IRRIGATION DEVELOPMENT OPTIONS AND INVESTMENT STRATEGIES FOR THE 1980'S

THAILAND

USAID

WATER MANAGEMENT SYNTHESIS PROJECT

WMS REPORT 5

THAILAND/USAID

IRRIGATION DEVELOPMENT OPTIONS AND INVESTMENT STRATEGIES FOR THE 1980'S

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agency or the United States government.

Prepared by

Jack Keller* - Team Leader and Civil & Irrigation Engineer
Wayne Clyma - Agricultural Engineer
Matthew Drosdoff - Tropical Soils Scientist
Max K. Lowdermilk - Water Management Extension Specialist
David Seckler - Agricultural Economist

*Utah State University
Agricultural and Irrigation Engineering
Logan, Utah 84322

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WMS Report 5

PREFACE

This study was conducted as part of the Water Management Synthesis Project, a program funded and assisted by the United States Agency for International Development through the Consortium for International Development. Utah State University and Colorado State University serve as lead universities for the project.

The key objective is to provide services in irrigated regions of the world for improving the design and operation of existing and future irrigation projects and give guidance to USAID for selecting and implementing development options and investment strategies.

For more information, contact the Water Management Synthesis Project for information about the project and any of its services.

Jack Keller, WMS Coordinator
Agricultural & Irrigation Engr.
Utah State University
Logan, Utah 84322
(801) 750-2785

Wayne Clyma, WMS Coordinator
Engineering Research Center
Colorado State University
Fort Collins, Colorado 80523
(303) 491-8285

FOREWORD

This report was developed to focus on AID's past effectiveness in assisting irrigation and the expected priority, size and nature of future irrigation efforts country by country. It includes recommendations for directing USAID/Thailand assistance programs in irrigated agriculture through the present decade.

The review team visited Thailand between October 19 and November 1, 1980 to develop this report. The members of this team were:

Jack Keller, Team Leader and Civil and Irrigation Engineer
Wayne Clyma, Agricultural Engineer
Matthew Drosdoff, Tropical Soils Scientist
Max K. Lowdermilk, Water Management Extension Specialist
David Seckler, Agricultural Economist

The team approached the task of dealing with irrigation development options and investment strategies in a less structured way than was used in the earlier Bangladesh and Pakistan studies. Rather than particularly trying to fit the typology of such comparatives as large vs. small, hardware vs. software, etc., this team elected to first develop a set of key recommendations based on analysis of documents, field visits and interviews. The background for arriving at these recommendations plus other pertinent information was organized and is the body of this report.

The team appreciated the information and long discussions we had with Dr. Anat Arbhabhirama, Deputy Minister of Agriculture and Chairman of the National Water Resources Committee. Mr. Kangwan Devahastin, Deputy Undersecretary of State, Ministry of Agriculture and Cooperatives, and Capt. Sunthorn Ruanglek, Director-General, Royal Irrigation Department (RID). We also want to thank Mr. Metha Hovaranga, Chief, Water Users Association Center, Irrigated Agriculture Section, O&M Division, RID, for accompanying us on our field tour, and the assistance of the many other RID personnel and Royal Thai Government personnel we met.

In addition, the team appreciates the thoughtful and cordial assistance from the many Mission personnel who helped us. We give special thanks to Mr. Jerry Wood and Mr. Sid Bower for arranging our schedule and accompanying us to interviews, to Assistant Director Bob Queener, for accompanying us on our field visits, and to Director Dan Cohen for the full cooperation of the Mission. We also wish to thank Dr. Sam Johnson of the Ford Foundation for his help.

Itinerary

October 19		Arrive Bangkok at 6:40 via PA 52 Check in at President Hotel
October 20	08:00	Pick up team at President Hotel - USAID vehicle
	08:30	Meet with USAID officials
	10:30	Meet with Dr. Sam Johnson, Ford Foundation
	13:30	Meet with Mr. Sanarn, Deputy Director-General of Department of Land Development and Mr. Samarn, Chief of Soil Survey Division, at Department of Land Development
October 21	09:00	Meet with:
		Mr. Kangwan Devahastin, Deputy Undersecretary of State, Ministry of Agriculture and Cooperatives
		Capt. Sunthorn Ruanglek Director-General, Royal Irrigation Department
		Dr. Boonyok Watanaphuti Chief, Project Planning Division, RID
		Mr. Liab Shanas Tahal Consulting Engineer Northeast Thailand Irrigation Projects, RID
		Mr. Metha Hovaranga Chief, Water Users Association Center Irrigated Agriculture Section O&M Division, RID at Ministry of Agriculture and Cooperatives

	15:00	Meet at USAID to discuss Lam Nam Oon Project with Louis Berger Team Leader and the team
October 22	10:00	Meet Dr. Anat Arbhabhirama, Deputy Minister of Agriculture and Chairman of the National Water Resource Commitee
	14:00	Meet Dr. Jackson, IRRI/Thailand Representative and Rice Breeding Specialist at Kasetsart University
	Evening Dinner, to be hosted by Dr. and Mrs. Sam Johnson.	
October 23	12:00	Leave Bangkok for Korat by USAID vehicle
	Overnight at Korat (Mr. Uoychai of USAID will accompany team).	
October 24	07:40	Leave Korat to visit NESSI Project sites
	Morning	Huai Chorakhe Mak Tank
	Afternoon	Huai Talat Tank
	Overnight at Roi-Et	
October 25	07:00	Leave Roi-Et
	Morning	Visit Huai Aeng Tank
	Evening	Travel to Khon Kaen
	Overnight at Khon Kaen (Kosa Hotel)	
	21:55	Mr. Uoychai leaves Khon Kaen for Bangkok
October 26	08:00	Opart Panya of USAID joins the team at Kosa Hotel, Khon Kaen
	Morning	Meet Dr. Suravutha, Engineering Faculty, Department of Civil Engineering, Khon Kaen University (former student of Dr. Keller)

	13:00	Leave Khon Kaen for Sakon Nakhon via Udon
	Overnight at Sakon Nakhon	
October 27	All day at Lam Nam Oon. Mr. Queener, Mission Assistant Director, will join team at site	
	Overnight at Sakon Nakhon	
October 28	Morning	Lowdermilk/Clyma/Opart team for Kalasin/UNDP
	Evening	Nam Pong/Nong Wai
	21:55	Team leaves Khon Kaen for Bangkok by train
October 29	14:30	Meet Khun Vorasak Pakdee, Director, Planning and Special Projects Division, Department of Agricultural Extension, MOAC. (Clyma, Drosdoff and Lowdermilk)
		Report drafting (Jack Keller and David Seckler)
October 30	14:30	Meet Dr. Somnuk Sriplung, Secretary-General, Office of Agricultural Economics, MOAC
	15:30	Discuss with D. Cohen, Director USAID/Thailand and debriefing with Mission staff
October 31	09:00	Discuss with RID staff
	12:00	Meet Mr. Paitoon Palayasoot, Director of Central Office of Land Consolidation, MOAC (former Keller student - Lunch)
	13:30	Meet Dr. Apichart and Soil Scientist at AIT Room EL-26 (Keller and Drosdoff)
November 1	19:15	Depart Bangkok

SUMMARY AND RECOMMENDATIONS

The main thrust of the USAID agricultural development program in Thailand is directed at the Northeast region. For purposes of water resource planning, the Northeast region can be divided into three major zones (or categories) based on irrigation potential:

1. Areas irrigable by large reservoirs, which can provide water for a total irrigable area of 2.1 million rai (6.25 rai = 1 hectare) and benefit eight to nine percent of farm families.

2. Areas irrigable by pumping from reliable rivers which can provide water for a total irrigable area of 1.9 million rai in the wet season and benefit a maximum of 10 percent of farm families.

3. Areas inaccessible from large reservoirs and reliable rivers which contain 80 percent of the rural population and where small water projects at the village level, as well as larger tanks in selected locations, are required to supply basic village water requirements. These small projects may take the form of small tanks, natural or dug ponds, weirs and topographical alterations to nearby watershed areas, and shallow or deep wells.

At present, only three percent (15 percent of the potential of 20 percent of the population in the Northeast is provided year-round irrigation from medium to large reservoirs or pumping from major rivers.

There is a general awareness, as pointed out in the Thailand CDSS for FY 1982, that the existing irrigation systems in the Northeast have largely failed to deliver the planned for benefits because of slow progress in completing on-farm distribution systems, difficulty in organizing water-user groups for effective water management, inadequate maintenance leading to deterioration of the systems, and insufficient market inducements to diversified and dry-season cropping. As a result, a majority of farm families in the planned service areas of irrigation systems continue with traditional rainfed agricultural practices to meet subsistence requirements despite the availability of high-yielding crop varieties (HYV) suitable for irrigated areas.

According to the CDSS, the Mission proposes to assist the Royal Thai Government (RTG), primarily on a functional basis, in developing and exploiting the productive potential of irrigated and irrigable areas of Northeast Thailand through the following means:

1. Rehabilitation and completion of existing small-scale irrigation systems with emphasis on on-farm water distribution.

2. Support for additional small-scale irrigation development through reservoir systems and through pumping from groundwater sources where technically/economically feasible.

3. Adoption of a comprehensive approach to irrigation system development that includes on-farm water distribution and appropriate provision for operations and maintenance (O&M).

4. Operations research on means of organizing farmers for effective water use and maintenance of irrigation facilities.

5. Promotion of increased and diversified agricultural production in the service areas of established irrigation systems, including attention to agricultural extension, market development, and food processing industry.

The basic principles for an improved small-scale irrigation program will be drawn from experience with the Northeast Small-Scale Irrigation (tank rehabilitation) Project scheduled for FY 1980 start-up, and from an overall strategy for small-scale water resource development in the Northeast, being formulated by a Royal Thai Government (RTG) task force. Consistent with AID's role definition, they do not propose financing for construction of large or medium-scale reservoirs and related main canal systems. These activities will remain the province of the international financing institutions.

The Lam Nam Oon (LNO) Reservoir and small tank project, which the team visited, relied on field to field (paddy to paddy) flow for on-farm distributions and only a limited amount of field leveling is evident. However, there were three small pilot areas with some Government-built watercourses and field channels. The main and lateral canal systems on these projects are only organized to deliver continuous (but unregulated or measured) streams of water at outlets, spaced 250 to 500 m apart. Each outlet has a potential command of 100 to 200 rai (16 to 32 hectares); but, in most cases, only part of the command receives irrigation water, even during the wet (monsoon) season, and there is practically no irrigation (except adjacent to the outlets) during the dry season. (Full details of the traditional method and pilot activities are presented in Appendix D, "Description of Irrigation Practices and Systems.")

The lined sections of the main and lateral canal systems are in poor repair with siltation and broken linings due to rapid drawdown and/or side drainage and spills. Unlined sections of the tank projects are completely missing. Many of the turnouts along the functioning canals (perhaps over 1/3 of them at LNO) are not even provided with sufficient structures and channels to supply water to any fields.

The Northeast has enough rainfall during the monsoon season to produce about 1.5 to 2 tons of sticky (glutinous) paddy per hectare without irrigation and irrigation without other inputs results in 0.5 to 1 ton per hectare increase. Other inputs, which could easily double yields when added to irrigation, are not applied because water deliveries are not dependable and advanced farming practices are not well understood. Without on-farm distribution systems, it is impractical to irrigate field crops and only a small area of paddy close to canal turnouts can be irrigated during the dry season.

The resulting situation, (i.e., an undependable and practically unmanaged canal system, field to field water delivery, limited production increases from wet season irrigation, and little possibility of irrigating during the dry season), is that less than 1/3 of the potential command areas receive any irrigation. The crop production increase (output) from these irrigation projects is probably less than 10 percent of the potential which could be achieved from irrigating all the command area during the wet season, half the area during the dry season, and adding the other important inputs, such HYV's and fertilizer.

The two major deficiencies in irrigation in Thailand are: (1) effective management and on-farm facilities of existing irrigation systems; and (2) planning and design of new irrigation systems. We therefore recommend that USAID concentrate its future efforts in providing these software inputs to irrigation in Thailand, leaving the larger hardware developments to the World Bank and other international funding agencies.

With respect to the USAID area concentration in Northeast Thailand, we strongly endorse the current USAID strategy of enhancing the productivity of rainfed agriculture and providing small village-based tanks for domestic water supply, nurseries and fisheries. We also endorse the two USAID irrigation projects (Lam Nam Oon and Northeast Small-Scale Irrigation), but would not undertake additional hardware-oriented projects before: (1) demonstrated success has been achieved (and even this may take redeployment and/or additional resources); and (2) the pool of technical Thai manpower needed at all levels for comprehensive irrigation system management has been significantly upgraded and expanded.

Our specific recommendations follow:

1. The Royal Irrigation Department (RID) has requested AID to provide technical assistance in large-scale planning and design of irrigation systems. Since this is a particular area of American competence, we believe that AID should sponsor some technical assistance and staff to work within the RID for this purpose.

2. AID should set up some model management systems for existing irrigation projects, for example, in the Lam Nan Oon project area (see Appendix A).

3. There is a notable lack of basic information about the physical and social environment of Northeast Thailand which we feel will be essential to any rational investment policy in that area over the future. Therefore, we recommend that AID sponsor collaborative basic investigations into the soils, hydrology and potential cropping systems, together with socioeconomic research into patterns of land ownership and extent and distribution of real poverty in the area so that it might better focus its efforts in this large region. Among these investigations should be serious consideration of the potential of alternative cropping systems, particularly of upland paddy and wheat production and the use of leucaena tree species for pulp, lumber and fodder supplies to animals.

4. One of the fundamental problems of irrigation in Thailand is that it is targeted mainly to wet season paddy production objectives. The problem with this target is that as the irrigation system provides only supplemental water for occasional dry spots in the wet period, the incremental return from irrigation is very low (on the order of 25 percent of the total product). We believe serious consideration should be given to retargeting the irrigation objective toward the dry season. This retargeting implies a re-evaluation of the irrigation distribution system in the various command areas to provide water distribution directly to each field (rather than paddy to paddy). Our investigations indicate that, at current prices, irrigation through the use of networks of buried PVC pipe (in areas with greater than 1/3 of one percent slope) appear to be feasible. Among the many advantages of buried pipe distribution systems is

that they are not subject to washing out during the flood season and will deliver water with very high efficiency in the dry season. This alternative should be thoroughly investigated, particularly for demonstration in the model management systems.

5. We strongly support the development of small village-based ponds for domestic water, nurseries and fishery production in Northeast Thailand. However, we do feel that much more attention must be paid to the distribution of the benefits of these small tanks in the various villages. As it now stands, there are not very clear guidelines on how the water or the fish are to be distributed among people in the villages. Simply handing it over to the local government authorities is, of course, fraught with dangers of maldistribution of benefits of these projects. AID should devise very firm guidelines to assure that all of the people in the area benefit from these projects and that the benefits are not concentrated in the hands of the few.

6. USAID should also guarantee that any people displaced from submergence areas in its project areas are, in fact, fully compensated for their losses. We recommend a close inspection of this problem in the Lam Nan Oon and Northeast Small-Scale Irrigation project areas.

7. In order to provide reliable and reasonably efficient irrigation to paddy during the wet season or to field crops at any time, it is necessary that watercourses be constructed and maintained to deliver water directly to each irrigated field (rather than field to field, which is the typical practice in the Northeast today). While land consolidation and/or leveling may appear desirable, it should not be publicly financed, except on a selective basis where essential for water delivery purposes. However, technical assistance and credit should be provided to encourage the use of appropriate land leveling practices (see Appendix B).

8. Lift irrigation systems are generally reported as being relatively efficient for both wet season paddy and dry season field crops. Furthermore, the power input records of the approximately 200 electrified lift systems can be used to estimate water inputs. At least 20 of the electric lift systems should be selected for studying various soil-crop-weather patterns under practical field conditions. In addition, these systems

should be diagnosed to evaluate system performance and pinpoint conditions which lead to success.

9. The water resources in the Northeast are limited, as pointed out in the report prepared by the Asian Institute of Technology (AIT) (see summary in Appendix C). Conflicts will begn to develop between small tank, large reservoir, and river run lift projects as developments proceed. Furthermore, there are relatively few good (deep) tank or reservoir sites and the rainfed farmland submerged by some new (as well as some existing) developments may actually reduce overall potential benefits in the region.[1] With these thoughts in mind, we recommend that USAID provide technical assistance and support professional training activities for RTG personnel in: project and basin-wide planning and design; reservoir operation and canal management to maximize benefits within equity restraints and reduce structural damage to canal linings; and basin-wide water routing to optimize the irrigation, fishery and hydro potential and reduce flood hazards.

10. We note that RID's O&M budget has been increased from 6.4 million Bhat in 1972 to a projected 463.8 million Bhat for 1981; however, during the period, O&M as a percentage of accumulated construction has decreased from seven percent to a project 2.6 percent (see Table 3). This is seriously inadequate. Therefore, we recommend that USAID, in negotiating support for new projects, should provide a sinking fund for O&M budgets over the projected life of the project.

11. In addition to the professional training activities mentioned in Recommendation 9, we encourage USAID to become involved in sponsoring the following:

    a. Training of multidisciplinary teams for diagnosing irrigation systems to:

        i. Pinpoint and understand successful elements in existing systems for improvement and transfer.

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[1]Since the average working depth of many tanks is only two or three meters, deep-water rice might be considered as a possibility for increasing benefits from submerged areas. The constraint is that the water level should not rise over five centimeters per day, so the rice can grow with it.

ii. Monitor and assess total system performance.

iii. Identify operational and technical problems.

b. Training technical personnel at all levels needed to undertake Recommendation 1 (see Appendix A). This training should involve main as well as on-farm system management.

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IRRIGATION DEVELOPMENT OPTIONS AND

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INTRODUCTION AND BACKGROUND

To meet domestic demand and maintain Thailand's share of the world's export market, production would have to increase from 15.1 million tons of paddy in 1976 to 22.7 million tons in 1990. Over the same period, assuming a yield increase of 20 percent in rainfed areas, irrigated paddy production would need to more than double from 5.5 million to 12 million tons.

Irrigation Emphasis and Development Policy

An irrigation development program designed to meet this demand is comprised of: improvement of existing systems (710,000 hectares), extension of existing systems (290,000 hectares), and new projects (315,000 hectares). Such a program would be well-distributed between the major regions of Thailand. A rough estimate of the construction cost of the indicated program in 1976 was $1,650 million, giving annual expenditures averaging $110 million through 1990, which is in line with the Royal Irrigation Department's (RID) budget in recent years. It was pointed out by a World Bank study team that, if these investments are to achieve the 1990 production targets, the planning, design and implementation of projects will need to be improved. This, in turn, requires improvements in RID's organization and management.

