WATER RESOURCE UTILIZATION IN SOUTHEAST ASIA

Summary of Symposium on Water Resource Utilization in Southeast Asia

Overseas Technical Cooperation agency
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Editor

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Foreword

Recently, the new words are added to the recognition of the supreme importance of the agricultural promotion in the developing countries, for it is considered as the precondition of their economic growth. Our country has carried on the technical cooperation to these countries, making outstanding effects in their agricultural development, especially in the field of rice culture. And it is true that the rice culture is inseparably connected with the supply of water.

Generally to say, the technical cooperation on agriculture can be resolved into three points: a) for the improvement of cultural methods, b) for the physical improvement of production basis, c) for the institutional reform. In our case, the cooperation activities have been concentrated on a) improvement of the techniques, but the emphasis comes to be put on the necessity to cooperate for the betterment of agricultural production basis that is the precondition for the improvement and extension of the techniques, for the purpose of increasing further the effects of the technical improvement. It is only the effective utilization of the water resources that can make it possible a jumping augmentation of the agricultural production in the tropical agriculture which is favoured with the sun light and high temperature.

In view of the fact that considerable achievements were produced by the Japanese experts who had been dispatched from the different specializations to join the research and study program or the planning and the execution of the development scheme concerning the water resources in the South-east Asian countries, it is very opportune too that the "Symposium on Water Resources Utilization in Southeast Asia" was held under the joint auspice of the Ministry of Agriculture and Forestry, the Center for Southeast Asian Studies of Kyoto University and Overseas Technical Cooperation Agency.

The Symposium took place very successfully for three days from September 17th to 19th of 1965, gathering more than a hundred specialist concerned which includes 20 reporters. There were published and discussed the studies and the experiences of the joined experts, which I believe to be very contributive not only to the all-round academic and technical training but also to the effectuation of the technical cooperation in future. So, here, I, as one of the sponcers, express my deep thanks to all of the assistants concerned.

The contents of the statements and discussions at the Symposium are compilated and published here, which, I hope, offers a useful materials as what shows the real situation of the water resources in the countries concerned and what promotes the technical cooperation of the agriculture, as samely as our preceding publication on the collection of the lectures of the "Symposium on Rice Culture in Malaya".

In conclusion, I will express my gratitudes to the personnels concerned of the center for Southeast Asian Studies of Kyoto University and of the Ministry of Agriculture and Forestry, who all made special efforts to the realization of the Symposium and of this publication.

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INTRODUCTION

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Southeast Asia is generally regarded an area yet to be developed; a statement we are obliged to admit as true even from the standpoint of agricultural utilization of its water resources. But on taking a closer look at this area, we find that each country and each locale has adopted most ingenious ways to take advantage of its natural conditions. These situations were also dependent upon the existing stages of development, political, social and economic, of each locale. Now they have come to employ stabilized forms of water utilization and of agricultural cultivation developed by the long processes of history. It may be said that the inhabitants have made it possible for themselves to lead steady and stable lives in their respective places of abode. This in itself embodies various difficult problems. The main ones; a general lack of the will and the desire in the farmers who are satisfied with their present state of livelihood, to further develop and improve their present livelihood and a difference in the goals of government officials and of the farmers. Other difficulties involve making artificial changes for water utilization, since the nature of such changes influences not only agriculture itself but also the society and the economy in general. Unless the plans are made to link with an ideal of development conceived from an overall standpoint, imbalance and weak points will appear somewhere in due course.

From an entirely different direction we must not forget that there is today a general demand for an increase in agricultural production, and productivity and development of the economy. During the past ten years there has been in Southeast Asian countries a steady increase of population at a rate well exceeding 2% a year. This is closely related to the problem of food, the problem of increasing the volume of export of primary goods, etc., all of which must be taken up and solved under the present political and social economic situations. Furthermore, it is said that the food production of the whole world must be increased four times its present volume before the turn of this century and that Southeast Asian countries must make active contributions toward solving this problem.

In what direction should Southeast Asian countries move to develop their water resources, especially to improve the state of irrigation and drainage? Two outstanding features of Southeast Asian countries lie in the clear division of the climate into the rainy and the dry seasons and in their present agricultural pattern which lays emphasis on paddy cultivation during the rainy season. It is, therefore, the general belief that fundamentally the direction to be taken lies in actively creating more areas of paddy fields either by reclaiming uncultivated land, controlling the floods in the rainy season or developing the land so that paddy and upland farm crops may by cultivated even in the dry season through artificial irrigation. The most important factor that governs the agricultural production in this area is water, but merely consolidating irrigation and drainage facilities cannot solve this problem. Unless corresponding techniques are brought in simultaneously, there will be caseswhere the efforts made may have adverse effects. Cultivation of agricultural crops can continue to develop only when all areas concerned are harmoniously combined. Thus it will be necessary to solve simultaneously problems concerning crop varietal improvement, improvement of fertilizing techniques, measures to deal with weeding, plant diseases and pests, colmatage to make use of natural conditions, and most important, drainage, and further land adjustment such as setting up roads to pave the way for future introductions of agricultural machines, etc.

Generally speaking, concerning methods for water resource utilization and agricultural development, the basis for maximum utilization of water resources is water control, that is, river control so no doubt this will be the basic method of development. But the problem is: Can the main water utilization facilities be utilized to the fullest extent? It has been observed from records over the past ten years that despite the carrying out of various development projects and the constructing of main water utilization facilities, the effects originally planned have not necessarily been attained. The most important problem today is how, then, this should be solved. A mere glance at irrigation and drainage facilities in the world enables us to see that in Western countries both the main and terminal facilities are set up at the same time. In contrast, in developing countries, the less developed they are, the less attention seems to be paid to terminal facilities that connect directly with actual agricultural production. That less emphasis is paid to main structural works is understandable in view of their wanting to uphold their national prestige and these are probably just the points that have been influential in creating such a gap in understanding and in goals between the governments concerned and the farmers.

What, then, is the method of development that should be adopted? In Southeast Asian countries the most difficult problem concerns not the setting up of dams and other main facilities but the method of distributing water effectively throughout the flat plains. As regards upland farmland irrigation, the opinion most often held was to study first of all, the irrigation method to be used, then to promote a development plan stressing terminal facilities. Thus development may be contemplated in two ways: a large scale method of development or a so-called gradual method of development with realization on a small scale wherever possible. The conclusive and overwhelming opinion for the latter was that of adopting the step-by-step method of development and keeping the former in mind as the ultimate objective.

It will first be necessary to grasp accurately the existing natural conditions in Southeast Asian countries. (This is, of course, closely related to the country's social condition.) Secondly, it will be necessary to make profound studies on specific social and economic circumstances. Thirdly, it will be necessary to make accurate judgments of just what the people want and to study ways to induce them to work actively toward realizing the development projects.

The first point was often stressed in the theses brought to this symposium. There were on-the-spot reconnaissance and research reports which grasped well the existing conditions in the Southeast Asian countries (on hydrology, soils, requirements of irrigation water, etc.). Along with these on-the-spot researches, thorough studies are first required on the structure of the monsoons, on hydraulic characteristics of low velocity waterways, on sedimentation of sand and mud in waterways, on salt water intrusion, on soil classification, soil productivity, etc., as such studies have not been made in depth in Japan; then the results are to be applied at the actual local site. Other studies should be made, for instance, on the technical side of irrigation and drainage, the history of processes of development, in what way the present temporary stable state has been reached; therefore, what kind of development would be most proper for the future and what would be the resultant changes.

As regards the second point, studies should be made on the prevailing conditions and the background from social and economic standpoints along with basic studies with a view to natural sciences and techniques as described in the first point. For instance, studies on land ownership, prices of agricultural products, set-up of circulation, agricultural financing systems and, furthermore, the connections between administrative set-ups and recipient terminals, etc. To promote discussions on these matters, it was suggested that another symposium should be held where specialist covering wider fields should be present.

As regards the third point, it has been emphasized as very important to set up organs to disseminate technical skill and knowledge, to set up pilot (extension and demonstration) farms to demonstrate to the farmers modern irrigation and drainage techniques and show the results and power of modern agriculture and to let them do their own selection after having been shown the various methods.

Those who have been actively engaged in various concrete development projects reported on these, all of which were very valuable. They engaged in making precise and concrete plans ranging from water source works to terminal water utilization facilities, such as electric generating stations, paddy field irrigation facilities, water utilization methods for dry season upland crops, and also cropping systems. I shall not dwell on them here, but I should like stress that all these people have brought to our general attention various actual difficulties that they had encountered. For instance, great difficulties on passing judgment on the economic effects of development projects due to lack of sufficient data and due to the obscurity of objectives, ideas and spheres; evaluating of infrastructures; establishing a standard for soil classification; standardizing the items of study on the physical properties of soil from the standpoint of agricultural engineering; making standards to judge the productivity of land, etc. On cropping systems and methods of land utilization, quite exhaustive discussions were held especially with reference to Cambodia and Thailand. In all cases it was unanimously agreed that the first requisite was to consolidate terminal irrigation and drainage facilities.

Last, I would like now to touch on the existing condition of technical aid and cooperation extended by Japan. As an advanced country among Asian nations Japan has a responsibility and a duty to extend aid and cooperation in various ways, both in quality and quantity to these Southeast Asian countries. The direction of her policy must lie in this responsibility.

What are the problems, if any, that now exist in carrying out overseas aid and cooperation? What may first be cited on the aid-extending side is the obscureness of the objective of the aid itself. Then there is the very difficult problem of selecting a country where the effects of the aid would be the greatest. (An important consideration is the political stability of the recipient country.)

As for the recipient country there is the drawback of not using the aid effectively. In the form of a loan, the anticipated effects usually do not fulfill the terms and conditions of the aid, and even less so when given as a gift. When their national prestige asserts itself, these shortcomings become all the more emphasized and deepen the gap existing between the government and the farmers.

It, therefore, was the general conclusion that the direction of Japan's aid should be directed in the following ways. First of all, the existing conditions of an area should be studied thoroughly, then an understanding should be reached as to what the other party really wants, then aid of the step-by-step method of development and promotion type should be extended. The method of aid is to be clarified from the many and varied studies made and wide points of view covering the existing directions and methods of water resource utilization of Southeast Asian countries. What is desirable are not temporary, stop-gap measures, but a systematic plan to aid the countries' independent economic development. The donor country will need a systematic longrange plan.

These remarks are, in one sense, a small portent of the contents of the discussions in the symposium, but in another sense, the main points for the development of agricultural water utilization in Southeast Asia. The following detailed reports on direction, method, technical cooperation and aid on water resource development and utilization contain many useful and important comments, opinions and proposals.

SPECIAL LECTURES

An Observation on the Problem of Water Resources

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The critical factor governing the development of life lies in the availability of sources of water. This is a phrase one often hears and in 1959 I first heard these words when I visited the Carnegie Institute to pay my respects to Dr. E. A. Ackerman. He stressed the fact that if the U. S. economy keeps on expanding at its present rate, by 1980 it will confront difficulties in securing adequate supplies of water and eventually further economic development will be hampered. His statement was based on the results obtained from his two-year study of this problem as a member of the U. S. Senate Water Resource Special Commission. He added that for its solution successful ways must be developed to induce artificial rainfall or to get fresh water by desalinization.

The water problem was studied earlier by UNESCO's Advisory Committee on Arid Zone Research, extending studies later to humid tropical areas. At a general meeting held in May, 1963, the International Hydrologic Decade (I. H. D.) plan was submitted and adopted. Starting from 1965 the plan was to study the situation of water balance in the whole world. The world today sees the evidences of a rapid development of industries and agriculture, an acceleration of growth of population and of an increasing desire of the people to attain an ever better standard of living. These factors call for increasing supplies of water in agricultural and industrial fields and for general use. Now that these two factors, securing adequate sources of water supply as mentioned above, and controlling surplus water sources, are the main elements to further economic development, it is certainly necessary to draw a clear picture of the water situation all over the world. All this prompted the adoption of the I. H. D. plan.

It is unnecessary to say that water is one of the most important of all elements needed to exist and thus it is the source of various problems in this world. Once when I was with ECAFE, an official addressed me, saying that so far, in Thailand rice has been grown mainly by taking direct advantage of the natural river floods, that is to say, her pattern of rice cultivation has been most appropriate considering her natural environment. However, it has been found that this pattern has its limits and that to increase productivity it will be necessary to adopt artificial irrigation methods. Now the question is to what extent should irrigation water be stored as a reserve when artificial irrigation is adopted? Studies of the existing state of artificial irrigation were made of several countries. It was found that Japan was an outstanding example of especially remarkable developments in recent decades, but that Japan used a far greater amount of water for irrigation in comparison with the U. S. A. or European countries. He then asked me which country he should use as a standard.

This reminded me of when I visited the Faculty of Agriculture of the University of California at Davis in about 1950. There experiments were being carried out in paddy cultivation. By using varying amounts of irrigation water they were trying to work out what would be the most appropriate amount of water to keep the cost of agricultural production low and yet keep at a minimum the cost of securing ample supplies of irrigation water. Conversation shifted to the problem of water consumption in Japan and we agreed that though it was true that considerable labor could be saved in weeding and in intertillage by deeply submerging the paddy fields it was time to view the question of water consumption from a different angle now that tillers and chemicals for weeding are available.

When I saw the paddy fields in Thailand shortly before they were submerged under natural river floods, I could hardly believe my eyes. Weeds and paddy were growing in a jumble. When the floods came, the water rose, submerged the weeds which rotted away. Though cultivation by this method yields only about one-third of what the Japanese farmers can produce per unit area of land, the productivity per unit amount of labor is certainly far above that of Japanese farmers.

Conditions comparable to the above may also be observed in other phases of water utilization. After the Second World War experts of the Natural Resources Dept. of the General Headquarters of the Allied Forces were said to have been greatly impressed by the way Japan had developed her hydraulic power and by her ingenuity of utilizing Nature. Truly Japan employed the afflux method to develop her hydraulic power. As demand increased she set up more electric generating facilities. She established electric and electrolytic furnaces to absorb the surplus electricity during the night and the wet seasons, in this way laying the bases for industrialization. As more electric power came to be needed she added steampowered electric generation depending mainly on hydraulic power, and using steam power generation as an auxiliary. It was a remarkable achievement but now she confronts the same problem that confronted the TVA. New industrial developments are making it more and more difficult for her to secure ample supplies of electric power by conventional methods alone, that is, concentrating on hydraulic power and using steam power as an auxiliary. Although steampower-generating has greatly improved and with it, thermal efficiency. To secure its justified technical results its rate of operation must be raised. The present positions of thermal- and hydraulic-generating must be reversed. If hydraulic power is to meet the peak loads, water reservoirs must be handled in such a way as to meet these needs. There are also changes on the consumers' side. Improved labor conditions and mechanized production facilities are making the consumption of surplus electricity difficult. Electricity will have to be supplied in a way to meet changing loads. The increasing demands for electric power and the changing consumption pattern necessitate the reservoir type electric generation. New problems are created that conflict with nature. The present system of utilizing the water resources will have to be studied anew.

Let us return to agriculture. In the various stages of economic development we Japanese have made the most of Mother Nature and devised the best means of production suited to the time. For example, in Japan, the water from a number of canals from rivers are used for irrigation and also for the homes. The canals were built to accomplish this as economically as possible. The arrangement of the villages is also an example. Economic development has made increasing demands upon water in new industrial fields and brought about an urgent need to adjust these varied demands properly. Water for agricultural use has always been an object of interest and the water requirement the problem. To satisfy the new demands upon the water utilization, it has become necessary not only to consider the actual need of irrigation water, but also to find out and secure enough supplies of water to run the farms and to plan ways of effective irrigation and drainage, including establishment of distribution and catch canals. These problems will be very important factors in the development of Southeast Asia where at present adaption of natural conditions is prevalent.

Suggested by the reconnaissance team led by Professor G. White of the University of Chicago, the Committee for Coordination of Investigation of the Lower Mekong Basin felt a strong need to collect information and data on the social and economic environment of these areas to carry out their development plans effectively. A survey group of experts in these fields was formed and studies were conducted for some time. In July, 1965, the first seminar relating to the studies of social economy of these areas was held. Taken up as an actual problem was that concerning the evacuation of the inhabitants in the projected Nam Pong dam area of northeastern Thailand, where dam construction is now under way and almost completed. Some of the local population still refuse to be moved to the new plots set aside for them, for they fear they may not be able to keep the form of existence they have been used to for years in the new environment. There have been similar cases in this area. Since 1951 the Thai government with U. S. help has been building about 140 tanks in the northeastern part mainly for agricultural purposes but a large number are not being used, serving merely as bathing pools for the buffaloes. The reason was given that due to lack of funds that could not afford to construct water distribution and catch canals to make good use of the tanks, but agriculture advisers working in this locality attribute it to the difficulty of resettling the farmers. They stress how difficult it is to redistribute and consolidate the farmlands whenever new artificial irrigation facilities are built. When it comes to this the farmers become very obstinate. Is this not just another picture similarly showing the difficulty of the problem of resettling the farmers in that dam area? Some of the farmers in this area are definitely against sacrificing themselves for the benefit of others that live in the lower basin areas.

At around the end of August after the seminar, I had an opportunity to go to Israel, where I made several visits to Kibbutzim. The word "Kibbutz" means "group" and is a cooperative agricultural organization. It is communal in all phases from matters concerning production to domestic affairs. The Israeli government grants it arable land and the members share it in common. The fruits of their labors, that is, the profit of the Kibbutz is used communally for joint benefits and to maintain their lives and their children's. More than 230 Kibbutzim are scattered over the country at present with an aggregate population of 100,000. This is a mere 4% of the nation's population but they account for nearly 30% of Israel's total agricultural production. "If we are to settle in a land like this we have no alternative but to adopt this sort of system. We only follow the teachings of Judaism."

These two examples illustrate the ways of life led in the humid and arid regions of the tropics. Where temperatures are high and water is abundant, paddy rice is the main farm crop. This enables the people to lead steady lives on comparatively narrow strips of land. They get rather individualistic and perhaps this is why they strongly but unconsciously uphold the rights of the individual. In vivid contrast are the tropical deserts where the population must look for underground water to set up their homesteads. Without basing their livelihood on a communal system it would be almost impossible for them to settle in such places. The basic question here points to how a limited supply of water can be distributed among the population and how more water can be found and how it should be utilized.

Nature dictates the form of production. It is on this that the particular system of each society is formed according to the area and the stage of its economic development. The more stable the conditions governing the production get, the more stagnant society seems to become. As water is an indispensable element for life I come to this reasoning regarding the relation between water and the people's livelihood.

In a developing country the majority of the population devotes themselves to agriculture and usually it is this that is first taken up in the country's development plan. Past records, however, show results that are contrary to the general expectation. Present day agricultural societies find it difficult to absorb new methods. The key to solving their difficulty is the modernization of their social system but this is largely hampered by deeply rooted counterforces that exist in the agricultural societies. That there is therefore a natural limit to the modernization of agricultural production has been a thought widely accepted.

The Mekong Committee, aware of this, set out to find the clues that may solve the problem. It decided to set up a seminar to study the social and economic situations of the Mekong area. The problem lies also in the field of natural science, and as I said at the beginning if natural resources are to be utilized on a larger scale we must admit that the distinctive characteristics of natural resources will strongly reflect how they are utilized, thus when the utilization of water exceeds its natural limits further utilization must take these characteristics into consideration. Unless this is realized it is impossible to utilize water to a higher degree. Basically UNESCO's I. H. D. plan aims at a solution.

These two problems concerning water utilization may be different in nature but they must be solved simultaneously. It is my opinion that the chief clue to the solution of these problems lies in a practical approach.

Drainage in Southeast Asia

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Asia has a land area of 243 million km², of which the larger part lies in the monsoon area. A distinctive characteristic of the climate is the rainy and dry seasons. Estimated roughly, the average annual precipitation is 1,200 — 1,300 mm. Since olden times the agricultural pattern centered on rice cultivation and harvested once a year is based on this climatic feature. The population of the area is estimated to be about 1.6 billion, with farmers numbering about 1.3 billion. The total output of rice is around 160 million tons a year, or roughly 100 kg per capita per year, thus we can see how acutely short is the supply of rice, the main staple food. This shortage is supplemented by other cereals and potatoes. Since the supply of rice is so insufficient the farmers are forced to maintain a very low standard of living and the raising of this standard is a very important problem of today. A large part of this area comes under the influence of the monsoons and it is estimated that 60 million ha-m of rainfall is lost as run-off every year. If effective use can be made of this large volume of water, a vast area of 30 million ha of land can be irrigated twice a year and used to grow rice. The use made at present can be easily trebled and an immense supply of electric power can be had in addition by using water to generate electricity.

The key to further development of Asia lies in the overall utilization of its water resources, that is, in enhancing the welfare of the farmers through its development, in improving the method of irrigation and in increasing agricultural production by making better use of the energy of water.

My chief concern in my present work in helping the developing countries of Southeast Asia and other continents is in developing water resources. My efforts have been warmly received but there remains a vast area to be developed and an enormous amount of money to be raised. This herculean task can be accomplished only if every man on earth contributes his share. The population is steadily increasing but the accompanying food production is far below the level hoped for. To solve this urgent problem which by no means can be neglected, the whole world must cooperate and all must contribute.

In every Southeast Asian country we find wide expanses of low lying lands made useless by the floods in the rainy season and so parched in the dry season that water is very difficult to obtain. It is easy to see how important the problem of drainage is. Generally, with a few exceptions, most of the rivers in Southeast Asia retreat sharply in the dry season in great contrast to the floods in the rainy season. It is necessary not only to control these rivers against flooding but also to equip farms and arable lands with proper drainage. The urgent need for proper drainage can be clearly seen in the wide expanses of marshlands which stretch along the coastlines.

In the eastern part of the island of Java there is a river called the Blantas which flows through an area almost equivalent in size to that through which our Tone River flows. The river travels around a basin from which Mt. Kelut, an active volcano rises in the center. This volcano erupts about once every 30 years, and in 1951 there was a violent eruption. Extrusions flowed out and filled the river bed so high that the overflowing water inundated 3,000 ha of good paddy fields lying in the upstream area of the Tlung Agung River, its tributary. A tunnel, 7 meters in diameter and 1 km long, was bored in one year to recover the flooded area, draining the flood waters into the Indian Ocean, not into the main stream. The Indonesian government had first planned to dig an open canal, 60 meters at its deepest but the project was abandoned and our proposed tunnel plan was adopted as theirs would take at least 10 years, despite the installation of machines, and mean a larger layout of money. After all, the flooded area was completely recovered at the construction costes eguivalent to only one year's crop production. This was a singular example of drainage.

Other very interesting projects involved irrigation and drainage in the southern coast of Kalimantan and the northern coast of Sumatra where vast stretches of swamp land lay. Generally, swamp lands consist of intricate networks of creeks weaving in and out from river to river and the patches of land look like islets surrounded by water. The borders form natural embankments and generally the areas near the center of the islets are flat and low. In Kalimantan and Sumatra the natural terrain was put to good use. Creeks were dug out of reach of the tide and, taking advantage of the tidal level, the mid-islet low lands were drained and put under control. In this way land in Kalimantan about 5 km from either side of the new canals and in Sumatra about 20 km were drained off. Another interesting project was carried out in the delta area of the Irrawaddy River in Burma where the natural embankments were strengthened and utilized. Here the "islets" surrounded by creeks extend from 20 to 50 km and river bed slopes with even the slightest incline of 1/10,000 draws the water level down by 3 meter between both ends, up- and downstream. As additional protection against floods tall embankments 2 or 3 meters high were built atop these natural ones that covered about half of the upstream area of these islets. The downstream side was left open. In this way the downstream floods were kept from reaching into the upsteam area. This made cultivation of rice crops possible in the area so reclaimed with an extraordinarily small layout of money.

But even as land utilization techniques progress it will be found that techniques alone can never be an overall satisfactory solution. For example, the Luzon plains of Luzon Island, the Cotta Bato plains of Mindanao Island and the Bengawan Solo plains of the island of Java are identical in their patterns of terrains in the downstream area. River beds approaching the seacoast dip only very slightly while swamps cover the upstream area. Though it may be exaggerating, the terrain may be termed an "earthenware mortar", which poses a very difficult problem in drainage. To begin with, a part of the swampland must be drained, then it will be necessary to control floods in the upperstream area and to widen the flood storage basin to serve as water storage basins. Mechanical drainage facilities would also be necessary. Also in the Fanran district of Vietnam where construction is being carried out by our company, there is only about 700 mm of rainfall a year but the rainy season causes great floods every year. The Annam mountain range in the hinterland is the cause. But the coastal area has very little rainfall. The peculiarities of this terrain and the climate make irrigation and drainage imperative.

Related to the problem of drainage there is also that concerning the quality of the water. Even in the most arid places, the land may turn alkaline, become whitish all over and render the land unusable if it is irrigated with strong alkalies, become whitish all over and render the land unusable if it is irrigated with strong alkaline water over a long period. Such soil is both widespread and scattered in the arid regions. I have heard of many a good piece of arable land reduced to waste in a few years because consideration was not paid to the quality of the irrigation water. Such farmlands can be saved from ruin only if proper drainage facilities are constructed to wash away the alkaline ingredients that accumulate in the soil during the dry season. This can be done by storing up sufficient supplies of rain water during the rainy season, if there is enough water to do so. I encountered a similar case during my reconnaissance trip in Nepal where difficulty would be encountered because of the high fluorine content in the water there.

The Pang River flowing through the city of Manila of the Luzon Island is notorious for its yearly floods and the consequent damage it inflicts on the city. There is a lake in its upstream area, Lake Lagna with approximately an area of 900 km^2 of ponded water. It would be interesting to utilize this source of water.

I recently travelled to Africa and went to see an object of interest—Lake Victoria, extending to the three surrounding countries, Kenya, Tanzania and Uganda. It is a very large area of ponded water of 67,000 km^2. During the past 54 years, until 1952, the lake had an average runoff of about 370 m^3/sec of water. The lake pours itself out from Owen Falls and here very good use is made of the 370 m^3/sec runoff of water. A hydroelectric plant functions there producing 120,000kw of electricity (the final goal is 150,000kw). In 1962 and 1963, two years in succession, the surface of the lake was raised by about 3 meters. With this additional volume it can now let out 700 m^3/sec of water for 10 more years or average about 140 m^3/sec for 50 more years. Assuming that the peak of the wet season comes every 50 years, this runs up to 510 m^3/sec (370+140) of water available, on the average, for use over the next 50 years. It means a huge increase of a rich vital water resource for the downstream countries, Sudan and Egypt that lie along the Nile. This wealth is theirs because of the control facilities at the Owen Falls Dam. Given such control facilities the waters of Lake Lagna can also be put to most effective use either in drainage or in water utilization.

I was given the opportunity to participate in over 10 development projects concerning water resources in Southeast Asia. Every project carried agricultural developments in its blueprint and related itself closely with the problem of drainage. The importance these projects placed on the problems of water utilization and drainage impressed me very much. This is why I have taken up the question of drainage in this lecture. If my attempt has succeeded in interesting my audience even to a small extent in this matter the purpose has been well served.

PROBLEMS ON DEVELOPING AND UTILIZING THE WATER RESOURCES IN SOUTHEAST ASIA

I. Political, Economic and Social Factors on the Development of Water Resources in Southeast Asia

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In this symposium agricultural utilization of water resources in Southeast Asia is the main theme and the emphasis is on its technical aspects. But the non-technical aspects should also be given proper attention since the political, economic and social factors are as important as the natural bases and technical plans when setting up and carrying out development projects. Moreover, unlike natural conditions, the political, economic and social conditions are prone to change. This is especially true of developing countries. It may, in fact, be said that these conditions are really rapidly changing in Southeast Asia at the moment.

The reason I stress the importance of analyzing the political, economic and social factors in Southeast Asia is that the Japanese experts who survey or work there are apt to regard this area in nearly the same way as they do in their own country and are not aware of the existence of diversities between Japan and Southeast Asia. This is partly due to the fact that there are even some experts who seem to forget the evident fact that all Southeast Asian countries are now independent and no longer colonies. It, therefore, goes without saying that any project which lacks sufficient basic insight into the non-technical aspects will never really succeed.

Participating in the Southeast Asian Studies Project of Kyoto University since October, 1963, I have been concerned with agricultural development in Southeast Asia, particularly in Thailand. As one of my field research reports, I intend to make clear some basic political, economic and social aspects which are closely related to agricultural utilization of water resources in Southeast Asia. Let me use Thailand as my example, though indeed she is different in many respects from other countries in this area.

1. Diversified and changing Southeast Asia

In geographical terms Southeast Asia comprises the total southeastern part of Asia extending north up to China, west up to East Pakistan and India and south up to Australia. It consists of these following ten countries: Burma, Thailand, Laos, Cambodia, South and North Vietnam on the mainland and Malaysia, Singapore, Indonesia and the Philippines in the archipelago. Owing to its location and also to its recent historical transformation, Southeast Asia is now playing a crucial role in international relations. Although it should be noted that compared with China and India, Southeast Asia is by no means a large area—only about 4.5 million km^2 in comparison with China, 9.76 million km^2 and with India, 3.04 million km^2 —nor is there an exceedingly large population—only about 250 million today in comparison with China's 700 million and India's 450 million.

Southeast Asia, so defined as a single area, has much in common in its basic natural background, historical processes and political, economic and social set-ups. Being geographically uniform to such an extent, it is plausible to apply the term of "Southeast Asia" to this area.

In spite of the apparent unity in this area, there are great diversities to be found among the countries that constitute Southeast Asia. These diversities are pointed out here to be the influential factors needed to be considered when plans are drawn for water development in this area.

The first diversity of this area lies in its natural conditions such as topography, soil, climate, fauna, flora and so on. And many different mineral resources enable each country to contribute variously to their economic development.

Secondly, the historical processes in this area are extremely varied and complex. With the sole exception of Thailand, all other Southeast Asian countries had been colonies of Portugal, Britain, France, Holland or the U. S. A. for more than one hundred years. Traits of the mother country culture still persist in these former colonial countries. Moreover, the overseas Chinese who had started their mass migration to this area in the 18th century, help further to complicate the society.

Thirdly, not only the difference in people and language in this area, but also the religious diversity has an important role in the movement of people and cultural development. In fact, there are Hinayana (Lesser Vehicle) Buddhism in Burma, Thailand, Laos and Cambodia, Mahanaya (Greater Vehicle) Buddhism in Vietnam, Islam in Malaysia and Indonesia, Catholicism in the Philippines.

Fourthly, based on these historical processes and also on the impact of international relations, the political situations in Southeast Asia are extremely different in each country.

Finally, but the most important point in relation to economic development is that these economic diversities have been the logical consequence of all the diversities mentioned previously. That the differences in economic situations among the countries of this area are so great is clearly shown by figures of the annual national income per capita of each country. Malaysia comes first with more than U. S. $200 (Singapore with more than $400 is exceptional), Indonesia and Burma stand at the lowest level with roughly $50, and Thailand and the Philippines come between with roughly $100. These figures show that the economic activities and standards of living differ a great deal from country to country. In addition to this statistical comparison, we find countries like Thailand where the annual growth rate of the Gross National Product (GNP) has been about 6% in comparison to about 3% of the annual rate of increase of population and countries like Indonesia where the growth rate of GNP is guessed to be at a rate lower than that of population increase, consequently, the rate of growth of income per capita is estimated at the moment to be below zero though indeed accurate figures cannot be obtained. Regarding the reserves in foreign currency, Thailand is enjoying her economic prosperity having U. S. $550 million which nearly equals the yearly amount of import, whereas Indonesia is now on the verge of bankruptcy having heavy foreign debts but no foreign currency. Indeed the economic policies differ from country to country, but it helps to understand Southeast Asian countries if we divide them into the "inward looking" countries like Burma, Cambodia and Indonesia and the "outward looking" countries like Thailand, Malaysia and the Philippines[1]. It should be emphasized that the countries of Southeast Asia have progressed considerably economically and are now in remarkably different economic situations.

It is therefore essential to pay very careful attention to the political, economic and social peculiarities of the country concerned when plans are made to develop her water resources. Also, the relation Japan maintains with each of these countries is so different that she must take into consideration these differences in particular when she sets up an aid policy for water development in each country.

Another characteristic of Southeast Asia at present which has a significant and serious impact on any planning of water development is its intensity of changes in political situations. In this connection we should point out two basic conditions. The first point to be observed is that some of the Southeast Asian countries have not yet achieved political stability. The second point to be born in mind is that most water development projects take a lot of time, sometimes more than ten years in the case of large scale projects. It means that some kind of political change is bound to occur during this period which could easily hinder the progress of the projects and that any suspension of the work could result in heavy losses of huge investments. These, in turn, make it difficult for us to draw up any long-range development plan concerning water resource utilization.

Therefore, we must carefully and constantly watch the political, economic and social occurrences in any country of Southeast Asia.

2. Stability of politics and efficiency of administration

It must be pointed out that nearly all water development projects in

1) Myint, Hla, "The Inward and the Outward Looking Countries of Southeast Asia and the Economic Future of the Region", *Japan's Future in Southeast Asia* (ed. by M. Inoki), Kyoto, 1966, pp. 1-14.

Southeast Asia are carried out by the central government of the country concerned. The reasons for this governmental monopoly are quite clear. There are few enterprisers who are interested in water development projects which used to be risky and to take many years before getting profits and also whose profits used to be under the interest rate in these developing countries. Therefore only the central government can bear the financial burden of the water development projects in developing countries not only in Southeast Asia but also all over the world. However, it must also be recognized that the central government cannot bear the burden of most of the large scale investment projects owing to their limited revenue and borrowing power.

To solve the so-called "North versus South" problems, aid in various forms to the developing countries is intensely advocated. Particularly, taking into consideration the increasing imbalance between the food supply and the population in developing countries as a whole, foreign aid for agricultural development in which water development projects have a major role, has been emphasized.

However, how large the scale of the foreign aid it is always the government of the country concerned, not the aiding nations or international organizations, that carry out the water development projects directly. Therefore, any project on water development is the concern of the government of the recipient country and consequently has to be closely related with politics and the governments under which the project proceeds.

Whether the project succeeds or not depends largely on whether the government is stable over a reasonably long period, whether the government puts priority on economic development, whether the administration is efficient and so on.

Let us look at Thailand. In contrast to some other countries, she was spared the devastations of the Second World War by allying herself with Japan, even though she never did declare war against the Allied Powers. The post-war years saw her swiftly moving into a friendly relationship with the U. S. A. and other Western countries. Also she has been politically stable for more than twenty years, although there were indeed several coup d'états after the war, but all of them ended up in peaceful transfers of power. This put her in a favorable position to get tremendous aid from foreign countries, especially from the U. S. A. and international organizations that formed the basic condition for the water development.

Again, let us consider the famous U. S. one billion dollar Southeast Asia Aid Program proposed by President Johnson of the U. S. A. in June, 1965 at Baltimore. I myself do appreciate his eagerness to help develop Southeast Asia, but wonder whether this program is feasible or not, because it has placed special attention on the development of the Mekong basin area and the present disturbances in Vietnam and Laos, in addition to Cambodian "neutralism", are hampering the enforcement of any large scale development project there.

As pointed out previously, with any development project carried on by the government, we have another basic problem of whether the governmental agencies responsible for the project are efficient or not. If the administration is not well-organized and operates at a low efficiency, the harm is evident in enterprises that require large investments and whose economic results are considered very important. In this case, I myself would like to recognize the importance of the organization and work of Royal Irrigation Department of Thailand that has a history of nearly sixty years and is now covering most of the water development projects in this country. However, this governmental organization is said to be an exception in Southeast Asian countries where most of the governments are suffering from lack of efficient organization and administration concerning water development projects.

In relation to the efficiency of administration, we heard some complaints about graft and corruption in relation to water development projects. As graft and corruption have their own roots in the historical and social context of developing countries, every effort should be made to avoid and to eliminate.

Efficiency of administration is closely related with coordination between and within governmental agencies. Some lack of coordination is always found in governmental agencies in every country, but generally speaking separatism in the governmental agencies is much more severe in developing countries.

