individual farmer is the ultimate dicision-making unit in the production process, the question of his response to the change in water control is of considerable importance. Under traditional agricultural conditions, the relationship of the farmer to the system has generally been a passive one. This does not imply that the farmers are unwilling to respond to the new water conditions, but rather reflects the nature of the system operating within the context of traditional agriculture. Since the major impact of the system was the reduction in losses caused by unfavorable water conditions, there was very little response required from the farmer. Furthermore, under the existing system, farmers have little control over the supply of water to their land. If there is too much water, there is generally no way for the farmer either to prevent additional "irrigation water" from entering his fields, or to facilitate the drainage of excess water. If the supply of water is inadequate, some farmers may be able to divert water from either a distribution or a drainage canal by pumping or by building a temporary weir across the canal to slightly raise the water level on the upstream side of the weir. Such activities, however, generally interfere with the operation of the water control system, and are actively discouraged by the RID officials.

There were two situations where active response was possible. The shift from broadcasting to transplanting required the active participation of the farmer, who had to build bunds in his fields, change his methods of management, and use much larger amounts of labor in producing the crop. The large increase in transplanting which took place demonstrates that under the proper conditions farmers can actively respond to changes created by the new water conditions. While some officials feel that this response has been slow, it must be remembered that some time was required for the farmers to observe the nature of the altered water conditions. The existence of a number of reported cases where farmers attempted transplanting, sometimes on the advice of government officials, only to have their crop destroyed by too much water suggests that farmers have not been unduly cautious in responding to the changed water conditions.

The second situation concerns the participation of the farmers in the construction and maintenance of the ditches which conduct water from the distribution canals constructed by RID. It was originally expected that the farmers would construct and maintain these ditches. Although such participation was required by law, very little construction took place. Eventually it was decided that RID would proceed with the construction of a skeleton network of such ditches, under the Ditches and Dikes program. Farmers were then required only to maintain these ditches. In many parts of the project, however, maintenance has been very poor. Clearly this is a situation where the farmers have not actively responded in the way expected or desired by the officials of the project.

In considering this lack of response, it is important to note that from the point of view of the individual farmer, the ditches may have both positive and negative effects. The negative effects stem partly from the fact that the ditches were dug on his private land, without consideration of land boundaries. They thus reduce the amount of land available for rice production, and may also cause some inconvenience due to the fragmentation of his land. Furthermore, the ditches may facilitate the flow of water off his land and onto lower areas during the early part of the season when he desires additional water for land preparation and transplanting. The relative importance of the positive and negative effects varies from farm to farm. It must also be noted that many of the ditches were not properly constructed, so that even with proper maintenance farmers far from the distribution canal could receive little or no benefit from the ditch.[1] Maintenance appears to have been poorest in the deeply flooded parts of the project, where the benefit of the ditches is rather questionable. Finally, even if the ditches are effective and there are no negative effects, a farmer living close to a ditch may have little incentive to maintain it simply because most of the benefits flow to his neighbors.

It thus appears that the active response of the farmers has been limited in part by the inability of the individual farmer to improve conditions on his farm by maintaining the ditches. While more effective social organization may help solve some of these problems, it must be recognized that in parts of the area the problems are a reflection of the limited capability of the system to change the water conditions impinging on the traditional agriculture of the area.

## Water Control in the Context of Modern Agriculture

Although there may be some disagreement regarding the exact details of design, there is general consensus concerning the changes necessary to support modern agriculture in the project area. For the wet season, the requirements are to provide (1) greater control over the distribution of water, enabling individual farmers to obtain it as needed, and (2) facilities to permit the drainage of excess water both from individual fields and from the system. Furthermore, to support modern agricultural production in the dry season, water must be available; it must be possible to deliver this water to the individual farms; and the farm fields need to be relatively level. To date, only in small pilot areas have all of these conditions been achieved.

A system meeting these requirements provides the environmental basis for the application of new agricultural technology. In the wet season, the potential of the new fertilizer-responsive varieties of rice substantially raises the "ceiling" of production imposed by traditional agricultural conditions. The possibility of production in the dry season raises the overall production potential still further. The returns which thus potentially could result from the development of water control to meet these conditions appear to be considerably greater than in the case of water control supporting traditional agriculture. These returns are actually joint returns to both the improvement of water control and the breeding of the new varieties. From a practical point of view, however, the fact that the new varieties have already been developed means that the potential increase in production resulting from the construction of the appropriate water control system is much greater than it would have been in the absence of this biological development.

In contrast to the situation with traditional agriculture, the potential returns resulting from this additional investment in water control are greatest in dry season. In part this is due to the greater difficulty of providing the necessary environmental conditions in the wet season. Even with substantial improvements in wet season drainage, there is still a certain risk that heavy rains or flooding in any given year will result in a crop failure if the new varieties are grown. Farmers may, therefore, be slow to adopt the new technology. A second reason for the higher potential returns in the dry season is the relative lack of opportunity for alternative productive activity. A system permitting dry season production allows for the utilization of labor which, from a national production point of view, would otherwise be largely unutilized. Thus the entire net value of the dry season production can be considered to be a benefit of the investment in water control, while in the wet season the benefit is only the net value of the difference between future and present production.

The limitations on the returns that can be expected from such a system are fairly obvious. In the wet season, the returns are limited by the ability of the system to create the conditions necessary for the application of the new technology. This is of particular importance in the deeply flooded areas, where drainage and flood control can be provided only at great expense. In the dry season the major limitations appear to be on the amount of water which can be stored for dry season irrigation, and on the ability of the system to actually deliver the water. This latter factor is again of importance in the areas which are deeply flooded in the wet season, since this flooding will tend to destroy any distribution structures built for use in the dry season.

Furthermore, the extremely flat nature of the southern part of the project area (the SB region) makes gravity delivery of irrigation water very difficult.

The opportunities for active farmer response to the change in water conditions are much greater in the context of modern agriculture than they were in the case of traditional agriculture. But if the potential returns are to be realized, active farmer response is much more important than in the past. In the wet season, this response involves using the new varieties, along with the "package" of management practices which is necessary to realize their yield potential. In the dry season, the response involves using the available water to produce a crop. The experiences with active farmer response under traditional agricultural conditions, plus the limited experience with modern agriculture in parts of the BT region and in the pilot projects suggest that while active farmer response cannot be taken for granted, and may not always occur in the ways expected or most desired by planners, it can be obtained when the appropriate changes in conditions at the farm level have occurred.