In the 1976 study, it was pointed out that a major feature of the program should be the widespread introduction of higher standards of tertiary or on-farm development---the construction of ditches, drains and farm roads needed to achieve the timely and reliable supply of water to farmers' fields; and that tertiary development should be the responsibility of the Government, rather than farmers or farmer groups, and be carried out along with improvement or new construction of main systems, and coordinated with system operation and maintenance. On-farm development can take various forms ranging from simple tertiary ditches to full "land consolidation" including land leveling and boundary realignment. The appropriate mode of on-farm development depends on soils, topography, cropping patterns and the configuration of plot and property boundaries.

The Bank study suggests that, as a general rule, land consolidation should be limited to areas with an assured dry season water supply sufficient to justify the incremental investment economically, and where beneficiaries are required to repay a reasonable part of the incremental cost. Furthermore, the Government should formulate a policy on the allocation of limited dry season water supplies within irrigation project areas as a matter of utmost importance. It is recommended that all aspects of an irrigation project from planning, design and survey through the construction of main and tertiary distributions systems, service and on-farm roads, are integral parts of a whole and should be under the direct control of a single project manager. Also, service divisions should be available to provide necessary technical support, because the fragmentation of project activities along functional lines leads to serious coordination problems and an unwillingness of any individual to accept overall responsibility.

The major thrust of the USAID agricultural development activities in Thailand is directed toward the Northeast region. This region covers 170,000 km^2 and includes about 1/3 of the land area of the Kingdom, as well as about 1/3 of the population. The region, mainly a gently undulating plateau which rises about 100 to 200 meters above the central plain and slopes southeastward to the Mekong River, is estimated to include about 10 million hectares of arable land.

The Northeast grows about 1/3 of the nation's rice, more than any other region. Rice occupied about 3.5 million hectares of the 8.0 million hectares of available farmland. Yields are low, averaging about 1.4 ton/hectare; virtually all the rice is rainfed and production is subject to wide year-to-year fluctuations. Kenaf became an important crop in the 1960's and in recent years there has been a rapid expansion of cassava cultivation. Both crops, which are now among Thailand's major exports, are grown on upland areas unsuited for rice and are important sources of cash income for the region's farmers.

Storage dams are essential to irrigation in the Northeast. During the dry season, the flow in all except the lower reaches of the larger rivers virtually ceases. In the wet season, river flows follow a similar pattern to rainfall with sharp recessions in flow, coinciding with drought periods. Runoff per square km is much lower than in the Northern and Southern regions, and the potential for year-round irrigation is limited to about 300,000 hectares, or less than 10 percent of the total paddy area. At present, about 30,000 hectares benefit in some degree from wet season irrigation and about 6,000 hectares are irrigated in the dry season. Throughout the Northeast, the deep groundwater is highly saline. Shallow aquifers with fresh groundwater are tapped throughout the region for domestic water supply, but yields are too low for irrigation.

Existing Irrigation Projects

Reservoir. The Royal Irrigation Department (RID)began a major program of dam and canal construction in the 1960's. At the present time, there are six large projects designed to irrigate about 160,000 hectares. The area receiving reliable and timely irrigation is far less than the potential of the existing projects because of technical deficiencies in the canal systems. Construction of distribution systems was not coordinated with main canals, and, in some places, main canals are falling into disrepair because they are not being operated, and consequently, are not being maintained. Details of the irrigation system at the Lam Nan Oon Reservoir project are presented in Appendix D.

Tanks. Over the past 20 years, RID has constructed about 200 small reservoirs or tanks in the Northeast with capacities varying from 40 MCM to less than 0.1 MCM. The area receiving reliable irrigation from these tanks is probably less than 10,000 hectares in the dry season. The potential for further tank projects in the Northeast is quite limited because terrain and hydrology are not conducive to small-scale irrigation from reservoirs. The flat terrain results in broad and shallow reservoirs and inundation of cultivated areas is large in relation to areas benefited by irrigation. Also, a significant part of the water stored is lost through evaporation. Details of these projects are presented in conjunction with the USAID Northeast Small-Scale Irrigation (NESSI)project and in Appendix D.

Low-Lift Pumps. Several projects to exploit the potential for pump irrigation in the Northeast are also being undertaken. The National Energy Administration (NEA) has a particularly successful program for pumping water from rivers in the Northeast and, since 1968, has expanded their coverage to about 40,000 hectares, almost 15 percent of the total existing potential. Plans call for more than doubling this total during the next three years. RID also has a mobile pumping program underway for supplementary irrigation.

The NEA low-lift pump projects have a reputation for being the most successful irrigation projects in the Northeast. There are approximately 200 low-lift projects now in place and 75 more in the budget. Reported cropping intensities range from 150 to 200 percent, and paddy yields are higher than for gravity systems. Apparently, the reason farmers respond so well is because they have an assured water supply when they need it and the excess water charges (over pumping power costs) revert back to a revolving credit fund. Some general system characteristics are:

1. Investments are limited to $2,000/rai.

2. Optimum project size is 2,000 to 3,000 rai.

3. Farmers must agree to pay for power and give land for canals.

4. Typically, use electric 150 HP pumps, each discharging 250 lps (8.8 cfs) for a 3,000 rai project. (This is equivalent to one lps/hectare, or 70 ac/cfs.)

5. Typical projects require approximately 800 m of pipe and 6,000 m of concrete-lined canals, plus unlined farm watercourses.

6. Water use fees are Baht 65/rai for paddy and Baht 50/rai for field crops and vegetables (Baht 20 = $1.00 and 6.25 rai = 1.0 hectare).

7. Estimated B/C is 1.9 and IRR equals 35 percent for typical 3,000 rai area over 30-year life, based on 200 percent cropping intensity.

IRRIGATION POLICY AND ORGANIZATION

This section deals with the present policies related to irrigation development and the organizations involved in implementing the policies. Special attention is given to developments in the Northeast of Thailand.

The present policies for irrigation have evolved over the years. Special social, economic, and political considerations for comprehensive rural development in the Northeast have created a healthy environment for policy formulations and program implementation.

Policies for Irrigation Development

In most countries, policies have evolved through three states. First, focus is given to the capture and conveyance of water; secondly, more concern is given to plant-water-soil relationships and water utilization; and thirdly, focus is usually given last to the on-farm improvements. In keeping with Stage One, the Royal Thai Irrigation Department (RID) has been involved heavily in the design and construction of works to capture and deliver water to command areas. Manpower training and policy formulation have been heavily influenced by this emphasis. The RID, however, is not tied to the past, as is typical of irrigation bureaucracies, such as those which evolved under British colonialism.

The earlier focus is now in question as the Government is concerned more with water distribution at the farm level in order to increase agricultural production. More attention now is needed on soils, crops, and basic agronomic elements to be incorporated in design, construction and operation of the system.

The special conditions in the Northeast are such that policy decision-making is influenced by concerns for rural development and there is general awareness that future projects must be justified in terms of agricultural growth, equity in income distribution, employment generation, and infrastructure to provide small farmers with higher levels of living. The Prime Minister declared that 1979 would be the year to begin to focus on the farmer.

The droughts in the Northeast over the past few years have influenced irrigation policy, as have social and political considerations. Official policy is now concerned with decentralization of decision-making to the provinces and integrated approaches utilizing the resources and expertise of a large number of agencies in a coordinated concerted effort. The Ministry of Agriculture and Cooperatives, in which most of these agencies are located, has declared that all future irrigation projects will be integrated, and intensive efforts will be made to coordinate all the departments.

The major international agencies involved, such as the World Bank, Asian Development Bank, and USAID have also had an influence on present policy in Thailand as they have realized the importance of intensive irrigation improvement to provide the end users with water control and services for improved agricultural production. The AID Mission in Thailand has developed a strategy with focus on improving management of projects and providing basic inputs and services to farmers with a focus on small farmers in both rainfed projects and a few irrigation projects. The Mission presently questions its role in future irrigation developments. The AID Mission does show interest in utilizing existing projects for training and testing of management modes, problem identification, and development of alternative solutions through adaptive, applied and evaluative research.

The Ministry has commissioned studies to provide information for improved policy decision-making. These focus on alternative organizational approaches, coordination and integration of services, decentralization models, manpower training needs, development of a long-range master plan, and an Information Center to maintain and evaluate program and projects on a regular basis.

The Director General of the RID suggested the need for special assistance in policy analysis, development of a master water resource plan, and the development of a long-term plan of manpower training. The types of training desired include both degree training overseas and short course related to project management and on-farm water management. At all levels, officials and project managers appear to be deeply concerned with finding ways and means to improve on-farm water management. To date, however, there are few who have training or understand the total requirements for this task. There is a growing awareness, however, of the complexity of irrigation improvements in the Northeast, but staff have little experience in applying team approaches to complex systems.

In terms of policy, the following Irrigation Acts have evolved over time:

The Field Dykes and Drainage Act of 1941
The State Irrigation Act of 1942
The Revised State Irrigation Act of 1954
The People's Irrigation Act of 1959

These Acts deal primarily with building and maintaining structures and penalties for violations, such as damage to structures. The present acts do not provide sufficient guidelines for operation and maintenance of the on-farm water distribution systems or provide a mechanism to levy water charges on water user organizations for operation and maintenance.

A new Irrigation Law is presently being considered which focuses on water user associations (WUA's), water utilization, and on-farm operation and maintenance. This Act will delineate the roles and responsibilities of the WUA's and will also call for the first water charges in RID projects. The funds collected (20B, or $1.00 per rai) are to be used by the WUA where collected in the O&M of the farm system.

Organizations Involved in Irrigation Development

This section deals with a brief description of the many organizations involved in irrigation development and suggests issues related to coordination and integration of services. Given the present stated policy of integrating agricultural agencies in all future irrigation projects, the Ministry faces a most difficult task. Many of the new agencies dealing with water were created in response to the 1978 Drought Relief Act and are still functioning. They are all headquartered in Bangkok; most of the departments operate under the Ministry of Agriculture and Cooperatives (except where indicated otherwise); and most of them have too few field personnel to accomplish their stated tasks:

1. The RID was organized in 1904, and until recently, has only been concerned with design and construction of dams and flood control devices. In the 1950's and through the 1960's, the RID developed gravity systems, but primarily, attention was given to extensive approaches to irrigation development. In recent years, there has been more focus on intensive approaches to assure more timely and reliable delivery of water to farms, but due to the tradition of a focus on design and construction, the results have been poor. Although RID is aware of the need for intensive on-farm improvements, there are not sufficient numbers (in RID or in any other Government agency) of field staff trained in on-farm operations.

The RID has devoted considerable attention and effort to developing pilot on-farm irrigation improvement projects, but the design and operation of these pilot systems leave much to be desired. Observations of some of these projects suggest poor design, lack of water control and management, poor enforcement of the existing water codes, damage to structures by farmers, and poor operation and maintenance (see Appendix D).

The RID is one of the largest departments in the Ministry with a staff estimated at about 80,000 people. RID has 22 functional divisions, 12 regional offices, a chief engineer, three Deputy Directors, and a Director General. Roles and responsibilities and lines of authority are not clearly defined and there are admitted weaknesses in planning, implementation and operation of projects. As mentioned earlier, the World Bank suggests: radical decentralization in decision-making, expansion of planning and program responsibilities, delegation of more responsibility and authority, and an improved program for career development in the RID.

2. The Office of Accelerated Rural Development operates under the Ministry of Interior and is involved in developing potable water by sinking deep wells and constructing small reservoirs and ponds as requested by villages through the Changwat Provincial Officials.

3. The Department of Mineral Resources operates under the Ministry of Interior and is involved in drilling deep wells to provide drinking water for villages. They also have mobile pumps for irrigation and take care of the operation and maintenance of these wells and mobile pumps.

4. The Department of Land Development (DLD) builds small farm ponds in the Northeast for soil and water conservation and some supplementary irrigation. There is an internal agreement that the DLD will handle projects which store less than 100,000 m^3 of water and RID will take care of larger projects.

5. The Department of Agricultural Extension (DOAE) has been involved in providing diesel-powered low-lift pumps on loan to groups of farmers in the Northeast since 1975. The farmers operate the pumps for supplemental irrigation and DOAE maintains them.

6. The Ministry of Interior (MOI) in 1978, under the Drought Relief Act, also became involved in building small irrigation tanks in villages and improving village ponds through its Department of Local Administration.

   This organization was also involved in building small dams, ponds, and canals.

7. The Community Development Department (CDD) has been involved since 1978 in working with villages to select village water projects and channeling requests to other agencies. They have had some success in organizing farmers to repair canals and earth dams in some areas.

8. The National Energy Administration (NEA) has been actively engaged in irrigation development since 1968. The NEA develops low-lift pumping projects along the Mekong, Nan and Chi Rivers. A typical system irrigates about 2,000 rai. In 1978 (as part of the Drought Relief Act), NEA was alloted funds for 130 new projects. The NEA projects have a reputation for success (as discussed earlier) and their irrigation activities continue to expand.

9. The Department of Health (DOH) develops village water (and sanitation) systems.

The above organizations have different standards and policies. For example, RID makes no water charges, while NEA assesses the farmers for the energy costs of pumping.

Issues of Coordination

There is, no doubt, a need for a water authority or some multi-agency approach for the better utilization of resources for water and irrigation development. Both the World Bank and a study prepared by the Asian Institute of Technology call for more rationality in planning and more coordination between agencies.

The Ministries of Agriculture and Cooperatives have also clearly stated the need to integrate the Agricultural Extension Services, Cooperatives, Credit Institutions, the Land Development Office, Seed Multiplication Program, and other organizations in all future irrigation projects.

The review team visited the Lam Nan Oon and Nong Wai Projects where integration of essential services has been attempted with some success. Integration will require strong policy commitment, trained manpower willing to work together, and time. Where it has been partially successful to date, a national coordination committee has been set up in Bangkok, personnel have been deputized to a project authority, personnel live and work on the project and give their loyalties to the project management.

Until this integration and coordination take place on a large scale, there will be much confusion and waste of scarce resources. Those likely to be impacted most will be farmers in irrigation projects who need more and better services than they now receive. To date, where a few on-farm developments have taken place, farmers have not adequately taken part in planning, design and implementation of the improvements. As the AIT Study reported, the demand for more and more projects has outpaced the ability of RID and other organizations to develop adequate approaches for farmer involvement.

If viable water users organizations are to play a significant role in operation and maintenance, then greater reliability and predictability of water at the farm level are needed to entice farmers to organize. Farmers will not and cannot complete unfinished systems because they need skills and incentives, as well as organizations, to support them. Far too many WUA's have been developed without adequate incentives or a legal basis, and these continue to exist only on paper. Strong policy commitments are needed in the form of increased budget and staff for operation and maintenance programs.

Studies of ways to increase farmer involvement in projects and long experience suggest that several components are essential. These components are: policy commitment which places focus on the importance of farmer participation in planning and implementation of projects; training farmers in the specific skills required to perform new tasks; developing and working with local leadership; and resource commitment by farmers in terms of labor and cash for implementation, operation and maintenance. The Water Management Synthesis Project (which supports this review team) has developed a field handbook which shows how to involve farmers in initial priority problem identification, development of solutions to problems, and implementation of projects. This approach gives farmers the sense that the project is theirs, and once the attitude is developed, they will likely maintain the improvements made, as they do for their other collective goods.

There is evidence in the north of Thailand, where water is supplied with some predictability, that farmers will organize for maintenance and cleaning. However, they must have a sense of the system being their own rather than the Government's. In some pumping station projects, and the Nam Yang Project, farmers are willing to pay as much as Baht 110/rai per year for water which they know they can get on a regular basis to their fields. Several farmers interviewed by the team indicated that they understand the value of water and would be willing to pay up to Baht 200 to 250/rai per year for water delivered on a regular and predictable basis.

In the Northeast, the Government is confronted with a demand to develop and improve more projects than are possible with available capital and manpower resources. Major questions which must be faced are:

1. Intensive vs. extensive projects;

2. How to coordinate a host of agencies competing for scarce resources;

3. How to integrate critical services at the farm level; and

4. What role farmers will play in terms of resource commitment and other forms of participation from project identification to the maintenance of improvements.

Until these questions are answered, development in the Northeast will not proceed according to the optimistic plans developed in Bangkok.

The situation in Thailand is by no means unique. The greatest weakness in irrigation development is the typical failure to include testing and on-farm distribution improvements as a vital part of the planning and design of irrigation projects. In most of the countries of Asia, the Governments plan and design large reservoirs and canals and provide only partial monitoring services. At the farm level, however, little is done effectively to improve water delivery, water use, or conservation of soil and water resources. Only in recent years, in most Asian countries, has this "no-man's land" of irrigation been recognized as being crucial in irrigation developments. This recognition will call for new organization approaches (see Appendix A), new modes of training, and expanded efforts of monitoring and evaluation from the reservoir to the last farm drain. Hopefully, Thailand will continue to move in this direction and achieve greater returns from its large and varied irrigation investments.

Positive Aspects of Irrigation Development in Thailand

These remarks are derived from conversations with officials, project managers and staff, brief interviews with selected farmers, reports, and reconnaissance surveys of a limited number of projects in the Northeast. These tentative conclusions are also based on intensive experience in some countries and limited experience in others in irrigation agriculture.

1. Thailand's irrigation policy and organizational arrangements are in a state of flux, as indicated by frank discussions of needs, policy, options, reservations about present levels of progress and questions about organizational approaches. This searching for options to meet changing needs is a very positive development and is to be contrasted to essentially inflexible bureaucracies with over 100 years of tradition in other countries of the region.

2. In Thailand, agriculture and irrigation are in the Ministry of Agriculture and Cooperatives. This integrated approach is useful for adequate irrigation development which reaches to the farm level; in contrast, in other countries, irrigation and agriculture are located in two separate Ministries. Where this is the case, farm water management is usually the component not provided by either Ministry adequately. Thailand is ahead of many countries in the region in terms of developing coordinated and integrated organization approaches.

3. The organization of farmers to regulate and use water more effectively, a spirit of priority for farmer needs, and a concern about supplying the farmer with water, inputs and other servces, are all positive aspects for improving irrigated agricultural development observed in Thailand. The Royal Irrigation Department is open about past failures, is aware of current needs and is not bound by long and cumbersome traditions.