Let us take Thailand to illustrate separatism in governmental agencies concerning her water development program. As explained earlier, Thailand can boast of her Royal Irrigation Department that covers not only irrigation and drainage, but also electric power (both hydraulic and thermal), river transportation and flood control all over the Thailand. Still, there is another governmental agency, that is the National Energy Authority which belongs to the Ministry of National Development and takes responsibility for not only the generation of electric power but also irrigation near the dams constructed by this authority. In spite of the fact that both of agencies belong to the same Ministry, and have nearly the same functions, though the main objective of the former is irrigation and drainage, the latter generation of electricity, it is likely that there is hardly any coordination between them. In addition to this, the Department of Land Development whose objective is to improve land use in general and the Department of Land Cooperatives whose objective is to organize and encourage the land cooperatives including improvement of irrigation and drainage through the activities of cooperatives, also belong to the same Ministry of National Development but do not work together with Royal Irrigation Department.

When it comes to the problem of augmenting the effects of irrigation, research on agricultural production is needed. But so far as agricultural experimental stations are concerned, the Departments of Rice and of Agriculture, both belonging to the Ministry of Agriculture are not only independent, each having experimental stations, but also do not have any coordination with the Royal Irrigation Department which has its own agricultural experimental stations. Whatever the causes, we can say that in reality all of these departments stay entirely aloof one from the other and show no interest in any kind of cooperation. However, we have to keep in mind that the separatism comes from the peculiar bureaucracy in this country.

These analyses on the stability of politics and the efficiency of administration indicate how difficult it is to carry on any large scale water development projects in Southeast Asian countries although they are extremely important to help develop the countries.

3. The economic effects of water development projects

With regard to the water development projects, the following points may be said to be common to all the Southeast Asian countries. Also these points must have priority when planning and implementing the projects.

a. As already stated, nearly every project is undertaken by the central government.
b. National prestige invariably accompanies the projects.
c. A general intense feeling that the projects are of urgent need precedes the projects.
d. Political considerations, including the personal interests of leading politicians, take preference in the planning of the projects.
e. It is desirable that projects be multipurpose, even though single-purpose ones are more feasible and economically reasonable.
f. Aid in terms of money and technical skill is expected to be given by foreign countries.

Indeed the importance of these points to the water development projects in developing countries is easily understood. They are mostly political, social or psychological problems. Most developing countries do not pay much attention to the economic planning or development and consequently must suffer heavy economic losses or misdistribution of their limited resources. Therefore, we should take up the economic side seriously in order to promote development projects for the benefit of the country and the people. What we can recommend is to adopt an analytical method to evaluate economic effects or of input-output relations for any development project.

However, according to my own research on economic effects of development projects in Japan after the War, I doubt whether the economic effects of her construction projects were thoroughly analyzed or forecast before they were carried out. It, of course, may be too much to ask Southeast Asian countries to prepare such analyses of input-output relations at the time of planning, because often technical plans are changed or corrected after the launching of a project due to defective pre-planning.

Secondly, because of the technical aspects of planning of output, for example, of rice production through the increase of yield or expansion of cultivated land by irrigation and drainage are not easily forecast. This kind of planning concerning output is so difficult as not to bear comparison with the planning concerning input. According to my own research in Southeast Asian countries, the estimation of the amounts of output is extremely difficult owing to the lack of enough statistics and of research. We have to recognize that the planning of output in most of the projects which have been announced officially are unreliable or uncertain, shown by the results which have been brought about after the completion of the projects in Southeast Asian countries. Thirdly, because these input and output amounts have to be evaluated monetarily in order to calculate the economic effects for comparison with other projects. But, the cost of different units of input and output fluctuate every day and also vary according to the method of estimation. Also the time-consuming character of the development projects contributes to more variations and fluctuations of cost.

These difficulties of estimating the economic effects of projects which are common in Southeast Asia, are used as a convenient excuse for not paying attention to the economics. However, it must be emphasized that, even though it is very hard to calculate economic effects, they have to be analyzed as much as possible.

4. International aid for water resource utilization projects[2)]

As previously mentioned, the water resource utilization projects in Southeast Asia are monopolized by the central government of the country concerned. There are no other undertakers. Local governments are financially too weak. Furthermore, the central governments wield too much control over them. The farmers are too poor and their sharing the expense as beneficiaries is unthinkable. In these points the water utilization projects of Southeast Asia differ largely when compared to similar projects in Japan. They are national in character, so naturally the necessary funds must come from the national treasury but these countries cannot afford this easily. Eventually they are obliged to seek foreign aid. For the Southeast Asian countries, therefore, foreign aid in various forms are urgently required for water development projects. Consequently, it is also true that a lot of foreign aid have been granted for the projects in Southeast Asia.

We have to recognize the fact that the post-war economic development in Thailand can be taken as a model case in developing countries and that one of the basic causes for this rapid development is to be found in foreign aid. Considering the reason that the foreign aid was accepted successfully, we can find that the basic condition to receive foreign aid for water utilization had been established, and that Thailand had political stability and a relatively well-organized agency for water utilization.

5. Village society and the farmers

To carry out the water utilization projects successfully, another important point to bear in mind beside the governmental policy and international

2) On international aid, there are detailed discussions on pp. 37-49 of this report.

aid is the attitude of the farmers toward the projects.

In recognizing the importance of the distribution dikes and ditches in the Great Chao Phraya Project in Thailand, the main canals that lead out from the intake weir are ready to function but most of the branch canals and minor waterways are still left in an incomplete state.

As Dr. Koichi Aki, the former Director of the Flood Control Division of ECAFE, pointed out[3), a good many water tanks for irrigation are standing idle for lack of irrigation ditches because the villages concerned cannot afford to build them due to lack of money or technical skills. In Northeast Thailand it is easy for us to find the statistics on number of tanks, but not the acreage covered by irrigation through tank-systems. This shows clearly that the tank-system does not work well mainly due to the lack of distribution systems in this area which suffers from lack of water.

These two facts suggest the following questions with relation to the water development projects in connection with village societies and the farmers.

The first question is the Thai village cooperative. Though this question cannot be hastily answered, it could be said that in general the Thai villagers are more or less lacking the spirit of village cooperative organization. Professor Herbert P. Phillips of the University of California who participated in Cornell University's Bang Chang Project pointed out the difficulty of obtaining any large scale help or cooperation among the local farmers in the Central Plain of Thailand.[4) My impression is somewhat similar. I have not been able to find well-organized cooperation among the farmers in the Central Plain or in the Northeast, though there are some instances of cooperation in the North. It is also my own observation that the cooperative movements have been encouraged and financially supported by the government from the beginning of this century but that little has been accomplished partly because of the lack of traditional cooperative organization.

The second question: Do the farmers concerned with the water development project have the will, the technical skill and knowledge, the funds and so on in order to carry out the water utilization system on farmers' level?

a We must clearly recognize that they have the will and are anxious to improve their own standards of living in contrast to the somewhat mistaken idea that the Thai farmers are so satisfied by their traditional life as to not want to improve their income or consumption. Visiting many villages to talk with the farmers in different parts of Thailand, I was shocked to find out the changing situations in the rural areas that are causing the Thai farmers to now acutely feel the need to increase their cash income in accordance with the rapidly changing consumption pattern. They are now becoming aware of

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3) Aki, Koichi, "Some Problems Regarding the Water Utilization and Development in Southeast Asia," *Tonan Ajia Kenkyu* (*The Southeast Asian Studies*), vol. 3, No. 1, Kyoto, 1965, pp. 52-64.

4) Phillips, Herbert, P., *Thai Peasant Personality, The Patterning of Interpersonal Behavior in the Village of Bang Chang*, Berkeley and Los Angeles, 1965, p. 17.

the fact that to attain better yields, emphasis must be placed on irrigation and drainage. Of course the extent of their awareness is still limited, but they are by no means ignorant or idle.

b. Even though they are now becoming conscious of improving their water utilization situation, they still lack the proper technical knowledge of agriculture, such as fertilizers, new varieties of crops, methods of cultivation and so on. Improvement of technical knowledge and the practice of farmers to adopt new methods of irrigation and drainage is connected with extension services.

c. The most important problem concerns the farmers' funds. Generally Thai farmers are not fortunate enough to be able to set aside enough money to invest toward water utilization. Indeed, problems of saving and investment at farmers' level not only in Thailand but also in other Southeast Asian countries must be given more study. At this moment, any water development projects by private investment on the part of the farmers are nearly impossible. As we observed in some parts of Thailand, they work for governmental construction projects for wages. Indeed, wages means cash income which is necessary for them and providing man power for construction of distribution dikes and ditches does not mean cash. Therefore they prefer to be employed by the government for money although in the long run, their own labors would pay off. Thus it is extremely necessary for the government to persuade the farmers to collaborate with the irrigation and drainage projects of terminal facilities by providing their labor without compensation during their leisure season.

d. It should be emphasized that the system of landownership influences these projects considerably. Strangely enough, sometimes big landownership is favorable to large scale irrigation projects as was shown in the Rangsit Area north of Bangkok in the early twentieth century. Generally speaking, if we limit our consideration to the feasibility of the projects, these large scale projects are much easier to be carried out where big landownership is predominant or governmental control is so strong as to be able to mobilize the farmers.

e. The education or propagation of agricultural techniques at the farmers' level must be highly advocated. It is now recognized that investment in education in the field of agriculture has been most productive and efficient in raising the agricultural production in advanced countries. This seems to us to be applicable to developing countries also. Practically no attention has been paid to education or extension in developing countries. Concerning water development projects, the plan to educate the farmers on the necessity of their cooperation and the necessary technical knowledge should be closely connected with the projects. Very often this point is disregarded when the projects have to be carried out. It certainly requires fuller attention.

In considering these points, we understand that it takes a lot of time to prepare the basic conditions for efficient projects. But also we know that it is urgently required by the developing countries to carry out the projects as soon as possible as these countries do not have the time. How to fill the gap between the need for the project and the lack of basic conditions is really a fundamental problem. In order to solve the problem, I do firmly believe that both developing and advanced countries should realize fully the importance of this gap. Otherwise all of the efforts for techniques alone will not be able to achieve the expected objectives.

6. Conclusion

As concluding remarks I would like to point out the fact that the existing projects of developing water resources in Southeast Asian countries have paid too much attention to the technical side but not much to the economic, social and political situations. Therefore most of the projects have not been able to be carried out as planned and expected. In order to carry out a project efficiently it is extremely necessary to pay full attention to these non-technical aspects as well as the technical ones at the planning stage. However it is a fact that these non-technical aspects have not been well studied and that the data we can use or we should have for planning have rarely been prepared. It means that the basic research on non-technical as well as technical aspects should be encouraged and done as soon as possible in order to adapt the rapidly increasing demand for water development projects in Southeast Asian countries.

II. Development of Land and Water Utilization in Delta Areas in Southeast Asia

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The delta areas of Southeast Asia may generally be referred to as being in the elementary stage of development at present. The general level of agriculture is very low and the whole social and economic structure leans heavily on the production and distribution of rice. The possibility of further development is being concentrated for the time being on the utilization of land and water in the agricultural field and on the improvement of agricultural techniques. For this, technical and economic aid must come from foreign countries. Japan's scientific know-how is rated high in this field and although she is at an advantage in comparison to the U. S. A. and European nations in the aiding of these countries, she still lags behind in shouldering her share.

During 1962—1964 the writer had the opportunity to participate in ECAFE and UNESCO activities. Various organs of the United Nations, including FAO, are now actively engaged in investigating and developing these areas and also in studying the actual conditions and in planning. I should like to draw a picture of the actual state of these delta areas and give my opinion on their state of development.

1. State of development of delta areas and related problems

The writer had the opportunity to make field surveys in three large delta areas, the Ganges (India, East Pakistan), the Irrawaddy (Burma) and the Chao Phraya (Thailand), at present being developed in varying degrees, as well as localities within each delta. Generally speaking, the further east one goes, the more developed the area becomes, and the intensity can be observed in the reverse order, the Ganges, the Irrawaddy and Chao Phraya. Of the Gangetic delta area, the coastal district of the Sundarbans is in the least developed state. The coastal area (south of Bangkok) of the Chao Phraya is quite advanced, a state more or less equivalent to that of Japan's pre-war Kiso River delta. Let us take as examples the Sundarbans and the Irrawaddy (the mid-stream delta area) and see what the general state of development is at present and study some of the related problems.

1. The Sundarbans (coastal area of the Gangetic delta)

This is a stretch of land so low that it is almost touched by the high tides (spring tide difference, 5 meters) of the tidal river. It provides for rice cultivation. It is a sort of a polder closed in by embankments 1—2 meters high. The embankments are in constant danger of erosion, leaving the area exposed to the ravages of the high tides. For irrigation the farmers have only rain water or stagnant water to depend upon. To drain water, human labor is employed to cut open a passage through the embankment. Wooden or concrete flood gates have been constructed only recently and the embankments reinforced. These facilities were private property before the war, but after the war they have become government property. The huge Pakistani government plan involves the construction of 5,200 flood gates and the reinforcement of embankments that extend over an aggregate of 5,000 km, enclosing a total area of one million hectares of 73 polders. The project is progressing slowly at present. It is estimated to require 13 years, from 1962 to 1974, and a total investment of $120 million. Many delays, however, are expected. There are no roads nor waterways inside the polders except those that run on the embankments. The rice grown here utilizes human labor only to a bare minimum, manpower being employed only when rice is planted, transplanted and harvested. Salt water damages the crops and no fertilizers are used. Under such adverse conditions one can expect but little production — only about 1,300 kg. (unhulled rice) per hectare, a mere fifth of Japan's average. The only other industry beside rice is the felling of the trees of the virgin coastal forests. Society here is still at a low level and rice is grown merely to exist. Industry is not yet even considered.

Several hundred thousand hectares of coastal land have surrendered to the virgin forests of saline resisting hydrophytes. They are the Sundari, the Gewa and the Tomal jungles that thrive in the dry beach lowlands. Giant trees towering 20 meters high present an imposing spectacle. Paths of all sizes interlace these forests and divide them into numerous islands, tens of thousand hectares in size. The Sundarbans are in both Indian and Pakistani territories. Both governments exercise control over the forest area to protect the reclaimed hinterlands from the high tides of the Bay of Bengal. To raise the forest floor, soil and sand accumulate, dead plants pile up on the forest floor and raise it little by little. Trees help, for as they rot away the forest floor rises above the high tide level. On the other hand, the forests encroach gradually into the sea. In this way several hundred thousand hectares of arable land have been created. Then although inhabitants can be permitted upon the reclaimed land, these lands still being relatively low and in danger at high tides and not suitable for farming due to high alkaline content, the governments concerned have not put great emphasis on their reclamation. The polders here in the Sundarbans are still in the most incredible low state of development. This is quite a contrast to methods used to reclaim lands in Japan and Holland which have become the most active in reclaiming new usable lands.

But the Sundarbans has not been and will not be left wholly undeveloped. The Pakistani government is working on a grand development project involving such features as flood control, water utilization, better agricultural methods, etc. At Khulna, the center of this district, an industrial development project is underway for jute, electric power generating, shipbuilding, etc. These projects are still local in scale and nature and as yet far from developing into larger ones that will extend over the whole area. To plan for further development the following matters must be taken into consideration.

a. In strong contrast to the green vitality of these coastal forests the rice crops and the farmers of the inland farmlands are droopingly withered. So bitterly salt bitten are they, that it is as if the causes come from vainly defying nature, attempting to use non-salt resisting rice where only the salt-resisting plants can thrive. The low lands surrounded by tidal rivers are frequently the victims of inflowing sea water, and the fresh water is insufficient to remove the salty ingredients from the soil.

b. The farmers and the crops depend on the often insufficient supply of rain water and when there is an excess it drains away directly into the rivers. Occasionally fresh water is found in hollows but the farmers make no attempt to pump it out for use as irrigation water, and it is used only for drinking, for miscellaneous household purposes and to water the nursery beds. Inhabitants living in places where the ground bed is sandy, habitually make great use of the underground water but only for drinking.

c. Though it is a most important aspect, the farmers here lack the will to increase production to raise their standard of living. The government as well as the inhabitants do not seem to have the will nor the economic strength to raise themselves from the miserable state they are in.

2. The Irrawaddy mid-stream area

The Irrawaddy delta lies in the center of Burma and is important politically and economically. Although the whole of the delta is blessed with comparatively favorable natural conditions, the mid-stream area is the most favored. It is a flat, wide stretch of land averaging in height midway between its highest and lowest water levels. When the floods come, the whole area disappears under a wide, but shallow body of water which looks like a placid lake, the water slowly running downstream. Even at the height of the floods the water rises only about 40—50 cm above ground level and provides a most ideal natural irrigation. The whole area is a well-protected rice producing land as it is. No embankments are needed to protect it from the floods. No flood gates are necessary for drainage. No flood control devices nor water utilizing facilities like waterways are required.

When the dry season comes and the rice crops ripen, the floods gradually retreat. The water level drops below the ground level. The rains stop and the surface water flows through the creeks back to the river, against the course of the flood waters and drains away under its own power. The ripened rice stalks are harvested at a leisurely pace throughout the long dry season, then stepped on and threshed by cattle. The land, the water and the weather combine to give it the most ideal set of conditions throughout the whole rice cycle. Conversely speaking, it is only rice that can adapt itself ideally to these natural conditions. Other crops and plants are not found growing wild in these low delta flatlands. As long as the monsoons, on which the farmers wholly, depend continue regularly this is really a land well favored by nature for rice.

Having found it so easy to make a living in this favored land, the farmers have depended too much and too long on Nature's favors. To this day no attempts have been made to improve the natural conditions. Naturally, due to a lack of irrigation and drainage facilities, Nature delivers heavier blows on this part of the country when the rains are irregular.

In unhulled rice it produces only about 2,000 kg/ha, a very low average, less than one third that turned out on Japan's Nobi Plains where the average is 6,500 kg/ha. It is due to the poor soil, a relative lack of cultivation, lack of fertilizer, unimproved varieties continuously grown since olden times, plant diseases, etc. Everything may be explained by the fact that up to the present the same primitive form of rice growing, as it must have been 1,000 years ago, still persists.

The Burmese government has set up several experimental stations for the purpose of improving the rice cultivation techniques, studying appropriate means of fertilizing, mechanization, etc. Efforts are being made toward disseminating the necessary information but the actual results have not yet been too good.

It is difficult to understand why rice growing has remained at such a low level in this area so favored by Nature with such ideal conditions as to be given the name "rice bin of Burma." It may be that my impression, based merely on outward appearances, is wrong. No increase of rice production can be expected unless the farmers' incentive is stimulated by prospects for a better standard of living and for an increase in corresponding outlays of money and appropriate set-ups. If the farmers find their efforts toward increased production not rewarding, not increasing their income, or even if they do make efforts and their livelihood is made more difficult by larger families or other such conditions, my impression is that the farmers of this area are inclined to leave the social, economic and religious conditions as they are and remain satisfied with their present state and lot. Fragmentary instructions of farming techniques on economic aid will not improve the conditions effectively. Along with the general education of the farmers, improvements must be made in technical matters as well as in social and economic affairs.

One feels somewhat pessimistic as to the future development of this delta area when one reviews its present state fraught with difficult problems, but this is because one expects too much in too short a time. There in no need to be pessimistic if longer views over, say, 100 or 200 years, are taken. Japan's own experience in the past 100 years since the arrival of the Black Ships well testifies to the possibility of an optimistic future for this delta area which occupies an important position in Burma's present unstable political situation. The U.S.A. and European countries are, in this sense, working actively today fully cognizant of the fact, as they do not necessarily expect success in the very near future. Are not we Japanese taking it too seriously and anticipating too quick an effect in the too near future?

2. The future of the delta area

As we have seen, in developing the delta area, emphasis should be laid on agriculture; first of all on the utilization of the land and water, the bases of production.

a. The rich potentials of the natural resources of this tropical delta area—the land, the water, the sunshine and the population—all these elements are indispensable to agriculture. Given modern farming techniques, the agricultural production will rise to such a high level as to defy comparison in any other part of the world.

b. History proves that those world cities and industrial centers presently occupying strategic positions in the realm of the second and third industries have started from an agricultural basis. This delta area is no exception. They will eventually develop along these lines. If light industries are set up here now, it is certain that these will take a much longer time to develop sufficiently to the extent of supporting the nation's economy than would agriculture.

c. Agricultural development should not be confined only to the farmland and technical improvements, for with it must come the development and improvement of other industries, such as transportation as well as education, etc. Naturally this leads to an overall development project for the whole area, for instance, a fertilizer plant can accompany a project for generating electric power; a transportation project of agricultural materials and products can bring ships, rolling stock, canals, etc.; a disseminating and promotion plan of agricultural techniques and information can bring plans for schools and education. An agricultural development project in this way connects itself with the development of the whole society and economy.

Prior to embarking on an agricultural development project for the delta area, first of all, the floods must be put under control. No part of the delta area can be developed without first providing it with the means to protect it from damage form the floods that rush from the inlands and from the sea. In a delta area flood control is very closely related to water utilization. It may be more proper to say that flood control is at the same time water utilization. For example, the irrigation embankments of the upper Irrawaddy delta area are the river banks themselves that in turn serve as flood controls. In the Chao Phraya delta, flood control gates facing the sea function simultaneously as check gates. On account of the peculiar topography and the hydraulic conditions, flood control and water utilization are considered as the same in this delta area.

A delta is a place where all the tributaries of a large river converge and this gives it a peculiar topography, characteristic soil composition, and hydrological and hydraulic conditions. If the natural flow of the river is tampered with by setting up facilities for flood control they will alter the hydraulic conditions of the delta. If some hydraulic works are put up in the delta both the upstream and downstream areas are affected. There will be changes in the action of the water, which is the power that governs the delta. Larger scale ones especially can be said to be nature reconstructing. They are important factors to consider in developing a delta area. The present natural state of the delta is affected by changes depending on the hydraulic works that will be set up. Whether the objective of the original hydraulic works is single or multiple it is certain that many effects other than the one originally contemplated will arise and these in turn will cause others. This is due to a very complicated and delicate balance maintained by the land and water conditions of the delta. Once the balance is lost, an unexpected set of new conditions may start working, at times contrary to the original aim of the project. Therefore, only a very carefully planned hydrological project can bring the existing natural conditions of the delta to complete its objective and only then can the potentials of the delta be highly utilized.

Since the end of the war not only developing countries but also many others and various organs of the United Nations have been engaged in social, economic, scientific and technical fields for many years to develop these delta areas, but the results do not always seem to be satisfactory. There are other elements besides the technical and economic ones that require our attention, which can be summed up as follows:

a. The countries, whose delta areas are to be developed, are not capable of carrying out their development plans independently. Although their governments and leaders anxiously seek aid from the United Nations and other countries, the general populace does not seem to share the enthusiasm. This of course will not do, as good results may not be expected in this way. From now on, if technical aid is to be given, it must be done in a way as to encourage self-development to rely less on foreign aid.

b. These delta areas have much in common in their natural and economic conditions but are diverse in their political, social and religious aspects. In promoting technical development it is necessary for each delta area to be considered separately in order to ascertain the best methods and how to apply them.

c. Past and future developments of these delta areas naturally differ largely from those of the small delta areas of Japan. It is, therefore, unwise try to employ the same methods of development as were used in Japan.

d. European and American techniques and culture found their way into these delta areas before coming to Japan. It must be noted that these delta areas were modernized fragmentarily long before Japan was.

e. These countries still possess pre-colonial, racial, religious and social characteristics which are very antiquated and conventional in nature and seem to hamper the otherwise smooth progress of social and economic development. They must be got ridden of if improvements are to be made but alternately no success can be had if they are completely disregarded.

3. Utilization of water of the delta area

The rich water resources of these delta areas are utilized not only for agricultural purposes and drinking but also for experiments as natural floods and reservoirs. The general level of utilization is still very low except in the Chao Phraya delta area but even here the modern facilities of water utilization do not yet seem to be well coordinated with the methods of utilization. Let us see in general what kind of water utilization facilities there are in their respective categories.

a. The method employed for water utilization and development of coastal delta areas involves the use of flood gates at the mouth to shut in and store fresh water from the rivers and to block the intrusion of sea water. It was adopted in the 19th century along the Chao Phraya. Now there is a plan for a more widespread use at the mouths of the three rivers. This "estuary dam" is acknowledged as the most effective water utilization facility for use on the delta seacoasts but its utilization at the estuaries of large rivers is not great due to the peculiar hydraulic and soil conditions as well as the great outlay of money involved. Other drainage facilities such as flood gates, pumps, embankments, etc., will have to be set up to control the water level in waterways converted into fresh water canals and also in lakes and ponds. Unless the whole system of water utilization of the whole area is reorganized it will not work effectively.

Although the day may come when projects to close large rivers at their estuaries may be realized in the coastal delta areas, this sort of a project will take many years of study and planning. Technicians concerned discuss the problem but its realization in the deltas of these large rivers is greatly doubted. Even in Japan such projects have only recently been adopted for establishment in her main rivers.

b. The most effective device that can be used in water utilization and development in the low lying plains is the pump. There are various other water lifting devices used in the delta areas at present involving the use of manual labor, wind or machines. The sole example of modernization in this field is found in the Ganges-Kobadak project now under way in East Pakistan, which aims at setting up pumping facilities in an aggregate area of 330 thousand hectares of paddy fields. At present 13 units of low lift pumps are operating in a 50 thousand hectare area. The practical effects have not yet been seen as difficulties in raising the necessary funds and in setting up an effective water distribution system have been encountered.

c. Development of irrigation and drainage facilities will revolutionize rice growing. It will be possible to grow rice even during the dry season and make it possible to get two or even three crops a year. It will also be possible to remove salty ingredients from the soil of below-mid-stream areas that have been occasionally ruined by salt water. In any event it may be necessary to improve the varieties of rice that are grown in order to meet the changing conditions that govern it, that is, the weather, the soil, the nature of the water and the other changes that will be effected by fertilizers, cultivation, etc. Rice that grows well under the present natural conditions of these delta areas may not grow satisfactorily under a new set of conditions.

d. Another target of the development plan of irrigation and drainage is the introduction of a regular upland farming system into the agriculture pattern of these tropical deltas. When farm products as yet only cultivated in limited areas of the uplands under protection of the natural embankments are cultivated in the whole delta area, agriculture itself will undergo a great change and will free itself from its present undeveloped state and advance to a more modern state.

e. If agriculture is to make this great stride through the development of irrigation and drainage projects it must have the support of the farmers and the government officials concerned, who need re-educating. All must realize that in order to achieve these changes, money must be appropriated in order to reap both better production and profits, and the farmers will necessarily have to undergo hardships and face almost complete re-orientation especially in production, distribution and their own lives. This is in short an overall revolution in politics, society and economy.

f. The development of water utilization affects to a great extent the livelihood of the inhabitants of the delta areas. Those who are accustomed to using salty mud water for drinking and bathing will find it hard to become used to fresh water. Water utilization will not only improve the water but also can help eliminate malaria and other diseases, which can be a great gift to human society.

g. There was a case in the Chao Phraya where the production of rice decreased in spite of improvements made in drainage in a large waterlogged area. A similar phenomenon was once also observed in Japan. It was because the aridness had acidified the soil. It is said that economically it is hopeless to improve an acid soil. The difficulty of keeping irrigation and drainage in balance is the same problem everywhere.

h. Much concern is shown over the problem of improving irrigation conditions which eventually may worsen drainage. In these areas where the inhabitants have long depended only upon natural drainage, the idea of putting money into drainage projects may be more resisted by them than irrigation projects.

4. Conclusion

In conclusion I will quote what some native technicians had to say on matters we considered important, which were quite contrary to what we believed and which made us reexamine the characteristics of these monsooon delta areas.

a. It is all very well to build embankments to prevent the floods but would they not worsen the state of drainage? (This shows a general lack of knowledge of setting up flood gates and drainage pumps.)

b. Similarly, would not the embankments impede the settlement of fertile silt onto the surface of the fields?

c. The facilities to improve the utilization of water will impede the transportation on the river.

d. Delta rivers carry large amounts of mud and saline ingredients. Even if dikes are constructed to close off the rivers, silt will soon pile up inside and make the saline ingredients inseparable.

e. Pumps are certainly effective but they cost too much.

f. What does development really mean? The natives are satisfied with their present state. They do not want any development. Why are foreigners so insistent upon making changes?

III. Some Technical and Economic Problems on Agricultural Development in the Mekong Basin

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A comprehensive development project of the Mekong basin is now being vigorously promoted with the Mekong Committee[1] forming the core. In some parts the project has already gone from the study and planning stage into construction.

Japan's role in this project is mainly that of carrying out investigations in various fields. Since 1961 I have been engaged in preliminary reconnaissance and planning work of the Prek Thonot, the Nam Ngum, the Upper Se San and the Upper Srepok Projects, all undertaken by the Nippon Koei Co., Ltd. I was in charge of the work in the agricultural field and I shall refer to the various points that drew my attention and impressed me during this period. I shall also refer to the many problems that served as objects of discussion and which were found to need revision and supplementation in the near future.

1. Problem of an international standard of classification of soils in the tropical zone

As regards the main soil group found in the Mekong basin, a schematic exploratory soil survey map, based on the reconnaissance results by R. Pendleton, F. R. Moorman and others, has been published by FAO in 1959. In 1960, Y. Egawa, participating in the Japanese reconnaissance team of the Mekong tributaries, investigated the soil there. The results of his survey have been published in the collective report. In 1961, F. R. Moorman published a schematic soil survey map and its explanation, in which he summed up the results of his studies on the distribution, the characteristics and agricultural utilization of the main soil groups of Vietnam. These schematic surveys aimed mainly at classifying and studying the distribution of the Great Soil Group. Uniformity has been attained to some extent but his classification cannot be regarded as wholly based on an uniform standard when compared with other classifications that have been made on the soil of the other low latitude tropical areas.

In making a detailed survey of the soil in the various areas of the Mekong basin, individual surveyors have so far depended upon varied methods of classification. The Bureau of Soil Science of the Vietnam Ministry of Rural Affairs, for example, in the main used the U. S. A. soil survey manual to classify the types, series and phases of the soil, while in Laos a French standard was used. This is

1) See the chapter dealing with international aid on pp. 37-39 of this report.

very inconvenient when projects to develop the Mekong basin have to be carried out through international cooperation. It is an important urgent matter to set up international standards of classification and nomenclature for the soils of these tropical regions.[2] For the present we have to be satisfied with compiling and adopting a temporary standard taken from the data obtained by field surveys and then provide an explanation whenever our terms of classification differ from those used by other classifiers.

2. Irrigation soil maps with detailed soil survey information

If the agricultural development plans of the tropical areas, especially of the Mekong basin lying in the Southeast Asian monsoon zone are to succeed, it is not an exaggeration to say that it can be accomplished only when irrigation facilities are consolidated and proper methods of irrigation and farming are applied. If improved varieties of crops are to be successfully grown, if the most appropriate kind of fertilizers and other improved methods of cultivation are to be employed, the soil moisture conditions must be kept constantly on a correct level. The application of a correct method of water utilization is the basis for an increase in farm production. I believe that to make successful plans to develop the agriculture of the Mekong basin, it is absolutely necessary to have access to data on the irrigation engineering characteristics of the soil and on the basis of these data to apply the most appropriate methods to the respective categories of the soil.

3. Field experiments at pilot farms

The extent to which the productivity of a given piece of land increases with the application of the irrigation farming method forms the basis from which the benefits-cost ratio is calculated. Usually in advanced countries reliable figures are available, worked out by well-managed test and research agencies. If not, it is usually possible to work out such figures by similar experiments on plots of land with conditions similar to those of the land under consideration. Not so, however, in the Mekong basin which is still undeveloped or at most in the earliest stages of development. Some of the local farmers may be able to furnish some figures on agricultural intake but they do not serve our purpose since they are derived from their unimproved agricultural methods (a rain-fed culture). The present methods of soil surveys clarify the fertility of the soil to some extent but this alone is not sufficient for us to arrive at figures that will truthfully represent the productivity of the land. It will take much time and money but it is a matter that must be clarified and fixed through field tests made at pilot farms set up at typical places in this area. In view of the widespread belief that the production of the rice crops grown in the tropics is very

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2) *Reconnaissance Report of the Development Plan in Ghana.*

low, this task assumes a greater importance in the planning of the development of the Mekong basin where irrigation farm management centers around rice. Accordingly, the field tests carried out at the pilot farms should at least involve field irrigation tests so that the basic figures needed to blue-print the most appropriate method of water application may be decided. Tests should also be made on the three chemical elements (N, P, K) of the main crops grown under irrigation and also to find out the effects of fertilizers on the main crops.

We have had experience of much value on this subject. The first concerned the Nam Ngum Project. This required a plan to be made, according to its provisions, by assuming the yield of the crops grown under irrigation conditions. There was no provision permitting prior investigation at pilot farms. No actual nor reliable figures were to be had from field cultivation soil survey results, so outdated data had to be borrowed from neighboring countries. We drew up the most conservative estimate possible—3 tons in the main-season and 2.5 tons in the off-season represent the estimated yield of unhulled rice after completion of the irrigation system. It was sent in as a feasibility report to the World Bank, who rejected it with the request to go through our "overestimated" figures again. There being no figures from pilot farms for support, it seemed it would be an endless argument, but fortunately some belatedly set-up FAO pilot farms in the planned area produced figures that proved that ours were not overestimated but too conservative. The World Bank accepted our report.

Another was connected with the Upper Se San Project in Vietnam. We drew up an overall irrigation plan that covered a piece of land that could be cultivated and irrigated. The area included a wide stretch of recent alluvial land as well as farmland covered with basalt-derived latosol. Some of the local European technicians opposed our plan on the grounds that this kind of soil is no longer fit for use because the fertility has been destroyed under the rough tilling methods of nomadic hill tribes. The decision had to wait for actual cultivation results so, although it was not provided for in the contract, Nippon Koei Co. underwrote the expense and set up a pilot farm at Pleiku which showed that yields up to 3.5 tons of unhulled rice can be had from this land when irrigated. The controversy was settled by actual facts.

4. Determining the size of the unit farm, variety cropping system and extent of farming intensification under irrigation

Sometimes in judging the merits of irrigation plans economically, very rough estimates are made without regard to the size of the field, the variety or combination of crops. It is judged merely by the total increase of the yields of the main crop and it is considered a profit when its value increases. In actual practice this is too rough a method. In considering the yield increase of an agricultural project the object should be placed in the standard yield that may be expected from a standard unit farm managed under a proper system of irrigation.

Our present plan is based on the actual state of the land system and we regard 2 ha as the size for a unit field set up in a recent alluvial land where the fertility of the soil is comparatively high, and 3 ha in the upland area where the fertility is comparatively low. In considering the crops to be cultivated, attention has been given to family consumption, self-sustaining fodder and local and national demand. This resulted in the selection of paddy rice, beans, peanuts, maize, pasture grass, green manure, vegetables and fruits. The plan further took into consideration the photosensibility of the plants and the nature of the crops as well as the apportioning of human labor. All this added up to adopting a 3-year crop rotation farming method which makes possible perennial utilization of all the arable land. The multi-crop index of the cultivated land used thus is approximately 1.75.

Much criticism and argument accompanied the adoption of these plans when they were sent in for examination. One objection was the possible difficulty of carrying out such an intensive cropping system with the farmers in Southeast Asia where only extremely extensive farming methods have been customary. Another strong objection to this multi-cropping pattern was that it only complicates control of irrigation water, which itself is adverse to the principle of irrigation farming. The first objection is groundless as the farmers have already proved the workability of our plan by actual results they obtained at our pilot farms. To the second objection we may say that the field experience at our pilot farms and at some of the farmers' fields have shown it not to be so complicated as to make it unmanageable by the farmers themselves.

A considerably large outlay of money, amounting roughly to $1,000 per hectare of cultivatable irrigable land has already been invested in the first stage of this project. I believe that an irrigation system already built up to this extent to develop agriculture should aim at raising efficiency by handling it in a way that will increase productivity to the utmost.

5. Estimating direct, indirect and nonmaterial benefits-costs

When a project is carried out in an area still in its earliest stages of development like that of the Mekong basin, the accompanying social and economic effects may well be expected to be great and widespread.