## Economic Questions in the Transformation of the Water Control System

Many of the details of the economic factors involved in the transformation of the water control system from one which supports traditional wet season agriculture to one which supports modern agriculture have been discussed in Chapter 4, and need not be repeated here. Instead, some of the broader economic questions concerning the transformation are dealt with in this section.

It should be emphasized first of all that the conceptual distinction between a water control system supporting traditional agriculture and one supporting modern agriculture is somewhat artificial. As pointed out in Chapter 4, possibilities already exist in parts of the project area for the adoption of the technology of modern agriculture, while in other areas, even after major improvements in the system, adoption of this technology may not be possible. There are thus different degrees of transformation affecting different portions of the geographic area of the project.

A second but related point is that the transformation itself is a gradual process. This is clearly shown in the development of the capability to store water for use in the dry season. The feasibility study for the first upstream storage dam (Bhumiphol) was conducted prior to the completion of the diversion dam at Chainat. During the period of the construction of the Bhumiphol dam, the feasibility studies for the second upstream dam (Sirikit) were conducted. This dam is now scheduled for completion in 1972 or 1973, more than 15 years after the planning began for the first dam. Another example of the gradual nature of the transition involves current proposals for the full development of the system to support modern agriculture. The NEDECO proposal envisions that these improvements would be constructed over a period of 15 years.[2]

Because the transformation is a gradual process, the question of the "optimal" timing of the construction of the various phases arises. Since there are so many practical and intangible factors involved in the determination of the actual timing of developments (such as budget allocations; loans for foreign exchange; the availability of the skilled manpower needed for planning and implementing the developments; and the availability of leadership skilled in obtaining these resources), it is not possible to determine a precise optimum pattern. The analysis of this study, however, does enable one to make some broad statements about the timing. It is clear that the transformation of the system immediately following its original construction would not have been optimal. The investment would have been made several years prior to the availability of the technology which it was designed to support. This would have substantially increased the costs without any immediate corresponding increase in the benefits. It is also clear that waiting until the new technology had been developed before beginning the transformation of the system would not have been optimal, since a long period of time would elapse during which the potentially large benefits of the new technology would have been foregone.

While the actual timing followed has been between these extremes, it has been closer to the latter of the two. One element which did precede the availability of the new technology was the construction of the upstream dams necessary to store water for use in the dry season. These dams, however, could be immediately used for power production, and the provision of irrigation water, at least in the case of the Bhumiphol dam, was only a secondary consideration. Furthermore, it was clear, even without knowing the precise nature of the technological developments which would later take place, that water was necessary for the development of dry season agriculture.[3] A second element which also preceded the development of the new technology was the construction of the ditches and dikes which, to a limited extent, improved the ability of the system to distribute water in the dry season. Planning for the implementation of the other requirements for transforming the system did not, however, begin until about the time that important developments in the breeding of the new rice varieties were taking place.

Although it might have been more desirable if such planning had been started sooner, two factors should be emphasized. First, it was not clear until the development of the new varieties at the International Rice Research Institute that the single most important aspect of modern technology for rice production was going to be that of varieties which would be quite short, and demand much more precise water control. Furthermore, the development of dry season cropping encountered more problems than had been anticipated at the time of the initial planning for the storage of water for use in the dry season. In particular, the difficulties of irrigated upland crop production on the soils of the project area were underestimated, while the capability of the system to deliver water by gravity in the dry season was overestimated. Only with some experience did it become clear that without substantial further investment, dry season cropping would remain quite limited.

The foregoing discussion suggests that the timing might have been closer to optimal if there had been greater foresight regarding developments in the technology of rice production, and if there had been greater understanding of the practical shortcomings of the system with respect to dry season cropping. The point to be emphasized is that greater knowledge may result in improved timing of the development of a water control system. Close coordination between the agencies planning for the development of water control and agencies involved in research leading to technological developments in agricultural production may result in improved knowledge. Even more important is the need for a method whereby systematic information on the relationships between the water control system, the farmer, and agricultural technology can be obtained and evaluated. The development of pilot areas where new ideas can be tested under farm conditions has considerable potential for providing this kind of information. Similar information might also be gathered from areas outside these pilot projects. It seems likely that if more such information had been available ten years ago, the timing of the development of the system could have been improved.

Closely related to the question of the timing of the transformation of the system is the problem of the lags that may occur between the completion of the physical facilities and the resulting increase in production. Such lags can drastically reduce the returns to the investment in water control. Experience with dry season cropping, both inside and outside the pilot projects, suggests several causes for such lags. First of all, the physical facilities may not be completely adequate to permit the desired change in production to occur rapidly and easily. Second, there may be technical agricultural problems in the production of irrigated crops. This is now particularly apparent with upland crop production, where many problems have been encountered both on individual farms and on experiment stations. Third, even after agricultural scientists have found practical solutions to the technical problems, the information will have to be passed on to the farmers, who in turn will have to learn, partly on the basis of trial and error, the appropriate techniques for successful production. Fourth, the shift to modern agriculture, especially when production occurs in both the wet and dry seasons, requires many new patterns of labor utilization and farm management. Some cropping patterns may require the mechanization of certain operations. Again, it will take some time for both the farmers and the supporting agricultural agenci s to work out these new patterns. Fifth, the introduction of new cropp ng patterns may encounter problems due to the initial lack of appropriate marketing arrangements. Finally, it may take a certain amount of time for the farmer to become convinced that the system can support the new type of agriculture at a reasonably low risk. This would appear to have been a factor in the (relatively short) lag between the completion of the original system and the reduction in broadcasting.

All of these lags involve the relationships between the system, the farmer, and technology. In order to reduce these lags, it is necessary for the reason for them to be identified as quickly as possible, so that methods for dealing with the problems may be found. More information is needed on the types of changes that are required on the individual farms, and on the conflicts and problems that are likely to arise that may limit the ability or willingness of the farmers to make these changes. Effort needs to be directed toward developing a research program to provide this information.