4. The movement toward an approach where all required departments are combined in one regional administrative project entity and all personnel and departments work in a cooperative and coordinated manner toward project goals to serve the farmer presents a tremendous opportunity for accelerated development of irrigated agriculture.

5. A focus, from the policy level through the project level to personnel on-farm, to provide direct improvements to the broad spectrum of needs in on-farm water management is an important emphasis in Thailand. Experience in other countries suggests that this is an effective and accelerated approach to improving irrigated agriculture.

6. There is a general appreciation that the object of irrigation is to significantly increase agricultural production and not just to build physical facilities.

7. Finally, the team is impressed by the fact that field level personnel and farmers are not intimidated by officials, as observed in several Asian countries. Problems and issues are discussed frankly and openly by farmers and field staff who do not appear to be threatened by officials. This same spirit, observed at all levels, probably results from the long and proud history of independence in Thailand.

CURRENT AND PROPOSED USAID PROJECTS

The Mission's agricultural development program is concentrated in the Northeast portion of Thailand, as explained earlier. The two main irrigation projects are the ongoing Lam Nam Oon Integrated Rural Development Project and the soon-to-begin Northeast Small-Scale Irrigation Projects. In addition, there are several other projects in process or various stages of development, which include some activities in supplemental, rice nursery, orchard and/or kitchen garden irrigation. These include the following projects : Land Settlements, Mae Chaem Watershed Development, Village Fish Ponds, and Northeast Rainfed Agricultural Development.

Lam Nam Oon (LNO) Integrated Rural Development

This project is a joint RTG/AID integrated rural development effort to increase agricultural productivity in a section of Northeast Thailand. The project includes:

1. The completion of the Lam Nam Oon irrigation system;
2. Construction of a road network;
3. Implementation of an on-farm water supply system; and
4. An integrated program of community development.

The project was begun in 1977 and is scheduled for completion in 1982. It covers 187,500 rai (30,000 hectares, or 75,000 acres) and serves approximately 10,000 farms. The total cost of the project is estimated at $43.8 million (or approximately $600/ac) and it is expected to increase agricultural production by 82,000 metric tons of grain annually.

Technical. The LNO project area consists of all the arable area downstream from the dam which is to be supplied with irrigation water, an area totaling 75,000 acres. Under the project, construction will be completed on the distribution (main/lateral canals) and drainage systems, the project road system, and land improvements, including land consolidation on 26,300 rai, ditches and dikes construction on 159,500 rai, as well as the establishment of three pilot projects with their associated operational research programs (1 rai = 0.4 acres; 6.25 rai = 1 hectare).

canals (having a total length of 345 km), the left and the right main canals, and is distributed to the lateral canals by gravity and/or pumps. The canals and laterals are concrete-lined, whereas the on-farm distribution system supplied from the canals and laterals by farm turnout structures (FTO's), is not lined.

Institutional. At the national level, project policy, direction and coordination will be provided from the National Irrigated Agriculture Committee through the National Coordinating Committee for the LNO integrated Rural Development Project, which, in turn, will appoint members and vest day-to-day project administrative responsibilities at the national level in a senior level working committee. At the field level, policy direction and coordination will be provided by the Provincial Coordinating Committee chaired by the Governor of Sakon Nakhon.

Project field operation/management will be headed by a Project Field Director and will include three Assistant Field Directors, as well as Team Leaders from the various RTG departmental cadres.

Economic. In the long run, the farmers stand to benefit handsomely if they seize the opportunity the project affords them. If the farmers are not required to pay for land improvement, the financial rates of return are estimated to be very high. However, according to the planners, farmers must forego income for the first year or so, as shown in the following Tables 1 and 2. The planners note that:

> Average Northeast farmers would probably be restive and slow to adopt required new practices given the initial period of foregone income. But having seen the longer range benefits on demonstration farms, these farmers can be expected to respond energetically. Model farmers will more readily accommodate the apparent risks because of their position in the community and because extension workers will be able to concentrate their efforts and encouragement on them.

It should be noted that it is the policy of the RTG and RID to provide water for irrigation at no charge to the farmer. AID and IBRD have counseled otherwise, but the RTG does not appear to be prepared to modify this policy at this time. Furthermore, the Dykes and Ditches Act provides that the individual farmers are responsible for the maintenance of the farm water distribution system from the lateral canals to their fields, and if RID, as is

Table 1. Financial impact - consolidated area farmer (US $).

Year	0	1	2	3	4	5
A. Off Farm Income	260	225	175	125	50	--
B. Gross Value of Farm Produce	412	410	610	1,110	1,610	2,360
C. Cost of Inputs	50	150	250	350	500	620
D. Net Value of Farm Produce*	362	260	360	760	1,110	1,740
E. Total Income A+D*	622	485	535	885	1,160	1,740
F. Total Income Without Project	622	653	686	720	756	794
G. Benefit Stream Without Having to Pay Capital Cost		-168	-151	+165	+404	+946 etc. (IRR 92%)
H. Benefit Stream if $115/rai Paid for Development		-2,468	-151	+165	+404	+956 etc (IRR 22.6%)

*Includes subsistence

Table 2. Financial impact - ditches and dikes area farmer (Baht).

Year	0	1	2	3	4	5
A. Off Farm Income	260	225	175	125	50	--
B. Gross Value of Farm Produce	412	510	860	1,360	1,710	1,994
C. Cost of Inputs	50	150	250	350	400	460
D. Net Value of Farm Crops*	362	360	610	1,010	1,310	1,534
E. Total Income A&D*	622	585	785	1,135	1,360	1,534
F. Total Income Without Project	622	654	686	720	756	794
G. Benefit Stream Without Having to Pay Capital Cost		-69	+99	+415	+604	+790 etc. (IRR 285%
H. Benefit Stream if $50/rai Paid for Development		-1,069	+99	+415	+604	+790 etc. (IRR 42.9%)

*Includes subsistence

the standard practice, provides construction or maintenance services, this is paid for by the individual farmer.

The team visited this project and details of the state of the on-farm system facilities and operation in the general system, the three pilot areas and the proposed AID demonstration system are presented in Appendix D. A brief description of the irrigation system is also presented in the Summary and Recommendations.

Northeast Small-Scale Irrigation (NESSI)

The objective of this $17 million, six-year project is to establish a replicable approach and the necessary institutional capabilities for increasing agricultural incomes for the rural poor in Northeast Thailand. The target group is the rural farm population within the potential command areas of existing small reservoirs (tanks) in Thailand's most deprived region. Approximately 4,600 households within the irrigation areas of seven tanks will be served by this project, but the potential replication area encompasses more than 200 similar sites.

The project will include the improvement of deteriorated embankments; the rehabilitation, extension and improvement of main canal systems; improved access roads, the design and construction of effective on-farm distribution systems; a land development component; the provision of assistance to farmers in water management and agricultural practices; assistance for water user groups; marketing linkages; improved operation and maintenance programs; a crop insurance component; operational research and demonstration; and the development of training programs for farmers and RTG personnel. There will be heavy emphasis on farmer participation in all facets of the project which will be supported by a sizable input of technical assistance.

By the end of the project, it is expected that the irrigated area at the seven project sites will have expanded by at least 100 percent and net farm income will have increased by a minimum of 40 percent on average. It is also expected that a viable organizational and training system will have been institutionalized to extend the project approach throughout the Northeast.

The project aims to establish a sustainable system for increasing the agricultural productivity and income of more than 30,000 rural poor within the potential command areas of seven existing small to medium-sized tanks in the Northeast of Thailand. The strategy of the project is to address the major identified constraints to improved productivity in the Northeast region through a package of consultant assistance, demonstrations, training and construction that would provide:

1. Basic infrastructure for reliable delivery of water to farmers' fields;

2. Improved arrangements for key RTG agricultural service organizations to deliver their services to farmers;

3. Adequate procedures to help link up farmers to necessary agricultural inputs and markets;

4. A strengthened farmer organization structure for managing and maintaining on-farm water delivery; and

5. A system of training and motivating farmers to properly utilize inputs to increase yields and market their crops.

The NESSI Project will test and refine the approach for accomplishing the above objectives on the command areas during a six-year period. It is intended that the seven tanks will establish the replication potential of the approach and will provide a pool of trained manpower to continue at other sites the momentum begun under the project.

The NESSI Project will be carried out primarily by two departments of the Ministry of Agriculture and Cooperatives: the Department of Agricultural Extension (DOAE) and the Royal Irrigation Department (RID). The Bank for Agriculture and Agricultural Cooperatives and local banks will provide credit; the Department of Land Development (DLD) will conduct soil surveys; and Provincial Governors, District Officers and village leadership will help direct and coordinate the project.

AID's major role in the NESSI Project will be to provide necessary technical assistance and provide financing for relatively high risk and/or innovative and experimental aspects of the project (on-farm water management structures and land preparation, market support components, crop insurance, demonstrations, observation, travel, research and training/workshops). These components are especially important to help assure that the infrastructure improvements financed by the RTG under the project have the desired impact at the farm level and maximize benefits for the rural poor in the target areas, as well as provide a model for future tank improvement projects.

Field Visit. The team visited three of the proposed project sites and details of the on-farm irrigation facilities and operations at one of the sites are presented in Appendix D. We concur with the program as outlined in the project paper with a few modifications in line with our earlier recommendations. The Huai Aong, a tank project near Roi-Et, was visited and the following information was obtained from the project report developed by the Asian Institute of Technology (AIT) and the site visit:

1. The AIT report appears accurate enough in general; that is, in terms of condition of the canals and structures.

2. Soils are (Roi-Et series) sandy and not too suitable for paddy; also, slopes are relatively steep. Soils are loamy sand to sandy loam over clayey subsoil; upper terraces are rolling; the bottom terrace is nearly level.

3. Potentially, 17,000 rai can receive water during the wet season by paddy to paddy flow (that is, the turnouts do command the potential area). But, in talking to tail-end farmers, there is not sufficient water at the end of the canal system.

4. RID only constructed outlets at 250 to 500 m along channels and laterals to irrigate 100 to 200 rai from each outlet. Field distribution is paddy to paddy, as only a short 50 m long watercourse is provided at each outlet.

5. One farmer said he doesn't fertilize, but cultivates eight rai of rainfed and eight rai of irrigated paddy. Both fields have similar soils and topography. His irrigated field is near an outlet along the upper reach of the canal. He obtains approximately 2,500 kg and 3,400 kg of paddy from his eight rai rainfed and irrigated fields, respectively (310 kg/rai from rainfed and 425 kg/rai from irrigated).

6. The average working depth of the reservoir is three meters. It has a water surface area of 4,600 rai, and, according to the AIT report, it can irrigate 16,900 rai of wet season paddy and 10 to 12,000 rai of dry season upland crops. The current wet season irrigation is said to be 11,500 rai and there is little or no dry season irrigation.

7. Based on the above, and assuming the 4,600 rai submerged by the impoundment is good quality land, overall paddy

production figures for the irrigated plus tank area during the wet season are:

Before project: (4,600 + 16,900) x 310 = 6,630 T.
Project as is: 11,500 x 425 = 4,890 T.
All potential land irrigated: 16,900 x 425 = 7,180 T.

Huai Aong was the best of the tank projects visited. The other tanks had larger inundated areas compared to the potential irrigated areas during both the wet and dry seasons. Furthermore, the irrigation facilities were even less complete and in poorer repair at the other sites. For example, Huai Chrookie Mak has a reservoir surface (inundated) area of 7,900 rai; it can only irrigate 4,100 rai at present, and when the irrigation facilities are fully developed, it will only irrigate 9,000 rai during the wet season (no dry season irrigation). However, it can provide 3.7 MCM of domestic water for a nearby town.

Another tank which was visited (Huai Talot) had an average working water depth of only 2+ m (as compared to 3 m for the other two). The tank area is 8,400 rai and the potential irrigated area is 14,000 rai during the wet season, plus 7,800 rai during the dry season. However, at present, it is serving 3,000 to 5,000 rai with wet season irrigation only.

Since the land submerged by the reservoirs is of similar quality to the land being irrigated, it is quite apparent that, in their current condition, these projects have actually resulted in reducing production. What is required to overcome this dilemma is full development of the irrigation potential plus the mobilization of the other inputs essential for high level production. More intensive fish production in the tanks would also help.

Land Settlement

This $8.5 million, five-year project is a joint RTG/AID pilot effort to improve the utilization of land in eight land settlements of Northeast Thailand. Among the services the project will furnish will be small water subprojects such as community farm ponds, deep and shallow wells, and watershed diversions needed to diversify crops and allow for some limited year-round cultivation in rainfed areas.

Wet season supplementary irrigation will increase yields by permitting earlier starts on paddy nurseries and protection from drought. Dry season irrigation will permit some degree of multiple cropping.

The project includes three major activities designed to improve incomes and levels of living of approximately 44,000 farm families residing within the boundaries of eight land settlements. These activities include: the construction or upgrading of laterite roads within the settlements; the provision of domestic water supplies; and the provision of technical agricultural assistance designed to raise yields of agricultural commodities, both for home consumption and for cash sales.

Mae Chaem Watershed Development

This $21.8 million, seven-year project is designed to increase real income and access to social services of the rural poor in the Mae Chaem watershed, while restoring and maintaining important environmental attributes of the watershed. Major USAID inputs support a project management/outreach component, technical assistance, land development/irrigation, capital costs, training costs, and funds for a credit component. Plans are to develop 1,280 hectares of leveled and diked or bench-terraced and diked land. The project will finance 102 small-scale waterworks in order to increase agricultural water supplies. This will include 35 existing diversion weirs, 62 new weirs, and five small water impoundment projects.

Village Fish Ponds II

This $21 million, proposed five year project is mainly directed at fish production, but also includes water for limited irrigation for horticultural crops as well as water for domestic, livestock and poultry use.

Northeast Rainfed Agricultural Development Project (NERAD)

The purpose of this proposed project will be to improve the agricultural productivity in areas not included within the service zones of major irrigation projects. The project will introduce a package of measures designed to make more effective use of existing soil, water, climatic, and labor resources. This proposed six-year duration, $18.6 million project is still in the Project Paper planning stage, and the PID lists six major project components: improvement in basic cropping systems; land improvement and soil/water conservation; supplemental water resources development; farming system development; supporting components (market development, farmer organizations and storage); and operations research/feasibility studies.

Although by definition, in the target areas of the project, there is no potential for year-round irrigation, the project will attempt to exploit limited water resources from surface catchments and groundwater. The water will be used for supplementary rainy season irrigation and dry season irrigation of small (1/4 acre) vegetable and orchard plots for each farmer.

OPTIONS AND STRATEGIES

The topics in this section are sorted using a typology similar to that which has been previously used in our earlier reports for Bangladesh and Pakistan.

Irrigation (Wet Season and Year-Round) and Rainfall Options

Climate in Northeast Thailand. Due to its geographical position, the climate of northeastern Thailand differs slightly from other parts of the country. However, the area is still largely influenced by the two monsoon winds: the wet southwest monsoon and the dry northeast monsoon. Typhoons from the China Sea also affect the local climate of this region. Generally, the tails of these typhoons hit Thailand, including the northeastern region, in April or May and cause high rainfall in the early part of the rainy season. When the sun moves north of the equator, the paths of the typhoons move northward beyond Thailand. In August, the sun moves south again and typhoon paths again pass through the northeastern area causing heavy rains in September and October. Because of the rain shadow caused by mountain chains between the central and northeastern parts of Thailand, typhoons are often the main source of precipitation in areas of the Northeast. The average rainfall is about 1,200 mm and is heaviest along the high ridges. The minimum average daily temperature of about 22°C occurs during December-January and the maximum average daily temperature of about 31°C is reached in April-May.

Due to both the seasonality of rainfall and the yearly variations in quantity and distribution, the Government of Thailand has actively encouraged both large and small-scale water resource development in the Northeast. At the same time, efforts to improve rainfed agriculture are important since, even after full development, only 20 percent of the rural population will be served by full irrigation.

Soils-Crops-Water. A brief description of the problems and issues related to the soils, crop, and water and fertility management in the Northeast is presented as Appendix E.

Research, Study and Field Trial Needs. Project planning and management processes are restricted by the lack of analysis of crop moisture availability based on rainfall probabilities and moisture budgets of different crops, soils, and seasons of the year. AID should consider providing more guidance and support to analyze existing weather, crop and soils data to develop crop production surfaces for paddy and other promising wet and dry season crops (see Figure 1).

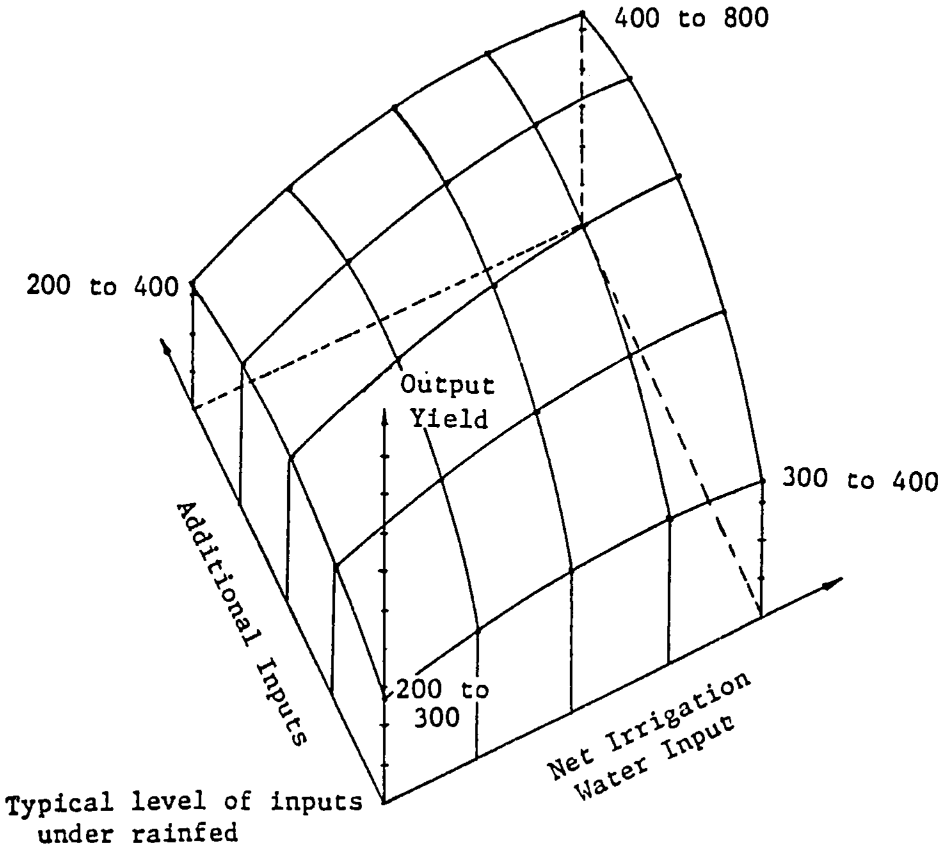

Figure 1. Illustrative yield surface in kg/rai (based on interviews and literature) for paddy production during the wet season in Northeast Thailand.