These countries are usually extremely poor and underdeveloped socially and economically. Therefore, it has lately come to be the basic thought of the United Nations and the other international development and cooperative agencies to carry out parallel investments in the other infra-structures to consolidate environmental and social conditions of the area with the intended irrigation projects. According to this reasoning, such indirect and nonmaterial social and economic effects that such irrigation plans of the advanced countries would bring about should be included in other plans. Such effects should not be considered directly as part of irrigation plans.

6. Fixing the rate of interest and the terms of payment of the initial investment

The funds for developing the projects of these countries should be advanced on the most lenient terms possible, that is, with the lowest rate of interest and the longest terms of redemption, a desirable feature for irrigation projects also. What then are the most reasonable figures?

When we drew up the plans for the present Mekong basin irrigation project, we consulted the Mekong Committee and fixed the rate of interest at 3% per annum, the unredeemable period for 10 years and redemption for 30 years in equal amounts per year. The initial amount invested in this project was about $1,000 per hectare whereas the annual amount of redemption averages $70. The terms were considerably lenient. Lately, as international cooperation extended to agricultural developments increase, the terms tend to grow even more lenient. An example in point is when the benefits-cost was calculated, the rate of interest was fixed for 3% per annum, the redemption set for 65 years to commence in equal amounts per annum 11 years after the project was completed and to continue until the 75th year.[3] These terms meant an average redemption of only about $34 per year per hectare against the initial investment of $1,000 per hectare.

7. Fixing the levy and applying the water rate

The problem of how the levy should be collected from the farmers is a very important one. For the farmers yet in the first stages of development, it is the creating of a debt of a nature unknown to them. So important is this matter that it is no exaggeration to say that the success of the project depends on how this is handled. For the farmers it is a vital question not only of whether they can afford to pay back the initially invested money but also of paying the fee allotted them for the use of the facilities out of the profits to be earned by farm management.

Mr. Kanwar Sain of the Mekong Committee proposed a method which he called the "water rate". His was a philosophical reasoning. In its original sense, water was heaven's blessing to earth. Every man was entitled to his share of this blessing. Naturally the farmers depended upon it for their livelihood. The "water rate" had no direct connection with the redemption of invested money nor did it have anything to do with the levy to pay the expenses of running the project. The farmers living in the cultivatable, irrigable area of the project should, as a token of gratitude, give a part of their share of this heaven-sent blessing of water to those who lived in the same basin but were denied it. There should be a fixed amount, but not as a compulsory

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3) Refer to the criterion shown in the *Manual on Economic Development Project*, United Nations, New York, 1958.

levy. This he called "water rate" which should be considered in the terms of the loan when it comes from international monetary agencies and in the benefits-cost ration of the loan when it comes from the country's national treasury funds. He considered it proper that in the Mekong tributary basin its initial amount should be fixed at about $5 per hectare with the ceiling at $25.

8. Infra-structural investments

The irrigation system itself is an infra-structural system but the question here concerns the extent of investment that is considered necessary for the building of other infra-structures so that the effects anticipated in the irrigation projects for developing countries may be realized.

There have been various irrigation projects carried out in these countries. The results have revealed that the kind of results expected of irrigation projects carried out in advanced countries cannot be expected in these particular countries and that in extreme cases the facilities set up are rendered useless. This teaches us that in carrying out this sort of project in developing countries, parallel investments should be made in other infra-structures so that environmental conditions may be consolidated in order to pave the way to successful irrigation farming. This involves setting up sanitary facilities, healthy surroundings, educational facilities, water works and housing, village and city planning, establishing markets, transportation and road facilities, undertaking more irrigation farming, etc., as well as setting up administrative establishments, guide programs for the farmers' organizations, etc., when and where necessary.

If our projects in the Mekong tributary basin where we investigated are to be carried out successfully we must set up a distribution system along with the essentials of the irrigation system and consolidate the fields where irrigation is possible, supply the necessary agricultural machines and tools, educate the farmers to become familiar with new and suitable seeds, seedlings, livestock and fowl and set up training centers to propagate better agricultural techniques. It will be necessary to supply the necessary funds, material and personnel to achieve these aims.

IV. International Aid

1. The purpose and the form of international aid[1]

The projects in the developing countries for the utilization of water resources depend on international aid largely in the form of funds and techniques.

International aid is given in various forms:

a. The form of international aid differs according to whether it is bilateral or multilateral. More than 90% of the aid extended to the developing countries throughout the world at present is bilateral. Cases of multilateral aid are extremely few.

b. International aid is often given as capital and/or technical aid. In some cases only technical aid is extended without capital (for instance, by Japan to Malaysia in growing Malinja, a new variety of rice). In general it can be said that technical aid without accompanying capital cannot be very effective.

c. There are two forms of capital aid. One is as a gift and the other a loan. The war indemnities Japan has paid to Southeast Asian countries are categorically gifts. Loans are generally made on long term bases at low interest rates and without securities. For instance, the World Bank helped Thailand largely with such loans.

There are many aspects to international aid. One is the obscureness of the purpose of the aid extended by the helping country; altruistic or not, the purpose is always obscure. In other words, the basic idea of the aid itself is not always clear. Some may say that the aid is for the benefit of the country concerned but in reality the aim may be the enlarging of the giver's own markets or it may be "insurance against Communism". There is further the question of the selection of the country where the aid can be used most effectively and also the difficult question of making the selection.[2]

The same applies to aid extended to water resource utilization projects. Whether the purpose of a project is altruistic or not, the helping country should take up a project whose effects can be felt. In making the selection it must be noted that the effects can be realized only when the aid is extended to a country that is politically stable. One of the reasons why, among the countries of Southeast Asia, much aid has been extended to Thailand lies in her political stability.

When the aid is extended in the form of a loan, the recipient country should first ask itself whether the water resource utilization project extended in such a form would in the long run pay off as a national expenditure. A miscalculation in this would cause much inconvenience to the national treasury and the foreign reserves of the country and compel it to groan under the heavy load of the loan. Thus the conditions and the effects of the loan must be

1) This is based on the report of Motooka, Takeshi of this symposium.

2) Myint, Hla, *The Economics of the Developing Countries*, London, 1964, pp. 181-183.

studied very carefully. However, in spite of its importance the countries of Southeast Asia tend to consider lightly the economic effects and the conditions of the loan.

When the aid is given as a gift, the recipient is apt to treat the economic effects lightly because it is a gift. These gifts and loans, moreover, tend to damage the morale of the recipient country and become the cause of graft and corruption. In observing the competition in the givers of aid in Southeast Asia, we should take notice of the fact that, relatively speaking, Japan has received little capital aid to develop her economy since the Meiji Restoration.

We have viewed in general various problems accompanying international aid and it is worth noting that in Japan's role in aid to the water resource utilization projects of Southeast Asia, there are many problems that need reconsideration, especially the following point that Japan is not in a position to extend foreign aid on such a large scale nor magnitude as the U. S. A., accordingly, she must emphasize technical aid, not capital aid. Fortunately it seems that there are more irrigation and drainage technicians in Japan than the country itself demands. Japan should make it her policy to supply such technicians regularly to Southeast Asian countries but she should not just ship them out. They should have the desired level of education and training to meet the varied conditions found in Southeast Asia. Knowledge of the local spoken language should be one of the requisites. The most effective way she can help Southeast Asian countries in developing their water resource utilization projects is by supplying efficient technicians the way Holland does, that is, by supplying agricultural technicians to developing countries as a part of her national policy.[3]

2. International aid for the Mekong project[4]

To illustrate how aid and cooperation are extended to a comprehensive development project, let us take that of the Mekong basin area as an example. Let us see briefly how the project came into being, what its basic conception was and what progress it has made so far. Let us see how Japan contributed her share and let it serve as an example to guide her technical cooperation in the future.

1. Process of development and international cooperation

In 1947 Economic Commission for Asia and the Far East (ECAFE) was set up under the jurisdiction of the Economic and Social Council of the United Nations.

In 1949 the Bureau of Flood Control was established as a subordinate organization, later renamed the Bureau of Flood Control and Water Resource Development in 1954 at the second water resource development meeting held

3) *i.e.*, the curriculum of the State University of Agriculture at Wageningen.

4) This owes much to Michitaro Sugawara, Kensaku Takeda and the report of Hiroshi Kimura in the ECAFE communication, No. 413, 1964.

under the auspices of ECAFE. Later it was renamed the Bureau of Water Resource Development.

At the seventh general assembly of ECAFE in 1951 the Bureau of Flood Control was requested, as a part of its economic and technical cooperation plan for the development of Asia, to study the technical problems involved in the development of international rivers. A proposal was made on this occasion to start on a comprehensive development project of the Mekong, an international river, and a plan was drawn up.

In 1955 a plan to develop the Lower Mekong Basin was made. ECAFE and the U. S. International Cooperation Agency (ICA) gave it active support. In the same year the U. S. Bureau of Reclamation conducted some field reconnaissance and reported results[5] that are still highly esteemed. In 1956, ECAFE undertook some field reconnaissance[6] throughout the Mekong basin in cooperation with the four countries through which the Mekong flows.

At the 13th general ECAFE meeting held in March, 1957, no more disputes were seen among the participating countries as there had been in the past. All the countries within and outside the area unanimously welcomed the plan officially drawn up and expressed their desire to see the large scale plan carried out. The four countries of the Mekong, Laos, Vietnam, Thailand and Cambodia, jointly expressed their desire to have further reconnaissance studies made to ascertain the potentials of the river's water supply for generating electric power, navigation, irrigation and drainage, flood control, etc. This meeting was significant in that it established an important precedent in the history of the development of the Mekong basin—a joint announcement made by the representatives of Japan, France and the U. S. A. of their promise to help in the Mekong basin development plan.

Later in May a meeting of the four Mekong countries recommended an establishment of a survey committee consisting of the representatives of the four Mekong countries and assisted by the United Nations. ECAFE made a concrete plan and in October, 1957, Committee for Coordination of Investigation of the Lower Mekong Basin (the so-called "Mekong Committee") was set up. The same year, responding to a request of the Mekong Committee the Technical Assistance Agency of the United Nations (UN/TAA) made a reconnaissance trip that covered the whole of the Lower Mekong Basin Area. It recommended in its report an outlay of $9.2 million for a 5-year survey plan, which the Committee adopted. This established the basic policy and the concrete method[7] for the Mekong basin development project.

With the cooperation of many countries a large part of the survey plan has now been completed. In it have been included the field investigations of the main tributaries, the setting up and operation of a hydrologic observatory network, the surveying and mapping of the river and potential arable land areas

5) U. S. Bureau of Reclamation, *Reconnaissance Report, Lower Mekong Basin*, 1956.
6) ECAFE, *Development of Water Resources in the Lower Mekong Basin*, 1957.
7) Wheeler, *et al.*, *Programme of Studies and Investigations for Comprehensive Development of the Lower Mekong Basin*, 1958.

Table II Development projects in mainstream and tributaries

Project	Investigation				Construction				Purposes, Scope of projects
	Cooperative countries	Contents	Expenses US	Remarks	Construction by		Expenses	Remarks	
Main stream Pa Mong (Thailand, Laos)	U.S.A. Australia Canada	General planning Geological survey Mapping	2,500,000	underway completed 〃					Irrigation; 1,000,000 ha Power 1,000,000 kw Flood control Navigation
Sambor (Cambodia)	Japan Australia Philippines Canada	General planning Geological survey Mapping 〃	515,000	underway completed 〃 〃					Power; 620,000 kw Irrigation; 160,000 ha Flood control Navigation Fishery resourses
Tonle Sap (Cambodia)	India France Philippines UNESCO IAEA[1] Mekong Commission	General planning Watergates Fishery Sediment Mapping Mathematic delta model Sedimentation Economic study on flooding	282,000 50,000	underway completed 〃 〃 underway completed underway					Fishery resourses conservation Flood control Saline damage prevention Navigation Irrigation
Tributaries Battambang (Cambodia)	SF[2] (Sogrehy[3])	General planning	195,000	completed	21,000,000				Irrigation; 68,000 ha Power; 31,500 kw
Prek Thnot (Cambodia)	Japan Israel	General planning Irrigation planning	61,000 50,000	completed 〃		France Australia Cambodia WFP[4]	800,000 760,510	$ 33mill. in loans design and control	Irrigation; 94,000 ha Power; 18,000 kw
Nam Ngum (Laos)	SF[2] (Nippon Koei Co. Ltd.) Japan	General planning Dam Power	83,600 140,000	completed 〃	27,000,000	Israel	50,000	in preparation	Power; 20,000 kw Irrigation; 5,000 ha Flood control Navigation
Lower Se Done (Laos)	France	General planning		completed	1,295,150	France Laos WFP[4]	591,000 163,200 508,000 32,150	loan gift	Power; 1,440 kw Establishment scheduled in 1968

Nam Dong (Laos)	France	General planning		completed	628,550	France Laos WFP[4]	326,500 142,900 138,700 20,450	loan gift	Power; 16,600 kw Completion in 1968
Nam Pong (Thailand)	SF[2] (Rogers International, U.S.A.)	General planning	195,000	completed	26,017,719	Germany Rep. China Thailand WFP[4]	12,650,000 40,000 13,057,369 270,350	loan 3% 20 years cement; 2000 tons	Power; 16,600 kw Irrigation; 22,000 ha Completion scheduled in 1965
Nam Pung (Thailand)	Japan	General planning	100,000	completed	5,129,850	Thailand Rep. China Israel WFP[4]	5,023,600 5,000 5,000 106,250	cement; 250 tons	Power; 7,000 kw Irrigation; 8,000 ha Completion in 1965
Lam Dom Noi (Thailand)	Thailand France	Dam Power station Soil survey		completed scheduled					Power; 10,000 kw Irrigation; 20,000 ha
Hue Bang Sai (Thailand)	Thailand	Reconnaissance		completed					Power; 5,000 kw Irrigation; 10,000 ha
Upper Se San (Vietnam)	SF[2] (Nippon Koei Co. Ltd.)	General planning	195,000	completed					Power; 640,000 kw Irrigation; 21,700 ha
Upper Srepok (Vietnam)	Japan	General planning	113,600 (untill now)	underway					Power; at Drayling \$ 2,750,000 Irrigation; in Darlac \$ 350,000 in Krong Buk \$ 3,900,000

1) International Atomic Energy Agency
2) UN/Special Fund
3) Société Grenobloise d'études et d'applications Hydrauliques, France
4) UN/World Food Programme

Table III Japan's investigation in the development of the Mekong area

Year	Investigation team	Period	Investigation area	Members	Dispatching agencies	Remarks
1958	First Reconnaissance Team on the Mekong Tributaries	13, Jan. 1959 ~ 12, Mar. 1959 (60 days)	Laos Thailand Cambodia Vietnam	18	OEISI[1)] IECA[2)]	Reconnaissance of 34 main tributaries, Advice 8 tributaries need to be developed as soon as possible
1959	*Second Reconnaissance* Team on the Mekong Tributaries	15, Dec. 1959 ~ 30, Mar. 1960 (105 days)	Laos Thailand Cambodia Vietnam	21	MCDSI[3)]	Reconnaissance of 16 tributaries, Advice to develop 7 tributaries first, Three of these were fully investigated and construction started (lower Se Done, Nam Pung, Prek Thnot) 1 project (lower Srepok) is now under investigation
1960	Third Reconnaissance Team on the Mekong Tributaries	10, Sept. 1960 ~ 21, Oct. 1960 (40 days)	Laos Thailand Cambodia Vietnam	12	MCDSI	Additional reconnaissance survey in the rainy season
(1962)	Nam Kam Investigation Team (First)	2, Oct. 1961 ~ *21, Oct. 1961* (20 days)	Nam Kam tributaries	4	MSI[4)]	Government of Thailand entrusted EPDA to design and supervise Nam Pong project
	(Second)	20, Dec. 1961 ~ 24, Mar. 1962 (95 days)		15	〃	Government of Thailand offered $5,000,000 (total project costs), construction started
	(Third)	5, Sept. 1962 ~ 12, Oct. 1962 (33 days)		6	〃	
(1961)	Prek Thnot Investigation Team	1, Oct. 1961 ~ 29, May 1962 (240 days)		13	MSI	Australian government accepted designing and supervising project, Cambodian government started construction
(1961)	Srepok Streamflow Gauging Team	Oct. 1961 ~ Sept. 1962 (1 year)	upper Srepok	15	MSI	Hydrological investigation
(1961)	Sambor Preliminary Investigation Team	18, Oct. 1961 ~ 1, Nov. 1961 (17 days)	upper Sambor	8	MSI	Preliminary investigation
	(Practical works)	1, Jan. 1962 ~ 28, Mar. 1962 (87 days)		3	〃	

(1962)	Sambor Preliminary Investigation Team	8, Sept. 1962 ~ 28, Sept. 1962 (21 days)				
1962	Sambor Investigation Team	13, Jan. 1963 ~ 28, Mar. 1963 (75 days)	upper Sambor	31	OTCA[5]	First year of main investigation Dams, power, power market, navigation and agricultural investigation
	(Additional)	24, Aug. 1963 ~ 11, Sept. 1963 (19 days)		2	〃	
1962	Srepok Agricultural Development Investigation Team	27, Dec. 1962 ~ 29, Mar. 1963 (93 days)	upper Srepok upper Darlac swamp	9	OTCA	Darlac swamp area development investigation (boring, soil survey, irrigation planning)
1963	Srepok (Krong Buk) Development Investigation Team	14, Nov. 1963 ~ 12, Feb. 1964 (91 days)	upper Srepok	6	OTCA	Investigated the upper Darlac swamp, Krong Buk, Krong Packe, etc. (irrigation planning)
1963	Sambor Investigation Team	27, Oct. 1963 ~ 10, Jan. 1964 (76 days)	Sambor main stream	25	OTCA	Dams and power (boring, model study of geology)
1964	Srepok (upper Krong Buk) Development Investigation Team	22, Mar. 1965 ~ 5, May 1965 (45 days)	uppermost Srepok	6	OTCA	Investigated upper Srepok (Krong Buk) on irrigation planning
1964	Sambor Investigation Team	6, Sept. 1964 ~ 15, Oct. 1964 (40 days)	Sambor mainstream	10	OTCA	Investigations including power market, agriculture, navigation, dams, fishing, power transmission, etc.
	(Third year)	7, Nov. 1964 ~ 8, Mar. 1965 (122 days)		23 (total 33)		

1) Overseas Electrical Industry Survey Institute
2) International Engineering Consultants Association
3) the Mekong Comprehensive Development Survey Institute
4) the Mekong Survey Institute
5) Overseas Technical Cooperation Agency

and a geological survey at each dam site. At its 20th meeting the Committee further adopted a "provisionary" second 5-year plan (1964-1968) which is now under way in research and construction.

An outstanding characteristic of the Mekong basin development project is the way international cooperation is being extended through the Mekong Committee. The four Mekong countries contain many different peoples and their political systems differ. Some have even severed diplomatic ties with others but the spirit they have in common is that of enthusiasm to see their countries progress economically and socially by utilizing the water resources of the great Mekong. This common goal has bound these countries together and made them cooperate with each other as far as the Mekong Committee is concerned, though political and diplomatic clashes did and do occur. From the very beginning ECAFE and other U. N. organs, the so-called "advanced" countries and the countries concerned have all contributed their utmost to cooperate and to help. The people concerned call this the "Mekong Spirit". That such activities are being carried out under the flag of the United Nations is indeed a fact well worthy of note. There are 21 countries that are helping present in addition to the 11 U. N. organizations, and the 3 foundations and other private companies. Aid extended as of November, 1965, in contributions and loans equals $67,765,793[8], which is

$27,143,814 for pre-investment exploratory planning
$40,621,979 for construction investments.

2. The Mekong Committee

The structure and organization of the Mekong Committee are shown in Table I.

3. Progress of the development project in the main stream area and its tributary areas is shown in Table II.

4. Aid from Japan

Japan's cooperation in the project began in 1955, before the Mekong Committee came into being, when she sent out a team to participate in ECAFE's reconnaissance trip. The "Comprehensive Reconnaissance Report on the Major Tributaries of the Lower Mekong Basin" made by the Japanese reconnaissance team that surveyed the main 34 tributaries and related main stream areas from 1956 to 1960 helped clarify the state of development of the whole Mekong basin area. It served as the basis on which concrete arrangements were made and carried out.

Since then Japanese teams of technicians have engaged in a pre-investment study of the Upper Se San Project in Vietnam under U. N. special funds, and under the funds of the Japanese government the Prek Thnot Project of Cambodia, the Nam Kam Project of Thailand and the Upper Srepok Project

8) For details, see Kimura, Hiroshi, "Outline of the Mekong Basin Development", *ECAFE communication*, No. 413, 1964.

Table I Development of water resources of the lower Mekong basin—Organization chart

- UNITED NATIONS ECONOMIC COMMISSION FOR ASIA AND THE FAR EAST
  EXECUTIVE SECRETARY
  Division of Water Resources Development
  Divisions of Industries, Transports and Communications, Administration, Information Services, Technical Assistance Unit
  ECAFE Secretariat is also Executing Agency for UN Special Fund/Mineral Surveys and Institutional Support Projects

- COMMITTEE FOR COORDINATION OF INVESTIGATIONS OF THE LOWER MEKONG BASIN
  (Cambodia, Laos, Thailand, Republic of Vietnam)
  Ad Hoc Sub-Committee
  EXECUTIVE AGENT
  Functions of Executive Agent: Day-to-day coordination of all component programmes and arrangement for new assistance

- ADVISORY BOARD

DIRECTOR OF NAVIGATION
- HYDROGRAPHER
- HYDROGRAPHER
- ASSISTANT HYDROGRAPHER

DIRECTOR OF ENGINEERING SERVICES (and MEMBER SECRETARY OF ADV. BOARD)
- CHIEF PLANNING OFFICER (and Chief of ECAFE Division of Water Resources Development)
- CHIEF HYDROMETEOROLOGIST
- ASSIST. HYDROMETEOROLOGIST
- ASSIST. HYDROMETEOROLOGIST
- DESIGN ADVISOR
- CONSTRUCTION ADVISOR
- HYDRAULIC ENGINEER
- LIAISON ENGINEER

DIRECTOR OF ECONOMIC AND SOCIAL STUDIES
- POWER AND INDUSTRY DEVELOPMENT ADVISOR
- AGRICULTURAL DEVELOPMENT OFFICER
- ASSIST. AGRICULTURAL DEVELOPMENT OFFICER

CHIEF, MEKONG ADMIN. SECTION (Outposted from ECAFE)
- LANGUAGES OFFICER
- PROCUREMENT OFFICER
- GENERAL SERVICES OFFICER
- LIBRARIAN (and ECAFE LIBRARIAN)

Component Programmes

BASIC DATA COLLECTION
- Mapping and Levelling
- Tributaries reconnaissance
- Hydrology

BASIN PLANNING
- Amplification of basin plan
- System analysis
- Mathematical delta model
- Physical model
- Project area preliminary mapping

MAINSTREAM PROJECT
- Pa Mong
- Sambor
- Tonle Sap

TRIBUTARIES PROJECTS
- Battambang (Cambodia)
- Prek Thnot (Cambodia)
- Stung Pursat (Cambodia)
- Stung Sen (Cambodia)
- Nam Ngum (Laos)
- Nam Dong (Laos)
- Lower Se Done (Laos)
- Upper Se Done (Laos)
- Nam Theun (Laos)
- Nam Pong (Thailand)
- Nam Pung (Thailand)
- Lam Dom Noi (Thailand)
- Hue Bang Sai (Thailand)
- Upper Se San (Vietnam)
- Upper Srepok Darlac (Vietnam)
- Drayling and Krong Buk (Vietnam)

NAVIGATION IMPROVEMENT PROJECTS
- Hydrographic survey
- Channel marking
- Channel improvement
- Port improvement
- Shipyard improvement
- Craft improvement
- Pilots
- Bridges
- Liaison with mainstream project planning teams
- Comprehensive transport studies
- Admin. and customs collection improvement

ANCILLARY PROJECTS
- Pilot, experimental and demonstration farms
- Study of possible flood warning system
- Mineral survey in NE Thailand and Laos
- Bauxite prospecting
- Mineral survey in Cambodia and Laos
- Power market survey: domestic
- Power market survey: global
- Power market survey: regional
- Geological map reproduction
- Pulp and paper industry survey
- Public health studies
- Anthropological and archeological studies
- Documentary film records
- Natural and social resources inventories
- Comprehensive agricultural planning
- Examination of juridical and related aspects of international administration of proposed projects

TRAINING PROJECTS
- In-service training at Committee's HQ
- In-service training in component projects
- Courses, seminars, conferences, etc.

SUPPLY PROGRAMMES
(Apart from considerable supplies contained in other component project)
- Petroleum products
- Cement
- Hydrologic network, spareparts and replacemetns
- Food
- Miscellaneous

Table IV Experts and technicians dispatched to Southeast Asian countries

Countries	Individual																Centers*						Investigation					Sum total
	Rice culture																Staff			Preparation								
	Cultivation	Pests and Fertilizer	Soil science	Total	Upland cultivation	Horticulture	Sericulture	Animal husbandry	Fishing	Forestry	Irrigation and Drainage	Agric. machinery	Food science	Statistics	Others	Total	Agriculture	Fishing	Total	Agriculture	Fishing	Total	Agriculture	Fishing	Forestry	Others	Total	
Burma	(1)	(0)	(0)	1	4	—	23	3	—	—	1	—	3	—	—	35	—	—	—	14	—	14	—	—	—	—	—	49
Cambodia	(1)	(0)	(0)	1	—	1	—	8	—	—	1	1	—	—	1	13	32	—	32	8	—	8	5	—	5	10	20	73
Indonesia	(4)	(0)	(0)	4	—	—	—	—	—	—	—	—	—	1	1	6	—	—	—	—	—	—	—	—	1	—	1	7
Laos	(0)	(0)	(0)	—	—	—	1	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	3	—	—	—	3	4
Malaysia	(16)	(2)	(1)	19	—	—	—	—	4	—	—	—	—	2	4	29	—	—	—	—	—	—	3	—	—	—	3	32
Pakistan	(29)	(0)	(0)	29	—	—	—	—	9	1	4	—	—	—	1	44	13	—	13	3	—	3	6	—	—	—	6	66
East Pakistan	20	0	0	20	—	—	2	—	7	0	4	—	—	—	1	34	—	—	16	—	—	16	4	—	—	—	4	54
Philippines	(0)	(0)	(0)	—	—	—	—	—	3	—	—	—	—	—	1	4	—	—	—	—	—	—	—	5	—	1	6	10
Thailand	(2)	(0)	(1)	3	3	—	2	4	6	—	—	—	—	2	5	25	—	—	—	—	—	—	6	16	—	16	38	63
Vietnam	(2)	(0)	(2)	4	—	1	1	1	10	3	—	—	4	—	2	26	—	—	—	—	—	—	—	—	1	—	1	27
Total	55	2	4	61	7	2	27	16	32	4	6	1	7	5	15	183	45	0	45	25	0	70	23	21	7	27	78	351

Note: Concerning water resource development in individual case, 7 persons.
Water resource development in survey, 30 persons.
* Centers set up under joint agreements (see p. 46).

of Vietnam. Since 1961 a pre-investment study of the Sambor Project of the Mekong main stream area was conducted and hydrologic studies made chiefly in the main stream area and its development project is now in the stage of pre-investment investigation, while for some parts of the tributary areas the pre-investment studies have been completed, feasibility reports sent in and the construction stage is approaching.

Japan has given technical aid mainly in the field of civil engineering since 1958. In the field of investigation she ranks after the U. S. A., Canada and France.

The results of the Japanese investigation of the Mekong basin development project are shown in Table III.

3. Japan's technical cooperation in agriculture, forestry and fisheries[9]

Twelve years have passed since 1953 when Japan started on the government sponsored overseas technical cooperation program, which is both bilateral and multilateral. The multilateral aspects are being carried out through the United Nations.

Her technical cooperation in the fields of agriculture, forestry and fisheries was made possible mainly by funds provided by the overseas technical cooperation budget of the Ministry of Foreign Affairs and was carried out in cooperation with the Overseas Technical Cooperation Agency. It involved the setting up and operation of the Overseas Technical Cooperation Center, the dispatchment of experts and the receiving of trainees and observers from abroad. We shall see how Japan cooperated technically in the fields of agriculture, forestry and fisheries with these Southeast Asian countries, especially in the field of water resource utilization, the theme of this symposium.

1. Experts sent to Southeast Asia, the countries and fields

Table IV shows that Cambodia, Thailand, Burma and East Pakistan took the majority. Rice culture was outstanding, followed by fisheries and sericulture.

2. Trainees received from abroad, the countries and the fields

Table V shows that Thailand, the Philippines and Indonesia were outstanding. Nearly half of the trainees engaged themselves in a short term study of agricultural administration. Quite a few took up agricultural techniques (rice culture), fisheries and animal husbandry.

3. Overseas Technical Cooperation Centers of agriculture, forestry and fisheries

These centers were set up under joint agreements concluded between the Japanese government and the Southeast Asian country concerned. In

9) This was written by Inoue, Yoshimaru.

Table V Trainees from Southeast Asian countries

Countries	Agricultural techniques	Agricultural administration and economics	Animal husbandry	Sericulture	Food science	Agricultural engineering	Forestry	Fishing	Total
Burma	8	46	12	3	4	—	3	10	86
Cambodia	4	81	23	—	—	—	7	2	117
Indonesia	36	62	10	2	2	6	17	70	205
Malaysia	17	56	—	—	—	—	2	14	89
Pakistan	13	35	2	5	1	4	2	14	76
Philippines	43	104	11	—	2	—	34	32	226
Thailand	81	104	46	2	4	3	19	50	309
Vietnam	4	55	24	1	3	1	4	23	115
Total	206	543	128	13	16	14	88	215	1223

Table VI Experts dispatched to Southeast Asian countries on irrigation and drainage

	Year	Members
Mekong development investigation	1958	1
〃	1959	5
〃	1961	6
〃	1962	2
〃	1964	7
Irrigation investigation in Burma	1958	1
〃	1961	4
Irrigation investigation in Cambodia	1963	3
Development investigation in delta area in Southeast Asia	1962	2
Irrigation project investigation in Pakistan	1961	4
Irrigation project investigation in Afghanistan	1959	2
Total	—	37

greater Southeast Asia were set up the Cambodian Agricultural Technical Center, the Cambodian Animal Husbandry Center, the Ceylonese Fishery Training Center, the Indian Fishery Processing & Training Center, eight Indian Model Farms and the East Pakistani Agricultural Training Center.

4. Experts sent to cooperate in irrigation and drainage development projects

Table VI shows experts that were dispatched to cooperate only in government sponsored technical cooperation projects (excluding the economic cooperation projects that will be referred to immediately following) and were mostly sent to the Mekong basin.

Table VII Economic and technical aid through Japanese government

Countries	Funds	Project	Contents	Cost ($1,000)	Remarks
Burma	Reparations	Baruchan power station	Machine, construction	28, 858	
Indonesia	Reparations	Kalibrantas project	Investigation, labor, construction materials	19, 738	2 dams, irrigation and drainage, power, flood control
		Rian Kanan project	Investigation, labor, construction materials	4, 608	1 dam, irrigation, power, flood control
		Bengawan Solo Project	Investigation, design	247	Flood control, irrigation
		Power development project in West-Sumatra	Investigation, design	113	Power
Laos	Gift	Waterworks in Vientiane	Design, construction materials, labor	1,683	
	〃	Nam Ngum project	Investigation, design	138	Multi-purpose
	〃	Vientiane power station	Setting machines, construction	708	
Philippines	Reparations	Pump	Equipment parts	155	Motors, volute pumps,
	〃	Malikina dam	Investigation, design	500	Irrigation, power, flood control
	〃	Irrigation pump	Equipment parts	997	
Thailand	Special Yen funds	Nam Pung project	Planning, supervision, machines	661	Irrigation, power
Vietnam	Reparations	Da Nhim power station	Design, construction, machines	27, 633	
	Loan	〃	Equipment parts	7, 500	Machines for power station
	Reparations	Fanran irrigation project	Investigation, design	205	
		Lania irrigation project	Investigation, design	161	
		Diesel engine	Machines	400	Irrigation use (427)

5. Economic aid extended to the water resource development projects based on Japanese war reparations, etc.

Table VII shows the various projects that the Japanese government undertook as reparations or as collateral for the rights of reparations renounced.

This is how the Japanese government has extended technical cooperation so far.

We find in retrospect that the following points should be considered when future projects are carried out.

a. Japanese aid has been generally passive and spontaneous in nature but in the future it should be more methodical and concentrated. For example, when Japan extended technical aid to irrigation development projects, she gave little thought to the connections it has with management guidance programs.

b. She should promote technical cooperation in closer connection with financial aid. This is all the more desired, for it is Japan's duty, even though it may not be requested by Development Assistance Committee (DAC) and United Nations Conference on Trade and Development (UNCTAD), to increase financial aid to these developing countries in the future.

c. She should extend technical cooperation in closer relation with financial aid that will be given not only by the Japanese government but also by other international monetary agencies such as the World Bank, the Second World Bank, and the Asia Development Bank that is scheduled to commence operation in 1966.

HYDROLOGIC AND METEOROLOGICAL CHARACTERISTICS

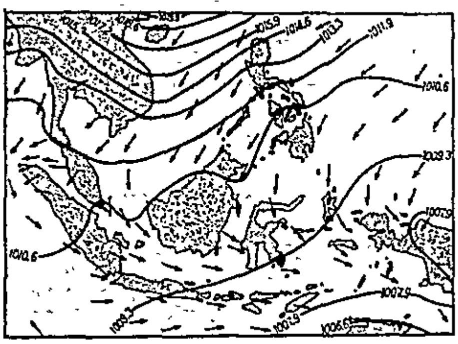
I. An Outline of Climate of Southeast Asia[1)]

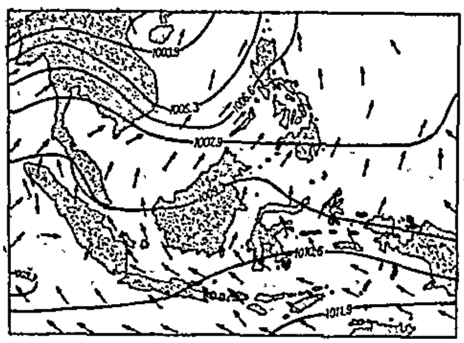
Southeast Asia fronts the continent of Asia at its northwest border, and confronts the continent of Australia beyond its southeast border, the Pacific Ocean at the northeast and the Indian Ocean at its eastern border. All kinds of climatic patterns exist in Southeast Asia which differ largely from region to region. These climatic patterns may be broughly classified as:

a. The equatorial climate area
b. The sub-equatorial climate area
c. The savannah area
d. The equatorial highlands.

Let us run briefly over the system of the winds, the precipitation and its seasonal changes, and temperatures throughout the year.

1. System of winds





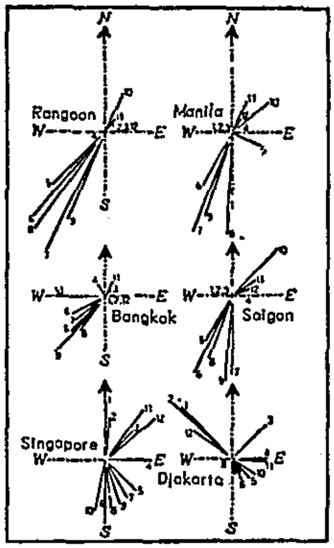


Fig. 1 Isobaric lines (mb.) and wind direction, January
Fig. 2 Isobaric lines (mb.) and wind direction, July
Fig. 3 Relationship between monthly precipitation and the direction of monsoon winds

1) This report has been especially written by editor for the convenience of readers. This owes much to Hatakeyama, Hisanao, *The Climate of Asia*, Kokin shoin, Tokyo, 1964.

Southeast Asia lies in the center of the most typical tropical monsoon area. In discussing the climate of this area we cannot disregard the monsoon since, India included, the rainfall characteristics as well as temperatures in each district are very much affected by the monsoon, especially by its seasonal changes.