It has been pointed out above that the timing of the transformation should be related to the availability of new agricultural technology. While the discussion of the new technology has emphasized the development of the high yielding rice varieties, there are many other requirements for the successful introduction of modern agriculture in the project area. The technical difficulties with dry season cropping which have been encountered emphasize the importance of a program of applied research (such as that currently in progress at the Central Region Agricultural Center at Chainat) beginning many years prior to the widespread transformation of the water control system.

Although much has been learned from the work of the center at Chainat, there remain many areas where additional information is needed. Technical and economic aspects of alternative dry season cropping patterns need further investigation. More knowledge is needed about the production of the new rice varieties at different times of the year. Given the probable importance of rice in the total dry season production of the project area, a very careful examination of the long-run effects of double cropping of rice on soil and pest conditions is needed. Without the supporting technology that results from this type of research program, the potential returns to additional investments in water control will be reduced.

Another economic factor in the transformation of the system involves the extent to which the resources of the individual farmers will be used in the transformation. To date the system has not been very successful in mobilizing the resources of the farmers. Hopes that farmers would dig farm ditches have not been fulfilled, and the experience with the maintenance of the ditches has been disappointing. Some observers place considerable emphasis on the attitude of the farmer toward the responsibility of the government in the provision of irrigation water.[4] These observers suggest that since the farmers have never had to pay for irrigation water, they have come to feel that the entire development of water control is the responsibility of the government. It has been suggested above, however, that the failure of the farmers to fulfill these responsibilities is partly due to problems of social organization, and partly due to the apparent low productivity, under traditional agricultural conditions, of the expected work. The fact that the ditches are more adequately maintained in areas where dry season irrigation water is readily available in the main canals, and the fact that some farmers will go to some expense to pump water from the canals to produce a dry season crop suggest that it is possible to mobilize the resources of the farmers. Furthermore, the experience at the Pho Nang Dam project, where farmers have paid for a portion of the costs of the development of their land, indicates that the attitude of the farmer toward payment is not an insurmountable problem in the mobilization of these resources.

Much more study concerning alternative methods of obtaining these resources is needed. In particular, socio-economic investigation should be directed to questions surrounding alternative approaches to the establishment and maintenance of effective organizations for dealing with the local problems and potentials resulting from the water control system. In recent years various government agencies have attempted to establish a variety of farmers' organizations. Among those partially or completely designed to deal with questions of water control are the Land Improvement Cooperatives of the Department of Land Cooperatives (Ministry of National Development); the Multi-Purpose Cooperatives of the Office of the Under-Secretary, Ministry of National Development; the People's Irrigation Associations of the Ministry of Interior; and the Water Users' Associations of the Royal Irrigation Department. As yet there have been almost no studies on the interaction between the farmers and these organizations. The variety of organizations offers considerable scope for comparative studies. Furthermore, comparative studies with the organization of farmers in the smaller projects in Northern Thailand might provide insights into the requirements for successful organizations.[5]

One economic issue which has not been carefully examined relates to alternative sources of water for dry season irrigation. It appears to have been generally assumed that the need for water in the dry season necessitated the upstream storage of water. Possibilities for the use of ground water do exist, however. The Ground Water Division of the Department of Mineral Resources (Ministry of National Development) has recently conducted surveys that indicate the existence of water-bearing aquifers underlying the entire Central Plain. The depth to these aquifers ranges from less than 20 meters near Chainat to about 100 meters near Bangkok.[6] Although there has been little or no development of tubewells for agricultural purposes in the area, numerous wells have been installed to supply urban centers.[7] Considering the success of tubewells in countries such as India, investigations into the economics of tubewell irrigation should be made in the Central Plain. Given the magnitude of the additional investment required to permit effective use of stored water, such studies might have important policy implications regarding the strategy for the further development of the system of surface water control.

Agricultural technology has a major impact on the economics of the transformation of the water control system. Much of the discussion in Chapter 4 regarding the transformation of the system is based on the agronomic characteristics of the high yielding rice varieties. Major new developments in rice breeding could, therefore, necessitate a re-evaluation of the alternatives available. In this regard, current efforts to develop high yielding varieties which will perform well even under conditions of relatively deep water are of particular significance. Should these efforts be successful, the importance of wet season drainage would be greatly reduced. This in turn would affect the economic relationships among all three of the alternatives discussed in Chapter 4. Obviously it is impossible for anyone to know with certainty the directions that new technology will take. But knowledge of the nature of research efforts in the biological sciences should assist planners in their efforts to transform the water control system into one which will satisfactorily and efficiently support modern agricultural production.

Another issue in the transformation of the system relates to the form of the resulting increase in production. As noted in Chapter 4, there are several agronomic and economic factors which make it unlikely that a large increase in upland crop production will result from the investment to transform the water control system. Although some of the limitations can probably be removed fairly rapidly, it must again be emphasized that the most limiting factor is the nature of the soils. Less than two percent of the project area has soils which are best suited for the production of upland crops, and over three-fourths of the area has heavy clay soils which are considered to be completely unsuitable for irrigated upland crop production. While technological developments may eventually improve the possibilities of upland crop production on these soils, no such developments are likely to take place in the near future.

The obvious conclusion is that while the transformation of the Greater Chao Phya water control system will lead to increased production, a large proportion of the increase will be in the form of rice. This demonstrates the importance of very close scrutiny of proposed development strategies which have as their goal the promotion of upland crop production. The returns that can be anticipated to the entire bundle or resources invested solely for the purpose of promoting upland crop production in the Chao Phya project may well be lower than the returns that could be expected if the same resources were invested in parts of the country where conditions are more favorable for upland crops. A related conclusion is that to the extent that resources for the promotion of upland crop production are invested in the project area, returns are likely to be greatest if these resources are concentrated in a few areas having especially favorable soil conditions for planted crops.

A slightly different approach to the problem is to consider the entire bundle of resources which the government is prepared to invest to increase agricultural production. If the investment is concentrated in the project area, there will be some increase in the production of both rice and upland crops. If, however, these same resources are used to promote rice production in the project area and upland crop production in some other part of the country, it is possible that the increase in production both of rice and of upland crops will be even greater. If this is true, then the concentration of the investment in the project area is an inefficient use of the resources of the nation. The possibility that such a situation exists suggests the need for a more careful examination of this question. In particular, the total resource requirements (including the services of government agencies) of a development strategy designed to promote upland crop production in the project area should be compared with the requirements of a program designed to transform the system to support only rice production. In addition, the resource requirements for the promotion of increased production of upland crops in other parts of the country need to be examined.