The crop production surface presented in Figure 1 was developed from data obtained during interviews with farmers and professionals and data obtained from literature. The net irrigation water is the irrigation water which is actually needed for evapotranspiration and seepage; and the other inputs include such items as HYV seed, fertilizer, lime, and better farming practices. The input vectors are not quantified because sufficient information was not available; and yields are given as suggested from estimates of actual farm production experiences.

Definitive information on soil-crop-water interrelationships is seriously deficient in most of the project areas in the

Northeast. There are a number of experiments and field trials reported, but the results are often conflicting because of the confounding of several factors. The soils are not adequately characterized, water supply information is lacking, mixed fertilizers are used so that it is difficult to interpret the response to any one nutrient, certain nutrients such as calcium, magnesium and potassium are not included in many of the experiments, etc.

The Lam Nam Oon project is as good a site as any to conduct investigations on soil-crop-water interrelationships. Soil types representative of extensive areas in the Northeast are in the project area. The ECI report and other reports on the project area provide some useful background information. The Berger Consultants who are the consultants for USAID on the project, are developing some information on rainfall probabilities and are doing some preliminary soils work.

What is needed is a long-term commitment, at least five years, to conduct the necessary studies under close supervision of a experienced, senior soil or plant scientist who understands soil-plant-water interrelationships. Selection of representative sites and design of the experiments should be such that more specific information can be extrapolated to similar situations in other areas. These studies would provide excellent opportunities for Thai personnel to gain experience in conducting definitive experiments. Thailand is seriously lacking in research personnel to do the kind of work required to obtain the necessary basic data for large investments in irrigation development programs.

A soil fertility specialist would be needed to outline field experiments and trials on the main soils to provide more adequate information than is available; specifically, requirements for nitrogen, phosphorus, potassium, lime, sulphur, zinc or other micronutrients, and the possible response to calcium silicate. Varieties would need to be considered and insects and disease controlled, as well as water supply.

This kind of information is essential before trials are suggested for farmers' fields and any practical recommendations made. These experiments need to be continued over a period of several years in order to get some measure of the uncontrolled variables such as seasonal effects, soil microvariability, etc. In the meantime, the basic agroclimatic data should be organized and a group of experts called upon to suggest fertilizer levels and HYV's which would have a high probability for success. Moderate levels of these inputs could be subsidized in order to essentially eliminate the farmers' risk of using them.

Direct and Indirect Investments

Direct investments are those for specific irrigation project areas and indirect investments are those which are designed for broader development strategies for a region in order to benefit a larger audience. In Northeast Thailand, as a result of development policy and donor assistance, many direct investments have been made such as the Lam Nam Oon and Nong Wai Irrigation Projects. There is also need for a number of indirect investments in research, extension, seed production, credit, health, education, cooperatives, etc. An example of indirect investment is the National Program for Agricultural Extension which is targeted to the whole country.

It is not a matter of either direct or indirect investments, but a proper mix of both, given the needs of the Northeast and the particular internal and external constraints which must be confronted. Both direct and indirect investment strategies have strengths and weaknesses. Direct investments, while benefiting project areas, are usually easier to design, sell to funding agencies, implement, monitor and evaluate than diffuse indirect investments. Area development strategies usually have a longer time horizon, are more complex, and have major problems related to implementation, monitoring and evaluation.

Expansion and Intensification Options

Thailand faces the classical issue of whether to invest in expansion of the irrigated area with new projects or more intensively develop the existing irrigated area. Existing irrigated areas are performing at much below expectation with yields much lower than expected (potential) in the rainy season (see Figure 1), cropping intensities are only a small fraction of design, and the output of most projects is much lower than potential. Excessive use of water occurs in the upper portions of the system, and inadequate and insufficient supplies are provided to the lower reaches of the system.

Farmers have been reluctant to change many traditional cropping practices, adopt new technologies, and increase kinds and levels of inputs. Furthermore, they do not effectively participate in disciplined operation or effective maintenance of the on-farm irrigation system. Output and economic returns on projects are less than design and profitability of crops is not as much as expected by farmers. Lack of credit, effective organizations, and availability of institutional services and inputs are in many instances limited. Social factors also inhibit effectiveness of the projects.

Existing irrigation projects must be improved or serious questions about the economic viability of irrigated agriculture and efforts to develop new projects must be asked. Farmers cannot be expected to make investments in inputs and adopt appropriate irrigated crop production practices if they do not believe that irrigation water will be available on a reliable and timely basis. If existing irrigation does not perform as designed and cannot be improved, it is not realistic to design new projects based on the same unrealistic criteria. Thus, irrigated agriculture must not only be improved for the sake of current investments, but also to ensure the economic viability of new projects.

New irrigation projects have an inherent attractiveness because they are frequently seen as a sign of progress and benefits appear more obvious. Furthermore, experienced people are usually available from completed projects and the management and monitoring efforts per unit of investment (donor loan) are relatively small. Equity issues also favor new projects because it is usually assumed that the new set of farmers to be served are poorer than those on existing projects; but this is not necessarily the case where there is so little equity in water distribution on existing projects.

Because of equity and political stability issues, investments in new irrigation projects should continue, but only in the context of providing a field laboratory for the best developed improvement model to be used in designing and implementing the new project. However, major emphasis should be placed on the improvement of existing projects.

O&M Budgets. Table 3 (which is provided by RID and reflects the budget summary of October 1980) illustrates a characteristic problem in the expansion phase of long-lasting projects, such as irrigation systems. The budgetary allocation to O&M has increased from about seven percent of total annual construction outlay in 1972 to between 10 and 13 percent for the period between 1974 and 1981. But since construction accumulates physical assets which must be maintained by recurring O&M expenditures, a constant percentage of annual construction costs devoted to O&M results in a drastic decline in O&M per unit of physical facility which must be operated and maintained. Thus, as shown in the bottom line of Table 3, the percentage of O&M to accumulated construction has declined from seven percent in 1972 to only two percent by 1981.

Table 3. Royal Irrigation Department budget in thousands of Bhat (Bhat 20 = $1.00).

Description	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
1. General Administration	578.6	571.9	657.1	851.1	1048.2	1071.7	1167.7	1375.1	1542.5	2045.9
(% total)*	35%				29%					28%
2. O&M + Improvement	187.7	186.2	203.8	336.8	519.5	605.6	790.2	963.6	1055.9	1491.6
2.1. O&M	61.4	72.5	79.2	109.3	205.5	230.8	259.6	263.4	291.5	463.8
(% construction)	(7%)		(10%)		(13%)		(13%)	(12%)	(11%)	(12%)
2.2. Improvement**	126.3	113.7	124.6	227.5	314.0	374.8	530.6	700.2	764.4	1027.8
3. Construction	896.0	635.7	763.6	1301.4	1601.6	1704.6	2011.7	2112.8	2736.4	3699.5
Large Construction Project	573.5	393.9	499.4	877.1	999.5	937.9	1327.3	1373.9	1447.8	1805.2
Small Construction Project	322.5	241.8	264.2	424.3	602.1	766.7	684.4	838.9	1288.6	1894.3
Grand Total	1662.3	1393.8	1624.5	2489.3	3619.3	3381.9	3969.6	4451.5	5334.8	7237.0
Accumulated Construction	896				5198.0				13760.0	17460.0
O&M as % of Total Construction	7%				3.4%				2.0%	2.6%

* Includes surveying, designing, and purchasing heavy equipment.

** Includes on-farm development.

It is impossible for us to determine the correct annual allocation to O&M as a percentage of total physical facilities in place, but if a rough figure of five percent is used, then the 1981 O&M budget should roughly be doubled to Bhat 873 million. Obviously, a careful study of O&M requirements should be made. Two obvious problems with using a simple percentage of total physical facilities are inflation effects and the difficulty of dividing rehabilitation or improvement between O&M and additions to total physical facilities. It is evident from discussions with RID Officials and Project Managers that funding for O&M is too low. The O&M Division of RID operates with a very small staff (10-15) and funds are not sufficient for either managing the irrigation systems properly or maintaining them in working order. The result is that farmers are not provided with a reliable supply of irrigation water. Furthermore, because of poor maintenance, the canal systems have become severely deteriorated and, in many cases, already need renovation.

With maintenance, there are two options: either provide enough funds for an effective maintenance program; or allow systems to quickly deteriorate and rebuild them often. For both the long and short runs, it is considerably less expensive to provide an effective maintenance program.

Main and On-Farm Investments

Historically, Thailand has followed the traditional practice of development of dams and other facilities for the capture and use of water for irrigation and, since 1970, has given greater and greater emphasis to on-farm activities. However, in 1978, only 35,000 hectares had intensive on-farm developments, but an additional 153,000 hectares were under construction and 119,000 hectares were being planned for development because the RTG recognizes the importance of on-farm development.

Apparent lacks in on-farm irrigation development in Thailand are appropriate technologies for more effective on-farm improvements, as well as an integrated approach to provision of service and inputs for greater incentives for change and new and improved levels of inputs.

The basic problem is illustrated in Figure 1. With wet season supplemental irrigation in Northeast Thailand, but with no additional inputs of seeds, fertilize , extension services, etc. ("other inputs"), the increase in yield may be from the present level of 200 to 300 kg/rai to 300 to 400 kg/rai, or about 100 kg/rai. On the other hand, with no irrigation, but with "other inputs" the yield may increase from zero to 200 kg or an average of 100 kg as well. It is only when both irrigation and other inputs are applied intensively that yields may be expected to increase to the 400 to 800 kg/rai level.

The problem is that improvement of existing irrigation facilities is very expensive while improvement of "other inputs" requires very intensive management effort and organization, at least over the short run, while the farmers are "learning by doing."

The cost of improved irrigation, including distribution systems, land consolidation, leveling, ditches, drains, and access roads is now running from Bhat 4,000 to 8,000/rai in Northeast Thailand (Bhat 20 = $1.00). If yields increase by only 100 kg/rai, or by roughly Bhat 300/rai in the wet season, the present value of the benefits (at 10 percent discount over 30 years) is only Bhat 2,800. Thus, the benefit cost ratio of wet season irrigation activity is only about 0.5. These figures are, of course, only rough estimates, which will vary from place to place and are subject to further refinement, but the essential message does not change, either:

1. More production must be obtained from intensive application of "other inputs" in the wet season, or

2. Much more water and other inputs must be allocated to production in the dry season with crops which require much less water than paddy -- estimated at 1,100 mm per crop at 100 percent irrigation efficiency! or

3. It must be concluded that it is not worth rehabilitating existing irrigation projects in the Northeast, much less constructing new projects.

Certainly, (3) is not an acceptable conclusion for the 20 percent of the Northeast that can potentially be economically served with irrigation water. Without the basic irrigation input, as shown in Figure 1, all areas of the Northeast will inevitably be tied to low and undependable levels of production, even with intensive application of other inputs. The only reasonable conclusion is that an appropriate organizational and managerial structure must be created to manage both (1) and (2) through intensive utilization of both irrigation and other inputs.

In Thailand, and in almost all other countries of the world, there exists an organizational and managerial gap between the outlet of the canal (managed to this point by the Irrigation Departments) and the farm gate (managed beyond this point by the farmer himself). Both sides of this gap may have excellent facilities and be well-managed, but unless the gap in the facilities and management chain is corrected, good facilities and management on both sides will have very little effect.

Canal system. The design of canals systems normally progresses from the water supply (dam, diversion or pump) to the inlet of the watercourse serving individual farms. However, canal design should progress from the field based on adequate on-farm delivery systems, to the water supply; that is, design from the bottom up instead of from the top down. Water deliveries should also be managed from bottom up. Operation of the system without adequate personnel frequently results in farmer regulation of the system in the initial stages of system operation. This undisciplined operation of the system usually results in inequities of water distribution and inefficiencies. Continued undisciplined operation of the system results in unreliable water supplies on lower portions of the system.

Design of the system does not always adequately consider flood water in natural drainage ways or runoff and erosion of the canal banks. Provision for control of water to each outlet, while possible, does not appear to follow any explicit or quantitative criteria. The result is inequitable distribution of water and quick lowering of water levels, which causes damage to canal linings.

Lack of personnel, constraints in the operation and maintenance budget, and inadequate rewards and incentives for operation and maintenance personnel result in less than effective system operation. Better system management is essential and training for operation and maintenance personnel is needed.

On-farm delivery system. Undisciplined and inequitable operation of the canal system results in uncertain and inadequate water supplies to many farms. The lack of on-farm and in-field distribution systems is a major factor in the uncertainty of water delivery at the field. This problem is repeatedly mentioned by farmers, personnel and reports in Thailand.

The above factors, along with inadequate farm-gate prices, are major causes of the farmers' unwillingness to risk investments in improved and increased inputs in both rice and upland crops. Adoption of dry season irrigation is affected by uncertainty of water supplies. Upland crops probably cannot be successfully irrigated without on-farm and in-field irrigation systems, or at least yields will be drastically reduced.

Regulation of the flow to each farm outlet and disciplined delivery of water to the farm are both important needs in good on-farm water management. Regulation of the flow provides dependable known flow rates. Prevention of unauthorized use of water reduces uncertainty and improves equity for other farmers on the system.

The total main canal and on-farm portions of the irrigation water delivery system must be comprehensively managed to obtain the planned production levels. The distribution of benefits, as well as the public capital and management costs, are functions of the intensity of water deliveries (flow per unit area) as well as the intensity of development provided per unit of flow. We are uncertain about the optimum intensity of water delivery values, but tentatively recommend:

1. Delivery capacities of 1.0 to 1.1 lps per hectare (0.16 to 0.176 lps per rai). (Information should be obtained from our Recommendations 3 and 8 to firm up these values for both wet and dry season irrigation programs.)

We also offer the following tentative development intensity guidelines:

2. Delivery systems should be lined and maintained to the end of sections designed to convey water for an average of three or more days per week during peak use periods. Where water slopes (canal to farm watercourse) exceed 1.0 m per 300 m, pipe distribution systems should be considered.

3. Rotational irrigation should be practiced holding discharge rates (to fields) between 20 and 30 lps.

4. Field ditches should be provided so at least 80 percent of the fields have direct access to water without requiring two or more farmers to cooperate, i.e., traverse another owner's land. However, these unlined field ditches should be maintained by the farmers under the supervision of the appropriate public management unit.

5. Drainage ditches should be constructed with the same basic guidelines as above.

6. Farm roads should be provided along all watercourses signed to convey water for an average of two or more days per week during peak use periods.

The above guidelines should be tempered in accordance with current commitments and practices and modified as experience is gained from the Lam Nam Oon Project and the diagnosis of existing systems such as the NEA low-lift pump system, as suggested in Recommendation 8.

On-field application system. In order to properly design the main on-farm delivery system, a detailed soil survey on a scale of 1:2500 or 1:5000 for the project area is recommended, preferably the former. This should be on a base map with contour intervals of 0.1 to 0.3 meters which are needed for the proper design and layout of water facilities to farmers' fields.

Physical and chemical characteristics of the different soils should be determined, including infiltration rate and permeability, depth to permanent water table, depth to perched water table and depth of topsoil. A soil scientist should interpret these data for paddy and dry season crops using weather data and rainfall probability in terms of available water supply at saturation, field capacity and soil depths to estimate the effects of landshaping operations. In addition, suggestions would be helpful for nutrient requirements based on chemical soil tests and information from experiments and trials on similar soils in the region.

Land leveling and system improvement, as now being practiced in Thailand, are done with ineffective machinery which requires heavy investments in foreign exchange. Repairs, spare parts and down-time add to the expense. The results (high bunds and wasted land, lack of precision in the leveled surface, breaking of the fields into small paddies again) all suggest a need for a more effective, less expensive program (see Appendix B).

Traditional approaches to irrigation development usually leave development of the on-farm irrigation system to farmers. A properly graded field is essential for efficient and fully effective irrigation. While land consolidation and/or leveling may appear desirable, we do not recommend publicly financing these activities except on a selective basis where essential for water delivery purposes. However, we recommend public support for technical assistance and credit to help farmers level their land.

Furthermore, we recommend publicly supported land leveling demonstration projects. On such projects, we would like to suggest leveling a given percentage (say, 10 percent) of every farmer's land rather than all the land owned by a few selected farmers.

Crop production practices. Crop production in any agricultural system requires management of the factors of production to increase yield. When one factor essential to production is limiting, response to other inputs supplied may be zero, or even negative. Water control is an important factor to increased crop production. Reliability of the supply is equally important. Most evidence suggests that lack of control and reliability are the missing factors to increased yields because farmers are unwilling to make adequate investments otherwise. Control and reliability of water are necessary conditions for increased investments and changes in production practices in Thailand.

Adoption of dry season irrigation by farmers is a major goal of the Government of Thailand. Reliability and control of water appear to be major factors in the limited success to date.

Increased use of fertilizer and more appropriate crop varieties would significantly improve yields. However, adoption by farmers has been limited. Major causes for less than desired adoption by farmers are lack of knowledge in the use of these technologies, lack of water control and reliability, shortages of services and the above inputs, and uncertain markets. A key requirement is that all of the above be managed appropriately for effective crop production (see Appendix A).

In the 1976 World Bank study, it was pointed out that impacts on production are twofold. First, the area which actually receives full benefits from irrigation is much less than the nominally irrigated area. This difference is hard to assess in the wet season, due to the effects of rain and local flooding, but is clear in the dry season. Second, there is an effect on yields and production in many areas which actually do receive irrigation water. Lack of confidence in the system discourages farmers from using HYV's and cash inputs. Furthermore, for the new semi-dwarf varieties of rice and irrigated dry season upland crops, an effective drainage system is as important as a reliable water supply.