Figs. 1 and 2 show the isobaric lines and the direction of the winds in January and July, respectively, and Fig. 3 the correlations between rainfall and the direction of the monsoon in some representative cities.

2. Precipitation and temperature

The precipitation is influenced largely both by the monsoon and the intercepting terrain. As we see in Fig. 4, Southeast Asia is one of the areas of heaviest rainfall in the world, averaging more than 2,000 mm per annum. In some places it exceeds 6,000 mm. Areas where there is little rainfall are found in the northern part of Burma, the central and the northeastern parts of Thailand and in the upstream and midstream areas of the Mekong. These regions lie in the so-called "rain shadow" areas—where topographically the intercepting terrain cuts the monsoon short in its path. However, what is important in carrying out water resource development projects in Southeast Asia is to take into consideration the striking differences of precipitation that exist between the rainy and the dry seasons in almost the entire area and to find the best means possible to deal with the characteristics of the natural surroundings of this monsoon area.

The patterns of seasonal distribution of rainfall may be put in four cate-

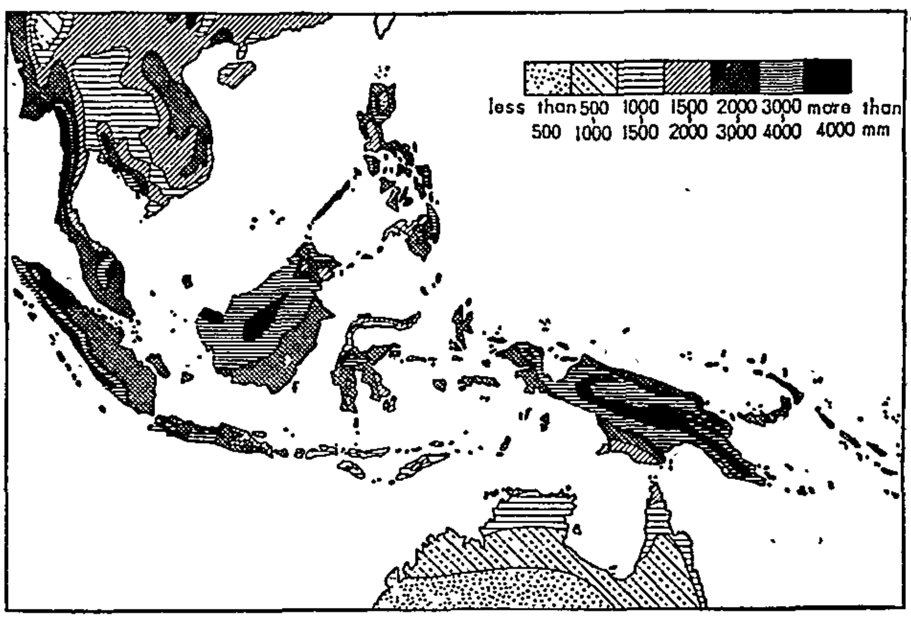


Fig. 4 Distribution of annual precipitation in Southeast Asia

Table I Monthly mean temperature and mean precipitation at some stations in Southeast Asia

Station	N E		Jan.	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean and Total	Period
Saigon (Vietnam)	10°47′	temp.	25.8	26.3	27.8	28.8	28.2	27.4	27.1	27.1	26.7	26.5	26.1	25.7	27.0	51–60 (10)
	106°42′	rain.	6	13	12	65	196	285	242	277	292	259	122	37	1808	51–60 (10)
Hanoi (Vietnam)	21°30′	temp.	15.6	17.2	19.4	23.5	27.3	28.9	28.5	28.5	27.1	24.4	21.4	18.2	23.3	
	105°52′	rain.	18	29	39	79	193	234	322	333	248	116	44	18	1673	
Phnom Penh (Cambodia)	11°33′	temp.	26.1	27.5	28.9	29.4	28.8	28.1	27.6	27.7	27.3	27.2	26.7	25.4	27.6	31–60 (30)
	104°51′	rain.	9	8	28	73	146	129	129	147	231	250	134	36	1320	31–60 (30)
Savannakhet (Laos)	16°33′	temp.	21.3	24.1	27.2	28.9	28.3	27.9	27.3	27.1	26.6	25.3	26.7	21.1	25.9	51–60 (10)
	104°45′	rain.	6	18	22	93	171	247	239	324	278	59	3	0	1406	51–60 (10)
Vientiane (Laos)	17°57′	temp.	21.5	23.8	26.7	28.8	28.4	28.1	27.7	27.4	27.1	26.4	24.4	21.4	25.9	51–60 (10)
	102°34′	rain.	51	14	25	78	209	260	259	354	399	50	14	1	1714	51–60 (10)
Bangkok (Thailand)	13°44′	temp.	26.1	27.6	29.2	30.3	29.8	28.9	28.4	28.2	27.9	27.6	26.7	25.5	28.0	51–60 (10)
	100°30′	rain.	9	29	34	89	166	171	178	191	306	255	57	7	1492	31–60 (30)
Chiangmai (Thailand)	18°47′	temp.	21.3	23.1	23.4	29.0	28.8	27.9	27.4	27.0	26.8	26.2	24.4	21.5	25.6	51–60 (10)
	98°59′	rain.	7	12	15	49	144	146	188	231	289	126	39	10	1254	31–60 (10)
Nakhon-Ratchasima (Thailand)	14°58′	temp.	23.4	26.5	28.8	30.0	29.5	28.7	28.2	27.9	27.4	26.2	24.3	22.5	27 0	51–60 (10)
	102°07′	rain.	7	33	45	83	157	111	132	139	244	171	37	3	1162	31–60 (30)
Rangoon (Burma)	16°46′	temp.	24.3	25.2	27.2	29.8	29.5	27.8	27.6	27.1	27.6	28.3	27.7	25.0	27.3	51–60 (10)
	96°10′	rain.	8	5	6	17	260	524	492	574	398	208	34	3	2530	51–60 (10)
Mandalay (Burma)	21°59′	temp.	20.2	23.0	27.5	31.8	30.9	29.6	29.5	28.6	28.8	28.1	25.1	22.2	27.1	51–60 (10)
	96°06′	rain.	3	0	16	14	151	110	77	99	127	152	25	2	776	51–60 (10)
Kuala Trengganu (Malaysia)	5°20′	temp.	26.7	27.4	27.7	27.8	27.9	27.4	27.1	27.4	27.0	27.0	27.0	26.7	27.2	24–36
	103°08′	rain.	292	163	160	155	135	109	117	147	191	279	610	554	2912	24–41 (15)
Labuan (Malaysia)	5°17′	temp.	27.2	27.2	27.5	28.0	28.0	27.8	28.1	27.8	27.5	27.5	27.5	27.2	27.5	16–54 (21)
	115°16′	rain.	112	117	150	297	345	351	318	297	417	465	419	285	3573	16–54 (14)
Singapore	1°18′	temp.	26.1	26.7	27.2	27.6	27.8	28.0	27.4	27.3	27.3	27.2	26.7	26.3	27.1	51–60 (10)
	103°50′	rain.	285	164	154	160	101	127	183	230	102	184	236	306	2282	51–60 (10)
Jakarta (Indonesia)	6°11′	temp.	25.9	25.9	26.3	26.4	26.9	26.6	26.5	26.7	27.0	27.0	26.7	26.2	26.6	11–40
	106°50′	rain.	300	300	211	147	114	97	64	43	66	112	142	203	1799	64–45 (28)
Balikpapan (Indonesia)	S 1°17′	temp.	26.1	26.4	26.4	26.1	26.4	26.1	25.6	26.1	26.1	26.4	26.1	26.1	26.1	(6)
	116°51′	rain.	201	175	231	208	231	193	180	163	140	132	168	206	2228	(43)
Manila (Philippine)	14°31′	temp.	25.4	26.1	27.2	28.9	29.4	28.5	27.9	27.4	27.4	27.2	26.4	25.4	27.3	51–60 (10)
	121°00′	rain.	18	7	6	24	110	236	253	480	271	201	129	56	1791	51–60 (10)
Chittagong (E. Pakistan)	22°21′	temp.	19.9	23.6	25.6	27.7	28.3	27.8	27.5	27.6	27.8	27.3	24.1	20.7	25.7	31–60 (30)
	91°50′	rain.	10	23	58	116	285	507	642	572	344	228	56	17	2858	31–60 (30)

gories.

a. The areas where there is much rainfall throughout the year
b. The areas where maximum rainfalls are seen twice a year
c. The areas where the rainy and the dry season are markedly distinguishable
d. The areas where the rainy season comes in autumn or winter

In general, these patterns spread northward from the equator in the pattern order of "a", "b", then into "c" or "d".

Figs. 5 & 6 show the isothermal lines of January and July respectively, and Table I the monthly average precipitation and temperatures in representative cities.

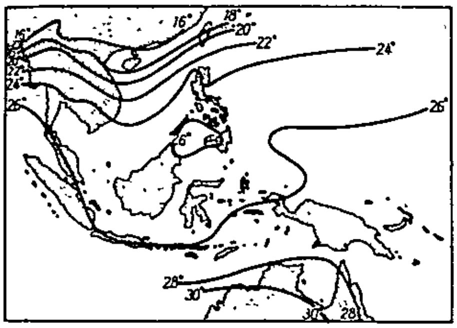


Fig. 5 Isothermal lines (°C), January

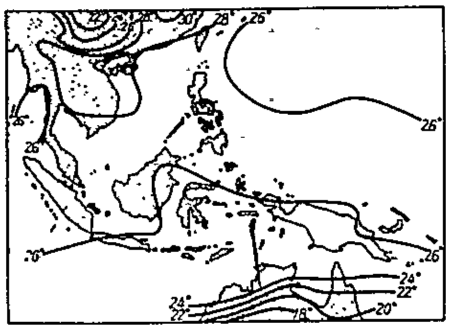


Fig. 6 Isothermal lines (°C), July

II. A Hydrologic Study of the Mekong Basin

Toshio TAKENOUCHI

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In 1960 the writer was a member of the Third Mekong Basin Reconnaissance Team and for 42 days investigated mainly the floods in the rainy season in Cambodia. Though there had been a striking lack of data on the hydrology of the Mekong basin, investigations in these areas have progressed fairly well with the help of U.S. experts. These last few years accurate data have been assembled and the hydrologic characteristics of the basin have been increasingly clarified. Analysis of the hydrologic state of the basin was begun using an electronic computer with the readily available data.

1. Hydrologic data

The lower Mekong basin sprawls across four countries. So far, each country has engaged in separate hydrologic studies. Our reconnaissance team made a round of various government agencies of these countries to collect data and found available data only sectional and separate although the meteorological phenomena overlap. So, there seemed to be no data available as a whole on the meteorological characteristics of the Mekong basin. There were available some data relating to water level but none had been done systematically regarding the discharge of the Mekong main stream except those that were obtained in 1948-1949 at Phnom Penh.[1)]

When ECAFE started on the water resource development project of the Mekong basin, what was most lacking was sufficient data concerning the hydrology of the basin. In this respect several countries offered aid and cooperated: Canada and the U.S.A. set up bench marks for measuring discharge, France supplied the instruments necessary to measure the water discharge and the sand discharge, Iran supplied oil, New Zealand supplied boats to observe the water discharge, Britain supplied evaporation pans, etc.

The U.S.A. took special charge of the hydrologic observation plan of the basin[2)] and assigned the Harza Engineering Company to supervise the field survey: performing such tasks as the collecting and compiling of the data concerning water discharge, sand discharge, water temperature, precipitation, evaporation and wind velocity, etc. The project involved a period of 5 years, from 1958 to 1962. The first two years were set aside as the preparatory

1) ECAFE, "Development of Water Resources in the Lower Mekong Basin," *Flood Control Series*, No. 12, Japanese translation, *Data of the Natural Resources Bureau, Board of Science and Technique*, No. 19, 1959.

2) Harza Engineering Company, *Final Report, Lower Mekong River Project*, 1962.

Table I Number of hydrological gauging stations

Country	Rain	Streamflow gauging station
Cambodia	22	9
Laos	6	13
Thailand	15	9
Vietnam	15	3

period to set up general facilities and provide for general training. In 1960 the plan was put into effect and the data observed and collected were published.[3] Table I shows the number of the observatory stations in 1961. The Harza Engineering Company adopted for observation the standard method widely in use in the U.S.A. and the company deserves much credit in having left a consistent observation system there which is now used by the countries involved. Technicians that were dispatched for this purpose by their respective governments were employed by the Harza Engineering Company and given training, which enabled them to carry on the observation when Harza withdrew two years later. The data of this 2-year period have already been published.[4] The latest distribution of the observatory stations is shown in the map of the Mekong River basin in the appendix.

2. Observations on the data

1. Precipitation

A small mountain range stands to the west of the Lower Mekong basin and a larger one to the east, and these intercept the monsoons that blow in southwest from the Gulf of Thailand. The distribution of annual precipitation over the basin, as shown in Fig. 1, is largely influenced by the terrain.

This gives us a picture of the rainfall distribution in this area. To set up a plan to develop the water resources of the tributary areas, further detailed investigations will be necessary. Fig. 1 shows heavy rainfall areas near the borders of Laos and Thailand. It is a highland and it is a matter of great interest to find out the extent of this heavy rainfall area. It is easily discernible on the map that the Laotian area east of the Mekong forms the largest source of water supply. It, therefore, is necessary to study further the characteristics of the rainfall in this area.

A large part of the annual precipitation is in the rainy season (in May-October). If we are to learn about the mechanism of this rainfall we shall have to study it over a shorter period. I studied daily rainfall distribution maps and tried to guess how the center of the rainfall area would shift during the rainy season. It was a complicated job and an accurate trend could not be worked out using the figures the observatory network could then supply.

3) *Hydrologic Data, Mekong River Basin,* 1960, 1961.
4) *Lower Mekong Hydrologic Yearbook,* 1962, 1963.

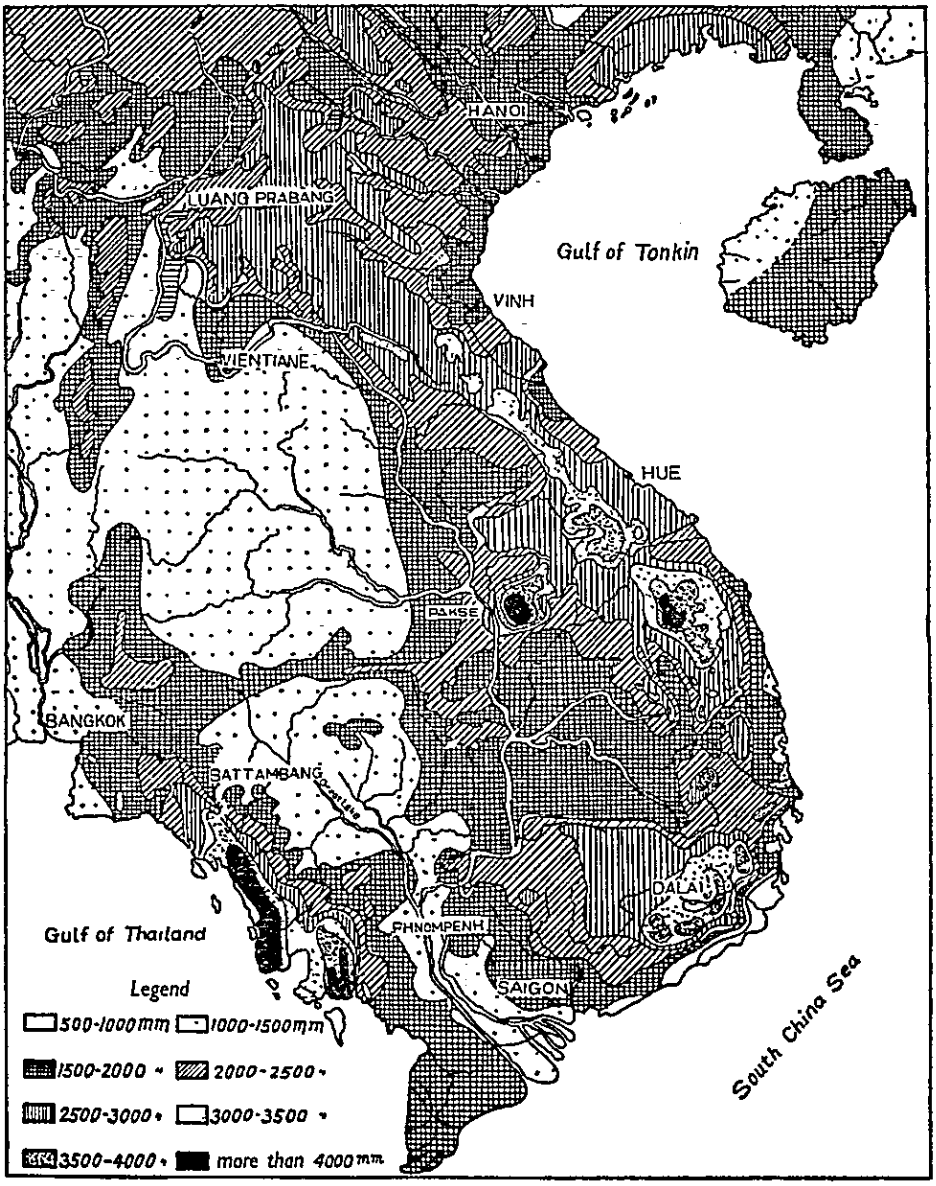

Fig. 1 Distribution of annual precipitation in the lower Mekong basin area

The annual precipitation and its seasonal variations are important requisites to understand the characteristics of rainfall in this area. I studied data[5] on the annual precipitation in Cambodia to find out the standard deviation of the variation rate and derived 12-19%.

2. Discharge

(1) Hydrograph of the main stream discharge

Let us take a look at the data collected over a period of four years (since 1960) when the discharge measurements in the Mekong basin began regularly and systematically. Table II shows the maximum and the minimum discharge observed during these four years at observatory stations that lie along the main stream of the Mekong from Laos to Cambodia. Fig. 2 is the hydrographs of the daily discharge. Let us see how the maximum discharge stands. The

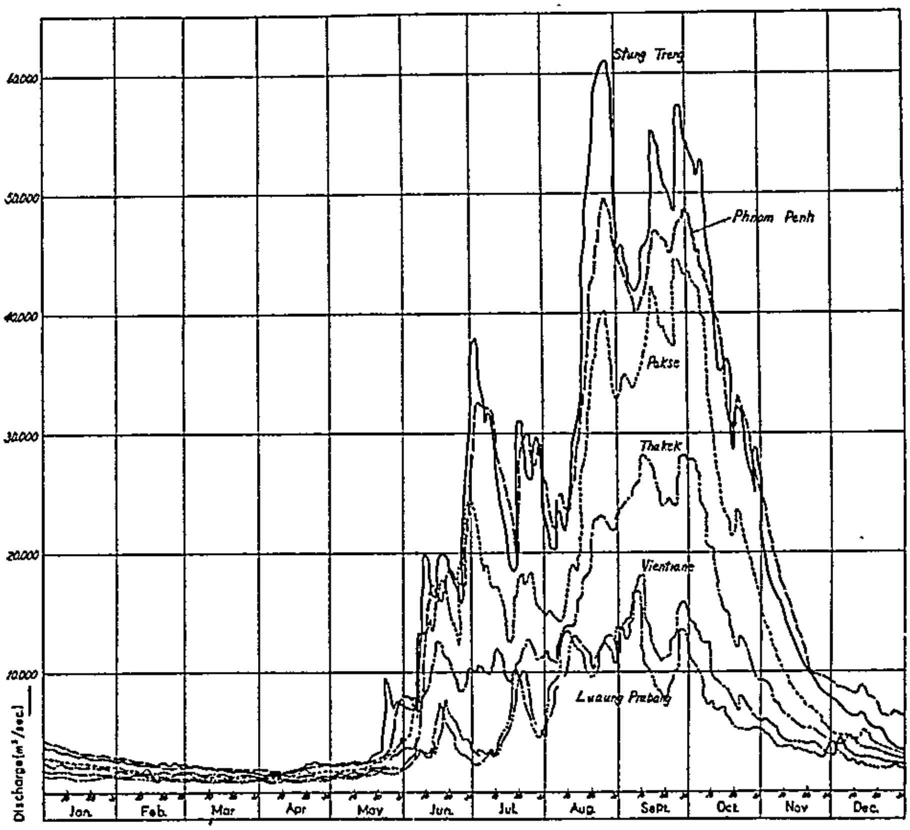

Fig. 2 Hydrograph of the Mekong main stream (1961)

hydrograph at Luang Prabang in the upstream area is very similar to that obtained at Vientiane, and there are no large tributaries joining the main stream between these two points. The peak discharge at Thakhek is twice

5) Shiraishi, Daikichi, *Data on the Annual Precipitation in Cambodia.*

Table II Annual minimum and maximum discharge of the Mekong

Station	Minimum discharge (m³/sec)								Maximum discharge (m³/sec)								Distance between two sections (km)
	1960		1961		1962		1963		1960		1961		1962		1963		
	Date	Dis-charge	Date	Dis-charge	Date	Dis-charge	Date	Dis-charge	Date	Dis-charge	Date	Dis-charge	Date	Dis-charge	Date	Dis-charge	
Chiang Saen			2–28 3-3∼4	674	3–26 ∼27	637	3–29 ∼30	574	8–10	10,700	8–9	10,500	8–21 ∼22	11,700	8–9	9,480	
Luang Prabang	4–24 ,25	880	3–24 ∼25	1,000	4–7	1,010	4–2	976	8–18	18,300	9–8	17,000	8–23	16,000	7–26	16,200	
Vientiane	4–28	815	3–25 ∼28	1,040	3–29	1,070	4–6	920	8–20	18,200	9–10	18,300	8–26	15,400	8–11	15,800	426
Thakhek	5–3	943	3–30	1,260	4–16	1,320	4–28 ∼5–3	1,190	8–24	31,700	9–12, 28∼30	28,200	9–10	19,800	7–29	30,800	368
Mukdahan	5–3	970	4–2	1,290	4–15	1,310	5–2	1,190	8–24 ∼25	34,500	9–30	31,100	9–6	23,000	8–13	36,000	90
Pakse	4–12, 5–4∼7	1,060	4–1 ∼3	1,360	4–7	1,380	4–14	1,160	8–25	42,200	9–27	44,700	8–7	34,800	8–12	39,500	
Ban Chan Noi			4–4	1,360	4–6,8	1,490	4–14	1,240	8–26	42,100	9–28	45,600	8–7 ∼8	36,100	8–12	41,700	
Stung Treng	4–12	1,250	4–7 ∼9	1,670	4–8 ∼14	2,030	5–5	1,580	8–26	54,600	8–27	61,300	8–8	52,320	8–13	53,390	
Kratie	4–17	1,250	4–8 ∼10	1,680	4–10 ∼12	2,030	5–7	1,600	8–27	53,200	8–27	62,400	8–9	50,100	8–14	50,840	133
Phnom Penh	4–18	1,250	4–13 ∼15	1,680	4–14 ∼15	2,030	5–11	1,600	8–29	43,300	8–28	49,700	8–13	44,200	8–16 ∼17	43,300	215

Table III Annual discharge and height of runoff in the main stream and main tributaries of the Mekong

Section in main stream		Catchment area 10km²	1960 Annual discharge		1961 Annual discharge		1962 Annual discharge		1963 Annual discharge	
			$10^9 m^3$	mm	$10^9 m^3$	mm	$10^9 m^3$	mm	$10^9 m^3$	mm
Luang Prabang – Vientiane	Average discharge between two sections	31.0	12.0	387	15.0	484	10.0	323	13.0	419
	Main tributary·Nam Khan at Ban Mout	6.1			3.06	502	2.79	457	5.23	857
Vientiane – Thakhek	Average discharge between two sections	74.0	95.0	1,248	106.0	1,432	74.0	1,000	110.0	1,486
	Main tributary·Nam Ngum at Tha Ngon	16.5					17.9	1,085	24.1	1,461
Thakhek – Mukdahan	Average discharge between two sections	18.0	14.0	778	25.0	1,389	25.0	1,389	2.9	1,611
	Main tributary·Se Ban Fai at Se Ban Fai	8.56			21.6	2,523			19.7	2,301
	Nam Pung at Dam Site	0.297							0.102	343
	Huai Bang Sai at Ban Kham Plaloi	1.24					0.686	553	0.585	472
Mukdahan – Pakse	Average discharge between two sections	154.0	53.0	344	101.0	656	85.0	552	41.0	266
	Main tributary · Se Bang Hieng at B. Keng Done	19.4			30.5	1,572	18.2	938	20.5	1,057
	Nam Pong at Pong Neeb	12.0							2.45	204
	Nam Chi at Yasotorn	43.1	7.59	176	9.15	212	11.7	271	8.90	206
	Nam Mune at Ubon	104.0	20.3	195	23.8	229	29.6	285	18.1	174
	Lam Dom Yai at Dej Udom	3.34							0.933	279
	Lam Dom Noi at Sae Falls	2.06			1.57	762	2.12	1,029	1.31	636
	Se Done at Ban Nanay	6.17			10.8	1,750	3.71	601		
Pakse – Stung Treng	Average discharge between two sections	90.0	128.0	1,422	150.0	1,667	134.0	1,489	105.0	1,167
	Main tributary·Se Kong at Ban Khmuon	29.6					47.3	1,598	40.7	1,375
	Se San at Ban Komphum	48.2					54.3	1,127	35.1	728

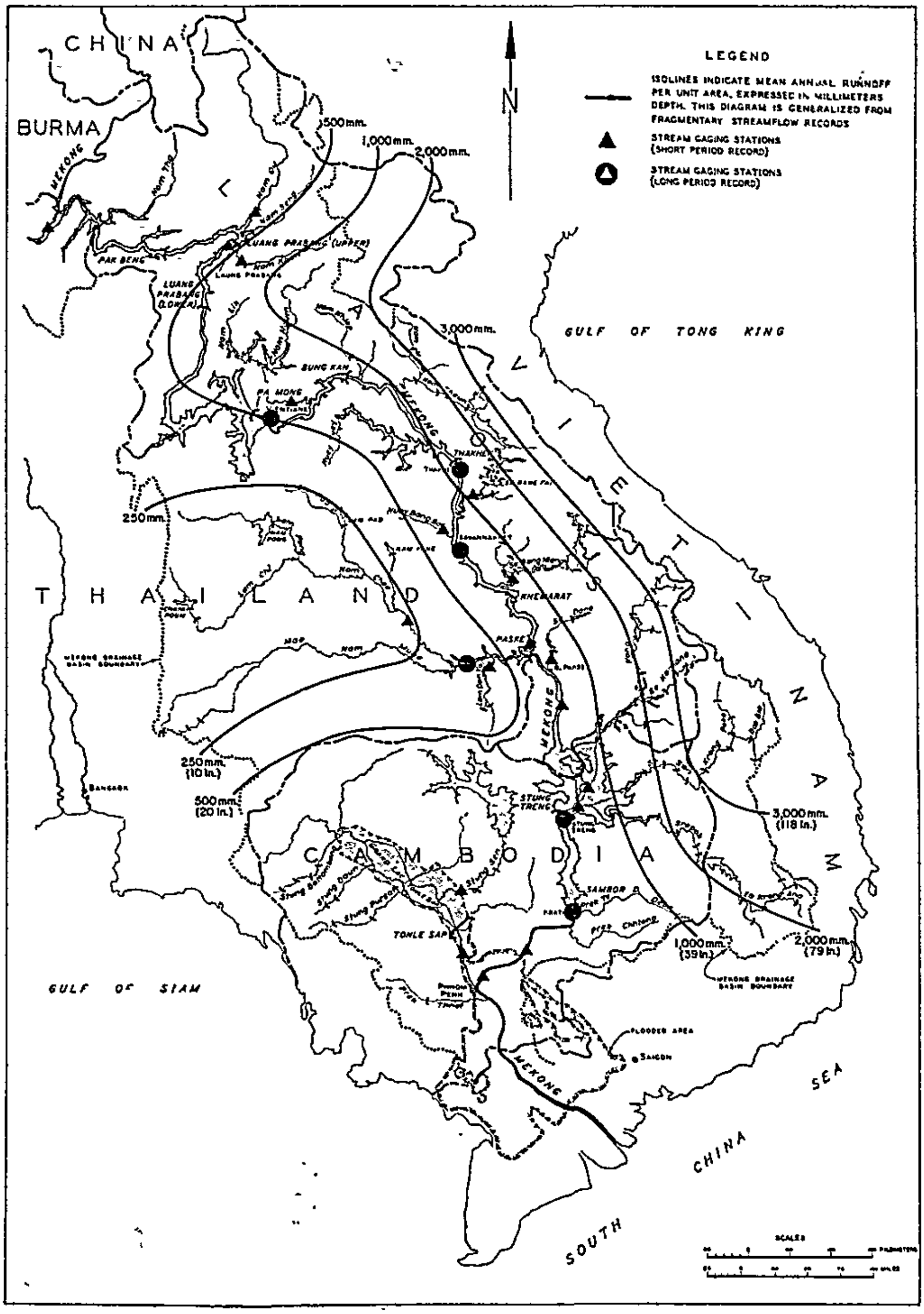

Fig. 3 Distribution of the annual height of runoff of the Mekong basin

that of Vientiane. That the peak discharge of the Mekong main sream at the end of August starts to appear between Thakhek and Pakse and the peak reaches the maximum between Pakse and Stung Treng shows that the aggregate discharge of the tributaries of these areas controls the discharge of the downstream area. The main tributaries are the Se Kong and the Se San and the peak discharge is reached 24 hours after there is a maximum rainfall here. By setting back the hydrograph at Ban Chan Noi by one day and by adding to it the hydrographs of these two tributaries, we obtain the hydrograph that represents the conditions around Stung Treng. That the peak discharge at Phnom Penh is found to be a little less than that at Stung Treng is due to the floods and the back-flow of the water of this section into Lake Tonle Sap.

(2) The annual runoff

Table III shows the annual runoff (m^3) and annual runoff height (mm) obtained by dividing the annual runoff by the corresponding catchment area along the main stream as shown in Table II. The effect of these tributaries are reflected in the annual runoff and the annual runoff height, that indicate the overall volume and runoff intensity respectively. 70-80% of the annual runoff is supplied by the Se Ban Fai in the section between Thakhek and Mukdahan. The Se Ban Hieng and the Nam Mune are the main tributaries in the section between Mukdahan and Pakse, and the Se Kong and the Se San command the Pakse-Stung Treng section. In Laos the annual runoff height is very large. It reaches 1,400 mm in the section between Vientiane and Thakhek. In the Thakhek-Mukdahan section it reaches 2,000 mm in the left bank area in Laos but 500 mm in the right bank area in Thailand. In the Mukdahan-Pakse section it reaches 1,000 mm in Laos but 200 mm in Thailand. As regards the Pakse-Stung Treng section, it is very intense with 1,500 mm in the area through which the northern river of the two tributaries flow.

Fig. 3 shows the estimate made by Lewis-Nelson[6] on the distribution of the average annual runoff of this basin. In this case, reference has been made

Table IV Variation of annual discharge

Station	Periods recorded	Mean annual discharge	Standard deviation of variation rate in annual discharge
Mekong River near Vientiane, Laos	35	485 mm	16 %
〃 at Thakhek, Laos	22	645	19
〃 Mukdahan, Thailand	34	666	13
〃 Pakse, Laos	29	606	11
〃 Stung Treng, Cambodia	5	573	10
〃 Kratie, Cambodia	21	732	11
Nam Mune at Ubon, Thailand	16	195	26
Nam Chee at Yasotorn, Thailand	9	186	29

6) Lewis, D. J. and M. L. Nelson, *Report on Computer Application to System Analysis, Lower Mekong River*, 1963.

to the discharge data[7] dating prior to 1960 plus the data indicated in Table III. These figures are merely assumptions, there having been, as we have seen, the data concerning only the water level dating prior to 1960. The map attempts a bold assumption on the distribution of annual runoff height and will require changes and additions by future observers and investigators.

Table IV shows approximate figures depicting the deviation of the annual runoff, which were arrived at by the same means that the rainfall was calculated. In order to study the matter over as long a period as possible data on the runoff dating prior to 1960 were also used. Standard deviations of the variation rate were found to be 11-19% along the main stream area and 26-29% in Thailand.

(3) The annual runoff coefficient

I tried to find out the relation between the annual precipitation and the annual runoff in the tributary basin. This could be done only in two tributary basins (Table V), as I had only limited data at my disposal. The annual runoff

Table V Annual precipitation and the height of runoff

Tributaries	Rain gauging station	Annual precipitation (mm)		Streamflow gauging station	Annual height of runoff (mm)		Annual runoff coefficient (%)	
		1962	1963		1962	1963	1962	1963
Stung Sen	Rovieng	1,753		Kompong Thom	574		33	
Se San	Voeun Sai	2,091	1,846	Ban Komphung	1,127	728	56	44
	Kontum	1,699	1,309					
	Lomphat	1,411	1,392					
	Draing	2,811	2,032					
	Dakmil	1,995	1,644					
	Mean	2,001	1,645					
Nam Mune	Nang Rong	842	1,125	Ubon	285	174	20	13
	Surin	1,502						
	Phoyak Phum	1,615	1,383					
	Sisaket	1,921	1,481					
	Chumphaen	1,236	1,133					
	Khon Kaen	1,230	1,337					
	Roi Et	1,695	1,299					
	Mean	1,434	1,293					

height, that is, the difference between the annual precipitation and its loss, was 900 mm in the Se San area and 1,200 mm in the Nam Mune area. Though it was not proper to try to calculate such a correlation merely from the data obtained only during a short duration of two years, the result obtained from the data over a longer period of observation in Thailand nevertheless proved to indicate the linear-relationship between the annual precipitation and annual

7) *Lower Mekong River Basin Discharge Data*, prior to 1960.

runoff[8].

Lake Tonle Sap lies approximately in the middle of the central plains of Cambodia and is connected with the Mekong River by a channel, about 80 km in length. When the floods come the water flows back into the lake and is kept stored there at times for as long as 5 months. The annual runoff calculated from the value of the discharge measured at Prek Kdam (catchment area 84,400 km), half-way out on the feeder channel, is shown in Table VI. The data concerning the Stung Sen (catchment area 14,000 km), a tributary that flows into the lake, are given in the same table for reference.

Table VI Annual runoff coefficient in Cambodia

Year	Lake Tonle Sap			River Stung Sen		
	Annual precipitation (mm)	Annual height of runoff (mm)	Annual runoff coefficient (%)	Annual precipitation (mm)	Annual height of runoff (mm)	Annual runoff coefficient (%)
1961	985	276	28			
62	1,576	444	28	1,753	574	33
63	1,279	390	30	—	359	—

3. Hydrologic and Hydraulic Analyses

1. The Lewis-Nelson report

D.M. Rockwood[9] of the U.S.A. was the first to propose and use a digital electronic computer to analyze streamflow. His basic equation stems from the Wilson equation on which the writer's is also based.

Lewis-Nelson group was commissioned by the U.S. Department of State to conduct a survey of the Mekong River for the purpose of analyzing its runoff.[10] In 1963 he left for the Mekong and in his report he proposed the use of the electronic computer IBM 1620, which was being used to analyze thaw runoff, to analyze the runoff of the Mekong River where there is no snow. He added that for the purpose, training should be started to acquaint the local technicians with the use of electronic computers. He offered to train technicians from the four neighboring countries so that they could take over the computing operations on their return to the computing center set up in the Mekong basin. His plan is now being effected and findings have already been made of the values of the discharge routing of the main stream in the section between Thakhek and Mukdahan, and of the runoff of the main tributary, the Se Ban Fai.

2. A research model of the Mekong delta area by UNESCO

An important hydraulic problem of the Lower Mekong basin concerns

8) Takenouchi, Toshio, "In Participating in the Third Mekong River Basin Reconnaissance Project," *Civil Engineering Technical Data*, vol. 3, No. 8, 1961.

9) Rockwood, D. M., "Columbia Basin Streamflow Routing by Computer", *Proceedings of ASCE*, 1874, 1958.