The final point to be made in this section concerns the relative magnitude of the additional investment necessary for the transformation of the water control system. This additional investment, exclusive of the cost of the upstream storage dams, was estimated in Chapter 4 to amount to as much as \$328 per hectare. The original investment of about \$136 per hectare is thus only from one-third to one-half of the total investment necessary to provide a system that will support modern agriculture. It has sometimes been argued that the original investment created a potential for a large increase in production, and that a small additional investment to improve or "complete" the system would, by permitting the realization of this potential, give very high returns. It is quite clear from the analysis of this publication that such an argument is not realistic. Most of the potential created by the original system has already been achieved. Further large increases in production can be achieved only through the development of conditions to support modern agriculture in the project area. While such development might lead to large increases in production, a major new investment would be required. Whether or not the returns to such investment would be favorable depends on a number of factors which have been discussed in this section. It is likely, however, that the returns to additional small investments would be disappointing.

## Broader Issues in the Evaluation of Water Control

This study has concentrated on the evaluation of water control in the northern part of the Central Plain of Thailand from the narrow point of view of economic efficiency. Emphasis has been placed on the nature and magnitude of the direct changes in production resulting from the water control system. Since increasing production has been a major objective in the development of water control, the information developed in this study is an important element in the evaluation of the project. There are, however, other factors and issues which need to be considered in a complete evaluation of the project. While these factors are not the subject of inquiry of this study, a brief mention of some of them will help place the analysis of this study in proper perspective.

First of all, issues of equity must be considered. Regardless of the economic efficiency, an investment which has raised net cash returns from crop agriculture by an estimated 25 percent is an important factor in the welfare of the farmers of the project area. It is not obvious that any altervative investment could have resulted in such a substantial increase in income to these farmers.

Another equity consideration concerns the relationship between the farmers in the project area and those in other parts of the country. There are two aspects to this question. First, to the extent to which relatively more investment has been made in the project area, the farmers living in the area may have become relatively better off than farmers in other areas. Second, the initial investment is likely to make further investment in the same area appear more favorable, on economic efficiency grounds, than would otherwise have been the case. This is one reason given in the third five-year plan of Thailand for a concentration of developments in the Central Plain. Thus the initial investment may not only benefit the farmers of the project area relative to other farmers, but may also tend to encourage additional investment, further benefiting these farmers, to be made in the area.

In addition to these equity considerations, there are political and developmental questions which cannot be answered by a simple economic efficiency analysis. The fact that Thailand has depended heavily on rice both for consumption and for export has made rice production a political question of major importance. Greater stability in production, leading to greater stability in export earnings, may be a factor in the maintenance of political stability. Furthermore, the reduction in the dependence of rice production on natural weather conditions gives the economy a greater degree of flexibility which may be important in permitting adjustments to changing technology and to changing supply and demand situations for various crops. While the specific changes that will occur cannot be known at the time an investment decision is made, there is a presumption that flexibility will be beneficial to the long-run development of the nation. Another aspect of this flexibility relates to the knowledge and experience of the farmers. As farmers gain more knowledge of and experience with modern agriculture, they are also likely to become more capable of meeting changing conditions.

Thus the development of a water control system such as the one investigated in this study may set in motion a cumulative process of "circular causation" which will have many implications for the long-run development prospects of the nation. Unfortunately, neither economists nor other social scientists have been very successful in documenting the exact nature of these kinds of changes. As a result there is, appropriately, a considerable amount of subjective judgment involved in an overall evaluation of any large water control project. In such an evaluation, the knowledge derived from the economic efficiency analysis may be of some use in assisting policy-makers to understand past results; to plan for future developments; and to focus attention on areas where greater knowledge is needed.

## Footnotes to Chapter 1

[1] United Nations Economic Commission for Asia and the Far East, Degats Causes par les Inondations et Travaux de Defense Projectes ou Executes en Asie et Extreme-Orient (Bangkok: Flood Control Series No. 1, January 1951), p. 20.

[2] United Nations Economic Commission for Asia and the Far East, A Compendium of Major International Rivers in the ECAFE Region (New York: Water Resources Series No. 29, 1966), p.17.

[3] Pierre Gourou, Le Tonkin (Paris: Exposition Coloniale Internationale, 1931), pp. 71-80; Dao Trong Kim and Tran Ngoc Hau, "The Control of Floods by Dikes in the North Viet-Nam Delta" in United Nations Economic Commission for Asia and the Far East, Proceedings of the Regional Technical Conference on Flood Control in Asia and the Far East (Bangkok: Flood Control Series No. 3, 1952), pp. 40-55.

[4] A. Volker, "The Deltaic Area of the Irrawaddy River in Burma," in UNESCO, Scientific Problems of the Humid Tropical Zone Deltas and Their Implications: Proceedings of the Dacca Symposium (Paris: UNESCO, 1966), pp. 373-379.

[5] The other three geographic regions of Thailand are the North, the Northeast, and the South. For discussions of the physical geography of Thailand see M. Y. Nuttonson, The Physical Environment of Thailand (Washington, D.C.: American Institute of Crop Ecology, 1963), and Robert L. Pendleton, Thailand: Aspects of Landscape and Life (New York: Duell, Sloan and Pearce, 1962).

[6] See James C. Ingram, Economic Change in Thailand 1850-1970 (Stanford: Stanford University Press, 1971), p. 242.

[7] The project is commonly referred to as the Greater Chao Phya "irrigation" project. But the broader term "water control" is more descriptive of the functions of the project.

[8] The 16 subprojects are: Pholathep (also known as Makhamthao), Tha Bot, Sam Chuk, Sam Chuk Extension, Pho Phraya, Boromathat, Channasut, Yang Mani, Phak Hai, Maharat, Noi-Maharat Extension, Manorom, Chong Khae, Khok Krathiam, Roeng Rang, and Nakhon Luang. Water control facilities have not yet been built in the Noi-Maharat Extension subproject.

[9] These are the West Bank tract and one portion of the Chiangrak-Khlong Dan tract.

[10] In accordance with common usage in Thailand, crops other than rice are referred to as upland crops.