It is hard to separate the benefits of effective water control from those of extension, cash inputs and improved cultural techniques. There is worldwide paucity of data on this topic, although IRRI is now accumulating this type of information on its Production Constraint Program in selected countries. Observations made by the Bank in the better-drained portions of the Central Plain suggest the yield relationships presented in Table 4. These figures are surprisingly similar to what we found independently (see Figure 1).

Software Investments

The RTG is fully cognizant of the need for better irrigation system management to increase crop production; but there is limited expertise in this area in Thailand (and worldwide). At present, water management at all levels in every system visited is lamentable and the absolutely critical need to improve it cannot be overemphasized! To achieve the quantum improvements in water management needed to make the projects viable will require a reorientation of emphasis and incentives in RID; plus a staff who understand the technology involved and the interdisciplinary nature of it.

The crucial software elements presently required in Thailand relate to manpower development, operation and management of the entire system, enforceable water codes and regulations, viable water users' associations, monitoring and evaluation systems, water charges for system improvements, a workable system of coordination and integration of all agencies involved, and an improved information flow from the field to decision-making centers. Basic, applied, and adaptive research are not treated in this section because there is special focus on this component elsewhere in this paper; however, it is a vital element of the needed software package.

Useful types of training. Given the growing and changing demands for irrigation development and improvement of existing systems, personnel development of the appropriate types is a high priority. The curricula of existing irrigation training institutes need to be evaluated in terms of the skills required. Specialized graduate training overseas will probably be needed in certain crucial skill areas, but emphasis should be given to developing the proper training capabilities at universities, colleges and institutes in Thailand. Short intensive in-service, hands-on courses are even more important for personnel with professional degrees to supplement their training by gaining skills in management of the system, diagnosis of irrigation systems, developing solutions to real problems, and project implementation. In addition, special courses need to be developed for project managers which focus on operational management techniques along with water management needs.

Table 4. Estimated average paddy yields (tons/hectare) in the Central Plain of Thailand under different levels of inputs.

Agricultural Services	Wet Season	Dry Season	Water Management
Existing services	2.0	-	No effective irrigation
Existing services	2.5	3.0	Unimproved irrigation system; poor water management
Improved services Improved cultural techniques	3.0	3.5	Unimproved irrigation system; poor water management
Effective agricultural services	3.8	4.0	Improved system; improved management
Improved techniques Moderate cash inputs Effective agricultural services Higher cash inputs	4.6	4.8	More intensive system; good management

For non-professionals, special intensive courses should be developed to meet the specific needs of field technicians, water masters, and zonemen. Specific types of training may also be needed for common irrigators and members of other organizations involved in farm and village water systems. In some countries of the region, such training programs are being institutionalized as a means for continual professional development.

Operation and management. This aspect of software is recognized to be of central importance, because, without it, investment in irrigation cannot deliver the needed benefits to users. The RID staff involved needs to be strengthened and given increased status and incentives. Present plans appear to be adequate except the farmer component is weak.

Farmers usually will not participate in water user organizations for the maintenance of a system until they are assured of real benefits. Once assured of improved control of water, and given the feeling that they are also joint owners of the system, farmers will work together when adequate supervision and incentives are visible. Proper commitment at policy levels is needed if farmers are to play a useful role. To simply build an unfinished system and expect farmers to complete the task without technical skills or support is the main reason systems to the common outlet appear modern and farm level distribution systems and practices appear ancient. To fill this gap in irrigation systems requires intervention and discipline.

In some countries where water user associations (WUA's) work, it has been found that, without resource commitment of users and involvement in certain levels of planning and implementation, there is little effective organization. There is ample evidence in Thailand that farmers will organize and pay for water under pump schemes, will maintain their own communal systems (in the north), and will manage their own systems. The review team is encouraged to note that the emerging RTG policy is to charge users for irrigation services and obtain resource commitments from farmers for on-farm delivery systems before irrigation budgets become too stressed. We recommend that AID support a policy which assures a commitment of farmer resources. The team members are not convinced that Thai farmers inherently will not pay for water when it is provided to them on a predictable schedule which will reduce their current risks.

Enforceable water codes and regulations. No irrigation system will function adequately or equitably until a certain level of order and discipline is established. History is replete with examples which prove this assertion. The present irrigation acts include the Field Dykes and Ditch Act of 1941, and the second issue of the Irrigation Act of 1954. These Acts have provisions for farmers to maintain all field channels and field dykes and sanctions against illegal outlets and intentional damage to structures. The Acts also provide for field inspectors and assistants, irrigation rates, and rights of way for channels and canals. However, in the present Irrigation Acts, there are no legal provisions for water user feedback to system operators, project managers and decision-makers in order to correct past errors, identify problems, and to improve both the design and management of old and new systems.

Special in-service training courses will be required to develop a cadre of individuals who can perform this function. Trained personnel from several disciplines and departments could monitor and evaluate all projects at the provincial level and provide information from the field to project managers and decision-makers. This could fit with the proposed Water Resources Information Center suggested by the AID study.

If major aspects of the system are to be monitored and evaluated, it is important to have personnel trained in the critical areas of the physical system, the biological system and the socio-economic aspects of the system. Such teams could also be utilized to identify new projects, provide limited technical support for projects and for strengthening the information system from the field level to the central offices.

In terms of information flows, it is important to design two-way flows between organizations involved in irrigation, between staff within organizations, between field offices and central offices, and most of all, between farmers and irrigation authorities. (The proposed plan for WUA's includes the importance of farmers-to-officials information flows.)

Coordination of agencies and integration of essential services. Given the large number of organizations involved in irrigation development, and the importance of integration of essential services in all new projects, this area probably represents the most complex software component. Organizations not only have histories, but all organizations invest many resources in maintenance of their own system, which limits resources available for task performance.

Given the particular conditions in Thailand, there are some positive signs of possible modes which probably can be replicated. In a few project areas, a national committee representing several agencies has agreed on a mandate for field personnel to work jointly together. Personnel have been assigned to a project authority and appear to have shifted loyalties to the project authority. Where this appears to work best is where competent and secure staff are involved, where staff live at the project site, and where staff have regular productive meetings to plan and discuss problems. The key is usually an able project manager. This model needs further testing for possible replication on a larger scale. An elaboration of this type of model is presented in Appendix A.

There are usually strong jealousies between organizations, all of which must struggle for funds and other resources. From conversations with RTG officials and studies of reports and proposals, there appears to be conflict developing concerning the role of the National Extension Service in relation to some research stations, RID's programs of WUA's, and operations and maintenance of irrigation systems. Before this is allowed to become a major conflict, definite roles and responsibilities should be clarified at the Ministry levels. Some of the conflicts may be reduced by decentralizing (involving the provinces in) decision-making.

Conclusions. The study team recommends that one or more existing projects be utilized to first determine priority needs for improvement. This should be followed by a systematic multidisciplinary team approach to develop and test solutions and to utilize the most appropriate solutions for demonstration of what is possible when a systematic, comprehensive or intensive approach is taken. A regular system of monitoring and evaluation is needed to assess needs, costs, and benefits to determine whether or not such systems can or should be replicated. This should likely take precedence over moving ahead with new projects.

This experimental demonstration project could sort out and examine alternative management modes for integration of all services required. Also, such a project could be utilized as a hands-on training center for personnel at many levels. The training, however, should not be academic or lecture-oriented as most training courses described, but be done in the field under real conditions where trainees learn basic skills. To date, there are no interdisciplinary teams or places where teams composed of engineers, agronomists, economists, and behavioral scientists can be trained in Thailand.

The proposed training would focus on: reconnaissance methods for understanding how the system is operating; intensive problem identification; field methods; systematic team approaches to development of solutions to priority systems problems; and systematic approaches to project implementation, management, monitoring and evaluation. Some of the needed prototype training courses, complete with training manuals plus some appropriate field manuals, have already been developed by projects in AID/Pakistan, AID/Egypt, and by AID's centrally funded Water Management Synthesis Project (which is doing this study). The existing training materials, plus data and information gained from the hands-on training in Thailand, could be utilized to begin developing field manuals in Thai and training materials for personnel involved as project managers, monitoring and evaluation teams, field staff (water masters, zonemen, common irrigators, etc.)

APPENDIX A

REGIONAL AGRICULTURAL DEVELOPMENT AUTHORITIES

by

David Seckler and Jack Keller

REGIONAL AGRICULTURAL DEVELOPMENT AUTHORITIES

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The purpose of this paper is to briefly describe some of the problems of managing agricultural development "below the outlet" of the secondary, or lateral canals; the experience in India; and the opportunity for building on existing organizations in Thailand to provide an innovative solution.

The basic problem is illustrated in Figure 1. With wet season supplemental irrigation in Northeast Thailand, but with no additional inputs of seeds, fertilizers, extension services, etc. ("other inputs"), the increase in yield may be from the present level of 200-300 kg./rai to 300-400 kg./rai or by 100 kg./rai.[1] On the other hand, with no irrigation but with "other inputs", the yield may increase from zero to 200 kg. or an average of 100 kg. as well. It is only when both irrigation and other inputs are applied intensively that yields may be expected to increase to the 400-800 kg./rai level.

Improvement of existing irrigation facilities is very expensive while improvement of "other input" requires very intensive management effort and organization, at least over the short run while the farmers are "learning by doing."

The cost of improved irrigation, including distribution systems, land consolidation, leveling, ditches, drains and access roads is now running from 4,000 to 8,000 B/rai in Northeast Thailand. If yields increase by only 100 kg/rai, or by roughly B300/rai in the wet season, the present value of the benefits (at 10 percent discount over 30 years) is only B2,800. The benefit cost ratio of wet season irrigation activity is only about 0.5. These figures are, of course, only rough estimates, which will vary from place to place and are subject to further refinement, but the essential message does not change either:

1. More production must be obtained from intensive application of "other inputs" in the wet season, or

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[1]The following approximate figures may be used: 6.25 rai = one hectare; 0.05 US$ = 1 Bhat.

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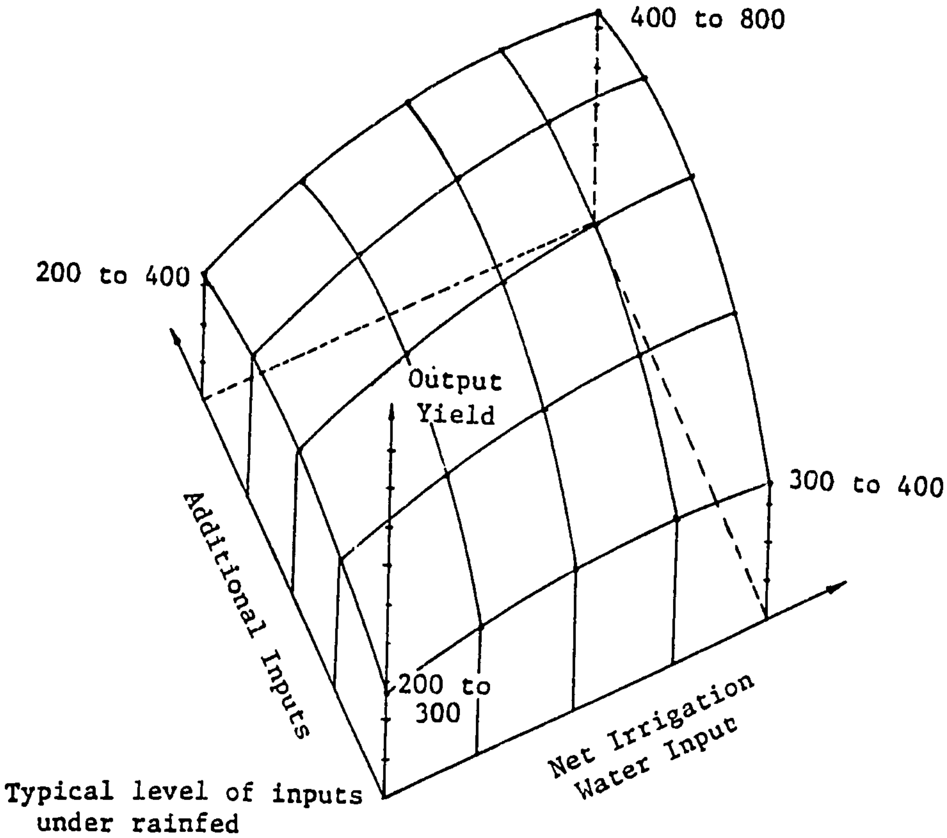

Figure 1. Illustrative rice yield surface in kg/rai (based on interviews and literature) for paddy production on Roi-Et soils during the wet season in Northeast Thailand. Net irrigation water input is the irrigation water which is actually needed for evapotranspiration and seepage; and the other inputs include such items as HYV seed, fertilizer, lime and better farming practices.

2. Much more water and other inputs must be allocated to production in the dry season (with crops which require much less water than paddy -- estimated at 1,100 mm per crop at 100 percent irrigation efficiency!) or

3. It must be concluded that it is not worth rehabilitating existing irrigation projects in the Northeast -- much less constructing new projects.

Certainly (3) is not an acceptable conclusion. Without the basic irrigation input, as shown in Figure 1, Northeast Thailand will inevitably be tied to a low level of production, even with intensive application of other inputs. The only reasonable conclusion is that an appropriate organizational and managerial structure must be created to manage both (1) and (2) through intensive utilization of both irrigation and other inputs.

In Thailand, and in almost all other countries of the world, there exists an organizational and managerial gap between the outlet of the main lateral (managed to this point by the Irrigation Departments) and the farm gate (managed beyond this point by the farmer himself). Both sides of this gap may be well-managed, but unless the gap in the management chain is corrected, good management on both sides will have very little effect.

About 10 years ago, the Government of India created a new kind of agricultural organization in an attempt to resolve this problem. This organization was called the Command Area Development Authority (CADA). CADA's were created within the State level ministries of Agricultural and Irrigation and charged with the function of receiving water from the main laterals (which remained under the control of the Irrigation Department) and delivering it to the farmers. On the whole, one can say that while there have been some notable successes in the CADA enterprise, these successes have been due to the dedication and leadership of a few individuals while the failures, which are many, are due to systemic problems in the structure and orientation of the CADA's themselves. A brief review of these systemic problems may help to prepare the way for the opportunity we perceive for Thailand.

First, the CADA's became mired down in problems of land consolidation. The farmers already had title to their individual plots and, thus, the "carrot" of land title was not available in India, as it is in Thailand. The farmers fiercely resisted consolidation of their scattered plots into one unit. While this resistance is sometimes interpreted as irrational behavior, it is our opinion that it was quite rational. In labor-intensive, small-scale agricultural systems, very little is gained by large fields, while scattered plots over different soils, slopes and elevations provide considerable advantages in dispersion of risks. Also, the farmers did not trust the design of the land leveling and shaping component of this program. They feared that they would end up with high spots, low spots, excessive loss of topsoil, etc. Unfortunately, mainly because the designs were made at headquarters with little field "on-the-ground" verification, these fears were all too often realized. Eventually, the CADA's had to abandon the land consolidation, and de-emphasize the land leveling components of their programs in order to get on with what was, after all, the essential part of their job: delivering irrigation and other inputs.

Second, they ran into a formidable problem in delivering irrigation water because the irrigation departments often refused to cooperate in delivering water to the laterals in the correct quantities at the proper times. Thus, when CADA personnel promised water to the farmer, they could not deliver the goods because the canal was empty. This problem substantially reduced the credibility of CADA personnel in the eyes of the farmers.

Third, the CADA's were never able to obtain control over "other inputs"; seeds, fertilizers, credit and extension all remained with the line agencies and there was little coordination of these essentially joint inputs, i.e., no coordination between irrigation application and fertilizer application.

Fourth, the CADA's were staffed mainly, (and exclusively, in places) with people deputed from other agencies. These people were oriented toward the single factor objectives of their agencies and generally kept their loyalties to the objectives and career opportunities of those agencies, rather than to the CADA's.

Fifth, the CADA's encountered the near universal budgetary problems of operation and maintenance activities in competition with construction activities. However, given the preceding four fundamental problems, the case for increased expenditure for the CADA's was hard to make.

By pointing out the problems of the CADA's, we do not wish to convey an impression of total failure. As noted before, some CADA managers were able to overcome these problems and establish success in bridging the gap between the outlet and the farm gate with corresponding increases in production.

We believe that the CADA experience, in India, combined with the type of organizational forms we see evolving in Thailand, points the way to the solution of the problem of the management gap. Specifically, we believe the RTG should carefully test, on a pilot basis in several command areas, what shall here be called a "Regional Agricultural Development Authority" (RADA). The following observations are intended to provide some of the necessary conditions to effective operation of a RADA, not to attempt to define the sufficient conditions. The complete operational procedure of a pilot RADA will vary according to specific conditions and must be left open to the process of discovery, of "learning by doing" by RADA personnel. However, there are six essential principles, as we see it, which must be followed to permit this process of discovery to evolve:

1. The RADA must be able to manage all the necessary inputs to agricultural production. It must not only have its own irrigation division but also a division responsible for seeds, fertilizers, credit and the like. It should, of course, cooperate with other agencies in provision of these services, but it must have the option to provide these services itself, if necessary.

2. Agricultural production and management is essentially a land-based activity. Thus, within each RADA, responsibility should be allocated in terms of comprehensible land areas, with the lowest administrative unit, the Farm Development Officer (FDO), able to personally know the farmers, soil types, and general behavior of his area of responsibility. Therefore, each FDO should be directly responsible for increased agricultural production on an area of 5,000 to 10,000 rai, depending on average farm size. The next level of responsibility should be an area manager for each five to 10 FDO's. The RADA itself should be limited to five to 10 area management units, or 25,000 to 100,000 rai. In very large Commands, there might be several RADA's under different canals with only a minimum overall command area authority.

3. As emphasized earlier, it is necessary to approach agricultural development with an open mind, testing and exploring various ideas in manageable pilot areas which can then be expanded as learning by doing proceeds. It is necessary to start small and grow as fast as knowledge and control warrant. It is also necessary to have a small multidisciplinary team at the RADA management level to avoid the "blinders" of professional expertise and to conduct brief orientation courses for each group

of new entrants so that the philosophy of a RADA can be conveyed. These courses also let people get to know each other on a personal basis. The training courses should be free and open seminars with the active participation of top management and visiting high officials as often as possible.

4. It is perhaps too much to expect that the RADA could be staffed by its own employees in the initial stages of development; this would require formation of a whole new agency of the RTG, a development best left for the post-demonstration phase. However, people from other agencies working in each RADA should:

   a. volunteer for this service because of personal interest in management problems and

   b. be formally deputed, for a set period of time, to the RADA with their career evaluation in their home agencies appraised in terms of their service to the RADA.