10) Lewis, D. J. and M. L. Nelson, op. cit.

the function of Lake Tonle Sap at the time of the floods. The Mekong basin comprehensive development project includes a plan to set up a control gate at the lake exit. The question UNESCO[11] took up was to find in what way this control gate would influence the downstream area.

The target area for analysis is the downstream area below Chhlong (below Kratie). An electronic computer is to be set up and data on the hydraulic characteristics of this area are to be fed to study the effects of the operation of the control gate at Lake Tonle Sap would have on the downstream area as the flood peak drops gradually and on the change of the discharge. Other questions concerning the intrusion of salt water, navigation and fishing are to be studied thoroughly at the same time.

In carrying out this plan the following method is to be employed. A consultant will be commissioned and be asked chiefly to take care of the planning. Sub-contracters will collect the necessary data and prepare for the research model. Five trainees will be taken in from the neighboring countries, to be trained and commissioned to undertake the computing operations.

When the plan is carried out UNESCO will deliver the computer operators to their four respective countries, where having acquired the necessary knowledge and experience and being familiar with the operation of the computers, they will be expected to carry on the work smoothly thereafter.

4. Conclusion

a. So far a large number of Japanese technicians have participated in the Mekong basin investigation projects. A great amount of data has been brought back which can be put to valuable use in the next stage of the projects if they are assembled and compiled for future use. I propose a setting up of a Southeast Asian hydrologic data center.
b. Looking back we are much impressed with the way the Lewis-Nelson group conducted its work abroad in scientific cooperation, that is, the way they employed their own methods and took advantage of their experience that proved effective in their own country. International cooperation is of such nature and in the future when Japan aids developing countries she should also start in a similar manner.
c. We have so far had to work in haste using what little hydrologic data were available to draw up the estimates for the Mekong River basin development projects that Japan had announced to undertake. But now as we are in possession of accurate data obtained after 1960 the previous data can be restudied.
d. Observing the rainfall in the basin in the rainy season, our impression is that it is a series of thunder storms and that only with the help of radar rainfall measurement equipment can accurate measurements be

11) United Nations Special Fund Plan of Operation, *Mekong River Delta Model Study*, No. 12, 1962.

made of the rainfall in the area.

e. I have spoken of three different ways of aid that were employed by Harza, Nelson and UNESCO. What was common to these three was that technicians from the four adjacent countries were given training and that together with the machines and instruments used in the projects were handed over to their respective countries. Unless aid to the developing countries is extended both in personnel and material no good results can be anticipated. There is much that Japan can learn.

III. Hydrology and Meteorology in Cambodia

Tetsuo KATO and Takashi KAWAI

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From early November, 1964, until mid-February of the following year we were engaged in surveying the Sambor District in Cambodia in connection with the Sambor Development Project as requested by the Mekong Committee of the Japanese government. We were asked by the Japanese government through the Overseas Technical Cooperation Agency (OTCA) to survey and study the existing conditions of irrigation and drainage there as a part of the agricultural development program. The survey was carried out mainly in Kratie Province. We also had the opportunity to study the Mekong River, the Tonle Sap and the Bassac Rivers. Though we were given only a short time to complete our investigations which were to be done only during the first half of the dry season, we shall attempt to analyze the data we collected and also the newer data available to us later and describe briefly the characteristic features of the region.

1. Hydrology and meteorology in Cambodia

Cambodia is a land lying between 10.4° to 14.6° north latitude. Without reverting to Köppen's classification it is quite evident that Cambodia is a country of tropical monsoon climate. To cite a few of its characteristics:

a. The area is greatly affected by Asian monsoons.

b. Rainfall during the monsoon period comes mainly as squalls. The precipitation varies regionally and seasonally.

c. The Lower Mekong Basin area is situated in the Pacific typhoon zone, though most of the typhoons spend their fury in the Indochina Peninsula. However, they are often accompanied by heavy rains.

d. The average temperature in this area changes little over a 12-month period. But the daily fluctuations of temperature are very great as the differences of temperature in one specific day in the dry season sometimes can be as much as 10°C.

2. Evaporation and evapotranspiration

In 1931 Thornthwaite classified representative types of climates based on the water balance.[1] The types are shown in Table I. They have been derived from the following formula:

1) Thornthwaite, C. W., "The climates of North America according to a new classification", *Geograph. Rev.*, vol. 21, 1931, pp. 633-655.

$$P/E = (P/5.0T + 62)^{10/9} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots \quad (1)$$

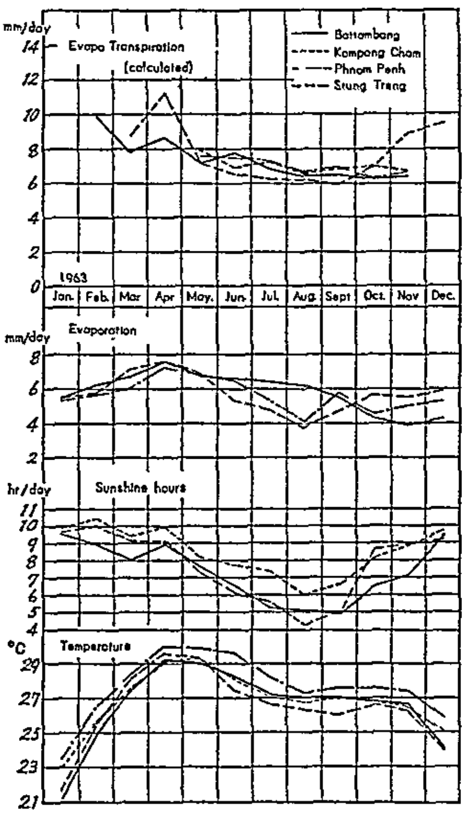
where E represents the evapotranspiration, P the precipitation, both are expressed in mm/month, and T represents the temperature in °C.

Table I Climate classification by Thornthwaite

	P/E		
Humid	A	Rain forest	107%
	B	Forest	53~106
	C	Grass land	27~ 52
Semi-arid	D	Steppe	13~ 26
Arid	E	Desert	12

Evapotranspiration in various parts of Cambodia worked out from the above formula (Fig. 1) are represented by P/E terms and shown in Table II. The table shows us that August and September of the rainy season correspond to that of the rainy forest area of category A and that March and April, when there is usually little rainfall, resemble that of the desert area of category E.

Evaporation reaches its peak around April just before the rainy season sets in and drops to the lowest level around August. The average evaporation



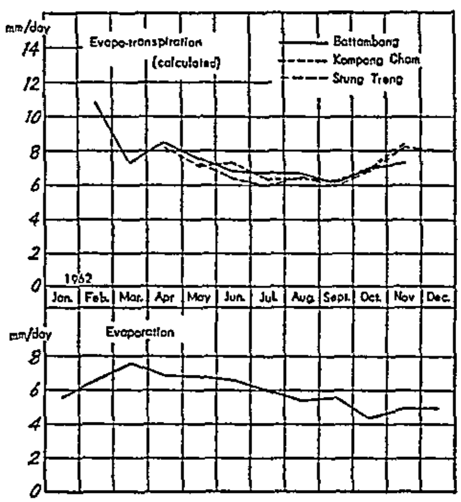


Fig. 1-1 Diagrams of evapo-transpiration, evaporation, sunshine hours and temperatures (1963)

Fig. 1-2 Diagrams of evapo-transpiration and evaporation (1962)

Table II P/E in Cambodia

	Battambang		Kompong Cham		Phnom Penh		Stung Treng	
	1962	1963	1962	1963	1962	1963	1962	1963
Mar.	51	20	—	13		9	—	8
Apr.	13	11	18	—		—	—	1
May	42	73	65	28		53	52	73
June	90	29	44	94		55	155	122
July	97	86	138	44		57	237	161
Aug.	98	158	127	102		108	102	164
Sept.	210	132	168	75		84	220	242
Oct.	57	173	54	66		210	60	61
Nov.	28	134	8	88		119	7	5

varies little in the rainy and the dry seasons, which seems to be a tendency common in these four regions also. The annual mean daily evaporation is less than 6 mm/day. As we may see by Fig. 1, the 12-month pattern of change of evaporation seems to be closely connected with the length of hours of sunshine and the temperature.

It is interesting to observe as we may see in Fig. 2, that in Cambodia the relation between the evaporation, is proportional to the evapotranspiration, and the temperature shows a marked difference between the April to November rainy season and the remaining months of the dry season.

Mr. Hing-Un[2]), Ingénieur du Génie Rural, after studying whether the Penman formula could be applied to the calculation of potential evapotranspiration, declared that it works as far as the rainy season is concerned but not

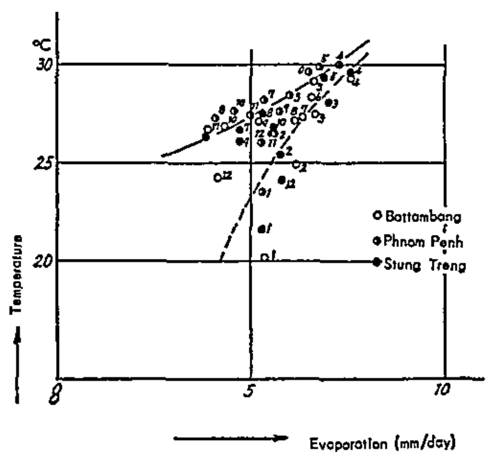


Fig. 2 Relationship between monthly mean evaporation and temperatures, 1963
Note; Figures to the right of the dots indicate month

2) Hing-Un, "Evaluation des Quantités d'Eau Nécessaires aux Irrigations," contributions au Symposium de Pekin, 1964.

with the dry season. From the nature of P. E., we find that this is clear.

3. Rainfall

Rainfall is the main supply source of irrigation water not only in Cambodia but also in the whole of the Mekong basin area. Consequently, it can be readily seen that monsoons exert important influences on agriculture.

Fig. 3 shows the rainfall at Phnom Penh where the longest observation was made. For the sake of convenience, by "rainy season" we mean the period during which time the monthly precipitation exceeds 5% of the annual precipitation.

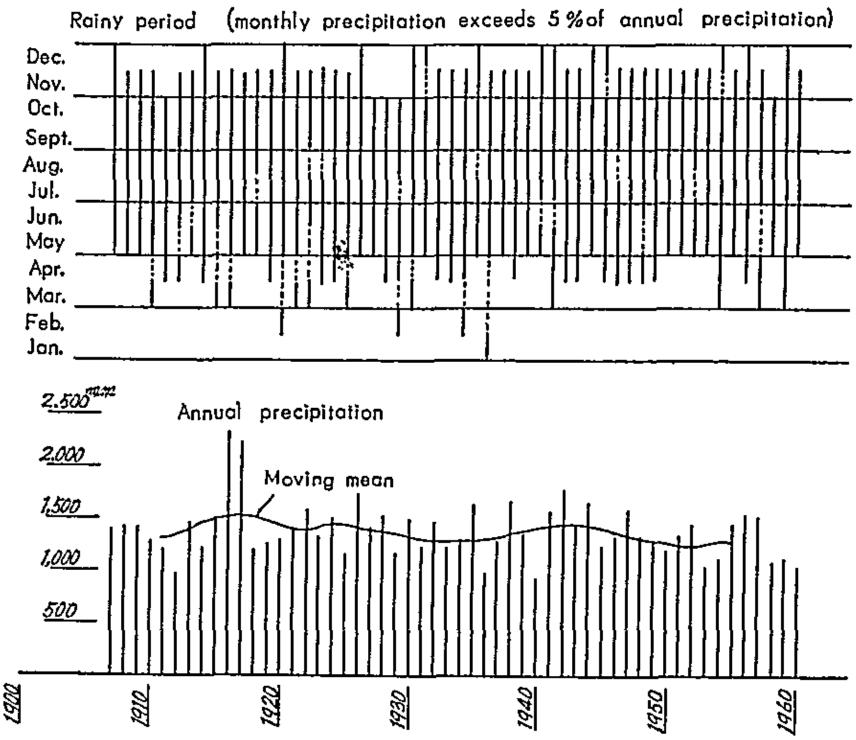


Fig. 3 Rainfall at Phnom Penh

We may observe in Fig. 3 that in a period of 54 years about 70% of the rainy seasons began in April-May but this was not always consistent. Moreover, during this period about 50% of the rainy season months were those of little rainfall (less than 5% of the annual precipitation). (See Table III.)

Fig. 4 shows the pattern of annual precipitation witnessed at Phnom Penh over quite a long period (1907-1960).

In the correlogram (Fig. 5) there was no particular evidence to be found of short periodicity of the trend of rainfall, so we averaged the original data by an arithmetical moving mean method, taking seven- and four-year units in turn.

Table III Rainy season

First months of rainy season		Coincidence of "dry" rainy season*	Last months of rainy season		Length of rainy season: Overall length		Length of rainy season: Actual period above average rains
Jan.	1	1	Oct.	5	6 months	2	6
Feb.	3	3	Nov.	35	7	15	23
Mar.	11	10	Dec.	14	8	19	17
Apr.	18	5			9	11	7
May	21	6			10	5	1
					11	2	—
Total	54	25		54		54	54

* See p. 70

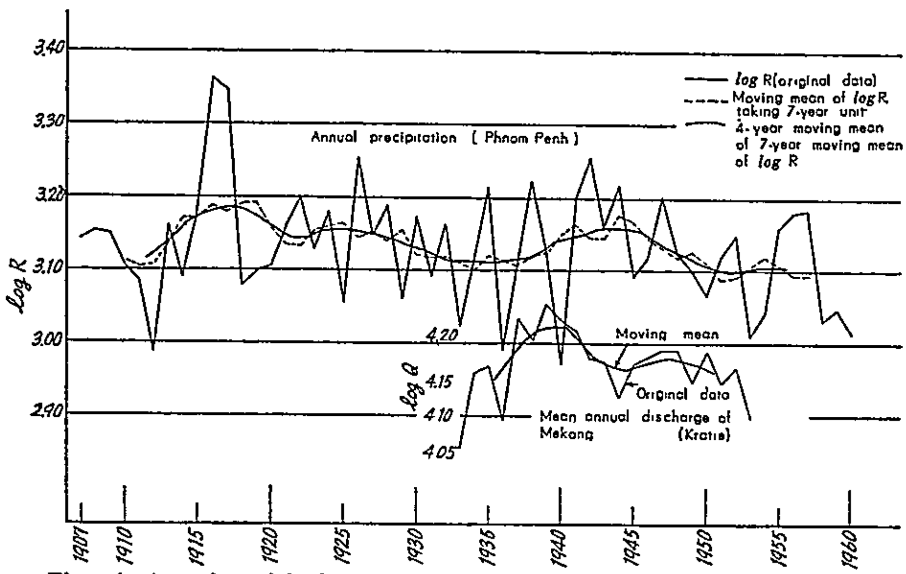


Fig. 4 Annual precipitation over a long period at Phnom Penh

As for the long term trend, two periodicities can be found ranging about one decade and several decades. In order to calculate the probable hydrologic data, we propose the following method which is effective when accuracy is required:

The original series is to be first divided into the determinable long-cycled components and the remaining components. The former is deemed as the singular process or the trend, but the latter as the stationary time series. The deviation of the remaining series is expected to be smaller and more precise than the deviation derived from the conventional arithmetic average methods. The peak or bottom of the long term trend is to be selected in accordance with the purpose of studies on floods or droughts and remaining components are added to this at a desired probability.

Fig. 4 also shows curves that illustrate the annual average discharge of

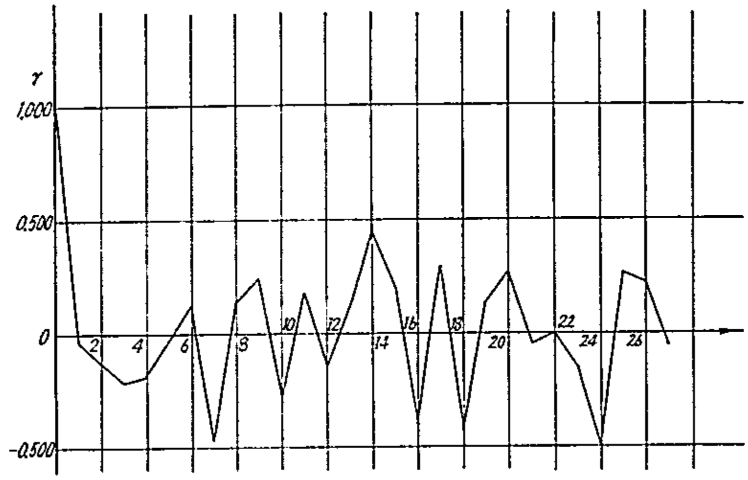


Fig. 5 A correlogram of annual precipitation at Phnom Penh

the Mekong River as observed at Kratie. The curves do not correspond to the trend of precipitation observed at Phnom Penh.

Although this is not inconsistent, it nevertheless suggests how complicated and how difficult it is to find the rainfall corresponding to the discharge of the Mekong in the lower river basin where melting of the snow has little effect.

From data on rainfall collected at Phnom Penh we find that in general the distribution pattern of annual precipitation is that of a logarithmic normal distribution. Average annual precipitation is 1,340 mm, and 1,820 mm and 990 mm when they are estimated by probability of excedance in 5% and 95% respectively.

Let us now see how the rainfall varies from area to area. In Fig. 6 the monthly preeipitation at Kratie on the Mekong is shown in contrast to that at Kompong Cham in the lower stream area. There is hardly any correlation between the two.

We will now consider the intensity of squalls. The rainfall intensity is one of the most important factors that should be taken into consideration when soil conservation and waterway desgins are concerned. The following analysis was made on rainfall intensity, and the data concerned were obtained through observations made of comparatively heavy rainfalls for a 1 hr., 1/2 hr. or 1/4 hr. period during the rainy season in 1964. The following mathematical expression may be applied in general to calculate the rainfall intensity within a 1 hour period:

$$r_T = C - 84 \log_{10} T \qquad \cdots\cdots (2)$$

where r_T is the rainfall intensity, R_T being total rainfall in mm in T hr., that is $r_T = R_T/T$ (mm/hr), C is constant, namely rainfall intensity when T is 1 hour, which is within 30-70 mm/hr., according to observations made in 1964.

Records show that the total daily precipitation rarely amounts to twice the value of one hour. Squalls soimes bring rainsmet lasting a few hours but generally they last less than 2 hours a day.

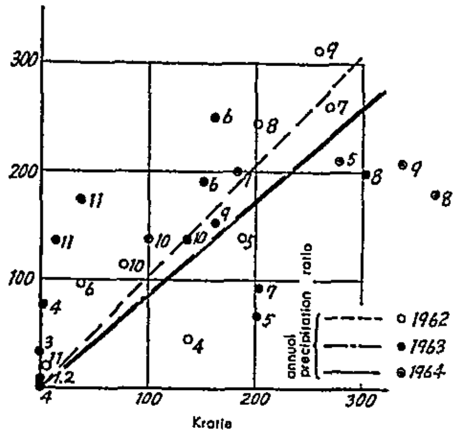


Fig. 6 Regional differences of monthly precipitation

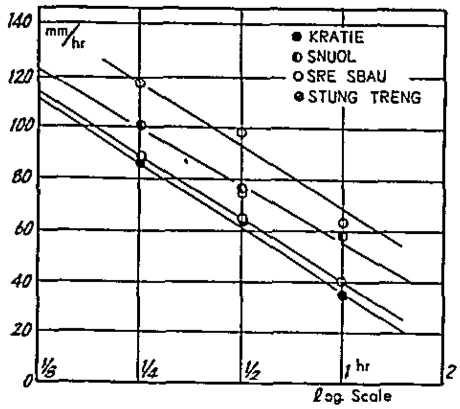


Fig. 7 Intensity of squalls

4. Rivers

The rise and fall of the water level of the Mekong repeats a 12-month cycle pattern. At the beginning of the rainy season, from around the end of April to May, the level starts rising slowly and reaches its peak in August or September. Then as the rainy season ends, the level drops quickly and continues dropping slowly as the dry season proceeds. This pattern changes a little according to the year. If we observe the pattern of a rainy season carefully, there can be seen multiple peak levels several times during the season, when each peak depends on independent rainfall. But the general annual flow pattern remains more or less the same. There are only a few places along the Mekong mainstream where flood waters overrun the natural embankments but along many of the tributaries there are quite a few spots where natural embankments stand below water level. In this way flood waters backflow up into the tributaries and flood the hinterlands.

In general, tributaries affected by backwater follow the pattern of the water level in the main stream but all the tributaries have additional complicated patterns of annual change which are affected by the discharge from their own basin area. When the water level of the main stream approaches its peak in the annual pattern, then nearly all the tributaries flood the adjoining areas for a comparatively long period (1-3 months).

At times squalls bring much rain into the vicinity of the tributaries and raise the water level very quickly (in several hours) to cause local floods here and there but such floods usually retreat in a day or two. In places, flood waters rise to a very high level (several meters). So far there have been no accurate data assembled on the discharge of the tributaries.

When plans are to be made, it is very important to know the various conditions of the floods, so in February, 1965, we set up water gauges at 21 sites along the main tributaries in Kratie Province. Simple rain gauges were installed in addition at 10 spots in this basin. It should be possible with these facilities from the 1965 rainy season to discover to some extent the rainfall distribution from locality to locality lying within comparatively short distances one to the other and to verify the discharge of the tributaries.

The Hydrologic Yearbook[3] contains recent data on the water level and discharge of the Mekong as obtained from the records taken at 16 sites after 1962. Let us try the Muskingum method on flood routing and pursue the conditions of floods between Stung Treng and Kratie where outflow and inflow from small tributaries are comparatively small. We will use the data concerning the peak discharge in 1963, from August 7 to 28.

$S = K\ [xI + (1 - x)\ O]$ .... (3)

where S is the storage volume $= (A_s + A_k) \times 130$ km/2, A_s is the cross-sectional area of flow at Stung Treng $= h_s \times 2{,}000$ m. The water depth h_s was estimated as $H = -0.3$ m from H-Q curve when $Q = 0$. Observed values stated in the Year Book were modified by $+ 0.3$ m. A_k is the cross-sectional area of flow at Kratie $= h_k \times 1{,}800$ m, and the water depth h_k was estimated $H = 2.2$ m, similar to the above case when $Q = 0$, and observed values were modified by -2.2 m, K and x are constant, and I and O are the discharge at Stung Treng and Kratie at the same time, respectively.

Dividing the flood period into a 24-hour unit and the value of x in expression (3) supposed from 0 to 0.5, the relation between S and $[xI + (1 - x)O]$ is plotted and shown in Fig. 8. We find that between the points where $x = 0.4$ and $x = 0.5$ the loop gets very flat, the Muskingum method may be applied. From the graph we get $K = 33{,}600$ sec. and $x = 0.45$. Rewriting expression (3) we get

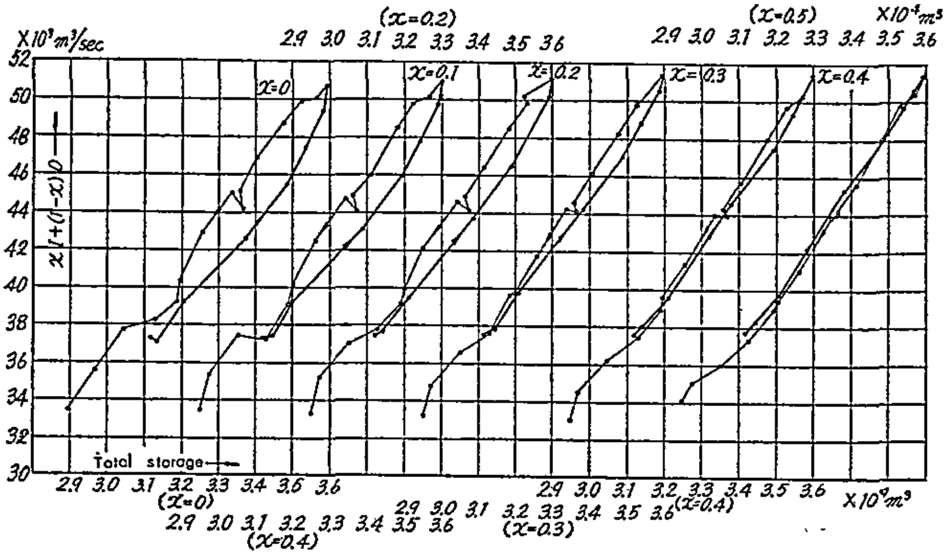
$O_2 = C_0I_2 + C_1I_1 + C_2O_1 = -\ 0.148I_2 + 0.885I_1 + 0.263\ O_1$ .... (4)

where the suffixes 1 and 2 in the above expression (4) represent the values at the time t and $t + \Delta t$. The coefficients C_0, C_1 and C_2, and the time interval Δt are given as shown in Fig. 8.

From Fig. 8 we see that since x approximates 0.5, inflow and outflow effects are about the same and that the flow velocity is fast so that the inflow hydrograph shifts to the point of outflow without undergoing much change. It was estimated that the water surface slope between Stung Treng and Kratie to be about 1/5,000 at the time, the average flow velocity 2.4-1.5 m/sec, and the coefficient of roughness at about $n = 0.035$. Since the river overflows a little in this section even at the time of floods we may consider the results in Fig. 8 as reliable.

Fig. 9 shows the flood waves from the upper to lower river basins of the Mekong River at Ban Chan Noi (catchment area 549,000 km^2), Stung Treng (catchment area 635,000 km^2), Kratie (catchment area 646,000 km^2) and Kompong Cham (catchment area 660,000 km^2). In this figure the curves are arranged to be consistent in height and to occur at the time of the flood peaks. When going downstream, the curvature of the flood waves become large and the curves are flattened. But because of the sectional change of the river

3) *Lower Mekong Hydrologic Yearbook*, 1962, 1963.



$$C_0=-\frac{Kx-0.5\Delta t}{K(1-x)+0.5\Delta t},\qquad C_1=\frac{Kx+0.5\Delta t}{K(1-x)+0.5\Delta t},$$

$$C_2=1-C_0-C_1,\qquad \Delta t=6\text{hr}.$$

Fig. 8 Flood routings of the Mekong between Stung Treng and Kratie

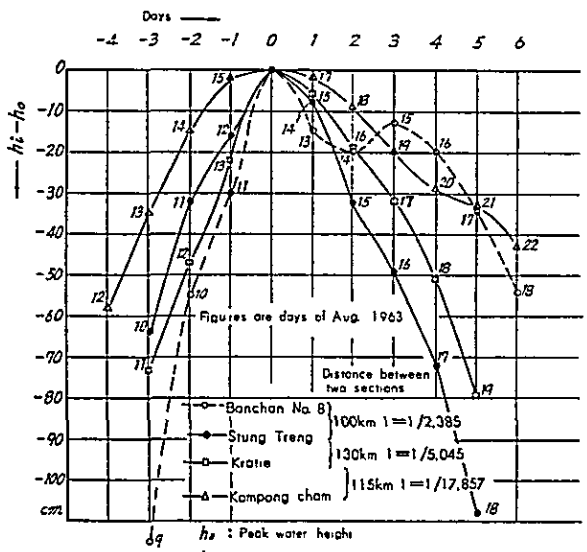


Fig. 9 Flood waves

course and the effects of inflow and storage of water, it is of course impossible to apply directly here the law of flood wave recession as it is.

Other features of the Mekong River concern its annual sediment load (about 300 ppm) amounting to 150×10^6 tons and the intrusion of salt-water into the stream. General attention has been directed to these two problems lately. The causes have been attributed to a general devastation of the river basin on the embankments and in the waterways, but here again the Vietnam war has mercilessly supplemented the damage.

IV. Cyclones in the Bay of Bengal

Masahito UWAGAWA

Second Engineering Division, Water Resources Development Corporation

In accordance with the Colombo Plan, I was dispatched from September, 1961 to September, 1963 to East Pakistan, where I took part in the Pakistani government's project of flood control and water utilization of the Gangetic delta area.

The Gangetic delta area is a flat alluvial land, about twice the area of Hokkaido Island, Japan. The coastal embankment project (creating new farm lands by setting up coastal embankments) under way along the shores of the Bay of Bengal is one of the largest government-sponsored projects in East Pakistan and involves an area of 1,500,000 ha.

Year after year cyclone storms inflict great damage to the embankments, the fields and the population of this area as well as to various establishments and facilities. Counter-cyclone measures have gained great importance in the government's eyes and projects are developing the coastal area.

Attempts have been made to concentrate data in this report mainly on cyclones that originate in the Bay of Bengal.

1. The cyclone

Around the middle of the 19th century an Englishman, Captain Henry Piddington by name (a marine meteorologist of the East India Company, Calcutta Head Office), made the first systematic study of gales (severe storms that originate in the Indian Ocean and the Bay of Bengal). He gave this natural phenomenon a Greek name "cyclone" meaning "the coil of a snake". Now a common noun, it means tropical atmospheric depressions that originate in this area.

Tropical atmospheric depressions generally originate near the equator. They are called by different names in various parts of the world—hurricanes, typhoons or cyclones. In the northern hemisphere the cyclone originates in the Bay of Bengal and in the Arabian Sea and in the southern hemisphere in the Indian Ocean, east of Mourishas and Madagascar. Typhoons develop along the coasts of China and Japan while hurricanes develop along the east coast of the U. S. A. They all have identical meteorological characteristics. These tropical atmospheric depressions sometimes develop to such an extent as to drop as low as 910 mb in central atmospheric pressure, measure over 300 km in radius, run up as high as 60 m/sec in wind velocity and travel at speeds of around 30 km/hr. They are frequently accompanied by heavy rains. There is an instance of a hurricane (South Carolina, July 14 & 15, 1916) that recorded 1,150 mm of precipitation in its course. In Japan as well as India and the U. S. A., damages wrought by strong winds and heavy rains are observed to be most violent in coastal areas. (Fig. 1)

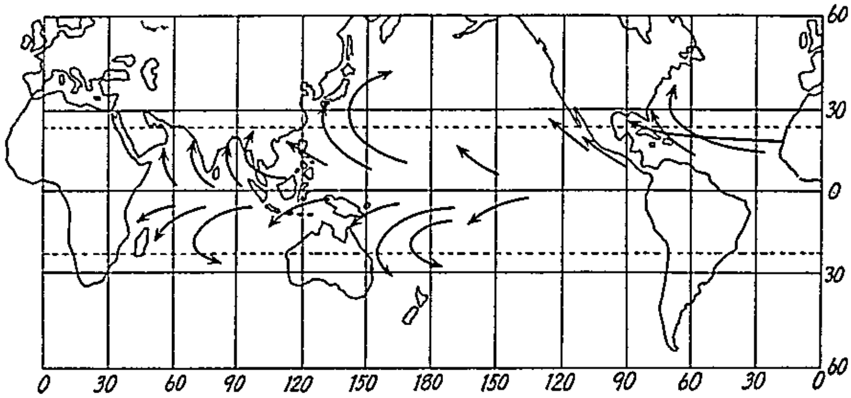


Fig. 1 Origins of tropical depressions and courses

The history of scientific meteorological observation in India began about 100 years ago in 1864 and 1865 when tremendous disasters two severe cyclones then wrought alarmed the British government. They left 80,000 and 40,000 dead, respectively in their wake in the Calcutta-Basulipatam region. The British government established observatory stations at strategic points to forecast approaching cyclones scientifically.

The available statistics[1] on the cyclone disturbances show that there is little occurrence of cyclones during the months of January and February. Pre-monsoon cyclones (those that appear before the monsoon period) in April and May travel mainly north-east through the vicinity of Cox's Bazar on the east coast. These cyclones are infrequent but when they come they inflict heavy damage. Cyclones during the June-July-August monsoon period occur frequently but are of medium magnitude. They originate in the central area of the Bay of Bengal, pass through Orissa, West Bengal and travel north-west. They generally wreak less damage. The post-rainy season cyclones (post-monsoon cyclones) that occur during the months of September, October, November and December are the largest in scale. They assail the entire area of the Bay of Bengal, including West and East Bengal, Burma and Madras. Generally speaking, post-monsoon cyclones are smaller in radius but travel faster than pre-monsoon cyclones.

Before going into a detailed description of damages wrought by cyclone storms it is necessary to dwell on the topographical features of the Gangetic delta, since the tremendous havoc recorded in the history of the cyclones, referred to later, are due to the extraordinarily flat topographical features.

1) Monthly charts have been published by the Indian Meteorological Department entitled "Storm Tracks in the Bay of Bengal", in which the magnitude of every cyclone during 33 years from 1891 to 1923 are indicated by thick lines.

2. Topographical features of the Gangetic delta

The Brahmaputra River that begins in the northern Himalayas and flows parallel to the Himalaya range and the Ganges that flows along the southern borders of the Himalayas, both similarily making eastward descents, meet around the middle of East Pakistan to form the Meghna River which empties itself into the Bay of Bengal.[2] During the past 500 years the Ganges has been shifting its course eastward on every flood occasion in the rainy season. So far it has edged about 240 km to the east, averaging about 5 km every ten years. This "eastward movement", helped by alluviation of the soil in the flood season, has constructed the present Gangetic delta which now comprises the larger part of East Pakistan. The whole area is a 140,000 km[2] stretch of lowlands interwoven by numerous rivers of all sizes and interlacing channels (*Khal*). The low rise of land is quite evident as its altitude barely reaches 2 or 3 meters above sea level even 160 km inland and consequently, the hinterlands even 300 km from the seacoast are subject to tidal influences and those 130 km away to saline influences.[3]

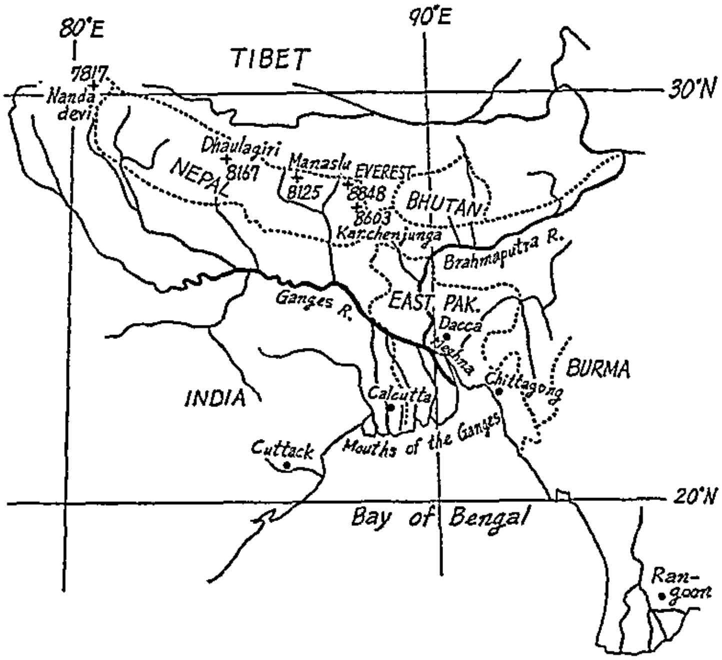


Fig. 2 The Ganges basin area

2) See Kimura, Takashige, "Agricultural Development in East Pakistan", p. 185 of this report.

3) See Minami, Isao, "Salinity Problems in Chao Phraya River," p. 87 of this report.

3. Damages wrought by recorded cyclones

In the foreword of his report to the East Pakistani government on damages by cyclones in 1960, a meteorologist wrote as follows:

"A cyclone is a natural phenomenon like a flood, an earthquake or lightening. We in our ignorance attribute it to God's "*Qahar*", but this is, to my mind, a wrong belief, as God who is so merciful does not cause distress to His creatures.

"It is, if at all, a manifestation of God's Power to remind man of his insignificance in the Universe. To an engineer it must be regarded merely as a reminder to build safely against the Powers of nature. . ."

(*Qahar* means "punishment of God" in Bengali.)

Let us look at the records of history where the cyclone has been put down as *Qahar*.

As old records, there is one of 1584, preserved in the *Ain-i-Akbari* (historic records of *Akbari*, the Mogul King). In it is described in detail the rumbling of the seas and the change of weather and an account of 200,000 people having drowned in a high tide.