[11] Food and Agriculture Organization, United Nations Development Program Survey Mission for the Chao Phya Delta, Thailand, Report to the United Nations Development Programme, 4 February to 30 April, 1968 (Rome: EA:SF/THA/68, April 30, 1968), p. 2.

## Footnotes to Chapter 2

1 Thailand, Royal Irrigation Department, Administration Report of the Royal Irrigation Department of Siam for the Period 2457 B.E.-2468 B.E. (1914/15-1925/26) (Bangkok, 1927). p. 2 (hereafter referred to as Administration Report).

2 Ibid.

3 Ibid.; Thailand, Royal Irrigation Department, Report of the Royal Irrigation Department of Siam on the Benefits which have already accrued to the State by Irrigation Works already completed, and what benefit may be expected from Works still to be undertaken (Bangkok [?], 1929). p. 10 (hereafter referred to as Report on the Benefits).

4 J. Homan van der Heide, General Report on Irrigation and Drainage in the Lower Menam Valley (Bangkok, 1903).

5 Thailand, Royal Irrigation Department. Project Estimate for Works of Irrigation, Drainage and Navigation to Develop the Plain of Central Siam (Bangkok, 1915, 4 vol.), vol. 3, pp. 10-12 (hereafter referred to as Project Estimate).

6 Ibid., vol.3, pp. 16-19.

7 Ibid., vol. 3, p. 23.

8 Ibid., vol. 3, pp. 23-24.

9 Administration Report, p. 3.

10 Thailand, Royal Irrigation Department, Report on a Scheme for the Irrigation of sommuch of the Valley of the Menam Chao Phraya as may be Possible for a Capital Outlay of One and Three Quarters Million Sterling (Minute by H.R.H. Prince Krom Luang Rajaburi Direkriddhi; Report by Mr. T.R.J. Ward. Bangkok, 1915), pp. 1-4 (hereafter referred to as Report on a Scheme).

11 The term "inundation project" was used to refer to projects served by canals which would only receive water from the main river during periods of high river flow. "Irrigation projects" referred to projects served by canals which could receive water from the main river regardless of the level of flow of the river. (See van der Heide, op. cit., pp. 32-33.)

12 Administration Report, p. 8.

13 Ibid., p. 6.

14 Report on the Benefits, pp. 4-6.

15 Administration Reports, p. 19.

16 Ibid., pp. 79-80.

17 Thailand, Royal Irrigation Department, Royal Irrigation Department (Bangkok, 1970).

18 Ibid.

19 Thailand, Royal Irrigation Department, Report on Irrigation Drainage and Water Communication Project of Chao Phya River Plain (Bangkok, 1949) (hereafter referred to as Report on Irrigation.)

20 International Bank for Reconstruction and Development, The World Bank Group in Asia: A Summary of Activities (Washington, D.C. [?], September 1963), pp. 79-81.

21 Report on Irrigation, p. 37.

22 United States Bureau of Reclamation, Report on Yanhee Project, Thailand, for Power, Flood Control, and Irrigation (Prepared for the Royal Irrigation Department of Thailand, n.p., 1955, 2 vol.).

23 Ibid., vol 1, p. 40.

24 International Bank for Reconstruction and Development, op. cit., pp. 79-81.

25 Thailand, Royal Irrigation Department, Yanhee Multipurpose Project Bhumiphol Dam, Thailand (Bangkok [?], 1962 [?], p. 15.

26 Food and Agriculture Organization, United Nations Development Program Survey Mission for the Chao Phya Delta, Thailand, op. cit., pp. 10-11.

27 Thailand, Royal Irrigation Department, "General Information on Dry Cropping of Greater Chao Phya Project and Petchburi Project Areas in 1969-1970" (mimeo, n.d.); Thailand, Royal Irrigation Department, "General Information on Dry Cropping Greater Chao Phya Project and Petchburi Project for 1970-1971" (mimeo, n.d.); United States Bureau of Reclamation, op. cit., vol. 1, p. 49.

28 Thailand, Royal Irrigation Department, Nan River Project, Thailand. Multipurpose Project Irrigation, Power, Flood Control and Navigation. Feasibility Report (Prepared by Engineering Consultants, Inc., Denver, 1964).

29 Thailand, Royal Irrigation Department, Supplementary Report. Nan River Feasibility Report (Bangkok, 1963).

30 Thailand, "Loan Agreement (Phasom Dam Project) Between Kingdom of Thailand and International Bank for Reconstruction and Development" (n.p., September 19, 1967, pamphlet).

31 Ibid.

[32] van der Heide, op. cit., p. 62.

[33] Report on a Scheme, p. III.

[34] Project Estimate, vol. 3, p. 19.

[35] Report on the Benefits, pp. IV and 2; P. A. Thompson, Lotus Land (London, 1906), pp. 75 and 174.

[36] van der Heide, op. cit., pp. 51-55.

[37] Report on the Benefits, p. 47.

[38] Report on Irrigation, pp. 50-51.

[39] United States Bureau of Reclamation, op. cit., vol. 1, p. 49.

[40] Thailand, Royal Irrigation Department, Additional Information to be Included in the Revised Project Report on the Dikes and Ditches Project (Bangkok, 1961) (hereafter referred to as Additional Information).

[41] van der Heide, op. cit., pp. 33, 89-90.

[42] Ibid., p. 91.

[43] Ibid.

[44] Project Estimate, vol. 3, p. 4, footnote.

[45] Report on a Scheme, p. IV.

[46] Ibid., p. 6.

[47] Ibid., p. 17.

[48] Report on Irrigation, p. 54.

[49] Thailand, "The Field Dikes and Ditches Act, B.E. 2482," in Laws Concerning Irrigation, published by the Royal Irrigation Department (Bangkok [?], 1960, second edition), pp. 20-28.

[50] van der Heide, op. cit., pp. 133-135. One baht was roughly equivalent to $.25 in 1903. (See Ingram, op. cit., p. 337.)

[51] Report on the Benefits, p. VII; Report on a Scheme, pp. 17-18.

[52] Administration Report, p. 63.

[53] Ibid., p. 134.

[54] Report on the Benefits, p. 19.

[55] Ibid.