5. Agricultural development requires on the spot decisions, an intimate knowledge of specific circumstances and flexible policy formulation. The authority to make major decisions should be delegated to the manager of each RADA with only annual or semi-annual review by an executive committee. Specifically, the manager should not be bound to long term plans. One year revolving "Plans in Principle" are sufficient.

6. With authority comes responsibility and accountability. Following the "Management by Objectives" philosophy, each department of an RADA should project its own objectives in terms of timebound targets and accept responsibility for either achieving these objectives, explicit mid-course corrections, or failures only because of obstacles beyond their control. The RADA manager is, of course, accountable for desgning and realizing the objectives of the organization as a whole. These objectives should be stated in terms of increased effective irrigated hectarage, increased yield per hectare, increased income, etc., at specific times and places. A separate monitoring team should be established in each RADA to evaluate output performance in terms of these objectives and these "watchers" should in turn be

"watched" by a monitoring team which checks sample monitoring surveys and reports to the RADA steering committee.[2]

7. Lastly, each RADA should deal with the unirrigated, as well as the irrigated land, within the command area of the projects served and attempt to deliver the most good to the greatest number of farmers as quickly as possible. The easiest inputs should be implemented first. Typically, these are fertilizers, seeds or short-term credit. With these leading inputs in place, and the goods actually delivered, difficult problems are more easily handled later. Promises should never be made to a farmer to deliver something about which there is the slightest uncertainty of proper technique or delivery. If expectations are raised and then disappointed, the program can be set back irreversibly.

These are the general principles of a RADA as we see them. In order to bring the discussion down to earth and to illustrate the kind of innovations which the RADA may develop, we may briefly describe an idea which has evolved within our team in our brief survey of command areas in Northeast Thailand.

Field to field flooding of paddies makes it almost impossible for either the project authority or the farmer himself to effectively control water. Unlined ditches are quickly washed away in floods, and lined channels tend to be destroyed by earth movements under saturated conditions. An alternative means of water conveyance is buried pipe.

A preliminary engineering and economic evaluation indicates that various combinations of concrete, asbestos, cement and plastic pipe on lands with slopes greater than 1 in 300, together with lined or unlined ditches for lands with less slope, could be

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[2]An illustration of the kind of monitoring and feedback system that might be implemented is this: each farmer is given a small coded postcard (with a happy face) which he is asked to deposit in a small village "mailbox" on the day he receives water. These cards can be collected by someone from the RADA office twice a week and the results shown on a map of the farms in the RADA. Thus, the advance of the water front during the irrigation season can be continuously monitored. Dry spots will quickly show up and teams dispatched to correct the problem. A separate card would be provided for each irrigation period.

installed with one outlet for every 12.5 rai, for a cost of about B2,000 to B3,000 per rai. Under these pipe conveyance systems, every two farmers could have their own outlet. Maintenance costs would virtually disappear. Perhaps most important, with this physical system of control, the management of water between users in both wet and dry seasons could be effectively implemented by the RADA in cooperation with Water Users Associations.

With an effective conveyance system, at least some of the land of every farmer can be irrigated without land leveling. With effective irrigation on some of the land (and with other inputs) the farmer will soon see that some land leveling is justified. The RADA can provide a custom land leveling service with appropriate machinery that the farmer can call on, and pay for, to perform the amount of leveling he wishes. The RADA can then concentrate on its proper business of solving the collective good problems of irrigation conveyance systems: leaving the determination of the private good problem of land leveling where it belongs, with the individual farmer.

Most of the principles outlined above are now being practiced in a Ford Foundation-USAID project in India, the "Sukhomajri project", which is a very small tank development now being extended over some 200 villages in the next five years. A copy of a paper describing this project will be provided by the authors upon request. While this approach has worked very well in these small 80 acre commands, it has never, to our knowledge, been tried in large commands. Problems of diseconomies of size will inevitably appear. We are, however, convinced that, with the dedication we have seen in Thailand, these problems can be managed and the gap between the outlet and the farm gate effectively bridged.

APPENDIX B

LAND LEVELING TECHNOLOGY: STATUS AND NEEDS IN THAILAND

by

Wayne Clyma and Max K. Lowdermilk

LAND LEVELING TECHNOLOGY: STATUS AND NEEDS IN THAILAND

by

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This note briefly discusses the procedures used for land leveling and intensive improvements on-farm when land consolidation is implemented. The discussion is based on information and observations in the Lam Nan Oon and Nong Wai projects in the Northeast. An option for an alternate technology of precision land leveling which will decrease costs and increase effectiveness is described briefly.

Present Methods

Land leveling when implementing land consolidation is accomplished through the use of large imported bulldozers, road graders and large self-elevating or regular self-propelled scrapers. No land planes for precision leveling are available or used in land leveling although the road grader functions as a land plane in the process of leveling, but is not designed for developing precision field levels.

The canal systems have been designed and constructed on the basis of a map with a scale of not less than 1:20,000 and usually one meter contour intervals. Farm channels are then designed with outlets, checks and drops. A survey and construction team then arrives to survey and level each field so that water can cover fields of irrigation of crops.

Surface elevation shots are taken at regular intervals and a field design developed. The contiguous area leveled to one elevation (level basin system) usually consists of 0.5 to 0.75 ha (three to four rai) in order to have adequate area for the large equipment to operate. Soil is used also to construct elevated roads. Sometimes extra cuts are necessary to achieve a field elevation which allows the field to be irrigated from the designated outlet. Large bunds are sometimes left around fields apparently because of excess cut. These bunds often are one meter or more in width.

Any factor which increases the volume of cut increases the costs of land leveling. Larger fields at one elevation and excess cut both increase cost. When equipment is purchased with foreign exchange, costs are increased and both spare parts paid with foreign exchange, transportation and down time waiting for spare parts all increase costs at a surprising and, often, almost a prohibitive amount.

Specifications for land leveling in Thailand call for field surfaces within ±5cm of the design elevation. Observations of fields and conversations with individuals suggest that ±10cm may be the more frequent standard. Results of extensive research in the U.S. and other countries resulted in a specification for fields with zero grade (level basins) of ±1.5cm. This precision leveling improves plant stands, uniformity of yield and thus total yield, increases fertilizer effectiveness and provides for efficient use of water. Thus, precision of leveling is important. A measure of the lack of precision of leveling in Thailand is that farmers usually subdivide their fields into 1/2 or 1/4 the approved design size after leveling is accomplished.

The large bulldozers used in Thailand are not designed for leveling of fields for irrigation. They are especially effective for dams, roads, land clearing and transportation of soil for short distances and in very irregular terrain. This may be necessary in initial work on a field. Hauling soil from one area of a field to another is the function best performed by soil scrapers. Once the design elevation has been approximately accomplished, a land plane achieves the precision of ±1.5cm very efficiently. (Road graders are not designed to accomplish this function and have limited maneuverability on small fields.)

Once leveling is done, there is currently no attempt to touch up fields which become unlevel due to ploughing and cropping which take place over two or more seasons. After consolidation and immediately after leveling, when topsoils have been shifted, there is no followup to specifically help the farmer in management of the cut and fill areas of the field for the first crop period. Those who work directly with farmers, i.e., extension, are said to have no training in either soil or water management to help the farmer immediately gain from the initial investment.

Suggested Approach

USAID experience with land leveling in the past in Turkey and Pakistan, and presently in Egypt, suggests that farm tractors using indigenously manufactured scrapers and land planes are cost-effective and very capable of achieving the precision required for level basin irrigation systems. Farm tractors have many alternative uses in addition to leveling and, in Thailand, farmers desire to have tractors to prepare fields for the second crop. Equipment manufactured in Thailand could easily copy the Turkish equipment and develop local industries which would stimulate the economy and reduce the spare parts problem and save valuable foreign exchange. A study of the stoppage of work at the field level presently due to dependence on outside machinery and the lack of spare parts to keep the equipment running would probably reveal a great loss due to equipment down time.

In both Pakistan and Turkey, a new local industry evolved with USAID technical support which now manufactures soil scrapers, land planes, soil chisels, ditchers and other essential farm equipment. Opportunity exists for a similar industry to develop in Thailand. Use of improved equipment can reduce leveling costs and the costs of land consolidation while improving the precision of land leveling. Also, farm tractors made available on a hire basis would help farmers with the first difficult plowing after rice for the timely second crop.

Recommendations

The team recommends that AID field a team to review present land leveling methods in Thailand. (We recommend Neil Dimick or Marvin Parker). If the alternative techniques for precision land leveling seem to have potential, then immediately import appropriate equipment from Turkey, Pakistan, Egypt or the U.S. and evaluate the technology. If successful, initiate manufacture of the equipment in Thailand and change the procedures used in land consolidation. Procedures for achieving leveling should also be reviewed and potentially revised, and improved.

Three members of the irrigation team also work with projects which have developed materials on precision land leveling. These include technical manuals, training manuals and a handbook utilizing domestic resources to the degree possible. Upon request, the team will provide these and other materials desired related to technologies and procedures for precision land leveling programs.

APPENDIX C

(Portions Taken from Volume I: Main Report)

WATER FOR THE NORTHEAST
A Study for the Development of
Small-Scale Water Resources

by

Asian Institute of Technology (AIT)
September 1978

WATER FOR THE NORTHEAST

A Study for the Development of Small-Scale Water Resources

by

Asian Institute of Technology (AIT), September 1978
(Portions Taken from Volume I: Main Report)

Introduction and Summary

1. This study has been commissioned by the Water Resources Development Subcommittee of the National Economic and Social Development Board for the purpose of providing the Subcommittee with current information on the status and potential for the development of small water resource projects in the Northeastern Region of Thailand. It forms a part of a number of related studies initiated by the Subcommittee to identify potential resources and programs for improved water supplies to farmers in this region. The region has been recognized by the Government of Thailand as a priority area for accelerated regional development efforts. The development of reliable water resources is seen by farmers in the Northeast, as well as by policy makers and administrators, as the highest priority for rural development.

The study team has made an effort to incorporate the considerable knowledge currently available with the additional insights of farmers, local officials and professionals, into a comprehensive strategy for the development of water resources in the Northeast, and a program to implement the strategy at this time.

2. The Northeast remains the poorest region in Thailand, subject to considerable fluctuations in wet season rice yields, as a result of inadequate supplementary irrigation during drought periods. Farmers are unable to develop year-round cultivation, because of incomplete distribution systems for delivering available water to the farm. In many areas, remote from available water resources, water is insufficient for meeting the minimum requirements of domestic supply for people and animals, subsistence agriculture and related activities. The resources for the development of the Northeast are limited and must, therefore, be spent on projects that hold the promise of real benefits to farmers. Investment in these limited resources in water projects can only yield the promised economic, social and hence political benefits, if water reaches the farmers in adequate quantities, and if it is effectively used by farmers to increase agricultural production, and to improve the quality of their lives.

3. The strategy discussed below, and the program for implementing it, focus on the next five years as a critical period for reaping the maximum benefits from water projects. Both political and economic considerations require that results be attained within this period. Thus, longer-term projects have not been considered. Two proposals which merit consideration are the construction of the Pa Mong Dam across the Mekong River, and trans-basin pumping from the Mekong River into the Chi River Basin. Neither project is likely to materialize within the next five years.

4. A water policy for the Northeast must follow a two-pronged approach: the effective distribution of available water resources from large reservoirs and reliable rivers to the people adjacent to these sources, and the development of small water resource projects to meet basic water requirements in areas which are away from large reservoirs and reliable rivers.

Thus, the two-pronged water policy can be summarized as follows:

(a) Emphasis on distribution from existing sources: rapid development of distribution systems from reservoirs and rivers, capable of actual deliveries of water to the maximum number of farm families; and

(b) Meeting basic requirements: rapid development of small water resource projects in every village capable of meeting the basic subsistence requirements for domestic water needs, for minimal supplementary irrigation, and for minimal dry season irrigation of garden plots. These projects can be justified on the basis of preliminary benefit/cost comparisons, but cannot be expected to provide the benefits of fully irrigated agriculture.

5. For purposes of water resource planning, we can divide the Northeast into three major zones:

Zone I: Areas irrigable by large reservoirs, which can provide water for a total irrigable area of 2.1 million rai, and benefit eight to nine percent of farm families.

Zone II: Areas irrigable by pumping from reliable rivers which can provide water for a total irrigable area of 1.9 million rai in the wet season and benefit a maximum 10 percent of farm families.

Zone III: Areas inaccessible from large reservoirs and reliable rivers which contain 80% of the rural population and where small water projects at the village level, as well as larger tanks in selected locations, are required to supply basic village water requirements. These small projects may take the form of small tanks, natural or dug ponds, weirs and topographical alterations to nearby watershed areas, and shallow or deep wells.

6. The emphasis on distribution of water resources in the region takes two major forms. Support, both political and financial, is essential to the completion and maximum extension of distribution systems from the large reservoirs and the reliable rivers. In the future, as more and more distribution systems come into operation, limited water supplies will have to be shared among water users in the various provinces. A Mun-Chi River Basin Authority may be needed to monitor and ration water supplies.

Planning of all projects, large and small, must be carried out with distribution in mind, making sure that the budget for distribution is available, that distribution is planned simultaneously with dam construction, or that no project receives funds without a distribution plan incorporated into it. Local participation in distribution cannot be successful without technical assistance and budgets.

7. Meeting the basic village water requirements of farmers in Zone III will mean the provision of domestic and animal water supplies, supplementary wet season water supplies, and dry season water supplies. In addition, water will be required for retting kenaf and for raising fish. In general, supplies will not be sufficient for year-round irrigation as a basis for economic development. Adding the various requirements, the basic water needs of a typical village are estimated to involve a storage on the order of 100,000 m^3, or alternatively 1,000 m^3 per family. Thus, one small reservoir of this capacity, a number of smaller farm ponds with this total capacity, or a combination of groundwater wells, ponds, and a weir or a series of topographical alterations, may be constructed to provide for these basic requirements. The field survey indicates that, in many cases, rehabilitation of existing systems could meet a considerable portion of this basic requirement. It must be accepted, however, that in many cases, villages will continue to rely on further development of rainfed agriculture, and cannot expect the benefits of fully irrigated agriculture.

8. A comparison of alternative project types on the basis of economic return and ease of implementation indicates that pumping from reliable rivers is the most attractive alternative. Small farm ponds, when initiated by farmers themselves and used for intensive vegetable or fish production, are also attractive, but benefit only small numbers per project. Shallow wells and diversion weirs are economic, but only some areas have suitable sites. Deep wells are the most effective answer to the need for village domestic water supply, but have limited scope for agriculture because of high costs. Large and small reservoirs can be economically viable, and can provide for basic water requirements of villages, as well as for profitable agricultural activities. The number of good sites, however, may be limited, and successful implementation is impeded by technical complexity, problems of land acquisition, and sociopolitical obstacles to organizing the distribution system.

9. The second part of this report presents a six-point program of action for implementing the strategy discussed in Part One. An attempt has been made to link together, with minor innovations, a number of recent developments, both in government administrative procedures and in funding procedures, into a coherent program which makes maximum use of these developments. The essence of the proposed program is a commitment to the provision of economically beneficial water projects to villages in the Northeast within the next five years. In order to reach the great majority of villages, a strong sense of direction will be needed to guide the actions of field agencies, as well as changwat governments and village committees. There are six key recommendations which form the backbone of the program.

10. Recommendation I emphasizes the need to move rapidly toward the adoption of a water resource development strategy for the Northeast by the recently established Accelerated Water Resource Development Committee, and to set in motion the Water Resources Information Center to monitor the implementation of this strategy.

14. Recommendation II emphasizes the need to lend support to the large number of existing programs which now deliver water to farmers in the Northeast and to improve the capabilities of line agencies to implement projects, without restricting their ability to act. The Accelerated Water Resources Committee will need to provide incentives for cooperation among agencies. Meetings among agency representatives may be set up for the purpose of compiling lists of projects to be carried out by each agency. Specific forms of cooperation between agencies can be streamlined, to enable two or more agencies to work together on the same set of

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projects. Budgetary incentives for cooperation can be provided by increasing the budget allocations of joint projects.

15. Recommendation III focuses on the need to strengthen the capabilities of changwats (provinces) to plan and supervise the implementation of a large number of small-scale water projects by increasing authority, budgets, and technical and managerial personnel at the changwat level. The Government has now established a clear policy of decentralization, a policy aimed at strengthening the changwat administration as the local decision-making unit, by building up the capability of changwats to plan and by channeling funds for rural development programs through the changwat administration.

18. Recommendation IV concerns the initiation of a program to meet basic village water requirements by setting in motion a changwat water requirements survey, to be contracted out to private firms for immediate execution. The survey will aim at identifying a water project for every village, examining both technical and economic opportunities. Coupled with this survey, a promotion campaign will be initiated, using community development workers to mobilize villagers to participate in selecting and planning village projects.

20. Recommendation V emphasizes the need to allocate subsidies for village water projects, based on a fixed amount of subsidy per family, and to make these budgets available immediately upon the presentation of approved project plans. Subsidies must necessarily be limited, both by financial constraints, and by the critical need to make villages self-reliant in the future, capable of taking care of their own needs without further assistance.

23. Subsidies must be used in conjunction with loans and farmers' contributions, to ensure that projects are designed and implemented with economic returns in mind. To instill a sense of responsibility and ownership, those farm families which benefit greatly from receiving water on a timely basis will pay for it and those who receive lesser benefits will, at least, contribute their labor and minor fees for upkeep of projects. The Government has already decided in principle that, for all new irrigation projects, it will recover all operation and maintenance costs and as much as possible of the investment costs directly from the beneficiaries.

24. Recommendation VI is concerned with strengthening the ability of villagers to own and operate village water projects

effectively by forming Village Water Committees, securing their legal status, involving them in the initial planning stages, providing them with small budgets for an initial growth period, and training villagers in operation and maintenance of small water projects.

Two-Pronged Water Policy

The strategy for achieving water policy objectives in the Northeast must be premised on the delivery of adequate water supplies to the largest numbers of farmers in the shortest possible time. Both political and socioeconomic premises pose a serious national challenge in putting into effect a promising water policy for the Northeast at this time. Natural topography, land capability and rainfall constraints make it impossible, within present knowledge and resources, to provide for irrigated agriculture throughout the Northeast. Large areas remain inaccessible to reliable water supplies. At the same time, development cannot be restricted to areas suitable for irrigated agriculture. The Government is committed to spreading the benefits of water throughout the region.