In 1797 is another in the *Bengal District Gazetteer* of a high tide engulfing the island of Noakhali.

In 1822, there was another cyclone from June 6 to 8 which pulled about 70,000 men and 100,000 cattle into the sea in the Hatiya and Bakerganj districts. In two years in succession, 1864 and 1865, cyclones took the lives of 80,000 and 40,000 inhabitants respectively in the Calcutta-Basulipatam district, which hurried the British Governor General of India into setting up meteorological observatory stations at strategic points to start forecasting the approach of cyclones.

The October 31 and November 1 cyclone of 1876 known as the "Backergunge Cyclone" has been given a comparatively detailed record[4], and caused much damage to the districts of Backerganj, Noakhali and Chittagong. In the district of Backerganj, 105,000 out of the 437,000 inhabitants were killed. The cyclone claimed the lives of 90,000 out of 403,000 inhabitants in the district of Noakhali and 20,000 out of the 222,000 inhabitants in the district of Chittagong. In all, 215,000 out of population of 1,062,000 were the victims of high tides. About 100,000 people were killed within a few minutes after the cyclone struck when the flooding Meghna River swallowed them up in an upsurge of the flow. Others died of an epidemic which the cyclone left in its wake.

These instances represent comparatively large disasters wrought by recorded cyclones. There are more recorded smaller ones such as those of 1825, 1832, 1855, 1867, 1869, 1870, 1893, 1895 and 1910. The one that struck in 1869 and the other on October 10 and 31 of 1960 represent rare cases in that

4) Commission of Chittagong Division, *Report of the Vizagapatam and Backergunge Cyclone of Oct. 1876.*

they assailed the same area twice in the short duration of a month.

Of recent instances there was one of May 16-19, 1958 when a large cyclone of the first magnitude attacked the combined area of Noakhali, Chittagong and the Sandwip Island and another in October 21-24 of the same year when the Noakhali and Barisal regions were the victims.

The cyclones of October 9-10, 1960 and October 30-31, 1960 which attacked the Noakhali, Chittagong and Bakerganj area terrified the inhabitants immensely. The earlier one had a wind velocity of 33 m/sec and the later one of 55 m/sec. The central atmospheric pressure was recorded at 980.5 mb and the accompanying rains 76 mm at the Chittagong Airport, 51 mm at Barisal, 76 mm at Cox's Bazar and 38 mm at Narayanganj and Khulna. (See Table I and Fig. 3.)

Table I Disasters caused by cyclones of 9-10th October and 30-31st October, 1960

District	Population	Dead	Total houses	Houses destroyed	Houses damaged
			houses	houses	houses
Noakhali	790,000	4,742	157,000	21,100	96,600
Chittagong	840,000	9,163	181,700	26,700	81,200
Bakerganj	250,000	2,952	50,000	—	—
Total	1,880,000	16,857	388,700	47,800	177,800

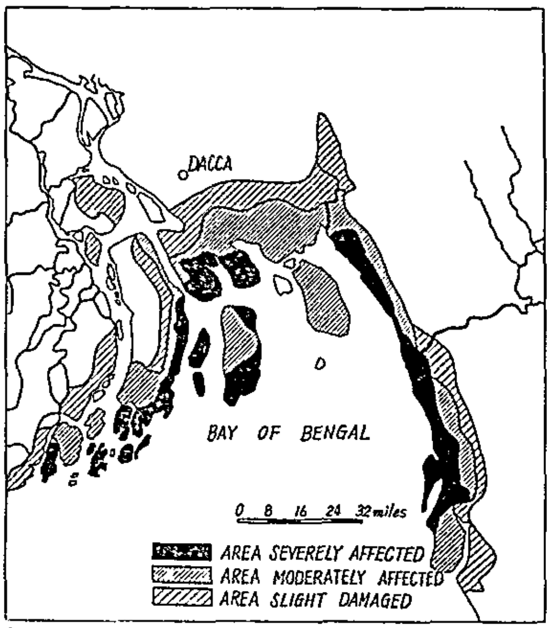


Fig. 3 Areas affected by cyclones of 10th and 31st October, 1960

Medium size cyclones are recorded to have attacked the district of Barisal Khulna on May 9, 1961 and the district of Chittagong on the 30th.

I personally experienced a cyclone that attacked Chittagong on May 28 and 29, 1963. Having been able to collect data from several government sources I will dwell on it somewhat in detail.

1. The East Pakistani government made the following announcement on damages.

a. Dead 9,742

Chittagong District	9,675
Noakhali District	65
Chittagong Hill Tracts	2

b. Houses damaged 660,100

Completely	231,100
Partially	429,000

c. Fields damaged 110,000 ha

Paddy rice (Aus rice 27,600 ha, Amon rice 80,000 ha)

Banana 1,020 ha, Betelnut 300 ha, Sugar cane 166 ha, Coconut 96 ha

d. Livestock damage

Cattle	25,000
Sheep	50,000
Poultry	125,000

2. Meteorological data

The central atmospheric pressure of this low atmospheric depression was 969 mb (Chittagong Forecasting Office, Patenga Airport). The cyclone was generated on the 25th in the East Indian Ocean and rushed north through the path shown in Fig. 4. Its estimated speed was 30 km/hr and maximum wind velocity recorded was 50 m/sec.

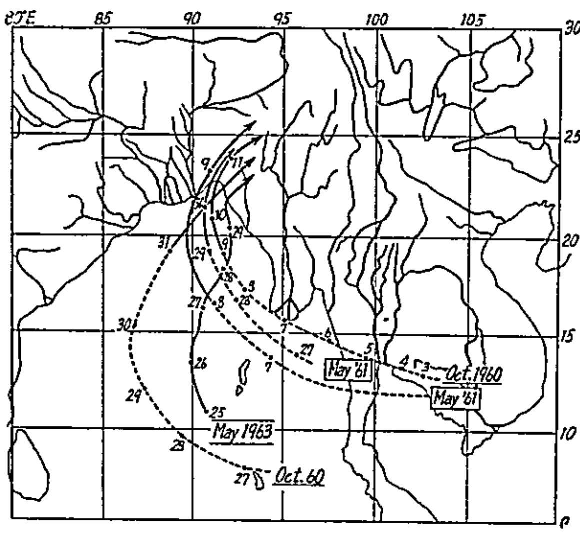


Fig. 4 Tracks of recent cyclonic storms

In India the following classification and names are generally used in defining cyclones. A cyclone with a velocity below 7 is called a "depression". Velocities of 8 and 9 represent a "moderate storm" and one over 10 a "severe storm". "Depressions" generated from 1890 to 1950 in the Bay of Bengal are classified by the month and shown on Table II.

Table II Total number of wind disturbances and cyclonic storms in the Bay of Bengal during 1890 to 1950 (after Dr. P. Koteswaram)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Disturbances of all intensities	9	2	4	25	48	76	113	129	132	119	92	44	793
Percentage frequency	1	0.3	0.5	3	6	10	14	16	7	15	12	5	
Cyclonic storms	4	1	3	14	22	30	36	22	29	54	15	22	288
Percentage frequency	1	0.3	1	5	8	10	12	8	10	19	18	8	

The cyclone that attacked the Barisal District on May 2, 1965 registered a velocity of about 10.

4. On the durability of coastal embankments built under the Coastal Embankment Project

1. The Coastal Embankment Project

We have seen what kind of a land, topographically, the Gangetic delta area is. In this vast area there is a extremely low stretch of land, only 1 to 3 meters above sea level and 50 to 80 km wide, that runs along the coastline from the eastern border of India and Pakistan to the Khulna, Faridpur, Barisal, Noakhali and Chittagong Districts. It is covered with Gangetic alluvial deposits from the Khulna District to the Meghna River and with Brahmaputra alluvial soil east of the Meghna River. The Sundarbans in the western estuary areas is one of the typical coastal forest areas of the world. This flat expanse of about 1,500,000 ha of land had been converted into farmlands by the Hindus from ancient times with polders but after 1947 when India was partitioned into India and Pakistan, the Hindu farmers evacuated the area, and as a result the polders were neglected causing ruin to the vast flat farm lands. Of all her post-independence development plans the Pakistani government gave top priority to the building and repairing of these coastal embankments in East Pakistan, and began a huge project of repairing the crumbling embankments from 1958 to 1960. Great advantages of this project were the possibility of creating vast farm lands, settling farmers there without using any of her foreign reserve funds and making good use of rich manpower sources that could be supplied by the dense population of this area which amounts to 350 people to 1 km^2. Also by simply setting up sluice gates at strategic spots traversed by rivers, well managed operation taking advantage of the fluctuation of tidal water level of these gates could wash away saline ingredients in the soil in two or three years. In this way full benefits from large tracts of reclaimed paddy land may be anticipated. A long-neglected large scale project to build great closed polders has been started under the guidance of American consultants and with the support of American funds. The principal target of this project is to make a complete range of large sluice gates at numerous points of many small and medium size rivers during a half-year dry season period. Rational blueprints have been drawn up and all essentials have been standarized. The project involves about $170 million in investment and an aggregate length of 4,500 km of embankments. Now as this dike construction progresses and approaches the coast line, counter-cyclone measures take on increasing importance as history and recent records show that the collapsing of dikes at high tides cause immense cyclonic damage.

2. Technical consideration of the durability of coastal embankments

Let us use the data on the damage wrought by the cyclone on May 28 and 29, 1963 and make a technical enquiry into the relationship between the cyclone and its damage.

The data concerning this cyclone have been given in the preceding section. We see that it approached land through a 24 km wide channel between the coast of Chittagong and the Sandwip Island and passed northward along the coastline and destroyed coastal embankments under construction. Fig. 5 shows that the center of the low atmospheric pressure passed through when the tide was at medium height. It was indeed fortunate that damage was not so heavy.

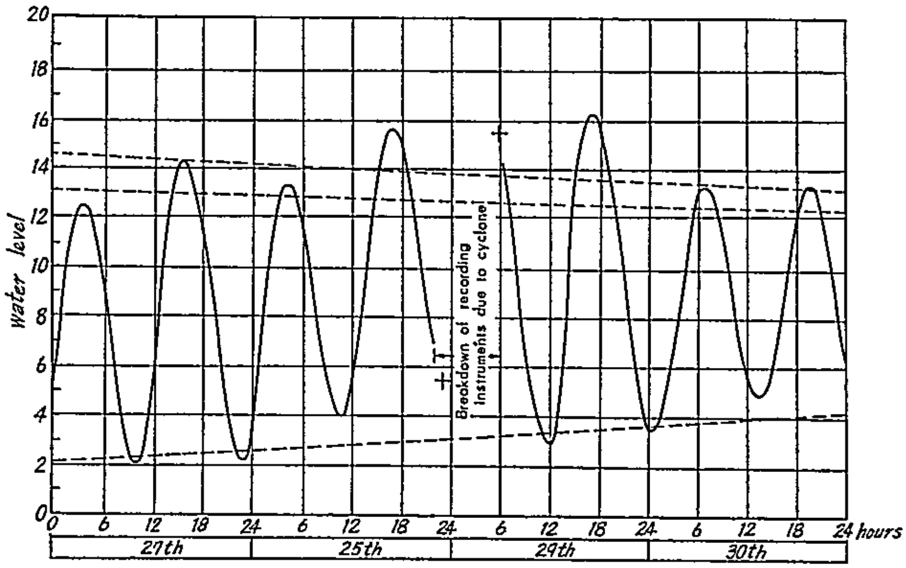
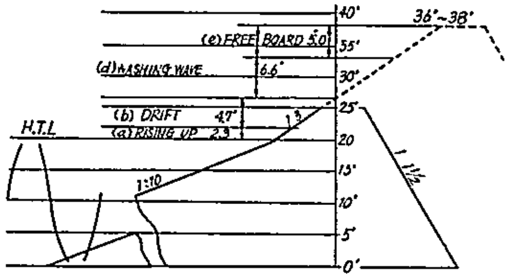


Fig. 5 Tidal water level variations in Chittagong Port due to cyclone of 28-29th May, 1960

The embankments now being built along the coast are high enough to leave an allowance of 1.5 m over the highest tidal level. On the sea side the slope is designed at 1:10 up to the highest tidal level, then the slope is 1:3 above its level (1.5 m). The crest of the embankment is 4.2 m wide and the opposite slope is designed at 1:1.5. But it is merely a huge earthern mound without any artificial protection given to its surfaces (Fig. 6). The following calculation may be applied:



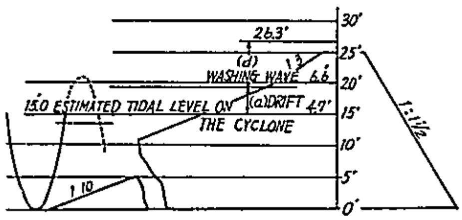


Fig. 6 Cross-sections of coastal embankment

Height of the embankment = highest tidal level (6.0 m)
+ (a) rise due to low pressure (0.7m)
+ (b) rise due to drift (1.4m)
+ (c) resonatic tide oscillation (≒0)
+ (d) wave washing (2.0m)
+ (e) free board (0.9 to 1.5m)
= 10.1m + (0.9 to 1.5m) = 11.0 to 11.6m

The result is that the embankment is too low for sufficient protection against extremely high tides as seen by the above calculation by a height of 3.3 to 3.9m. The sea side of the embankment must be well protected on the surface. Unless embankments can be made that hold the tides off completely it seems futile to develop farm lands and to colonize near the coast.

V. Salinity Problems of the Chao Phraya River

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1. Introduction

Lately in Southeast Asian countries there has been much development of water utilization in delta ares. This means that intrusion of salt water in estuaries has come to be regarded with concern. This can be observed in the lower basin of the Mekong and also in the Chao Phraya delta area where the writer did some investigations. Saline damage in these areas is greater than what can be imagined in Japan. Therefore, prevention of salt water intrusion should be studied earnestly.

The following hydrological characteristics of the delta areas may be attributed to saline damage.

a. Large decrease in discharge in the dry season caused by increasing intake of water in upper stream.

b. Decrease of specific discharge in the dry season due to the decline of the water retaining capacity of upper basin, where various improvements and developments have turned forests into paddy fields and upland farmlands, thus having changed their topographical features.

c. Delta areas, hitherto a buffer land against natural disasters, suffer from saline damage through land development.

d. Inadequate prevention against saline damage.

We can see from what has just been stated that the mechanism by which saline damages occur is a very complicated one. In order to prevent these damages, the following investigations and analyses are very important factors.

a. A systematical analysis from the point of view of the hydraulics of the mechanism by which saline damages occur.

b. Quantitative analysis of the process of salt water intrusion into rivers.

c. Analysis of the discharge of rivers over wide areas.

If and when an acceptable quantitative analyses on the mechanism that causes saline damages and salt water intrusion can be presented in an extensive water utilization plan, then it is easy to work out concrete preventive works as follow:

a. Construction of closed embankments

By building embankments around the benefitted areas, the intrusion

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1) I am most grateful to the Center for Southeast Asian Studies of Kyoto University and to Mr. Boonchob of the Irrigation Department of Thailand for the help extended to me for my studies.

2) Aki, Koichi, "On the Control Factors for the Water-Resources Exploitation Planning in Southeast Asian Area", *The Southeast Asian Studies*, vol. 3, No. 1, 1965, pp. 52-64.

of salt water from the open sea or tidal rivers can be warded off and fresh water can be drawn from upper stream sources for irrigation purposes.

b. Construction of back-tide gates

By setting up back-tide gates where rivers or waterways flow into the sea, the intrusion of salt water can be prevented.

c. Increasing the discharge of rivers in the dry season

By building reservoirs in upper stream, the discharge of rivers may be increased in the dry season and thus the intrusion of salt water can be prevented.

d. Construction of estuary dams

By building estuary dams with large back-tide gates near or at the estuary, the salt water within the gates can be replaced by degrees by the in-flowing fresh water and at the same time the fresh water can be utilized for various industries in the delta areas.

With agricultural engineering techniques at the present level it is an easy matter to lessen the saline damage in the delta areas. To do this, the first thing is to make a detailed quantitative analysis of the correlation between the discharge of rivers and the degree of salt water intrusion.

For a basic study on prevention against saline damage, I will take the saline

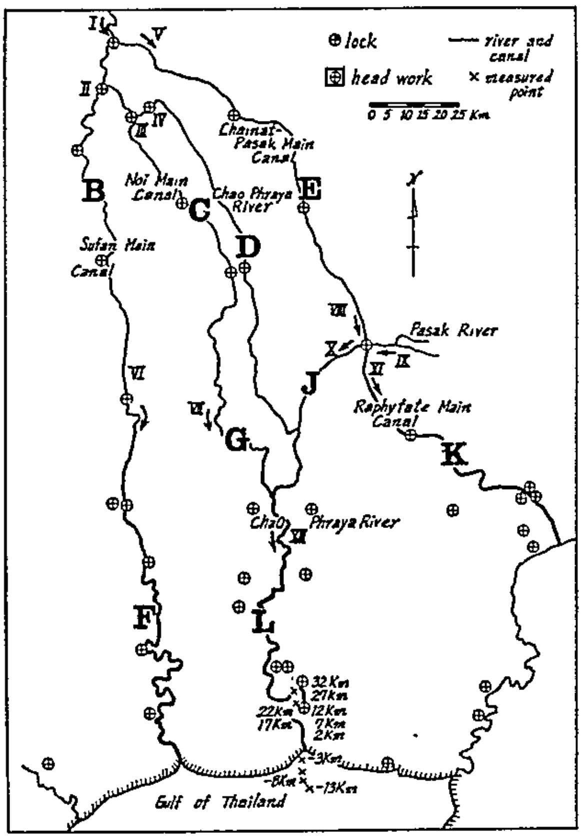


Fig. 1 Rivers and canals of Chao Phraya delta

damage of the Chao Phraya delta area as a model to represent a system in the delta areas of Southeast Asia and delve into the relationship between the intrusion of salt water and the discharge of the river.

2. The intrusion of salt water and discharge

1. Dry season discharge characteristics

The Chao Phraya delta is the main rice producing area of Thailand. It is a low flat area that lies along the banks of the Chao Phraya (Fig. 1). A simplified waterway system in the Chao Phraya delta is indicated in Fig. 2.

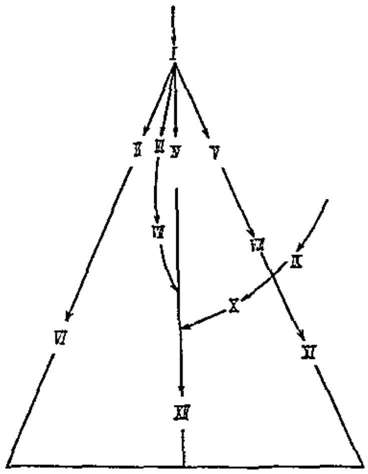


Fig. 2 Schematic diagram of river and canal networks of Chao Phraya delta

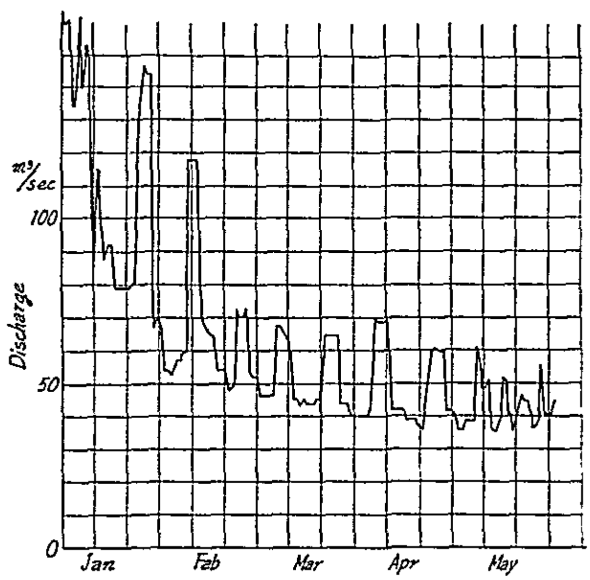


Fig. 3 Streamflow discharge of Chao Phraya (dry season, 1963)

Fig. 3 shows the discharge curve of the Chao Phraya in the 1963 dry season when saline damage in the delta area was at its worst.

The values of minimum discharge measured by the Thai Irrigation Department in 1963 and 1964 were:

May 25, 1963	32 m^3/s
April 18, 1964	87 m^3/s

Worth noting is that the minimum discharge differs largely from year to year. The Chao Phraya has a catchment area of 162,000 km^2. The estimated flood discharge at the Chainat head work is 6,500 m^3/s and the droughty discharge is 60 m^3/s. There is a very shallow estuary that stretches over 15 km from the river mouth towards the Gulf of Thailand. As we may see from Table I, the slope of the river bed is very gradual and consequently a tidal river constitutes a very long section of the Chao Phraya.

Table I Chao Phraya river bed slope

Location	−15km Estuary	0 River mouth	40 Bangkok	Ayutthaya	Nakhon Sawan
Slope	$\frac{1}{\infty}$	$\frac{1}{\infty}$	$\frac{1}{25,000}$	$\frac{1}{10,000}$	$\frac{1}{7,000}$

2. Salinity distribution as investigated by the Royal Irrigation Department of Thailand

Fig. 4 shows the salinity distribution in the Chao Phraya River as investigated by the Thai Irrigation Department. The numerals in the map indicate chlorine ions present in 1 liter of water in grams.

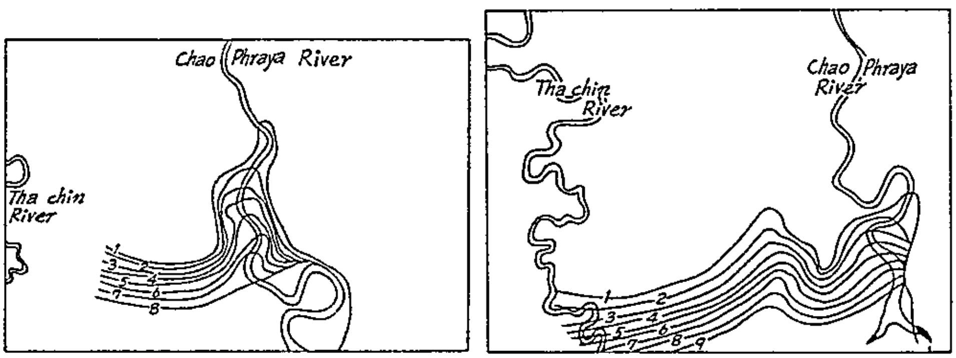
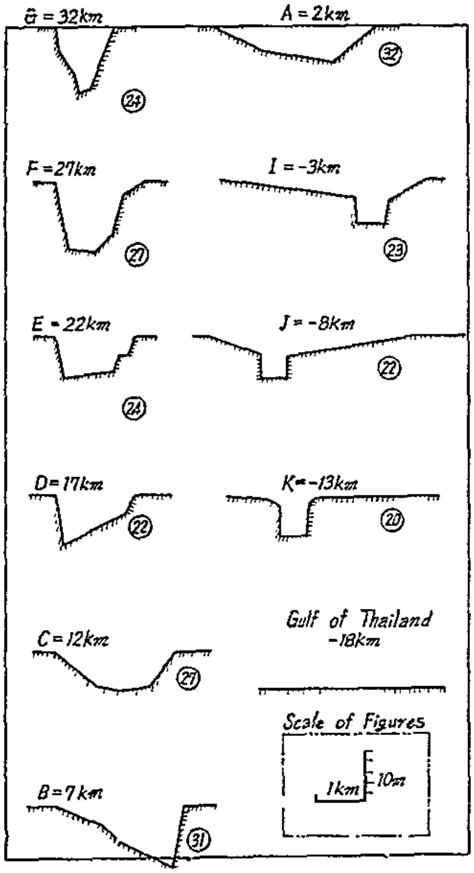


Fig. 4 Salt water intrusion into Chao Phraya delta area (Figures on isoconcentration lines indicate grams of Cl in 1 liter of water—after RID)

3. Salinity distribution at the estuary

During March 4-14, 1965, the writer conducted studies on salinity distribution in the estuary of the Chao Phraya. In Fig. 5 are shown cross sections of the river bed at each observation point and in Fig. 6, some results of measurements.



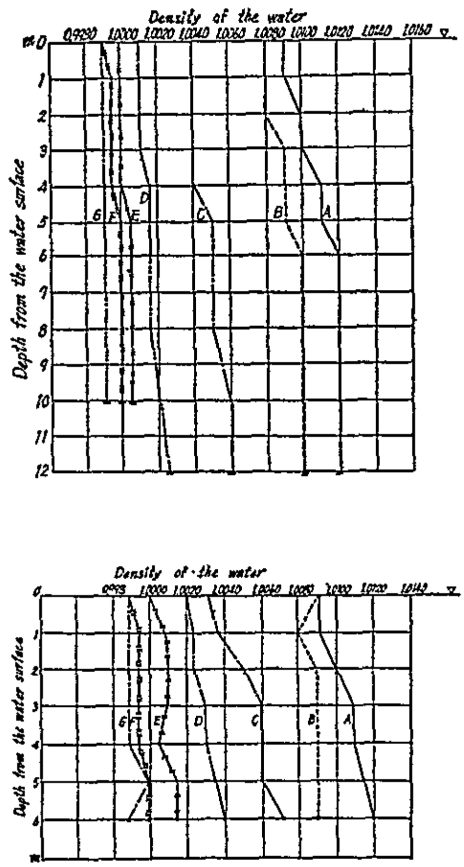


Fig. 5 Cross sections of Chao Phraya river bed where chlorine concentration in water was measured

Fig. 6 Vertical distribution of chlorine concentration in Chao Phraya (A/G correspond to Fig. 5)

Specimens taken from the river revealed the following characteristics which were found by measuring the specific gravity of the salt water (discharge then was 150 m^3/s.)

a. It was found that the salinity content at the estuary was somewhat higher in deeper sections, 1.014 in specific gravity of salt water, than that at the surface, 1.009.

b. Vertical salinity distribution was more or less equal except at the estuary, that is, the intensely mixed type.

c. No salt water wedges were observed at the estuary.

d. Salinity at the estuary was found diluted by fresh water. The specific gravity was far lower than that of standard sea water, of which the specific gravity is 1.025.

e. There is a possibility of the appearance of three types of salinity distribution. If the discharge of the river decreases greatly, back-flow areas with salt water wedges may appear.

3. Preventive works of salt water intrusion

As preventive works the following three ways are recommended:

a. The use of a reservoir

There is no salt water intrusion when the Chao Phraya maintains a large discharge but it commences immediately after the discharge decreases. By maintaining adequate control over the discharge, intrusion can be prevented. This necessitates the building of a large reservoir in the upper stream to increase the discharge in the dry season. Fortunately, there is available the recently completed multipurpose Yanhee Dam. According to plan, the dam is expected to store a very large volume (12.2 billion cubic meters) of water. By releasing this vast volume of water the dam can increase the discharge of the Chao Phraya in the dry season to 350 m^3/s. This volume, however, has already been set aside for large irrigation projects in the upper basin, but even if a small part of it, even about 100 m^3/s could be used to eliminate salt water from the lower basin, the effect would be tremendous.

b. The construction of back-tide gates

If back-tide gates are set up where the lower exit of the discharge meets the tidal river, the salt water can be prevented from flowing back. These gates should be well controlled and maintained to keep the differences of water level between the up- and downstream at the gates in excess of the following:

$$\Delta h = \frac{\rho' - \rho}{\rho} h$$

h = depth of water

Δh = difference of water level of the up- and downstream at the gate

c. The construction of an estuary dam

A large reservoir that would carry an immense volume of fresh water could be had if a dam is constructed at the river mouth to separate it from the open sea. Further it will keep the sea water from invading. There are, however, many factors in this plan that require adjustments relating to the use of river as the port of Bangkok, and thus requires further study.

It will be my intention to analyze quantitatively the mechanism of salt water intrusion in delta areas, to compare the results with those of other investigations and study further how to prevent saline damage in the delta areas.

IRRIGATION AND DRAINAGE WITH SPECIAL REFERENCE TO AGRICULTURE

A. Basic Investigation on Irrigation and Drainage

I. Water Supply, Soil and Soil Productivity in Cambodia

Masamoto Yasuo

Overseas Technical Cooperation Agency

In Cambodia, where rice cultivation is so extensive and little use is made of chemical fertilizers, natural conditions as water and soil play important roles in determining the yield of crops.

The aim of this report is to make clear how water and soil affect crop growth in Cambodia.

1. Relationship between growth of rice crops and water

1. The effects of precipitation and its seasonal distribution on paddy rice production

In contrast to Japan, which is located in the temperate zone where crop growth is governed mainly by temperature and photo-intensity, rice growth in Cambodia in the tropical zone is governed by precipitation and its seasonal distribution.

Derived from agricultural statistics of the Cambodian government on precipitation during three years chosen at random when each province had

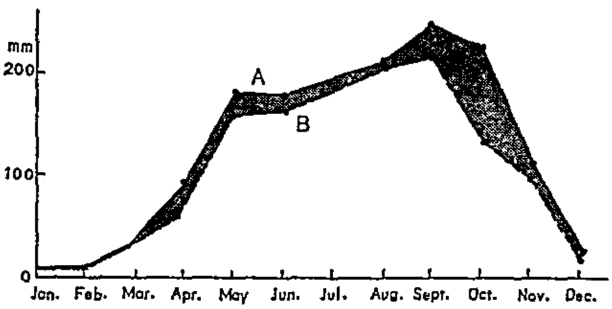


Fig. 1 Average monthly precipitation of 3 years of high or low yields (after Shiraishi)

Note:

A: Monthly precipitation (3 high-yield yrs.) 1,592 mm
Mean rice yield, three years of higher yields 1,420 kg/ha

B: Mean annual precipitation (3 low-yield yrs.) 1,422mm
Mean rice yield, three years of lower yields 800 kg/ha

bumper crops and another three years when production yields were small, average monthly precipitation was worked out in relation to production yields as shown in Fig. 1. More precipitation is seen during abundant years.

Fig. 2 shows the relation between annual precipitation and crop yields, figures worked out that indicated an increase of unhulled rice yields per hectare of each province for every increase of 100 mm of annual precipitation.

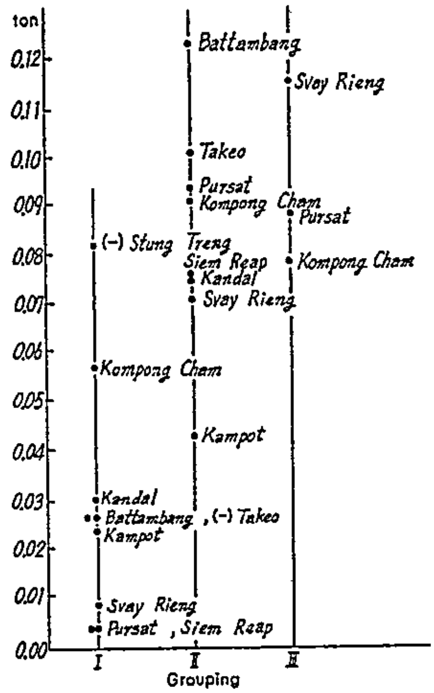


Fig. 2 Amounts of increased yields per 100 mm of annual precipitation (after Shiraishi)

Figures on crop yields of Kompong Cham Province during 15 years show an average increase of 0.058 tons of unhulled rice per ha for every increase of 100 mm of annual precipitation, showing a positive correlation. In the same length of 15 years (excluding 6 years when rainfall distribution was very irregular) the average crop yield increase was 0.091 tons as shown in Classification II, broken down by provinces. The average increase of crop yield of these other 6 years was 0.079 tons, the breakdown of which by provinces is found in Classification III. Figures representing 12 years in Takeo Province and 19 years in Stung Treng Province show a negative trend but in Takeo Province there is a positive correlation of 0.101 tons to be observed in all the years except two when weather conditions were unfavorable.

2. Quality of irrigation water

Table I shows results of simple analyses made to test the quality of irrigation water in several parts of Cambodia during the growing period. Generally speaking, the water is dilute.

Table I Water quality analyses

Location	pH	K_2O	SiO_2	Degree of alkali	Sampling date
Mean value at 13 locations	6.4	1.3	17	35	July~Oct.
Mean value of 203 samples in Japan	6.9	1.8	18	35	
Mekong main stream Kompong-Cham	7.3	1.2	24	62	21, Nov.
Mekong main stream Samrong-Thom	7.0	1.2	14	46	21, Nov.
Barai Occidental	6.0	0.8	10	10	23, Nov.

Soil nutrients assumed to be fed naturally by irrigation water during this period were worked out from average values stated above. Assuming that the rice growing period is 100 days and that 13 mm of water is used for irrigation a day, we get 14,000 tons of water used per ha. Natural supplies of soil nutrients per ha come to 18.1 kg of pottasium(K) and 238 kg of silicic acid (SiO_2) and thus we may assume that pottasium and silicic acid fertilizers are not so effective except in sandy soil areas where only the ears of the paddy rice are taken, leaving the stalks standing.

3. Effects of ponded water on the growth of paddy rice

Observing the state of paddy rice grown in Cambodia we can find a trend characteristic to respective localities. Where rice crops grow badly, irrigation water is generally insufficient, and the paddy fields are located at high altitudes and in many places the ground surface is exposed. Where rice grows well, paddy fields are favorably located where there is a plentiful supply of irrigation water, and the soil is reduced in early stage of submergence and has changed to a dark grey color. In these paddy fields not only is the necessary volume of water for the growth of rice supplied, but can be expected so that supplies of plant nutrients and fresh mud and active multiplication of algae, effects of soil productivity produced by nitrogen and phosphoric acid can take place. Therefore, the further reduced the soil is and darker grey its color,

Table II Growing conditions of rice plants and soils

Location	Growing condition	Soil color (original)		Available phosphorus
Battambang breeding experiment station	excellent	5GY 5/2	dark grey	20 mg/100g
	excellent	5YR 5/2	dark grey	10
	normal	10 YR 6/2	dark brown	5
Farms adjacent to the experiment station	excellent	5GY 5/2	dark grey	20
	normal	10 YR 6/4	brown	2
Skilled farmer's field	excellent	5Y 5/2	dark grey	25
	normal	10 YR 7/4	brown	1

there may be expected more soil nutrients. On the contrary, where irrigation water is insufficient and the ground is often exposed there is lack of nitrogen, phosphoric acid and other soil nutrients. Table II shows an observed instance by which is noted that rice also grows well in soils of grey reduced color, where the available phosphoric acid content is high. To bring soil to this state farmlands should be well-prepared so that irrigation water is sufficient, supplies of manure increased, green manure plants introduced and other means adopted to activate soil reduction. If soil reduction advances too far, plant roots may rot and stalks may droop from excess nitrogen. There may also be other damages, however, generally, the present state of the soil in Cambodia is still far from such a state. Year after year rice stalks grow as high as two meters or more with an abundant spread of leaves. Moreover, what is amazing, is that all this is accomplished naturally by soil in its natural state of fertility so caused by flood waters that submerge the rice fields almost two meters deep.

The effects of ponded water toward soil reduction were verified by pot tests (Fig. 3). The soil, which was submerged in pots for 52 days before transplanting, was already reduced and was a grey color by the time of transplanting. It is assumed that large amounts of soil nutrients became available through soil reduction caused by ponded water.

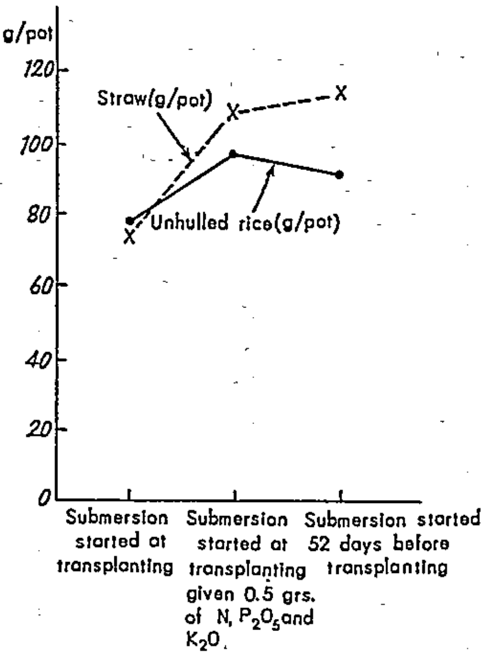


Fig. 3 Effect of water-logging periods on rice yield

2. The "soil" and growth of paddy rice and upland crops

1. Response of paddy rice and upland crops to fertilizers

Fig. 4 shows results of fertilizer tests carried out at the Agricultural Technical Center of Friendship between Cambodia and Japan set up in

Battambang Province.