## Footnotes to Chapter 3

1 The name "floating" comes from the ability of these varieties to elongate rapidly, especially under conditions of rapidly rising water. See Asanee Yantasast, et.al., "Breeding Dwarf Varieties of Rice for Tolerance to Deep Water," in Thai Journal of Agricultural Science III (1970), 119-133.

2 For purposes of analysis, the project was originally divided into six regions, rather than three. But since the analysis indicated that the water control system had affected four of them in a similar way, I have, for convenience of discussion, grouped these four together into this single BT region. A detailed description of each of the original six regions is given in Leslie E. Small, An Economic Evaluation of Water Control in the Northern Region of the Greater Chao Phya Project of Thailand (Cornell University, unpublished Ph.D. thesis, 1972), Chapter 3 (hereafter reffered to as An Economic Evaluation).

3 Thailand is divided into 71 changwat (provinces). Each changwat is subdivided into amphoe (districts), which are further subdivided into tambon (communes). Each tambon consists of several muban (villages).

4 Thailand, Ministry of Agriculture, Department of Rice, Nua Thi lae Phonphalit Khao khong Kan Tham Na Raya 26 Pi Pho So 2480-2505 (in Thai) /Area and Production of Rice during 26 years, 1937-1962/ (Bangkok, 1965); Thailand, Ministry of Agriculture, Department of Rice, Rai Ngan Sarup Phon Kan Tham Na /Annual Report on Rice Production in Thailand/ (Bangkok, annual, 1963-1965, published in Thai and English; 1966-1968 mimeo in Thai); Thailand, Ministry of Agriculture, Department of Rice, Sathiti Khwam Sia Hai khong Na Khao Pho So 2490-2508 (in Thai) /Statistics on Damage to Rice Production, 1947-1965/ (Bangkok, 1967).

5 A brief description of these methods is given in Jere R. Behrman, Supply Response in Underdeveloped Agriculture: A Case Study of Four Major Annual Crops in Thailand, 1937-1963 (Amsterdam: North-Holland Publishing Company, 1968), p. 203.

6 The suggestion that such pressures have led to biases in the production data was originally made in Pendleton, op. cit., p. 135. It was later quoted by Behrman, op. cit., p. 201.

7 S. S. Zarkovich, Quality of Statistical Data (Rome: Food and Agriculture Organization, 1966), pp. 330-333.

8 This statement is based on an interview with Dr. Sala Dasananda, former Director-General of the Rice Department.

9 The results of this survey are reported in Thailand, National Statistics Office, Census of Agriculture, 1963 (Bangkok, 1964, 76 volumes), Whole Kingdom Volume, pp. 57-71.

10 Thailand, National Economic Development Board, National Income Accounts of Thailand 1965 (Bangkok, 1966), pp. 108-112.

11 The comparison was made by aggregating unpublished tambon data of the Rice Department into units roughly comparable with the areas of each of the subprojects. The data for these comparisons are presented in Leslie E. Small, "Northern Chao Phya Projects: Tables Comparing Rice Production Data from the Royal Irrigation Department and the Rice Department, 1958-1969" (Bangkok: Kasetsart University, 1971, mimeo).

12 Behrman, op. cit., pp. 202-204; T. H. Silcock, The Economic Development of Thai Agriculture (Ithaca, N. Y.: Cornell University Press, 1970), p. 32.

13 For certain crops, data for 1964 and 1965 were submitted by only some of the subprojects. Use of the totals reported by RID for the entire project area for these years can therefore be quite misleading.

14 See, for example, Thomas Floyd Weaver, Irrigation and Agricultural Development in Raipur District, Madhya Pradesh, India (Cornell University, unpublished Ph.D. these, 1967); and Thomas Henry Wickham, Water Managment in the Humid Tropics: A Farm Level Analysis, (Cornell University, unpublished Ph.D. thesis, 1971).

15 Examples of this type of study are S. K. Basu and S. B. Mukherjee, Evaluation of Damodar Canals (1959-1960): A Study of the Benefits of Irrigation in the Damodar Region (New York: Asia Publishing House, 1963); D. R. Gadgil, Economic Effects of Irrigation: Report of a Survey of the Direct and Indirect Benefit of the Godowari and Pravara Canals (Poona: Gokhale Institute of Politics and Economics Publication No. 17, 1948); Divakar Jha and Satish Chandra Jha, "Land Value as a Measure of Primary Irrigation Benefit in Tribeni Canal," in Indian Journal of Agricultural Economics XVII (July-September 1962), 69-73; and William K. Kapp, "River Valley Projects in India: Their Direct Effects," in Economic Development and Cultural Change VIII (October 1959), 24-47.

16 Thailand, Royal Irrigation Department, Tables Showing Water Resources Development in Thailand Completed to the End of 1969 and Under Construction in 1970 (Bangkok, 1970). The only exceptions are the Sam Chuk and Pho Phraya subprojects, which were in operation prior to the construction of the Chao Phya dam. The official completion dates for these two subprojects are 1933 for Pho Phraya and 1950 for Sam Chuk.

17 Following the definitions used in the Thai statistics, this is called the "percent damaged".

18 There is a general background article on the development of the Greater Chao Phya project, in which it is stated that the construction of the project has caused rice in the low, deeply-flooded areas (which comprise the CB region) to become less stable than

previously. (Takashi Tomosugi, "Histroical Development of Irrigation and Drainage in the Chao Phraya Delta," in Water Resource Utilization in Southeast Asia /Kyoto University, Center for Southeast Asian Studies, Symposium Series III, 1966/, pp. 165-176.) No evidence is given to support this claim, however, and considering the very general nature of the article, it must be concluded that the author is suggesting a possibility rather than stating a proven fact.

19 Farmers do not generally consider transplanting to be feasible if the rice is subject to deep flooding, or if a very rapid increase in the depth of the water standing on the field is expected. Inadequate water for field preparation may also make transplanting difficult or impossible.

20 Experimental results have shown that under certain management conditions there is no significant difference between the yields of broadcast and transplanted rice. (See Anonymous, "Analysis and Interpretation of Data from the Experiment on 'Agro-Economic Study of Production Management Systems for Rice', Suphanburi Rice Experiment Station, 1969 Wet Season" /Bangkok (?), Kasetsart University (?), n.d., mimeo/. It would appear, however, that the management conditions necessary for these results to hold require a degree of water control which is seldom achieved under farm conditions in the project area.