Thus, water policy for the Northeast must follow a two-pronged approach: the effective distribution of available water resources from large reservoirs and reliable rivers to the people adjacent to these sources, and the development of small water resources projects to meet basic water requirements in areas which are away from large reservoirs and reliable rivers. The two-pronged water policy can be summarized as follows:

1. Emphasis on distribution from existing sources: rapid development of distribution systems from reservoirs and rivers, capable of actual deliveries of water to the maximim number of farm families; and

2. Meeting basic requirements: rapid development of small water resource projects in every village capable of meeting the basic subsistence requirements for domestic water needs, for minimal supplementary irrigation, and for minimal dry season irrigation of garden plots.

Emphasis on distribution. Realizing that the water resources of the Northeast are still grossly inadequate to meet irrigation needs for the region, long-term development will require substantial additional investment in large and medium-scale dam construction. In the short and medium term, however, water from the existing dams and rivers must reach the farmers' fields.

This can be achieved primarily in two ways: by the rehabilitation and completion of the canal systems of the existing major reservoirs, and by the acceleration of pumping from the reliable rivers. Both programs are currently underway.

The Royal Irrigation Department (RID) is progressing satisfactorily with the completion of distribution systems in several downstream areas of large reservoirs. RID and the National Energy Authority (NEA) are effectively developing irrigation schemes for areas along the banks of the major rivers: The Chi, the Mun and the Mekong. Both of these developments hold considerable promise and must be encouraged and strengthened. Extensive distribution systems for irrigation may benefit the substantial population along the major rivers: first, by providing adequate supplementary irrigation which can substantially reduce risk and second, by providing dry-season irrigation for double-cropping. A successfully implemented water distribution program in the Northeast will accelerate economic growth, by increasing incomes of farmers receiving supplementary irrigation, and by practically doubling the incomes of farmers who plant in the dry season. Reliable irrigation water will facilitate the introduction of new and improved varieties of rice, will promote the use of fertilizers, and will help introduce new crops and new farming techniques.

Meeting Basic Requirements. The second key priority is meeting the basic water requirements of farmers by reaching every village. Gravity irrigation schemes from reservoirs are essentially limited to approximately eight to nine percent of the farm families in the Northeast. Pumping irrigation, when it is fully developed, may supply supplementary wet season irrigation to an additional 10 percent of farm families living along reliable rivers. This means that the benefits of irrigation from the major reservoirs and reliable rivers are limited to less than 20 percent of the farming population. Thus, 80 percent of the farmers will have to continue to rely on rainfed agriculture, or partially supplemented rainfed agriculture, in the foreseeable future.

The total farming population of the Northeast comprises approximately 2 million rural households living in approximately 20,000 villages. Many villages have not been reached effectively and improvement of water supplies is still their highest priority. Small projects to provide village water supplies have not benefited from an overall plan of action and from proper scheduling.

A few good examples of successful projects do exist, however, and will be discussed below. The value of small projects is that they can reach the entire farming population of the Northeast within a relatively short time. They help provide basic water needs and, if planned and executed properly, can provide basic irrigation requirements for early planting of seed beds, and for small plots of diversified crops in the dry season. While these small projects cannot substantially raise incomes, when planned properly, they can and do provide reasonable rates of return, and are thus to be perceived in economic cost and benefit terms. These benefits, if realized, will improve subsistence agriculture and reduce out-migration.

APPENDIX D

DESCRIPTION OF IRRIGATION SYSTEMS AND PRACTICES IN THAILAND

by

Wayne Clyma

DESCRIPTION OF IRRIGATION SYSTEMS AND PRACTICES IN THAILAND

by

Wayne Clyma

Operation of the Irrigation System

General Characteristics

The farm outlet is located on a lateral or branch lateral with a gated inlet. The flow rate for each outlet is established from the area served with 0.00013-0.00020 cubic meters per second per rai (cms/rai) (8.6 mm/day) being the allotted flow rate. The supply of this flow rate is established from the full supply level (FSL) of the canal and the diameter of the pipe. The head assumes submerged operation, I believe.

Allocation of water past the outlet is left for the farmers to arrange and regulate under present circumstances. The presumed method of canal rotation is continuous flow. The usual field distribution is to allow the water to flow from paddy to paddy and farm to farm without any farm or field distribution system. Field distribution is also by continuous flow.

When on-farm improvements are instituted, then an appropriate farm distribution and field system is constructed with checks, drops and other appropriate control structures. The water is delivered to each farm by rotation under the direct supervision of a common irrigator.

Various levels of on-farm improvements have been implemented in different project areas. These improvements range from limited farm channel development to land consolidation including farm channels, land leveling, and consolidation of holdings. Equipment used includes bulldozers, road graders, elevating scrapers, and a tractor with plow and blade. The flow rate provided at the field ranges from 25 to 30 liters per second (l/s). This flow rate can limit the size of field especially if the soils are not silt loams and heavy clays that have been puddled.

The organization of a chak includes a common irrigator responsible for distributing water to the farmers on an outlet which varies in size from 50 to 150 ha. The common irrigator is elected by the farmers on a chak. The farmer elects a chak representative as chak leader who is their representative in the Water Users

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Association. The Water Users Association consists of a hydraulic unit of the irrigation system and may equal as much as 6,000 ha. Thus, the association may have as many as 100 representatives, depending on the size of each outlet.

The assocation functions as a communication mechanism between farmers and the Royal Irrigation Department (RID). There is definitely communication down to farmers from RID through the association. The question is: how does communication from farmers go up through RID? An example of communication from RID to farmers is when on-farm improvements are to be made, the plan is communicated to farmers through the association.

Huai Chorakhe Mak Tank

The tank and the canal system for distributing water were completed in the 1960's. The storage capacity was 21 x $10^6 M^3$ with the cost of construction equal to 10 million Baht. Design irrigated acreage is 2,000 ha, (12,500 rai), which is assumed to be all paddy rice during the wet season. Only small areas were irrigated during the dry season until 1979-80. Then 830 ha (5,200 rai) of paddy and 80 ha (120 rai) of corn and vegetables were irrigated.

This tank and a number of the other tanks offer interesting design alternatives. Because of the shallow depths of the reservoirs, area inundated relative to area irrigated tends to be relatively small. This is especially true where reservoir operation, high evaporation and seepage losses, and poor use of the water by farmers combine to result in irrigation of a much smaller area than the designed capacity.

Farmers appear to perceive the water supply to be undependable. Thus, poor use of the water and limited adaption of improved inputs result. Under these conditions, a net reduction in rice production may occur because of the area inundated by the reervoir. No evaluation of the reservoir as a drought prevention benefit was made by this team or by the AIT study. During most seasons, short term interruption of the monsoon and, in some years, longer duration droughts may severely reduce both area and yields per unit area. In any event, the most important emphasis for each tank should be to identify and implement improved water management both at the reservoir and canal operation levels, and at the farm level to achieve increased area irrigated and improved yields. Results would be beneficial to present tanks and provide a better basis for designing new tanks.

Hydrographs of the storage volume of water in the reservoir raise several questions about operating rules. For several seasons, the amount of water in storage at the time of heavy monsoon suggests inadequate use of water, especially if dry season irrigation were not being practiced, then there was no reason to conserve water. Inspection of the rates of decline of the reservoir level raises questions about a realistic distribution of the components of the water budget. A good budget could be developed from existing data.

Operation of the canal system for irrigation releases during the wet season is as follows: need for water (the actual flow rate) is supposed to be established by information supplied by the laborers (who maintain the canal) to the chief inspector on a daily basis as he travels the length of the canal. This information is supposedly gained by observations of farmer needs and use in the area where they work. This information is brought back daily to the project site for use in regulating the flow. When a general rain of 20 mm or more occurs in the area or at the request of the farmers, the flow in a canal is stopped.

Canal capacity reduces at intervals along the canal. When the flow exceeds the design capacity, an escape and return channel to the river is provided.

Flows less than full supply level (FSL) reduce the flow of an outlet (usually an orifice). Temporary checks by RID or an earthen check by the farmers apparently are used to regulate the depth of flow.

Irrigation water during the dry season is provided on a 5 days on-10 days off or 4 days on-3 days off partial capacity flow. No system of providing farmers with information about the water supply for the dry season nor the rotation was explained. A major complaint about undependability of the water supply is repeatedly mentioned. No explanation of factors which would cause undependability was provided.

The second tank provided an opportunity to review the distribution of water at the farm outlet. A canal is designed for a full supply level with an outlet of an appropriate diameter and located to provide a head which results in a design discharge. The outlet was not gated. A lined channel distributes water either to a paddy or along the paddy to the next farm channel outlet to a paddy. Distribution below the outlet is assumed to be continuous flow. There are no division structures to apportion the water after it passes through the canal outlet.

Water distributed to a paddy apparently goes from paddy to paddy until the last paddy in the sequence is reached. Then the water would outlet to a drainage channel or the river. In the instance checked, the water traveled in sequence through 10 paddies and then would return to the river.

Vegetables appear to be produced on beds with several rows per bed. Water is distributed through furrows but within a closed basin. Primary tillage is accomplished with a heavy-bladed hoe.

Superficial inspection of several harvested rice fields suggests that fields have significant elevation variations within a paddy. There are both high areas and low areas by as much as six cm within the paddy.

Huai Ang Tank

There is a set of written rules for operation of a tank, but apparently they have not been implemented. The rules by which this tank operates are very interesting. Initiation of the delivery of water to any section of canal is at the request of the group of farmers on that section of the canal. The request is brought to the project from the farmers through the Water Users Association. The person authorized to deliver the request is the president, but perhaps some other person also.

Water is delivered to each section of length of the canal when and for the length of time requested by farmers. Check structures allow the appropriate flow rate to be delivered to the desired section of the canal.

The canal lining was in a poor state of repair. The gate control for a lateral was broken and apparently requires seasonal repair. Another section of the canal had been washed out by flood water. Inlets from the fields were at periodic points along the canal for drainage of excess water. The method by which the flood water was controlled and routed through the canal was not clear.

At least one ungated, farmer-installed (illegal) outlet was observed on the main canal. Apparently, this was not an unusual occurrence.

The gated lateral had several outlets, check structures and one drop structure in the section observed. Several lengths of farm channels had been developed with checks and outlets to the paddies served by the on-farm channel. The structures in the farm channels were no longer functional. Only the evidence of their previous installation was present. The channels were overgrown with weeds and grass with no evidence of maintenance during the previous season. Outlets to paddies adjacent to the lateral were ungated. Water flows from paddy to paddy for the remaining area. Careful inspection of several harvested paddies provided the following data:

1. Transplanted spacing ranged between 20 and 26 cm.

2. Number of tillers per plant most frequently was six, but range was four to nine.

3. Most frequent high water mark on rice plants was 20 cm, but within a basin, height ranged from 12 to 23 cm which is some measure of the range in surface elevation.

The engineer answering questions seemed to think the transplanted spacing should be 30 cm by 30 cm. The paddy areas were small, but variable in area presumably because of elevation differences from paddy to paddy. The farmer expressed interest in having all his area in one paddy, at the same elevation and leveled.

A discussion between Dr. Lowdermilk, Mr. Uoychai and the farmer was conducted. The criteria for when to irrigate a paddy was when the water level receded to six centimeters. The criteria for how much to apply was a depth on the arm of approximately 30 cm. The farmer's perception was that rice needed standing water on the field.

A discussion was held with RID personnel about what happens to water distributed through the canal to farmers. The consensus was that, with the unregulated outlets, farmers will continue to take water when water is available. After a sufficient depth of water accumulates in the paddies of the farmer adjacent to the outlet, he will release water to the next farmer's fields. In this system, maximum water accumulates and is stored first in the upper paddies delaying the availability of water in the lower paddies.

With all the upper paddies releasing water long after the lower paddy has received sufficient water, the lower paddy will likely receive too much water in the end of a water availability period.

The lower paddies on a system have outlets to a natural drainage way, a stream or river. A brief inspection of the lower paddies on the right bank canal revealed that the last paddies had outlets to the river that had been used to release water from the paddy. In the one paddy that received water from two different directions because of the land slope, a pipe had been installed through a roadbed to outlet water. A small field of rice below the pipe had highwater marks of 45 cm. A concrete post in the field had high water marks of 1.5 m. The latter, I assume, was caused by river flooding.

The lower end of the left bank canal was visited. The impression was that the brief section visited was typical of other canals. The section was unlined, poorly maintained and delivery of water severely affected by the rules of operation. According to the AIT report, some sections of the canal have been washed out because of no provision for handling floodwater in natural drainage ways that cross the irrigation canal. The section briefly inspected had the following specific conditions:

1. Outlets to paddies cut directly through the canal bank;

2. Earthen checks in the canal presumably operated by the farmers above the check to the detriment of farmers on the lower reach of the canal;

3. Grass and weeds extensively growing within the canal;

4. One area of brush and trash that almost completely choked the canal;

5. Two outlets where the canal bank had been completely removed for several feet.

The above poor conditions of maintenance and an operating condition that allows farmers on any reach of the canal to take water as long and as much as they want suggest that farmers on the lower reaches of the canal will have a very undependable supply of water. Studies in Pakistan on poorly maintained to moderately maintained systems showed two orders of magnitude ranging between the mean and the maximum water delivered to a farmer, during his turn, with the minimum delivery equal to zero. A very undependable supply is the result.

Lam Nam Oon

The Project is an integrated rural development program. There are eight departments from three ministries and a team of AID consultants involved in the project. The agricultural program involves assistance and services from all essential departments.

The large reservoir services an area of 30,000 ha (187,500 rai) with both of the canal systems under construction but especially the right bank canal. The canals operate on a continuous flow delivery. Outlets operate both on a continuous flow and a rotation system. Design discharge of each canal outlet is 0.15 lps/rai. Each farm outlet is a 20 cm pipe with periodic check structures to provide a sufficient head to give each outlet the desired discharge. This discharge is stated as 25 lps but heads can be sufficient to supply a greater flow.

Distribution of water on a farm lateral outlet is adjusted in response to farmers' requests for more water or less water. Zonemen on the project, who are responsible for operation and maintenance of the canal and for regulating the water supply to each farm lateral outlet, have not been increased as rapidly as the irrigated area. The result is that one zoneman supervises 60,000 rai on a motorcycle with two liters of gasoline per week. A more realistic area to supervise would be 10,000 rai. This shortage of zonemen in the past has resulted in farmers regulating their own outlet. As a result, farmers have resisted takeover by RID personnel of the regulation of outlets. This has created conflict in the past with one engineer shot and killed.

The principle of system operation is that water is allocated in response to farmer needs with provision for opening and closing an outlet at the request of farmers. Zonemen are available on a regular basis at locations along the canal bank, at an office location along the canal, and at their home in the village. Farmers deliver requests in person or by messenger to the zonemen at any of these locations.

The operation of the distribution system from the farm lateral outlet to the field was of interest. In many areas of Thailand, the distribution system stops at five to 50 meters from the outlet. In this project area, on-farm improvements had been installed with a channel that included divisions, checks, drops and concrete pipe outlets. A road also is provided along with the farm distribution channel. Pipe outlets allocate water to either side of the road.

Check structures wre available to regulate the water level at each outlet. Typical slopes were 0.0004 to 0.0006 and, in several instances, checks did not seem to be located to optimally serve each outlet. Slots were available in each check for regulating water levels but no boards were available.

Most drops also function as checks but several drops were observed that did not regulate the water level upstream to prevent

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erosion. The crest of the drop was too low to maintain a non-erosive water surface upstream of the drop. As a result, erosion occurred both downstream and upstream of the drop.

Even with extensive channels throughout the command area, paddy to paddy irrigation occurred on every farm and some farm to farm paddy distributions were still in operation. In one area, the farmer responded that seven farmers were involved in the paddy-to-paddy sequence. Each farm would have several to five or more paddies in the sequence.

Several on-farm systems were visited where both farm laterals and drains were provided. The use of the drain by adjacent paddies was inspected. The outlet to the drain was located. Then the high-water mark on the rice stalk was determined. In almost every instance, the high water mark was sufficiently high to cause outflow from the field to the drain. The conclusion was that rainfall and irrigation applications result in frequent overflows to the drain from each paddy.

The conditions of farm and field channels on several commands were checked. Both channels frequently were full of grass and weeds, had extra cuts in the farm laterals in addition to the pipe outlets, and were of inadequate capacity and needed repair and maintenance. Inclusion of the farm laterals in the development of an irrigation system does provide better water control to each farm. Lack of regulation of the flow to each outlet and poor maintenance of the system reduces this control.

Farm outlets without gates and with limited regulation of the delivery of water to each farm result in a less than dependable water supply. The common irrigator apparently serves the function of distributing water on-farm and between farms for each outlet. Where Water Users Associations are organized and functioning, the common irrigator seems to supply a necessary function in principle. No evidence of this functioning was observed.

In land consolidation projects, land leveling is one of the services provided. Observation of outlet commands where farmers have built paddies to conform to the topography suggests nearly level, irregularly shaped, complex paddy systems will result. The control of water to each paddy is more difficult and for the wet season irrigation, careful cooperation and supervision of the system is required for effective water control. Such a paddy-to-paddy system adds to the undependability of water supply to farmers on the tail of the system. In the dry season, paddy-to-paddy distribution precludes the growing of rice on farms away from the

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outlet. When upland crops are grown, lack of a farm-to-farm and field-to-field distribution system makes dry season cropping difficult and probably precludes growth of upland crops. The inundation times which result in paddy-to-paddy distribution would destroy or severely retard upland crops. Lack of a farm and field distribution system may be a major constraint to effective production of dry season crops.

The approaches to on-farm development seem to take a larger number of variations to a basic approach. The basic approach is government design and construction of farm and field channels, land leveling, roads and drains. Ditch and dyke approaches provide roads and various percentages of the farms with direct access to a farm channel. At the other extreme is land consolidated with construction of roads, drains, consolidation of holdings of farmers to one contiguous area, land leveling and a delivery channel to each farm. No field channels for irrigation of each bunded unit are provided. Today (1980), costs range from 3,000 to 8,000 Baht per rai for these improvements.