In spots where only phosphatic fertilizer was used, paddy rice plants grew comparatively well directly after they were transplanted, but later a lack of nitrogen became evident. The ultimate yield was only 2,360 kg/ha. As to spots where only nitrogenous fertilizer was used, paddy rice plants first suffered from acute shortage of phosphoric acid but as soil reduction set in from around the latter half of September they began growing rapidly. It was eventually possible to get 2,984 kg of unhulled rice per ha.

In paddy rice cultivation soil nutrients can be supplied by irrigation water and good use can be made of potential soil productivity, but in upland cultivation this is not the case. Effects of fertilizers are more evident in upland cultivation and lack of phosphoric acid is specially noticeable.

Fig. 5 shows the average results of fertilizer tests made on ten species of upland crops including maize, cotton, cassava, green beans, klotararia, etc. These tests were carried out at the same sites where paddy rice plants were grown and tested.

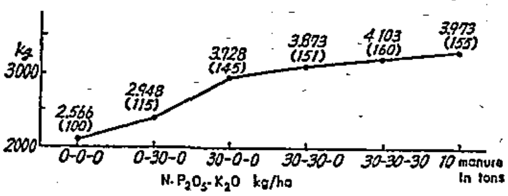


Fig. 4 Response of fertilization for paddy rice

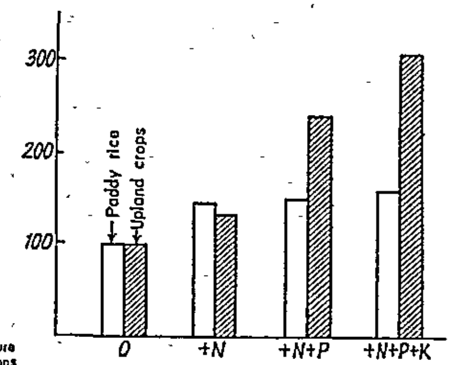


Fig. 5 Response of fertilization for paddy rice and upland crops

The chemical properties of the soil found at these farm sites were as follows, effective phosphoric acid (by Truog method), 1 mg/100 g soil; exchangeable pottasium, 0.1 m.e.; exchangeable lime, 5 m.e.; saturation degree of lime, 33%; pH, 4.7 (H_2O), 4.2 (KCl). Nevertheless, it was found that additional use of phosphatic fertilizers on upland crops proved very effective, so also did pottasium fertilizers. Application of lime for the purpose of modulating soil reaction proved to be fairly effective on Mung beans and klotararia of the Leguminosae family, increasing the yields up to 109 in contrast to the yield index of 100 in sections where only the three elements (N, K, P) were used. But lime had no effect on pasture grass such as the *Sesbania Sesban* of the grass, and it had adverse effects on maize and merely served to lower the yield. Clayey soils are in most occasions either too solidified or too wet to mix in the lime. When applying lime to tropical crops we should study very carefully its effects on the specific characters of crops and on the properties of soils.

2. Agricultural land classification in Cambodia

In soil surveys Cambodia employs an American method whose system of classification and naming is incomprehensible to us in some points. It would be necessary for every soil surveyer to establish a soil survey manual of the tropical soil in order to perform a systematic investigation.

There is a report by Saeki *et al.* of Japan on soil investigations in Cambodia, which is mainly made up of chemical analyses. In this report, however, I intend to use my own system of land classification to describe the relationship that exists between soil and its productivity factors.

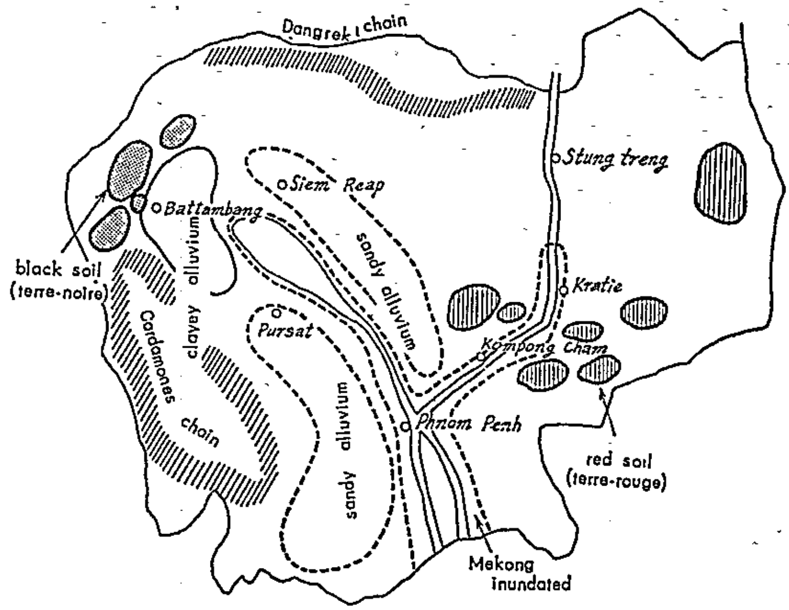


Fig. 6 Soil map of main arable land in Cambodia

(1) Alluvial lowland soil

(i) The Mekong inundated soil

This is an alluvial soil that covers areas flooded every year by the Mekong or the Tonle Sap in the rainy season. These in floods bring fresh supplies of mud. Maize, tobacco, green beans, peanuts, sweet potatoes and other upland crops are grown here before and after the floods. This soil covers an area called the treasurehouse of upland cultivation. Here and there in the area floating rice and other dry season rice crops are cultivated by making use of water reserved in swamps.

(ii) Sandy alluvium

This soil is derived from the Mesozoic sandstone. In some parts of the area at higher altitudes iron becomes loose in the rainy season and coagulates during the dry season and forms a laterite sub-soil layer 40-50 cm below the ground level. The soil indicates a comparatively high water holding capacity and it makes it possible to grow watermelons in the early dry season in some parts of the area. The area covered by this soil comprises about two-thirds of the total area of about 2,300,000 ha of paddy fields in Cambodia.

(iii) Clayey alluvium

This is the soil that has been formed by the alluviation of the Tonle Sap. It covers about one third of the total paddy field area in Cambodia.

(2) Residual plateau soil

(i) Red soil derived from basalt

This is the terre-rouge that is derived from plateau soil consisting of weathered basalt lava of the Quaternary Period. Isolated iron acts as cementing substance and forms soil aggregation which bestows favorable physical properties to the soil in air permeation, porosity and water holding capacity. The soil, therefore, is widely utilized for plantation cultivation such as rubber, coffee, pepper, pineapples, bananas and other upland crops like maize, cotton, beans, etc. At present 56,143 ha of this soil is used for rubber plantations and 350 ha for coffee plantations.

(ii) Black soil derived from limestone

This is a black Rendzina soil resulting from weathering of soft limestone of the Paleozonic stratum. Organic matter has accumulated in combination with lime and it has a somewhat high carbon content. It is in an advanced stage of weathering and takes on a blackish color, thus being unique of the soils in the tropics. In soil reaction it is basic or neutral. The soil forms aggregated structures wherein humus acts as cementing substances. Clay mineral consists of montmorillonite of the 2:1 type. In porosity and water holding capacity, it is rated high. Lately, it has been found good for cotton growing and considerable development has been made in this field but the distribution is limited to residual limestone hills of the Paleozoic stratum. 30,000 ha of this soil is under cultivation now.

(3) Other types of soil

In addition to the five types of soil stated above there is yet another type of soil in valley floors seen locally in sandstone plateau. It is used almost exclusively for paddy rice cultivation.

There is a wide stretch of low lying swamp land called the Jonc Plains which extends through the southern part of South Vietnam from near its border on the left bank of the Mekong. The soil here is an accumulation of sulfates which acidify when dry. A plan to develop this area has been made and an agricultural experiment station has been set up for the purpose.

3. Soil productivity

1. Index of productivity

In Fig. 7 examples are observed of the growth and yields of such crops as paddy rice, maize and cotton that were raised in test pots containing varied types of soil. The index of clayey alluvium is 100. We can see a large deviation in the degree of productivity among various soils tested, in the cases of the Mekong inundated soil, terre-rouge and terre-noire.

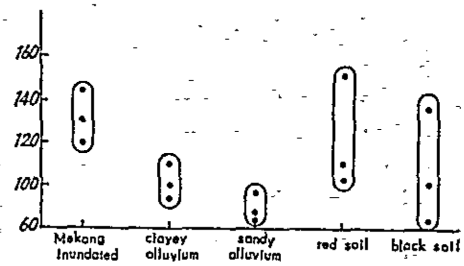


Fig. 7 Productivity index of each soil type

2. A study on elements of productivity

Following are the results of studies made on elements believed to contribute to the productivity of various soil types.

(1) Soil texture

The results of mechanical analyses of soils of representative soil types are shown in Table III. All of the soils disperse well under the dispersing agent, sodium hexameta phosphate. Clayey substance abounds in all the types except sandy soils and in general, soil properties pertaining to light or heavy clay may be observed.

Table III Mechanical analyses of soils

Soil type	Coarse sand 2~0.2mm	Fine sand 0.2~ 0.02mm	Silt 0.02~ 0.002mm	Clay <0.002mm	Soil texture	Heavy minerals in primary minerals
Mekong inundated	9.3%	22.6%	42.8%	25.3%	Light clay	0.28%
Sandy alluvium	40.4	46.7	12.9	0	Sand	0.25
Clayey alluvium	5.5	22.7	32.8	38.9	Light clay	0.28
Red soil	6.3	9.8	15.4	68.5	Heavy clay	1.9~5.0
Black soil	5.9	13.5	13.7	67.0	Heavy clay	2.2

(2) Composition of primary minerals

It has been found, on studying primary minerals, that all the types of soil here contain a small percentage of heavy minerals that exceeding 2.9 in specific gravity. This is shown in Table III. The heavier minerals consist largely of magnetite and the lighter minerals of quartz. Primary minerals do not seem to play important roles as suppliers of soil nutrients.

(3) Clay minerals

Fig. 8 shows the results of X-ray diffraction analyses of the clay minerals of each type of soil. These diagrams along with the results of differential thermal analyses enable us to determine clay minerals as follows:

a. The Mekong inundated soil

The main components of this soil are illite and kaolinite. Some vermiculite is also found. It is a young expansive clayey soil rarely found in Japan.

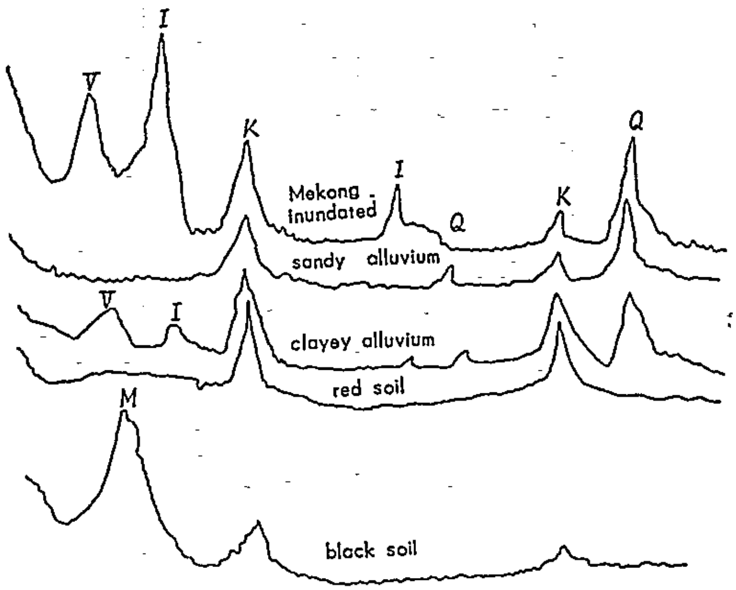


Fig. 8 X-ray diffraction diagrams of clays of representative soils

b. Sandy alluvium
Kaolin is dominant.

c. Clayey alluvium
The main component is kaolinite. Some vermiculite and illite are also found.

d. Red soil (Terre-rouge)
Terre-rouge shows an X-ray diffraction curve typical of kaolin in an advanced stage of crystallization. Fairly large quantities of isolated iron and aluminium oxide.

e. Black soil (Terre-noire)
This is a 2:1 type mineral, the montmorillonite. It has a large water holding capacity.

(4) Water holding capacity of each type of soil

Fig. 9 shows the pF-moisture curves of representative types of soil.

We can see that terre-rouge and terre-noire have an especially large water holding capacity. In terre-rouge isolated iron and aluminium and in terre-noire montmorillonite, the clay minerals of which it is composed, act as the water retainer. At the peak of the dry season, even these types of soil are unable to sustain ordinary plants due to lack of water. Even coffee leaves in plantations wither for lack of water. Terre-rouge is made up of a thick layer of soil several meters deep, but terre-noire, with some exceptions, has only a shallow layer less than 50-60 centimeters deep before it reaches the lime layer.

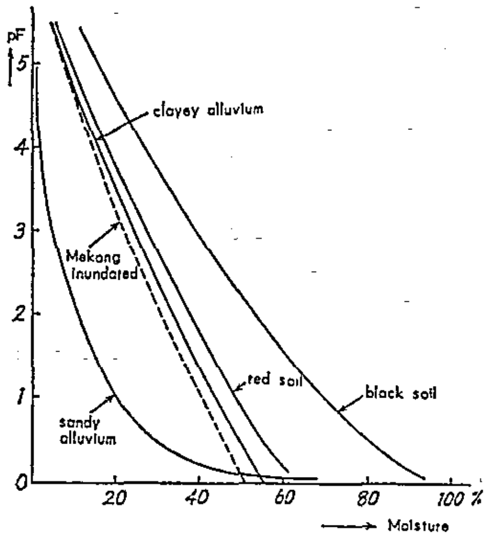


Fig. 9 Soil moisture extraction curves

(5) Tilth

In terre-rouge free R_2O_3 serves as aggregating agents and in terre-noire, humus. They are rich in aggregate structure and offer comparatively few obstacles toward cultivation. Clayey alluvium has a weak soil structure. The soil turns to a muddy state in the case of excessive rainfall, enough to make wagon wheels slip, and in the dry season the soil becomes hard and makes cultivation exceedingly difficult. The Mekong inundated soil carries a comparatively large percentage of silt and sand which makes cultivation comparatively easy. It is in an especially well developed state of prismatic structures, and aggregate structure made by earthworms are found in abundance.

In the case of sandy soil, wooden sticks have to be used sometimes in transplanting rice seedlings to protect the hands.

(6) Chemical properties of soil

Figs. 10-16 show chemical properties of each type of soil analyzed. We can see that each type of soil is characteristically different.

(i) Soil reaction and degree of lime saturation

If we consider soils lower than 5.0 in pH (KCl) value are acid soil, then the acidity of all the types of soil except clayey alluvium may be not so high (Fig. 10). Therefore, the application of lime is of little effect except on beans even in the case of clayey soil.

Figs. 11 and 12 show the contents of exchangeable calcium and the capacity of exchangeable cation. From this the degree of lime saturation may be derived, as shown in Fig. 13. Assuming that damage from acidity comes about when degree of lime saturation is below the limit of 30%, we find that cases where soil acidity is a decisive damaging factor are unexpectedly rare. It is assumed that the scorching heat of the dry season that continues for half the year keeps the soil from becoming strongly acidic.

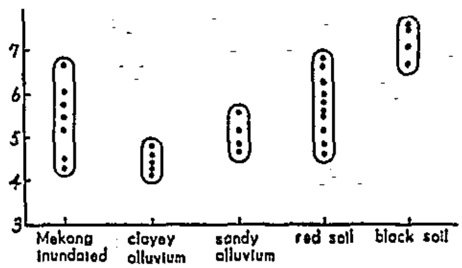


Fig. 10 pH (KCl)

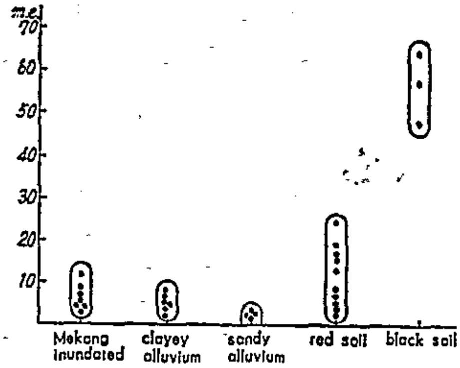


Fig. 11 Exchangeable Calcium

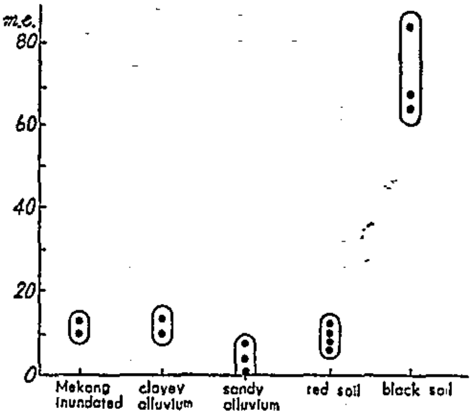


Fig. 12 Cation exchange capacity

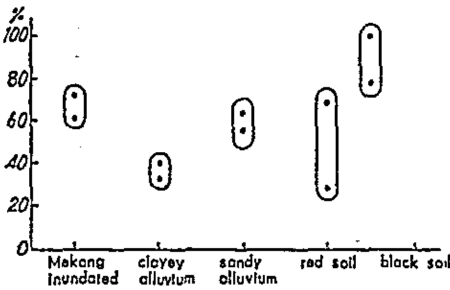


Fig. 13 Degree of Calcium saturation

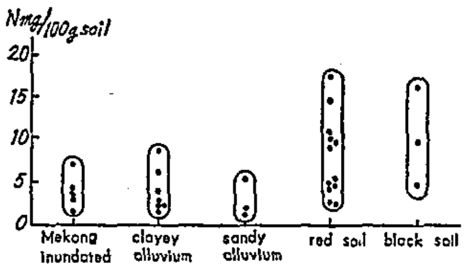


Fig. 14 Available Nitrogen

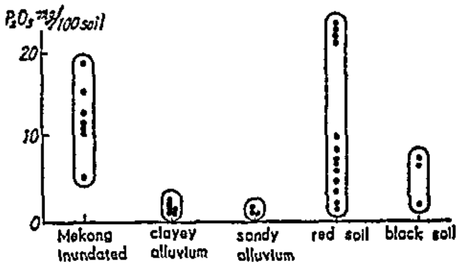


Fig. 15 Available Phosphorus (Truog's method)

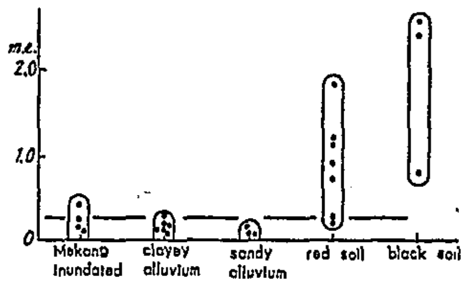


Fig. 16 Exchangeable Potassium

(ii) Nitrogen components

In general, the total carbon content in all types of soil is low except in the terre-noire which has a carbon content of 3-6%. Carbon content in terre-noire is also high. This is because organic matter combines with the lime in the soil, resists the decomposing action by microbes, accumulates, polymerizes, contracts and forms humus in an advanced state.

The values of nitrogen in Fig. 14 are the result of $N\text{-}NH_3$ added to $N\text{-}NO_3$ of the original soil, the $N\text{-}NH_3$ in turn having been obtained by immersing dry soil in the water for 30 days at a temperature of 30°C.

This value is high in terre-rouge and terre-noire, which shows that large quantities of nitrogen turn available when fields are cultivated for the first time.

The productivity of terre-rouge decreases sharply within 3 years after the first cultivation. It is said that even yields of cotton crops drop by about 50% during this period. In such localities where annual crops are grown it would have been necessary to allow the land to remain fallow once in every few years. As a countermeasure the government encourages cultivation of perrenial rubber plants and advises farmers to grow ordinary crops as cash crops until the rubber plants grow.

Fig. 14 shows us that the Mekong inundated soil in which maize can be grown without fertilizers does not have an especially high nitrogen supplying capacity.

(iii) Phosphorous components

The productivity of the soil is closely related with the available phosphoric acid content of the soil. Especially in upland crop cultivation lack of phosphoric acid decisively hampers crop growth. Assuming 3 mg is the minimum contents of available phosphoric acid necessary for soil, we find in Fig. 15 that both clayey soil and sandy soil rate below this limit and that to cultivate ordinary crops in these types of soil, fertilizers containing some degree of phosphoric acid should be used. On the other hand, the soil of the Mekong flood area where maize is grown is comparatively rich in available phosphoric acid content and consequently considerably increased crop yields may be expected by using nitrogenous manure only. At present, there is an experiment going on in Cambodia to make use of its phosphate ore to manufacture phosphatic manure but a method worth consideration is the use of the sediment mud of the Mekong River that contains abundant volumes of available phosphoric acid as soil dressing in adjacent Mekong areas.

(iv) Pottasium components

Assuming 0.25 m.e. is the limit of exchangeable pottasium content necessary in soil then most clayey soil, sandy soil and the Mekong inundated soil fail to rate above the limit. This must be the reason why, as stated before, pottasium fertilizer worked so effectively on upland crops grown in clayey soil. As is the case with other chemical components it is noticeable that the pottasium content greatly fluctuates in the same type of soil in terre-rouge and terre-noire.

3. The relation between productivity and component factors of soil

We have studied and compared the productivity and component factors of each type of soil and by analyzing their physical and chemical properties we were able to ascertain productivity characteristics of each type of soil.

Generally speaking, in productivity, three of the five types of soil, the Mekong inundated soil, terre-rouge and terre-noire exceed the remaining two, the clayey soil and sandy soil. Below Phnom Penh, in the lower stream area of the Mekong, floods are advantageously used for mud irrigation (colmatage) which proves that the high rate of productivity of the Mekong inundated soil is commonly recognized. Terre-rouge and terre-noire vary greatly in soil productivity. Degraded soils of low productivity are found in both types of soil and analyses of their chemical properties show great variations. This is due to the state of soil formation both types of soil are in. Some are in an early stage of soil formation from the basalt lava or limestone the original rock while some are in a more advanced stage or degradation. It also depends upon how frequently the soil has been worked after the land has been cleared. This is why productivity varies so much even in the same type of soil.

Sandy alluvium is a poor retainer of soil nutrients and naturally productivity is low. This type of soil needs every possible means of help toincrease its productivity.

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II. Water Requirements in Sambor, Cambodia

Tetsuo KATO and Takashi KAWAI

Sanyu Consultants International, Inc.

As mentioned previously (p. 67) we were commissioned by the Overseas Technical Cooperation Agency and undertook reconnaissance of Sambor District on the Mekong in Cambodia from November, 1964 to the middle of February, 1965. Our duty was to study the problem of irrigation there. Paddy fields, upland farmlands, swamps, forests and jungles were investigated to find out the amount of water necessary to irrigate these areas. Results of the observations using several different methods have been studied and will be given in this report.

1. Water requirements for paddy fields

From December, 1964 to February, 1965, we carried out a series of experiments in eight localities, in 36 testing fields altogether and studied the question of water requirements of dry season paddy fields during two months. We also set up shallow pond-type testing plots, about 2 m×2 m×20 cm at 14 sites, using nine paddy fields where rainy season rice crops had been harvested in December. We filled these ponds with water and measured the total volume of percolation and water surface evaporation as well as the water holding capacity. The sites where these measurements were taken are shown in Fig. 1. While measurements were taken of water requirements we also made measurements to estimate evapotranspiration in dry season paddy rice testing fields and also in rainy season paddy rice testing fields. We used cylindrical containers equipped with lids, measured the quantity of vertical downward percolation, and we arrived at the evapotranspiration rate by subtracting it from the volume of water requirement in depth.

1. Dry season paddy fields

Examples of measurements taken of water requirements in depth are shown in Figs. 2 and 3. The figures obtained are in the case of silty or clayey alluvial soil. Dotted lines show periods when measurements could not be taken. Water was drawn into the field mostly from the outside by the free flooding method, and so we looked for paddy fields that were irrigated by ponded water and took measurements there but the results were not satisfactory, for there were some paddy fields where the ridges had a considerable number of holes evidently made by crabs and rats. "C" indicates measurements taken by means of tin-plate bottomless cylinders about 30 cm in diameter. We sank them about 30 cm below ground surface, put the lids on and tried to measure percolation water only. There is, however, the possibility that the water may

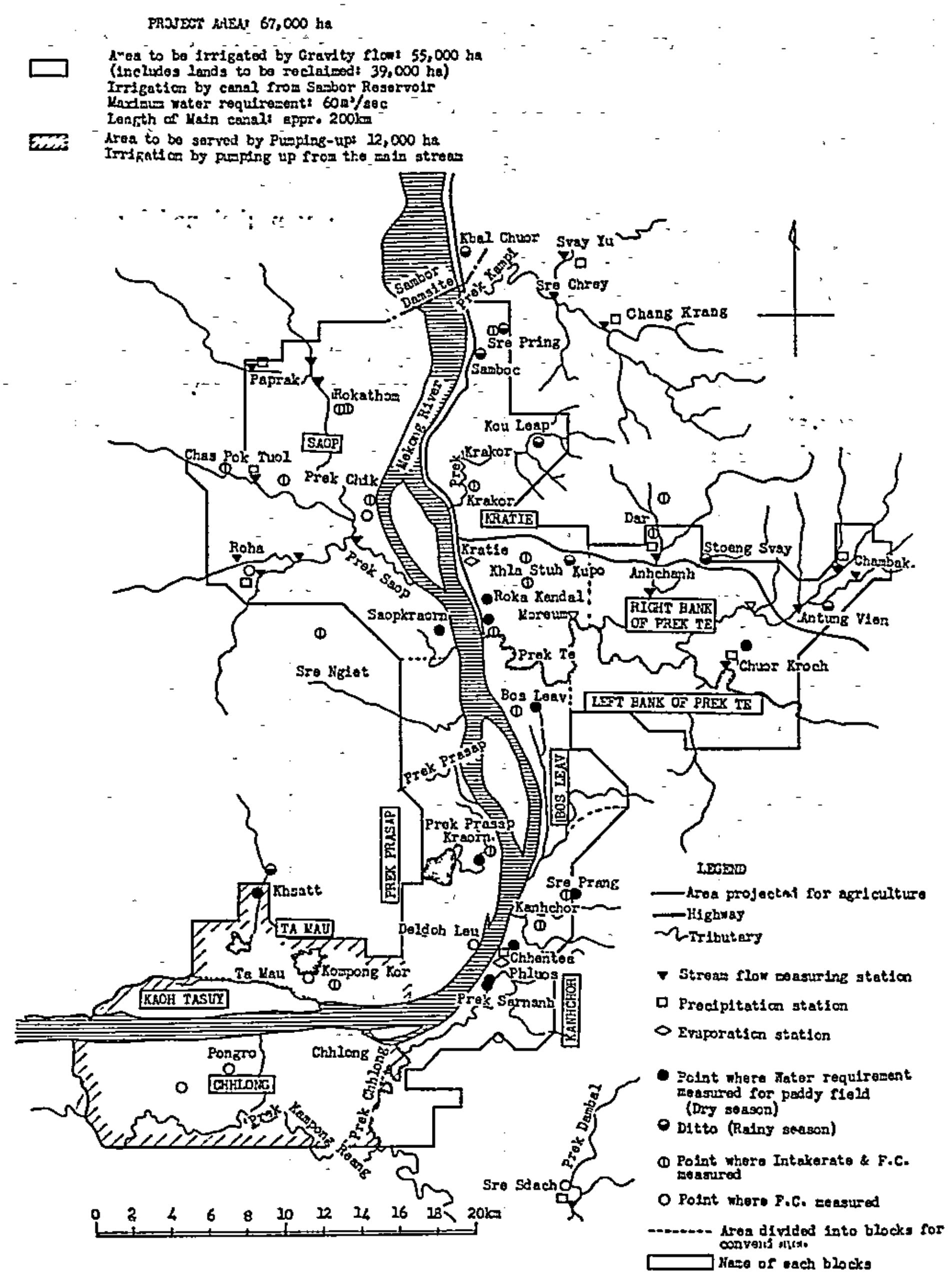
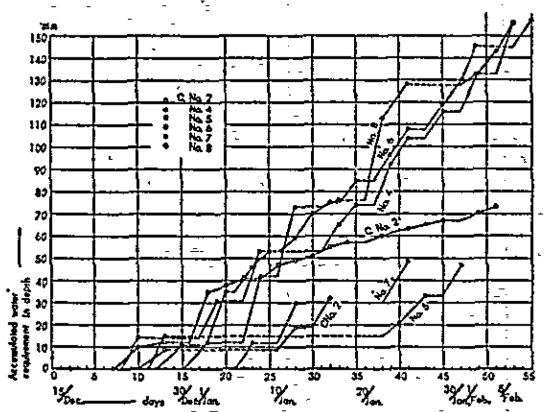


Fig. 1 General plan of Sambor project

have oozed up from the bottom into the cylinder when the water level inside sank lower than that outside, in volumes that cannot be disregarded if taken on a 24-hour unit. We took these measurements only during the time when the ears of the rice stalks were developing.



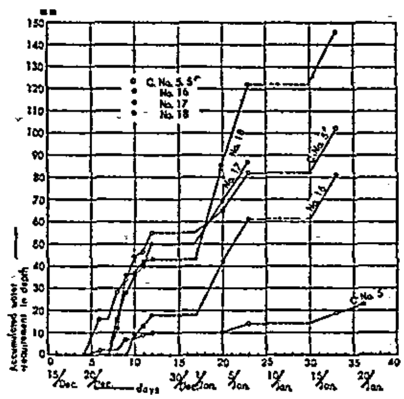


Fig. 2 (left) Water requirements in depth of the rainy season paddy fields (Ph. Rokakandal)

Fig. 3 (right) Water requirements in depth of the rainy season paddy fields (Ph. Bos Leav)

2. Rainy season paddy fields[1]

The testing fields that we used for this purpose were of clayey or sandy sedimentary soil and also in part of alluvial soil. As shown in Fig. 4, a steady percolation state was apparently reached in one or two days after water was let into the testing fields. As shown in Fig. 5, the degree of saturation (10 cm deep from the soil surface) was 80-100%, the volumetric moisture percentage (Mv) was 37% after the soil absorbed the water.

3. Measurements of vertical downward percolation of water

The vertical downward percolation of water was measured in both dry season and rainy season paddy fields. Field percolation meters were used as they were considered more reliable in obtaining data. Table I and Fig. 6 show an arrangement of the results of the measurements, and the properties of the soil and the stage of rice growth disregarded.

The relationship between "y", the water requirement in depth and "*x*", the volume of water percolation, may be expressed in a simple linear equation, $y=ax+b$. We find the value of "a" somewhat in excess of 1.0, which may be accounted for by inclusion of lateral percolation loss, "b" represents the volume of evapotranspiration.

There are considerable deviations to be observed and moreover taking measurements of "water requirements" of rainy season paddy fields in the dry season itself is in question but the actual value of lateral percolation was

1) Rainy season paddy fields were measured for water requirements during the dry season under artificial conditions created to resemble rainy season conditions.

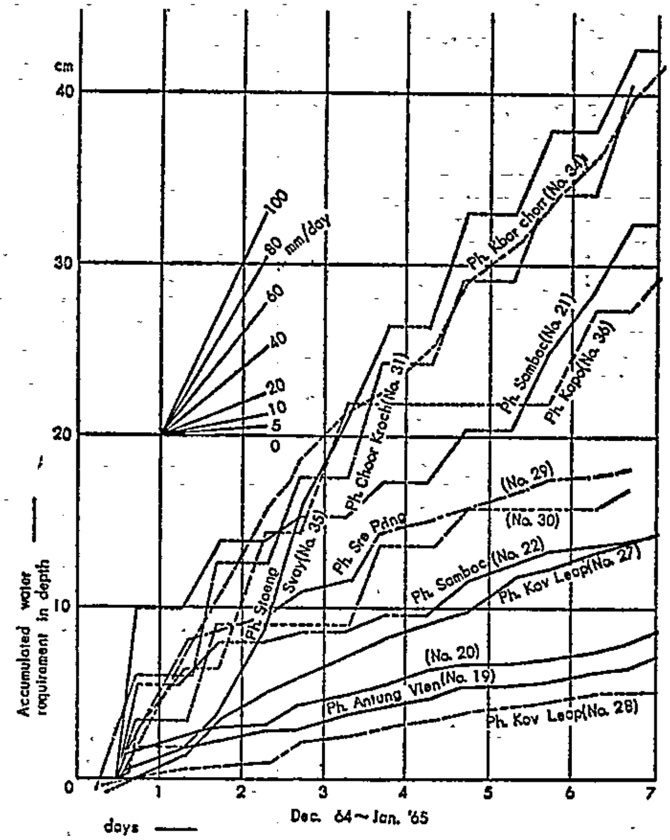


Fig. 4 Water requirements in depth in the rainy season paddy fields

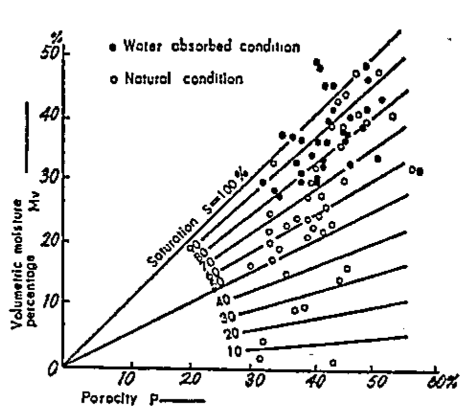


Fig. 5 Volumetric moisture percentage (Mv) and porosity (P) (in rainy season paddy fields)

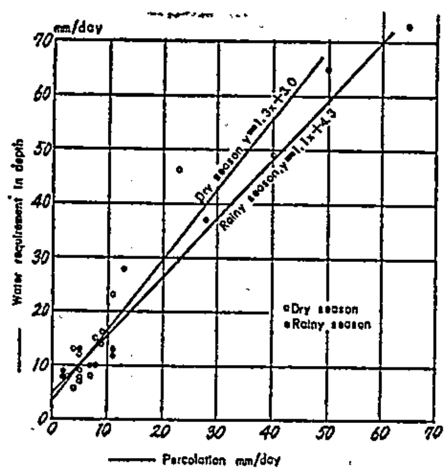


Fig. 6 Water requirements in depth and percolation rate

Table I. Percolation rate and water requirements in depth

Location		Date December 1964	Water requirement in depth	Percolation	Evapotranspiration	Remarks
Ph. Rokakandal No.*	1	13	13 mm	4 mm	9 mm	Dry season paddy
	2		46	23	23×	
	4		8	5	3	
	6		12	5	7	
	7		8	3	5	
	8		15	8	7	
Ph. Sre Prang	2	17	7	5	2	
	3		8	7	1	
	4		6	4	2	
Ph. Levea Thom	1	18	14	9	5	
Ph. Bos Leav C.No.	5	19	10	7	3	
	17		9	5	4	
Ph. Saop Kraom	1	23	10	8	2	
	2		16	9	7	
	5		23	11	12	
	6		14	9	5	
(Mean)			(13.7)	(7.6)	(6.1)	
Total	16		219	122	97	
Ph. Sre Pring No.	30	26	37	28	9	Rainy season paddy
	29		48	11	37×	
Ph. Samboc	21		49	40	9	
	22		9	2	7	
Ph. Chuor Kroch	31	27	144	67	—×	
Ph. Antung Vien	19	27	13	5	8	
	20		8	2	6	
	〃		8	3	5	
Ph. Stoeng Svay	35	27	78	56	22×	
Ph. Kapo	36	27	73	65	8	
Ph. Kov Leap	27	27	28	13	15	
			13	11	2	
			12	11	1	
Ph. Stoeng Svay		28	65	50	15	
(Mean)			(33.9)	(22.5)	(11.4)	
Total			441	293	114	

* Coordinated with Figs. 2, 3, 4

× Excluded from the calculation of water requirement in depth less than we had expected and it was really impossible to take accurate measurements of water requirements in the rainy season. Still we consider that the methods employed served our purpose. However, the volume of water percolation turned out to be considerably larger in the rainy season paddy fields than in those of the dry season, which was due to differences of the depths of ground water levels and to the occurrence of vertical cracks in the soil. Accordingly, we consider that some minor adjustments are necessary.