21 Thailand, Ministry of Interior, Department of Local Administration, Tham Niep Thong Thi (in Thai) /Directory of Local Administration/ (Bangkok, 1969).

22 Reports on these surveys are given in Thailand, Royal Irrigation Department, Land Consolidation Project Phase II. Report on the Farm Management Survey (Arnhem, The Netherlands: Netherlands Engineering Consultants /NEDECO/, 1969) (hereafter referred to as Report on the Farm Management Survey); and in Thailand, Royal Irrigation Department, Northern Chao Phya Study (The Hague: Netherlands Engineering Consultants /NEDECO/, 1970, 3 vol.), vol. 2 (hereafter referred to as Northern Chao Phya Study).

23 The transformation applied was $Y_t = \sqrt{Y + .5}$, where Y is the pecent damaged, and $Y_t$ is the transformed variable. See Robert G.D. Steel and James H. Torrie, Principles and Procedures of Statistics, with Special Reference to the Biological Sciences (New York: McGraw-Hill, 1960), p. 157.

24 For a detailed discussion of the results see An Economic Evaluation, pp. 188-193.

25 Thailand, Ministry of Agriculture, Division of Agricultural Economics, Unpublished data from the 1970 Farm Production Economics Survey (hereafter reffered to as the DAE survey); Thailand Royal Irrigation Department, Unpublished data from a survey in the Sam Chuk subproject, conducted in 1968 by the Economics Section of the Planning Division, in cooperation with the U.S. Bureau of Reclamation (hereafter referred to as the Sam Chuk Survey).

26 Thailand, Department of Customs, Annual Statement of Foreign Trade of Thailand (Bangkok, annual).

27 Food and Agriculture Organization of the United Nations, UNDP/SF Soil Fertility Research Project in Thailand, The Marketing of Fertilizer in Thailand (Prepared by Wolf Donner and Banlu Puthigorn, Bangkok, 1970), p. 25. Information from my interviews with local agricultural officials also supports this statement.

28 Ibid., pp. 9-10.

29 Ibid., pp. 25-29.

30 The details of the analysis are presented in An Economic Evaluation, pp. 368-374.

31 Brook A. Greene, Rate of Adoption of New Farm Practices in the Central Plains, Thailand (Cornell University Department of Agricultural Economics: Occasional Paper No. 41, 1970), p. 26; Philip Judd, "Irrigated Agriculture in the Central Plain of Thailand" (Paper presented at the Seminar on Contemporary Thailand, Australian National University, 6-9 September, 1971, mimeo), p. 19.

32 But data for two provinces lying mostly in the CB region (Singburi and Ang Thong) do not lend any support to this suggestion.

33 Many farmers from other areas come into this area during the dry season and rent land from the local farmers for watermelon production. While good soil conditions and established marketing channels are undoubtedly important in attracting farmers into the area, the most significant factor appears to be that of water.

34 These varieties are known as RD-1 and RD-3. See Ben R. Jackson, et.al., "Breeding, Performance, and Characteristics of Dwarf, Photoperiod Non-Sensitive Rice Varieties for Thailand," in Thai Journal of Agricultural Science II (1969), 83-92.

35 There has been much written on the economic effects of the rice premium. An excellent short summary of the main arguments of the rice premium debate can be found in Ingram, op. cit., pp. 243-261. The premium was removed from most grades of rice in 1971 in an effort to make rice exports more competitive.

36 Dan Usher, "The Thai Rice Trade," in T. H. Silcock, ed., Thailand: Social and Economic Studies in Development (Canberra: Australian National University Press, 1967), pp. 206-230.

37 The details of the derivation of this estimate are presented in An Economic Evaluation, Chapter 4 and pp. 225-233.

38 See Ibid., Chapter 4 for a discussion of the information on which this estimate is based.

39 See Ibid., Chapter 4 for details.

40 See *Ibid.*, Chapter 4 for the estimation of the total net cash returns earned by farmers in the project area.

41 Thailand, Royal Irrigation Department, *Report: Operation and Maintenance. Review and Recommendations for Irrigation Projects in Thailand* (Prepared by Robert M. Fagerberg, consultant, Bangkok, 1965).

42 The techniques and underlying theoretical assumptions of benefit-cost and internal rate of return analysis are discussed in Otto Eckstein, *Water-Resource Development: The Economics of Project Evaluation* (Cambridge, Mass: Harvard University Press, 1965) and in Roland N. McKean, *Efficiency in Government Through Systems Analysis, with Emphasis on Water Resources Development* (New York: John Wiley and Sons, 1958).

Footnotes to Chapter 4

[1] Chinese Agricultural Development Study Team, "Project Proposal for Cooperative Agricultural Development in Sappaya, Chainat, Thailand" (Report prepared jointly with Thai Counterpart Specialists, Bangkok, 1968); Chinese Agricultural Technical Mission to Thailand, "An Economic Feasibility study on Agricultural Development in Sappaya Area, Changwat Chainat, Thailand" (n.p., 1969, mimeo); P. Judd, D. Matheson and J. A. Geltch, "An Approach to Farm Development in the Northern Chao Phya Basin Project Area" (Australian Colombo plan Team, Central Region Agricultural Centre, Ministry of Agriculture, February 1971, mimeo); Thailand, Royal Irrigation Department, Land Consolidation Project. Phase I: Report on the Feasibility of Land Consolidation (The Hague: Netherlands Engineering Consultants, 1968) (hereafter referred to as Report on the Feasibility of Land Consolidation); and Northern Chao Phya Study.

[2] Unpublished data on the areas that can be irrigated by gravity were provided by the Irrigation Agronomy Section of the Royal Irrigation Department.

[3] Northern Chao Phya Study, vol. 2, p. 81.

[4] William Burton, Potential Changes in the Distribution of Income among Rural Households in Thailand Resulting from the Adoption of New Rice Varieties (Cornell University, Ph.D. thesis in process).

[5] A 30 percent increase is considerably less than the potential of the new varieties. It has been suggested that farmers growing these varieties can expect increases in yields ranging from 15 to 100 percent, depending on management conditions (Ben R. Jackson, et. al., op. cit.). Given the difficulties of optimum water management, plus the farmers' lack of experience with the new varieties, the figure of 30 percent is probably realistic for the yield differential that can be expected in the near future.