Perhaps several limited but innovative approaches to farm delivery, field improvement and roads and drains should be tried which make more of an effort to use indigenous materials and resources with an emphasis on cost reduction. Some careful studies are also needed to define the necessary level of improvements for various types of irrigated agriculture. For example, are there basic differences between the needs for wet season rice, dry season rice and upland crops? Do farm channels, field channels, drains and roads benefit all three? What are the primary requirements for a dependable water supply? These and other questions are basic to improving irrigated agricultural production. They are basic to providing answers to how to increase benefits and reduce costs of project development while ensuring benefits to farmers in irrigated agriculture.

Approaches to improvement should include innovative field channel improvements with farmer participation such as pipelines, earthen and lined open channels and improved control structures. Pipelines have a number of advantages and appear to be a locally available resource, but until tested for quality of construction, maintenance costs and operating characteristics are not necessarily effective. Farmer participation to improve design appropriateness, reduce costs of construction and perhaps instill pride to result in maintenance may be an effective strategy. Lam Nam Oon offers excellent opportunity for these efforts.

Water Management in Rainfed Agriculture

Rainfed agriculture, by its basic character adds an element of risk which influences to a significant degree a farmer's willingness to make investments in any alternative improvement of his agricultural system. Thus, technologies which can reduce risk, but also technologies which can perform, on the average, better, given actual conditions which involve risk, are needed in rainfed agriculture.

The Thai farmer in the Northeast has developed an agricultural system which maximizes the conservation of a limiting natural resource, water. First, he uses a "level" basin system with a high bund which stores all rainfall. Second, he puddles the soil in the field to minimize deep percolation. Third, runoff is reduced to zero except in those instances when excess rainfall produces a flooded condition. Fourth, he encourages the development of a high water table which can be a resource or at least reduces field losses to deep percolation. Fifth, soil moisture is at least at field capacity and may even store to saturation with a high water table. The major disadvantage of the crop, rice, is its sensitivity to soil moisture stress. I am sure the five previous advantages partially compensate for this disadvantage and may fully compensate.

For the level basin cropping system in Thailand, what are some strategies for improving dryland water management based on principles? First, maximize the storage in each basin without negatively affecting the crop. Two, precision leveling increases the effectiveness of water use. Consider the marginal cost of improvements in precision leveling versus the increases in yield. The precision leveling needs to be developed as a low cost technology for farmer resources and conditions.

Third, breed both flood-resistant and drought-resistant varieties. Fourth, use alternative storage technologies to conserve any excess rainfall and runoff for use in a rainfall-deficient time interval.

Alternative storage technologies include both surface and subsurface methods. Surface storage must store the maximum volume at the least cost in the minimum area at the maximum depth for the longest time. Obviously, a multi-objective strategy must maximize net benefits or minimize costs. Use from ground water involves costs but would have added value because of undependability. In all storage alternatives considered, water made available for plant use must be the criteria for evaluating effectiveness. This criteria would recognize that water in storage may never be effectively used by farmers.

The fifth strategy would be a simulation study of rainfall probability, crop water requirements, and the dynamics of water use by rice in a level basin such as that used by Reddy and Clyma (1981)[1] for an irrigation system. The objective would be to understand the amount of water available for a soil, crop and climate regime for a given field condition. The study would also look at the year-to-year variabilty in expected yields and the incremental value of additional amounts of water in those specific years. The goal would be to place a value on additional amounts of water made available at the field. This would allow the determination on a more realistic basis of what the costs are which could be incurred in making the water available.

Superimposed on the above strategy from principles of water management is the traditional strategy of how to increase yields through improved varieties, cropping practices such as tillage and seeding, fertilizer and insecticides. The adoption of these activities by farmers normally occurs through improved extension.

The risk element of rainfall agriculture usually is not valued properly by traditional approaches to improving production. This is because the penalty of failure to a farmer with limited resources who must mortgage his land is too great. All of the traditional strategies for improving production depend on unknown and often unmeasured levels of water management conditions and rainfall for their success. Both water management and rainfall are stochastic variables as far as the farmer is concerned. This randomness of water management conditions and rainfall input immensely increases the risk to the farmer. Farmer adoption of traditionally defined improved practices frequently is slow both as a rate of adoption and level of adoption because of the risk. The five strategies from principles of water management are the base on which to build the traditional strategies.

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[1]Reddy, J. M. and Clyma, W. 1981. Irrigation System Improvement by Simulation and Optimization. I. Theory (submitted to Water Resources Research). II. Applications (submitted to Water Resources Research).

APPENDIX E

SOIL-CROP-WATER MANAGEMENT:
PROBLEMS AND ISSUES IN NORTHEAST THAILAND

by

Matthew Drosdoff

SOIL-CROP-WATER MANAGEMENT: PROBLEMS AND ISSUES IN NORTHEAST THAILAND

by

Matthew Drosdoff

The following discussion deals primarily with the Lam Nam Oon Project, but the observations have application to similar projects in Northeast Thailand.

Rainfed Rice with Irrigation

Water. From the available rainfall data, the amount of supplementary irrigation needed for the critical dry periods during the wet season is on the order of 100 to 200 mm for other than the exceptional years. The design and operation of the irrigation system, however, provides farmers on the order of five or more times that amount. This substantially reduces water use efficiency and carryover of water for the dry season.

The excessive use of water poses several constraints on increased producion:

1. In the saline or alkaline areas, excess water without adequate drainage may accentuate a salinity or alkalinity problem;

2. Where fertilizer is used, the efficiency is greatly reduced. As most farmers do not incorporate the fertilizer in the soil, the irrigation system of water flow from paddy to paddy carries much of the fertilizer with it, so that the benefits are greatly reduced and may account for lack of response to fertilizer in many paddy fields and increased risk; and

3. The amount of water received by each paddy field apparently has no relation to the soil requirement.

The loss of water is considerably greater on the deep sandy soils than on those with either a relatively shallow water table or a perched water table. Lack of information on depth to water table or perched water table on the different soil types or phases of soil types makes it difficult to estimate the soil moisture-crop relationships.

Measured terminal (steady-state) infiltration rates on fields in the area were as follows:

Intake Rate (cm/hr)	Water Table Depth (m)
0.1 to 1.3	0.5 to 2.0

Fertilizer. From the various reports, it appears that about one-third to one-half of the farmers use fertilizer on rice, but generally in low amounts and one formula, 16-20-0. It appears that most of the farmers do not incorporate the fertilizer in the soil, but broadcast it on the surface. Considerable loss occurs in the nutrients:

1. Water flow carries it from paddy to paddy either in solution or solid particles;

2. Nitrogen fertilizer applied on the surface is lost by volatilization; and

3. Leaching of nutrients occurs in greater amounts with excess water.

Because of the high cost of fertilizer and the demonstrated benefits of fertilizer in increasing rice yields under good soil and water management practices, attention to fertilizer use efficiency is an important consideration. One difficulty in interpreting the results of the fertilizer trials which have been done is the confounding of the treatments applied: water, kind of soil, method of application, variety and other uncontrolled variables.

The lack of continuity over time in conducting the trials is also a serious handicap. Long-term trials, at least five years, are necessary to evaluate:

1. Effects of seasonal variations;

2. Water supply variability; and

3. Residual effects, especially of phosphorus.

Where phosphate is incorporated in the soil, it moves through the profile very slowly, and thus tends to accumulate, even on sandy soils. As the actual amount of phosphorus removed by the rice crop is very small in comparison with nitrogen and potassium, it may well be that in time, the annual amount of phosphorus to apply can be substantially reduced. Where only 16-20-0 fertilizer is used in trials, one cannot determine how much of the response is due to nitrogen and how much is due to phosphorus.

In the model demonstration land consolidation farms, a blanket application of 20 to 30 kg/rai, depending on the soil, of triple superphosphate or 30 to 50 kg/rai of 20 percent superphosphate incorporated in the soil may suffice for several rice crops. With nitrogen and some potash added annually, this could give a big boost in yields.

In addition to the recognized deficiencies in nitrogen and phosphorus, soil analyses of the major soil types indicate very low levels of potassium, calcium, magnesium and sulfur. Apparently, very little attention has been given to these elements for paddy rice. The almost universal use of 16-20-0 fertilizer (16 percent N, 20 percent P_2O_5, zero percent of K_2O) where fertilizer is used for paddy rice, neglects potassium, which may or may not be important. Some experiments with dry season crops such as groundnuts indicate a response to potassium. Calcium and magnesium can be supplied by limestone containing magnesium, and its use will be discussed in the next section under liming.

The possibility of zinc deficiency ought to be explored, as many soils elsewhere similar to those in Lam Nam Oon have shown a response to small applications of zinc. Some soils may have a deficiency of sulfur, and this should be examined. Where triple superphosphate is continually used either alone or in the 16-20-0 moisture, sulfur may be lacking. Where ammonium sulfate is used to supply nitrogen, this would take care of any sulfur needs.

Application of calcium silicate or other silicate materials has given increased yields on poor sandy soils similar to those in Northeast Thailand. In Japan and South Korea, for example, large areas of sandy alluvial soils have given economic responses to applications of silicate materials. It is paradoxical that silicate may be needed on sandy soils, but the silicon in sand may not be available to the rice plant which normally is much higher in silica content than most other plants.

Liming. Lime has been used on paddy fields to a limited extent. The lime requirement for the principal soils in the Northeast needs critical study. The ECI report discusses methods of determining lime requirements based on soils studies in the temperate regions and may not be applicable here. Recent research in the tropics has indicated that much less lime is needed on acid soils than was previously thought bcause of the location exchange

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capacity. Especially on the sandy soils which are low in most nutrients, the application of too much lime may be harmful because of nutrient imbalance.

There may be some question about the reliability of some of the analyses on which a lime recommendation is based. The pH of the Roi-Et soil, for example, which is extensive in the Northeast, has been reported to range from 4.5 to 6.5 in various publications. These may be different phases of Roi-Et, or the analyses may be in question. In any event, one should be cautious in recommending lime. Where lime is needed, an application of 500 to 1,000 kg/ha will probably suffice for the sandy soils which have a low exchange capacity. As magnesium is apparently low in most of these soils, a magnesium-carrying limestone should be used. I understand that this material is available locally.

Varieties. The performance of the various rice varieties used is related to the soil-water-nutrient interaction. There is little evidence from the various reports and other information sources that, at present, this relationship gets much consideration in the recommendation of varieties for use by the farmer or in the development of new varieties. The proposed USAID Rainfed Agricultural Development Project recognizes this deficiency and recommends support for continuing research on soil moisture-nutrient-plant relationships.

Glutinous rice varieties are preferred by most farmers for their staple food, and these are tall growing varieties. Generally, tall varieties are much less responsive to nitrogen fertilizer for grain yield increases and are also much more susceptible to lodging, especially during periods of high water. The development of fertilizer-responsive dwarf glutinous varieties would increase grain yields substantially, but whether or not these would be acceptable to farmers is a question. Traditional tall varieties have considerable insect and disease resistance, and farmers are reluctant to risk new varieties which may not have this resistance. Also, it is reported that farmers value the straw in tall varieties for their animals more than possible increases in grain yields.

Though farmers might prefer to grow the tall glutinous varieties for their own consumption, they might be interested in growing the high-yielding fertilizer-responsive dwarf varieties on some of their land if they had better water control and were given price incentives along with credit facilities and assured market, availability of inputs such as fertilizers, and technical guidance. This was done in South Korea, where farmers were encouraged to shift from traditional varieties to higher-yielding improved dwarf varieties in which the preferred eating qualities were incorporated after some years of development.

Dry Season Crops with Irrigation

It has been estimated that only three percent of Northeast farmland is presently served by all types of irrigation works and only 20 percent is ultimately irrigable. Of this amount, only 20 percent is actually being irrigated in the wet season and less than five percent in the dry season. The limited amount of water available for dry season crops should make rice cultivation unattractive because of its high water requirement. However, if water is available, even in insufficient quantity, farmers will tend to grow rice.

A second crop of rice may be successfully grown on soils with a high water table or perched water table without an excessive demand on the water supply. On the deep, well-drained sandy soils with substantial water losses from percolation, incentives should be provided to grow crops other than rice.

A first requirement in formulating a policy in this matter would be a detailed map of the main soils in a project with measurements of: the water table and perched water table, available water-holding capacity, nutrient status, texture (sandy, loamy, clayey) at depths down to one meter, and other parameters. This would provide the basis for rational policy decisions on what areas could grow rice in the dry season with minimum additional water supply and what areas would be best for crops such as groundnuts, kenaf, mungbeans, cassava, etc. with a much lower water requirement.

Incentives would probably be needed to encourage farmers to shift from rice to other crops on those soils ill-suited to rice production. Some farmers are growing specialty cash crops during the dry season such as chillies, when there is a market demand and prices are favorable. However, farmers will not shift from rice unless there is a reliable marketing mechanism and favorable price incentives.

One of the most important questions discussed with the research personnel was: why don't farmers grow rice or another crop in the dry season? A multitude of reasons were given and most apply to every farmer. First, there is risk. The farmer is uncertain what the market price will be. There is risk that if he

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invests his limited resources the uncertainty of his water supply or other factors will create a loss rather than a return on his investment. Both uncertainties and the associated risk cause him to decide not to grow a second crop during the dry season.

Second, to grow a crop, especially rice, but generally any crop, requires more investment and higher costs than wet season rice. The farmer must buy seeds for the new variety of rice or the upland crop. He would expect to purchase fertilizer for which he is uncertain of a return. The fertilizer is relatively expensive. Other farmers' experiences suggest that insecticides for rice are necessary and, even with insecticide, the stem-borer may damage his crop. These investments are much greater than for wet season rice. There is still the uncertainty of the new variety, the return on the investment in fertilizer and the effects of insects. These all involve considerable risk and change.

Third, labor is a constraint for the farmer. Removal of the vegetation from the old crop, preparation of the land or alternatively hiring the tillage done with a tractor all require labor over a short interval of time. Labor migrates to the city, or government employment programs compete for his labor. There is also less risk on his own part in taking a job himself.

Fourth, harvest is another constraint. Labor is less available. Prices of rice or an upland crop are uncertain. Because of high humidity and rains during the harvest, quality of the rice may be lower than rice from the rainy season resulting in an even lower price. Furthermore, the marketing facilities are less dependable.

The uncertainty of a regular rotation and a sufficient supply of water in the main canal, and the lack of an on-farm delivery system which is properly maintained result in an undependable water supply. Since water is absolutely necessary for dry season production, uncertainty of the water supply is a significant, and perhaps the major constraint. Many farmers indicated that the unreliability of the water supply was the primary deterrent against cropping during the dry season.

A good variety of peanuts is one of the most profitable dry season crops when provided with the following: at least 20-60-40 kg/ha of N-P-K; an in-field water distribution system; and basin-furrow irrigated fields with about a 50-meter length of run. Water consumptive use for peanuts is almost 420 mm for 120 days with a peak use rate of about 6.7 mm/day at flowering. Yields of 1.2 T/H can be expected on farmer fields.

APPENDIX F

THE WATER BALANCE AND TECHNOLOGY TRANSFER*

by

George H. Hargreaves, Research Director
International Irrigation Center
Utah State University

*This appendix is added for the purpose of illustrating a methodology and for indicating how possible benefits from rainfed agriculture can be compared with those from irrigation. Probabilities of precipitation and pan evaporation occurrence and rainfall intensity-duration-frequencies are available in a publication by the Asian Institute of Technology (AIT). Additional work directed at applying these values to agricultural technology transfer is strongly recommended.

THE WATER BALANCE AND TECHNOLOGY TRANSFER

by

George H. Hargreaves, Research Director
International Irrigation Center
Utah State University

AIT[1] has completed a study of rainfall and evaporation for Thailand. Probabilities are presented for occurrence of precipitation during 10 and 15 day and monthly periods. Daily and monthly pan evaporation are given. Rainfall-depth-duration-frequency and intensity-duration-frequency curves are included.

Numerous studies at Utah State University have related the selection of desirable agricultural practices to a moisture availability index, MAI. MAI is the 75 percent probability of precipitation occurrence, PD (75 percent chance of exceedence), divided by potential evapotranspiration, ETP (MAI = PD/ETP). The economically feasible crop growing season for rainfed agriculture has been found to correlate well with the number of consecutive months with MAI values exceeding 0.33. Needs for surface drainage are related to excessive rainfall as defined by MAI values exceeding 1.33.

The response of crops to fertilizer application correlates well with moisture adequacy. In general, potential yields are determined principally by water adequacy and fertility. A simple model that has produced excellent results in some locations in Latin America is N = 0.32 ET in which N is nitrogen in kg/ha and ET is projected total evapotranspiration by maize for the crop growing season. MAI values were used to estimate projected crop ET.

MAI provides an index of drainage requirements. If soil infiltration, slope, topography and MAI are all similar, then similar practices of water conservation or surface drainage can be expected to produce similar benefits.

Potential crop production is determined to an important degree by the amount of water that enters the soil and becomes available in the crop root zone for use by the crop. If rainfall

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[1]The Asian Institute of Technology, "Rainfall and Evaporation Analyses of Thailand." October 1980, 301 p.

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intensities significantly exceed soil infiltration rates, then benefits may be possible through conservation practices that increase the opportunity time for water to enter the soi The AIT publication provides information on intensities of precipitation.

A useful equation that facilitates comparisons between infiltration rates and depth-duration amounts of precipitation, D, can be written:

$$D = K \times T^{1/4} \times R^{1/6} \qquad (1)$$

in which K is a constant for a given location, T is duration in hours from 0.5 to 96 and R is return period in years from 5 to 100.

The relationship between pan evaporation and potential evapotranspiration will vary somewhat with water availability in the adjacent area. Significant differences are found between irrigated and non-irrigated sites and between rainy season and the dry season. However, in spite of these limitations, the ratio of the 80 percent probability of rainfal exceedence shown in the AIT report divided by pan evaporation would be a convenient index for comparing potentials for rainfed agricultural production.

Such an index would be most useful in technology transfer for determining desirable levels of fertilizer applications, the type of drainage practices to be selected and the crops or cropping systems most suitable for production. It is therefore strongly recommended that follow up studies to that prepared by AIT be made relating rainfall probabilities to pan evaporation and using the ratios to assist in agricultural technology transfer.

In addition to a water balance index, the climate of each region or area needs to be more clearly defined. Mean temperatures, the temperature range between maximum and minimum values, relative humidity, solar radiation and wind movement all influence crop selection and crop yields to some degree. A good summary of climatic conditions provides a major assist towards practical agricultural technology transfer and the development of agriclimatological models.

Crop yields are directly related to water availability. A comparison of water balance index values with amounts required for full moisture adequacy can provide a convenient means of comparing rainfed and irrigated potentials for crop production.