[6] See An Economic Evaluation, Chapter 4, Tables 6a-6f for estimates of these amounts.

[7] Northern Chao Phya Study, vol. 2, p. 150.

[8] Ibid., vol. 2, pp. 102, 143.

[9] Unpublished data from the Royal Irrigation Department.

[10] Northern Chao Phya Study, vol. 2, p. 150.

[11] Ibid., vol. 2, pp. 150, 276.

[12] Ibid., vol. 2, pp. 157, 276.

[13] Ibid., vol. 2, pp. 90, 213; August L. Ahlf, Technical Record of the Design of the Greater Chao Phya Project of Thailand, Constructed 1951-1956 (Bangkok: Royal Irrigation Department, 1956).

[14] Thailand, Royal Irrigation Department, "Consumptive Use of Water by Crops" (Paper prepared by Paitoon Palayasoot for presentation at the Multiple Cropping Seminars, Chiengmai University, Chiengmai, May 7-8, 1970, mimeo).

[15] Northern Chao Phya Study, vol. 2, pp. 182-184.

[16] Ibid., vol. 2, pp. 165-280.

[17] Report on the Feasibility of Land Consolidation; Thailand, Royal Irrigation Department, Land Consolidation Project. Phase II: Planning and Implementation of Land Consolidation in the Project Area (Arnhem, The Netherlands: Netherlands Engineering Consultants, 1969).

[18] Report on the Farm Management Survey; Thailand, Department of Land Development, "Rai Ngan Phon Kan Wichai ruang Kan Tham Na Khrang Thi 2 nay Khet Khrong Kan Chat Rup Thi Din, Amphoe Bang Rachan, Changwat Singburi, Pho So 2513" (in Thai) /Report on the Investigation of the Production of a second Rice Crop in the Land Consolidation Project, Amphoe Bang Rachan, Changwat Singburi, 1970/ (n.p., 1971, typewritten) (hereafter referred to as "Report on the Investigation").

[19] This is a regional experiment station under the direction of the Ministry of Agriculture. An Australian Colombo Plan Team of researchers has been working at the Center for several years.

[20] Australia, Department of External Affairs, "Thai-Australian Chao Phya Research Project: Second Report to the Ministry of Agriculture of Kingdom of Thailand Covering Activities in 1969" (Canberra, July 1970) (hereafter referred to as "Thai-Australian Chao Phya Research Project").

[21] The analysis is being done by Mr. John Longworth of the Department of Agricultural Economics at the University of Queensland, Australia.

[22] Chinese Agricultural Development Study Team, op. cit.; Chinese Agricultural Study Mission to Thailand, op. cit.

[23] Unpublished information furnished by the Chinese Agricultural Technical Mission to Thailand, Chainat.

[24] Report on the Farm Management Survey; and unpublished data furnished by the Netherlands Engineering Consultants, Bangkok.

[25] All of the yield data reported for the NEDECO project are based on field measurements taken from a sample of farms.

[26] Unpublished data furnished by the Netherlands Engineering Consultants, Bangkok.

[27] "Report on the Investigation."

[28] Ibid.

29 Report on the Farm Management Survey.

30 Even in this case, however, the possibility of some production of this type cannot be ruled out. Farmers from the CB and SB regions, as well as those from outside the project might seek to rent some of the developed land in the dry season.

31 "An Approach"; Thailand, Royal Irrigation Department, "Report on the Growing of Some Field Crops under Furrow Irrigation during the Dry Season in 1970 in the Channasutr Land Consolidation Project" (Bangkok: Netherlands Engineering Consultants, August 1970, mimeo) (hereafter referred to as "Report on the Growing").

32 Unpublished data provided by the Australian Colombo Plan Team.

33 Unpublished data provided by NEDECO.

34 Thai-Australian Chao Phya Research Project," op. cit.

35 Unpublished data from the Royal Irrigation Department.

36 Thailand, Royal Irrigation Department, Chao Phraya Project Land Classification Feasibility Report (Prepared by Clarence C. Burnham and Somtohb Senawongse, Bangkok, 1970).

37 Philip Judd, "Irrigated Agriculture in the Central Plain of Thailand" (Paper presented at the Seminar on Contemporary Thailand, Australian National University, 6-9 September, 1971).

38 Unpublished data provided by the Australian Colombo Plan team.

39 "Report on the Growing."

40 "Thai-Australian Chao Phya Research Project", op. cit.; Thailand, Ministry of Agriculture, "preliminary Report on Activities of the Chao Phya Research Project Central Region Agricultural Centre Dry Season 1970" (n.p., September 1970, mimeo) (hereafter referred to as "Preliminary Report").

41 New developments in rice breeding could change this situation. Some work is currently underway to develop high yielding rice varieties which will tolerate relatively deep water. A breakthrough in this area could greatly alter the economic returns to the alternative approaches to the development in water control.

42 The word "probably" is included because of the possibility that the holdings of all the farmers include higher and lower land in roughly the same proportion. While this is not likely, there is virtually no information available on this matter.

43 "Preliminary Report"; and unpublished data provided by the Australian Colombo Plan team.

44 A similar conclusion regarding the relationship between Alternatives 2 and 3 cannot be made, since the average returns for Alternative 3 are less than those for Alternative 2.

## Footnotes to Chapter 5

[1] Report on the Feasibility of Land Consolidation, pp. III-20 to III-22.

[2] Northern Chao Phya Study.

[3] Upstream storage of water is only one method of supplying this water, however. The possibility of using ground water is discussed below.

[4] Shigeru Ishikawa, Agricultural Development Strategies in Asia: Case Studies of the Philippines and Thailand (Japan: The Asian Development Bank, 1970); T. H. Silcock, The Economic Development of Thai Agriculture (Ithaca, N. Y.: Cornell University Press, 1970).

[5] For a first step in this direction see Rose H. Frutchey, "Socio-Economic Observation Study of Existing Irrigation Projects in Thailand" (Prepared for the U.S. Bureau of Reclamation and the U.S. Operations Mission to Thailand, Bangkok [?], April 1969, mimeo).

[6] This information is based on an interview in June 1971 with the Chief of the Ground Water Division.

[7] One large well was drilled in 1971 to provide additional irrigation water for the pilot project at Khao Tha Phra in amphoe Muang Chainat.

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