4. Calculation of unit water requirements

The calculated results of the evapotranspiration turned out to be more or less equal to the observed values obtained by the evaporimeter in the same period, however, the values of the dry season paddy field might be a little larger.

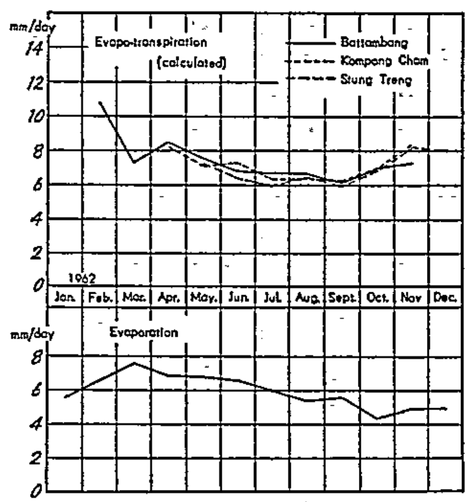


Fig. 7 Evaporation and transpiration, 1962

It goes without saying that when plans are worked out to obtain the estimated water requirements for particular areas, consideration should be given to the soil texture, the rice varieties, the changes that occur at different stages of growth, the selection of the sites to do the measuring and an overall assessment be made, but detailed study of the matter shall be left to future measurements. Roughly, it can be said that the unit water requirements, including various losses, would come to around 15-20 mm/day for the dry season paddy fields and 20-25 mm/day for the rainy season paddy fields.

These unit water requirements should be considered as valid only in cases where both the dry season paddy and the rainy season paddy respectively, are grown in terrain and soil similar in condition to those where they are at present cultivated. When plans are made to grow double crops in the dry and rainy seasons in similar terrain under similar soil conditions, a somewhat smaller unit water requirement should be accounted for the rainy season paddy fields. The matter requires further study as it is closely connected with future land utilization plans.

2. Tests on infiltration rate and field capacity

From January to February, 1965, we measured cylinder infiltration rate at 18 selected sites including upland farms, forests, jungles, grassland (inundated) and paddy fields. The tests were carried out under dry and wet conditions (about 24 hours after water was supplied in the dry condition test). Soil specimens were taken on each occasion and the volumetric moisture percentage was measured.

Though there were a few exceptions[2], the basic infiltration rate (i_β) in these soils indicated figures far less than 40 mm/hr. Compared with the critical infiltration rate for sprinkler irrigation method 75 mm/hr, we see that it is entirely possible to irrigate these lands by a surface irrigation method.

We get Table II by taking field capacity (Fc) the volumetric moisture percentage drained from saturation for 24 hours and calculating the wilting points and the amount of available moisture. The relation of Fc to the apparent specific gravity of soil(Sa) may be observed in Fig. 8. An inverse proportion that is generally observed is also observed here. In comparing the

Table II Fc, Wp, Sa, and A.M.

	Soil texture	Sa	Fc	Wp	A.M.	A.M./Fc	A.M./Wp
			%	%	%		
Ph. Chas Pok	C	1.627	27.6	9.0	18.6	0.67	2.1
Ph. Sre Prang	C	1.397	37.5	13.0	24.5	.65	1.9
Chong O Kapo	C	0.964	34.5	11.8	22.7	.66	1.9
Ph. Krakor	L.C	1.451	34.7	11.9	22.8	.66	1.9
Ph. Kompong Kor	L	1.34	44.5	15.5	29.0	.65	1.9
Ph. Khaan Khvien	L	1.213	36.5	12.6	23.9	.65	1.9
Ph. Prek Chik	S.L	1.317	41.2	14.3	26.9	.65	1.9
Ph. Kanchor	S.L	1.178	48.4	17.1	31.3	.65	1.8
Ph. Dar	S.L	1.573	19.9	6.4	13.5	.68	2.1
Ph. Roha	S.L	1.542	22.3	7.3	15.0	.67	2.1
Ph. Sre Pring	S	1.682	19.6	6.3	13.3	.68	2.1
Ph. Veal Vong	S	1.771	20.5	6.6	13.9	.68	2.1
Ph. Roha Thom ①	S	1.641	22.2	7.1	15.1	.68	2.1
Ph. Roha Thom ②	S	1.647	23.9	7.8	16.1	.67	2.1
Ph. Rokakandal C.No. 7	S.L	1.274	45.7	11.3	34.4	.75	3.0
〃 No. 32	S.L	1.528	47.8	22.5	25.3	.53	1.1

Note: Sa: Apparent specific gravity, Fc: Field capacity, Wp: Wilting point, A.M.: available moisture=Fc−Wp, $Wp=0.238\ Fc^{1.102}$

2) For example, in Ph. Veal Vong and Chong O Kapo which areas were immersed. Here the soil consisted of clay. It was very dry and octangular cracks were found here and there in the dry soil. Alternate processes of drying and dampening of the soil developed the vertical structure. There were also horizontal cracks observed.

soil characteristics to general values of Japanese soil, we find that the values of both the Sa and Fc are considerably larger. It is assumed that this is due to differences of grain size distribution and other physical soil properties. Further soil analyses must be made to study the matter. These soil characteristics of each land category as seen on Fig. 8 are due to the causes that developed the soil and to the soil texture itself. Following is a brief description of the various land categories as depicted on Fig. 8.

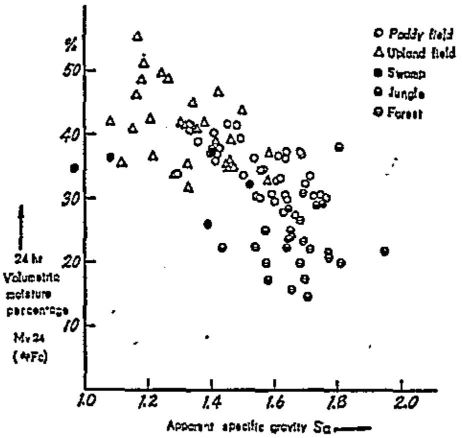


Fig. 8 Field Capacity (Fc) and apparent specific gravity (Sa) by land use

a. Upland farmlands consist of alluvial soil that is derived from micaceous silt of the Mekong silty clay. The aggregate structure is in a well-developed state and accordingly, the value of Sa is small and that of FC is the highest.

b. Forest lands consist in general of aquatic soil in hills of shallow soil layers and contain considerable amounts of gravel and ferrous soil and gravel, or of residual soil that resulted from violent weathering of sandstone and shale. Streaks and tubercles of iron are in the state of drying and hardening, and it is quite impermeable. Fc amounts are small and Sa are large. The soil can be used only to grow paddy rice.

c. In some of the paddy fields there are also found silty or alluvial soil made up by sediments of the Mekong River as well as aquatic soil. In Fig. 8 we see the points of a white round dot indicating the characteristics of this soil widely distributed between upland field soils and forest soils. (Fig. 8 also contains measurements taken at rainy season paddy rice testing fields.)

d. Generally the jungles are composed of alluvial soil that developed along the former course of the Mekong. The water holding capacity of the soil is comparatively large. Its Fc value lies between those of the paddy fields and the forests.

e. The grass land and swamps of the inundated area are almost all composed of alluvial soil. The Fc value is almost the same as that of the paddy fields. Those of clayey soils can be converted comparatively easily to paddy fields and those of silty soil to upland farmlands.

III. Some Experiments and Investigations on Rice Plants in Relation to Water in Malaysia

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1. Introduction

In accordance with the request of the Government of the Federation of Malaysia for technical assistance in a rice physiology program with special reference to the establishment of the new Soil-Water Research Station at Tanjong Karang, the Food and Agriculture Organization of the United Nations (FAO) appointed the author to advise and assist the Government in: Planning the work of the station; formulating the program of research which will involve finding the most efficient way of irrigating rice, the effects of different depths of water, time of watering, etc.; and training Malayan scientists.

The author served in the country from 5 April 1960, until 28 December 1961, with a leave of absence from 29 June to the end of July.

Rice is the staple food of the great majority of the people of Malaysia. Yet locally less than two-thirds of the requirements of the population have been produced. In order to increase rice production, the governmental policy has emphasized increasing the yield per unit area and double cropping rather than utilizing land more profitably used for export crops.

Increasing the yield per unit area can be achieved in many ways, but one of the most important, is by improving water control in this country. Water control in Malaysia means controlling excess water, making the best use of a limited supply of water, and irrigating with adequate water under ordinary conditions. There is no doubt that efficient water control must have the help of public works. It can, however, be stated that water control can also be achieved through knowledge of rice physiology.

It must be emphasized that in Malaysia there are large areas capable of off-season cropping if only water could be made available. The weather conditions during the off-season are generally much better than during the main season, and in fact the Government has already started encouraging farmers to grow off-season rice. Shortage of water is usually the most serious problem confronting off-season crops: to solve this problem, irrigation facilities must be improved and the most efficient way of using the limited amount of water available must be found. If water consumption can be reduced without adversely affecting yield, larger areas can be brought under cultivation.

2. Experiments on rice growth and yield

1. Drought experiments (Effects at different growth stages)

The object of the experiments was to find out the growth stage most susceptible to drought, that is, the most effective stage for irrigation.

The entire growth cycle was divided into 11 periods: at each period four plots were subjected to drying treatments and their yields and yield components were compared. This experiment was carried out in the off-season (variety used, PeBiFun) as well as in the main-season (variety used, Radin China 4) with two different kinds of soils (Tanjong Karang soil, Negri-Sembilan soil). The results conformed with the different seasons and the different soils.

The stage most susceptible to drought was found to be the reduction division stage (miosis) of the pollen mother cell. This was followed by the heading stage and the spikelet differentiation stage. The most susceptible period could be said to be approximately a 30-day period from 20 days before heading to 10 days after heading, centering at the reduction division stage. The serious damage caused by drought is the reduction of ripened grains by defective fertilization.

The experiments indicated that the susceptible stage did not vary with seasons, varieties or soil types and they closely resembled results obtained in Japan. The results from these experiments, therefore, are probably applicable to paddy cultivation throughout the world. In practical application, it is necessary to identify the reduction division stage of the variety, and the author has therefore given a simple and accurate method of doing so.

2. Flooding experiments (Effects of different depths of flooding)

The object was to clarify the growth stage most susceptible to flooding, that is, to determine the effective stage for draining.

The entire cycle stage was divided into 11 periods; at each period four plots were subjected to the following flooding treatments:

a. Whole plant submerged (for 4 days in the off-season, 5 days in the main-season).
b. 75% of plant height submerged (8 days, off-season; 12 days, main-season).
c. 50% of plant height submerged (8 days, off-season; 12 days, main-season).
d. 25% of plant height submerged (8 days, off-season; 12 days, main-season).
e. 5 cm depth of water (control).
f. Non-flooded condition but soil saturated.

The most susceptible stage was found in the reduction division stage of pollen mother cells, followed by the heading stage and the spikelet initiation stage. The damage to rice caused by submersion treatment was more serious the deeper the plant was submerged, but there was a great difference between the "whole-plant-submersion" treatment and other treatments. It was particularly noticeable that only little damage was recognized at heading time if only heads and the top-parts of boot-leaves were above the water surface, while serious damage resulted when the whole plant was submerged. The marked reduction in yield was caused mainly by the reduction of ripened grains due to non-fertilization.

The submersion which significantly reduced the yield was above 50% of the plant height; moreover only at the critical stages did the submersion affect the yield.

The results were in conformity with different seasons and different varieties, hence they could be applicable to other cases of flooding.

3. Water requirement experiments (Transpiration ratio experiments)

The object of the experiments was to determine the amount of water necessary to produce one gram of dry-matter of rice plant, and to find out the seasonal distribution of water requirement.

Using specially designed pots with apparatus to prevent evaporation from the water surface, the amount of transpiration from the plants was measured every day. The measurements were made with a short-term variety (Pe-BiFun) in the off-season as well as in the main-season, and with a medium-term variety and a long-term variety in the main-season.

The author succeeded in determining for the first time the transpiration ratio and the seasonal distribution of transpiration of rice plants in Malaysia.

The transpiration ratio was found to vary considerably with varieties differing in maturation periods but it varied little with season and vigor. It was noted that the yield of grains of PeBiFun in the main season was half that in the off-season and that the weather conditions during the two seasons differed considerably; nevertheless, the values of transpiration ratio in both cases were similar.

A new and interesting finding is that the amount of water necessary for transpiration per day to produce one gram of dry-matter is almost constant (approximately 5 cc) in all cases. There exists a surprisingly high correlation between the transpiration ratio and the maturation period ($r=0.977$). From the relation between the transpiration ratio and the maturation period, the following regression equation was derived:

$$y=4.91\,x+11.1$$

Where y is the transpiration ratio, x is the maturation period expressed by the number of days after transplanting. If the maturation period of a given variety is known, the necessary transpiration ratio can be determined exactly by the above equation. Since the experiment involved different major soil types, varieties and cultivating seasons, the results thus obtained are probably applicable to all conditions in Malaysia.

As a result of calculating the amount of water of transpiration necessary for producing one gram of grain, it is clear that the longest term variety needs three times as much water as the shortest term variety, and that the shorter a variety in maturation period the more economical it is in the use of irrigation water.

The amount of transpiration for each 10-day period increased notably with the growth of the plant after rooting, attaining 70 to 90% of the maximum amount of transpiration at the spikelet differentiation stage and the maximum at the reduction division stage (or at the heading stage). Transpiration decreased markedly after heading as ripening advanced. Since similar results have been obtained in Japan, it can be assumed that there is probably little difference between countries in the tropical and the temperate zones so far as seasonal distribution of water requirement of rice is concerned.

4. Water-depth and movement experiments (Effects of different irrigation water depths and its horizontal and vertical movements)

The object was to determine the optimum depth of irrigation water and whether water should be moving or still to obtain maximum yields.

Combining 4 water depths (0, 6, 13 and 26 cm) and 3 kinds of water movement (standing, horizontal and vertical), rice plants transplanted in tanks (9 hills per tank) were treated for the entire growth period in 3 random blocks. The experiments were conducted in the main-season (1960-1961) as well as in the off-season (1961) with different varieties.

It was conclusively demonstrated that the shallower the water depth, the better the yield, so long as the soil surface was at all times completely submerged. This conclusion was also supported by other pot experiments. In these experiments the yields were strongly affected by the number of panicles per unit area, i.e. the shallower the water depth, the greater the number of panicles. The reason that the shallowness causes the plant to increase the number of panicles and, thereby the yield, was probably due to the fact that shallow water brings about higher water temperatures in the daytime and lower temperatures at night than does deep water. (This serves to encourage tillering, as the author has previously shown in Japan.[1]) Furthermore, shallow water favors the decomposition of organic matter in the soil resulting in a better root-system development. From chemical analyses of the plants and soils used in the experiments, the reason for the 0 cm-treatment always being poorest in yield could be ascribed to the denitrification of the soil.

Since there are hardly any reliable data on the optimum depth of water to be maintained in paddy fields in tropical countries, the results obtained from these experiments will be of great value to the improvement of water management in the tropics.

Only a slight, or no significant difference, between water-movement treatments was found. The effects of moving water, however, will differ with soil types, quality of irrigation water, rate of movement, water temperature, etc., and the results obtained should be re-examined before any definite conclusions are drawn.

1) Matsushima, Seizo, *Agriculture and Horticulture*, vol. 34, No. 5.

5. Ground water table experiments (Effects of different heights of the water table)

The object was to determine the optimum height of the ground water table in the growing season for producing maximum yields.

Results showed clearly that when the water table was above the soil surface, the shallower the water table the better the yield and growth, with the exception of the 0 cm-treatment which was the worst, and when the water table was below the soil surface, the shallower the water table the better the yield and growth. In short, the yields obtained from the various treatments were in the following order: water table 5 cm above the soil>15 cm above the soil>30 cm above the soil>0 cm>5 cm below the soil surface>15 cm below the soil surface>30 cm below the soil surface. These findings support the results of the water depth and water-movement experiments.

6. Water-saving experiments (To determine the most efficient method of irrigation)

The object was to find out the amount of water that could be saved without sacrificing yield.

The following 9 treatments were used:

a. Shallow flooding throughout growth
b. 100% water content throughout growth
c. 80% water content throughout growth
d. 60% water content throughout growth
e. 40% water content throughout growth
f. As in c, but increased to 100% between the spikelet initiation stage and the middle ripening stage
g. As in d, but increased to 100% between the spikelet initiation stage and the middle ripening stage
h. As in e, but increased to 100% between the spikelet initiation stage and the middle ripening stage
i. Intermittent irrigation (during off-season), ideal irrigation[2] (during the main-season).

The water content in each plot was adjusted every other day by the weighing method. In the off-season, only Tanjong Karang soil was used, but in the main season in addition Negri Sembilan soil was also used.

In the off-season the plots were shallowly flooded, so that their mean yield was as much as 94 gm per pot (corresponding to 750 kg/10a). Nevertheless, the 100% water-content plots attained nearly 80% of the yield of the shallowly flooded plots, saving 47% water. The 60% water-content plots showed a marked reduction in yield and the 40% water-content plots barely

2) The "ideal" irrigation was performed as follows: after transplanting up to the time of the final emergence of bearing tillers, water was kept flooding at a depth of 5 cm, after which the soil was dried up to the initial stage of spikelet differentiation and the soil was flooded from the spikelet differentiation stage to the final stage of the most active ripening, but once or twice a week the soil surface was exposed to the air for half a day.

headed. On the other hand, when the soil moisture was increased to 100% between the spikelet initiation stage and the milk-ripening stage, even 40% water-content plots produced as much as 80% of the yield of the 100% water-content plots, saving 20% water.

In the main season, the same trend as in the off-season could also be seen in the Tanjong Karang soil, but a noticeable point was that the "ideal" plots showed better yields by 6% in mean values than those of the flooded plots, saving 20% water. In the Negri Sembilan soil the flooded plots produced many sterile grains caused presumably by an excessive reduction of the soil. Despite the sterile grains, the 100% water-content plots showed better yields than those of the flooded plots. The "ideal" plots produced as much as 159% of the yield of the flooded plots.

In the three series, all flooded plots were only shallowly submerged (2.5 cm), so that better yields were probably obtained than if they had been deeply submerged. Accordingly, the difference in yield in the Tanjong Karang soil between deeply flooded plots and "ideal" plots would be much greater than in this experiment.

In conclusion, it would appear possible to reduce the amount of water used in rice cultivation in Malaysia by at least 30 to 40% without sacrificing yield. The results, moreover, suggest that adequate water management should make it possible to save 15 to 25% of the water used and to get much better yields as well.

7. Soil drying experiments (Effect of varying the length of periods of drying the soil before transplanting)

The object was to determine the minimum length of drying period which would result in maximum yield.

Constantly submerged soil samples obtained from Negri Sembilan were dried for the following periods prior to transplanting: 3 months, 2 months, 1 month, 15 days, Control (water-logged throughout the year).

Judging from the significant level of 5%, "control" and 15-day drying treatments showed a significant difference from all others and there was no significant difference between the other three kinds of drying treatment. The experiments showed that one month is the minimum drying period necessary to produce a near maximum yield and the yields are affected mainly by the number of panicles. Chemical analyses of the soils in the five different treatments showed that the amount of available nitrogen is greatly increased by drying the soil.

These findings agree with the local Malaysian paddy planters' saying that when 4 to 6 weeks of dry weather occur during the non-paddy season, a better growth of the paddy crop will follow. These results must, however, be confirmed under field conditions and with different soil types as well.

On one hand, there are actually many fields dried for too long periods in Malaysia and there is a possibility of shortening the drying period in order to raise two or three corps a year, provided that there are sufficient irrigation and drainage facilities. On the other hand, in Malaysia there also are many fields water-logged all the year round, and in such fields the yield of grain can easily be increased by merely drying the soil. Therefore, improvement of irrigation and drainage facilities in the country must be emphasized.

8. Investigations on the seasonal change in water surface evaporation and evapotranspiration in a paddy field

An evaporimeter (24.5 cm × 25.4 cm) was placed between hills on the surface of water in a paddy field at Tanjong Karang Station, and the amount of evaporation from the water surface between hills was measured every day during the growing periods. In the off-season the rate of evaporation from the water surface varied with the growth stage of the plant, showing a mean value of 0.37 cm in the early growth period, 0.22 cm in the middle period and 0.16 cm in the late period.

An evapotranspirimeter (90 cm × 90 cm × 60 cm) in which rice plants (9 hills) were transplanted at usual spacing was set up in the middle of a paddy field, and the amount of evapotranspiration (the evaporation from water surface plus the transpiration from plants) was measured daily. Readings showed that the amount of evapotranspiration in the paddy field in mean value is 0.50 cm/day in the off-season (1960), 0.49 cm/day in the main-season (1960-1961) and 0.35 cm/day in the off-season (1961). The grain-yield in the evapotranspirimeter was estimated at nearly 240 kg/10a in the first two seasons, and 195 kg/10a in the last season. Assuming the yield in the first off-season to be 240 kg/10a, the amount of water necessary for transpiration based on the transpiration ratio is calculated as 8.38 cm per month. The amount of water per day necessary for evaporation from the water surface between hills can be obtained from the previous investigation as 0.25 cm, viz. 7.50 cm, per month. Hence, the amount of water necessary for transpiration from plants and evaporation from the water surface between hills can be estimated as $8.38 + 7.50 = 15.88$ cm per month. On the other hand, the amount of water for transpiration and evaporation per month in the off-season can be calculated from the results obtained from the evapotranspirimeter as $0.5 \text{ cm} \times 30 = 15$ cm. These values agree with one another.

9. Investigations on the amount of water required for bringing a dry field into a puddled state for transplanting

Several paddy fields with different soil moisture content, ground water level, and seepage of water-through bunds were investigated. As a result the largest amount of water needed (262,190 *l*/10a) was found in a field where the top soil had 24% water content and the depth of ground water table was 65 cm, while the smallest amount needed (107,020 *l*/10a) was registered in a field where the soil moisture was 45% and the depth of ground water table 20 cm.

10. Investigation on seasonal change of percolation in a paddy field

Setting up a tank (90 cm × 90 cm in area and 60 cm in depth, without a bottom) in the middle of a paddy field, the author in 1961 investigated the amount of water lost daily by percolation in the off-season. (In taking means of every 10-day period, only bright days were used. It must be noted that these values include the amount of water evaporated from the water surface in the tank).

Readings showed that during the period from early June (just after transplanting) to early September (maturity) the range is from 0.22 cm/day to 0.57 cm/day. Taking into consideration that these values contain the amount of water evaporated from the water surface between hills, the rate of percolation during the growing period of rice may be considered negligible. The value, however, increases markedly from mid-September, showing 0.84 cm to 1.72 cm; this is clearly due to draining the water in the field as well as in ditches (the water being completely drained after rice reached maturity). It can be concluded, therefore, that the rate of percolation in the field of Tanjong Karang Station is strongly affected by the water level in the ditches. This more or less holds true in any paddy field in Malaysia.

11. An estimate of the actual water requirement per month in the paddy field

On the basis of his experiments and investigations and data available from other sources, the author made an estimate of the total depth of water required per month.

The amounts of water needed in a paddy field were grouped by the follow-

Table I Water requirements

	Period	Water requirements per month (cm)			
		Puddling	Evapo-transpiration	Percolation	Total
Off-season	mid-Mar.~mid-Apr.	Nursery stage; 1/30 of the total area might be irrigated			
	mid-Apr.~mid-May	17.8	10.2	17.8	28.0*
	mid-May~late May	Mid-summer drainage			
	late-May~mid July		21.1	17.8	38.9
	after mid July	Drained out			
Main season	early Aug.~early Sept.	Nursery stage; 1/30 of the total area might be irrigated			
	early Sept.~late Nov.	17.8	10.2	17.8	28.0*
	late Nov.~mid-Dec.	Mid-summer drainage			
	mid-Dec.~early Feb.		21.1	17.8	38.9
	after early Feb.	Drained out			

* This figure does not contain water requirements for puddling

ing factors:

a. Water for initial soil preparation (for transplanting)
b. Water for transpiration from the plant
c. Water for evaporation from the water surface between hills
d. Water for percolation or seepage

a and c were estimated from the results of actual investigations in Tanjong Karang Station; b was obtained from the results of the transpiration ratio experiments: d was assumed from much data from other sources. As a result the necessary amount of water for initial soil preparation was estimated to be about 17.8 cm and the average water requirement in centimeters per month after transplanting was estimated as follows:

8.4 cm (transpiration) + 7.6 cm (evaporation) + 17.8 cm (percolation and seepage) = 33.8 cm.

From this calculation, and taking the seasonal changes of the necessary amount of water for transpiration and evaporation into consideration, a tentative estimation was given on (excluding rainfall).

12. Water temperatures in paddy field

Water temperatures in a paddy field as well as air temperatures were measured daily during the growing periods. At the same time the diurnal changes of water and air temperatures were also investigated.

Results showed that the maximum water temperature does not exceed a mean of 100°F (37.8°C) over a 10-day period, the maximum mean water temperature does not exceed 88°F (31.1°C), the maximum water temperature in each season occurs during the early growth stages due to the small amount of shade by plants on the water surface, water temperature is higher than air temperature in most cases, except in the rainy season, and even in diurnal changes, water temperature is always higher than air temperature, except for a short period. According to the author's experiments (1959) in Japan, in which temperatures of 15°C, 20°C, 25°C, 30°C, 35°C and 40°C were used during the growing period, the maximum yield was obtained at 30°C and only 55% of the maximum yield was obtained at 35°C. His other experiment (1960) in Japan proved that a water temperature of 35°C during the period from the neck-node differentiation stage to the reduction division stage caused a reduction in the rice plant of the percentage of ripened grains, resulting in a marked decrease in yield. From these experiments it is evident that a water temperature of 35°C is too high for good yields.

The author therefore considers that in Malaysia yield is seldom reduced by excessively high water temperature, but in some cases, e.g. stagnant water, bad soil conditions, poor growth of rice plants, etc., there is a fear of marked reduction in the percentage of ripened grains and in yield as the result of high water temperatures[3].

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3) For details, see Ministry of Agriculture and Co-operatives, Federation of Malaya, *Some Experiments on Soil Water Plant Relationship in Rice*, 1962.

B. Water Utilization and Cropping

I. Rice and Field Crops in Cambodia

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I would like to discuss here the problems of cropping and water utilization in Cambodia. My discussion is based on the results of field investigations made when I participated in the Survey Team for Forest Development and Irrigation of Cambodia from March 29, 1964 to May 4, 1964.

1. Regional division of Cambodia

Cambodia, considering agricultural and water utilization development, may be divided into the following areas.

1. The Mekong stream area (upstream from the apex of the delta area)

This is an area extending out from both sides of the Mekong River before it starts forming the delta, and consists of plateau hinterlands, hill country and a region which is flooded by the back water of the tributaries of the Mekong rather than directly by the Mekong floods. There are more upland farmlands in this region than paddy fields. A considerable area still waits to be developed, and there are suitable sites for future construction of dams along the Mekong main stream and its tributaries. With the construction of such dams development of agriculture in this area has a bright future.

2. The Tonle Sap shore area

In the rainy season Lake Tonle Sap grows three to four times (about 10,000 km^2) as large as in the dry season (about 3,000 km^2) as the Mekong backflows up the Tonle Sap River into the lake and the discharge from its own basin increases.

The soil of the flood area is similar to that of the apex of the Mekong delta, and will be considered later. It is comparatively rich in soil nutrients that the muddy flood waters bring every year in the rainy season. The flood area is well developed with paddy fields, where various varieties of rice of varied cultivation periods are grown according to the state of the floods and conditions of the soil.

Flood control of Lake Tonle Sap is closely related to the projects that cover the entire basin of the Mekong River, but there are still many problems to be studied. There is the famous irrigation project "Barai Occidental" on the northern shore of Tonle Sap. On the southern shore are several sites where large scale irrigation and drainage projects are under way—in the Bovel area there is a project under construction; in the Banam area a project is in the planning stage and in the Moung area a project has been already completed. In future there will be developed other similar projects in this area.

3. The apex of the Mekong delta

This is an area where Mekong floods still carry in sedimenting mud and sand. The land and soil of this area is somewhat different from that of the delta of the lower Mekong basin. That is, the area is constantly theratened by both floods and droughts as the periods and the scale of the floods very considerably every year.

Topographically the area is divided roughly into two categories — that which consists of natural embankments and that which is made up of swamp hinterlands. The former area is normally utilized as upland farmlands and the latter as paddy fields. In general, the soil is rich as the floods bring mud and sand to this area every year, but some parts have a somewhat low productivity where the floods bring only small or coarse sediments.

Measures to utilize water in this area should be considered with the measures for the entire Mekong basin, but measures to control water over a comparatively smaller area should also be effective. These should include those to prevent damage from the floods that occur irregularly every year and those to secure ample sources of irrigation water for the flood retreating varieties of rice widely grown in this area.

An important measure to develop upland farm cultivation and to maintain and raise its productivity is colmatage (mud irrigation), a systematic way of supplying natural fertilizer to the fields in the form of muddy water brought from the main stream at flood periods.

4. Coastal plains

The coastal area in and around Kampot Province consists of plains that are completely independent from the influences of the Mekong River. The lowlands are utilized as paddy fields, on the other hand, in the areas ranging from the plateaus to the hills, upland farmlands are well distributed. There is a bright future for this area if effective water utilization projects are carried out to make good use of the rivers and underground water and to bring in means of fertilizing as well as to put Sihanouk-Ville harbor to good use.

5. The highlands

Agriculturally, the highlands are in a very underdeveloped state, especially in Rattanakiri and its vicinity where roads are not improved, but there is a good and promising future. In planning development of this area it is also necessary to consider measures to utilize the forest area.

2. The present state of agricultural production

1. Arable land area

Though there are no statistics to rely on, the total area of arable land is estimated to be around 2,200,000-2,500,000 ha. This amounts to only 12-14% of the total area of Cambodia and it may be said that there are still considerably large tracts of land that have the potential for future development. At present about 60-70% of the total arable and is utilized as paddy fields.

2. The number and the size of farming households

It is estimated that the total number of farming households is about 700,000. If we divide the total area of arable land by the number of farming households we get about 3 ha or more. This represents the average farmland cultivated by one farming household. It may be said that this figure represents more or less the overall average of the whole country. In Battambang Province, which is the most well developed paddy field area, there are some farmers who cultivate paddy fields extending more than several score hectares in area. In the fertile Mekong area there are farmers who, although the size of their farms are comparatively small, make considerable money by cultivating their land intensively. Most of the farmers are owner-farmers but there are also some cases where farmlands are leased to others though not completely in the form of tenancy.

3. Main agricultural products

Needless to say, the most important agricultural product in Cambodia is rice. Rubber and maize are the most important upland crops. With rice, the latter two constitute the three main agricultural export products of Cambodia. Other usual agricultural products include almost everything such as green beans, soy beans, cotton, peanuts, castor beans, tobacco, pepper, kapok, coconuts (palmira palm), sweet potatoes, and sesame. Various fruits, tea, coffee, etc. are also grown. Inhabitants do not keep milch cows, consequently, no pasture grass or other fodder is cultivated.

The dry season is exceedingly arid, which compells the majority of upland crop growers, lacking irrigation facilities, to take advantage of the rains in the rainy season to cultivate their land only once a year. Exceptions are a very limited number of horticultural farmlands where irrigation is by manual labor, and some upland areas where maize and a few upland crops are grown in soil whose productivity has been restored by flood water or whose soil moisture has been retained to some extent.

Productivity of the crops is in general very low, with some specific exceptions, since fertilizing and protecting crops are not yet wide-spread. The wide-spread distribution here of an acid soil which shows a great lack of phosphoric acid and nitrogen content was noticed.

Table I shows the areas cultivated, productions and yield per hectare of the main agricultural products.

Table I Main agricultural crops (1962~63)

	Area planted	Production	Yields/ha
	ha	ton	ton
Unhulled rice	1,740,000	1,689,000	0.97
Rubber	41,680* (28,851)**	41,183	1.43
Maize	125,025	182,000	1.45
Mung beans	35,615	20,660	0.58
Soybeans	16,380	9,626	0.59
Cotton	4,550	3,600	0.79
Peanut	19,902	12,451	0.63
Castor beans	6,200	4,664	0.75
Tobacco	10,185	6,000	0.59
Pepper	520	1,398	2.69
Kapok	1,828,300(trees)	6,453	——
Sugar palm	——	47,373	——
Sweet potatoes	——	29,401	——
Sesame	18,670	11,767	0.63

* Area planted ** Area under gathering

Note: After Annuaire Statistique du Cambodge, 1962.

3. Paddy cultivation in Cambodia

1. *Classification of paddy fields*

Paddy rice is cultivated in almost all the provinces. Table II shows the acreage of the paddy fields of each province. Topographically, these paddy fields can be classified into four types as follows:

(1) Paddy fields found mainly in the vicinity of Lake Tonle Sap and in the flood areas of the Mekong and its tributaries. Making use of the flood waters and the rains, they are cultivated during the rainy seasons. (Mainly situated in the low alluvial plains.)

(2) Paddy fields also found mainly in the vicinity of Lake Tonle Sap and in the flood areas of the Mekong and its tributaries. The paddy fields are covered by very deep layers of flood water and are thus cultivated from after the time the flood water retreats at the beginning of the dry season. (Mainly in the low alluvial plains.)

(3) Paddy fields outside the flood area where rice cultivation is carried out only by utilizing rain water. (In the somewhat higher altitude alluvial plains.)

(4) Paddy fields between the plateaus and the hills where rivers and rainwater are made use of for cultivation. (Mainly in the fan area and in the valleys.)

The paddy fields of category (1) are favored with comparatively stable supplies of irrigation water and rich fertile soil constantly supplemented by supplies of soil nutrients that the flood water brings. The productivity, there-

Table II Distribution of area planted (ha) in rice (by varieties & provinces)

Provinces \ Varieties	Early maturing	Semi-seasonal	Seasonal	Late maturing	Floating	Dry season	Total
Battambang	6	13,909	204,793	88,859	71,538	—	379,105
Kampot	10,907	14,776	86,889	19,928	5	600	133,105
Kandal	50	10,929	40,934	14,267	17,136	14,880	98,196
Kompong Cham	7,457	24,760	60,375	42,415	3,820	11,184	150,011
Kompong Chhnang	3,105	14,852	22,954	9,829	10,105	7,560	68,405
Kompong Speu	566	18,542	72,585	7,212	—	—	98,905
Koh Kong	495	1,944	2,771	—	—	—	5,210
Kompong Thom	407	5,422	29,557	23,943	41,607	152	101,088
Kratie	296	2,068	6,683	—	—	903	9,950
Prey Veng	6,890	11,897	89,264	50,736	36,799	16,892	212,478
Pursat	938	12,020	15,648	10,150	2,711	—	41,467
Stung Treng	25	1,049	1,611	—	—	—	2,685
Siemreap	2,503	6,612	25,929	12,722	19,472	3,980	71,218
Takeo	7,223	15,260	103,175	31,710	24,270	16,339	197,977
Svay Rieng	8,372	47,934	71,567	19,474	933	1,828	150,108
Total	49,240	201,974	834,735	331,245	228,396	74,318	1,719,908
Percentage	3	12	49	19	13	4	100

fore, is, in general, high. The paddy fields of categories (1), (2), (3) and (4) are partially supplied with irrigation water from ponds and rivers, maintaining a stable level of productivity in comparison to other paddy fields.

2. Classification of rice varieties

Rice varieties cultivated at present are the early maturing, the semi-seasonal, the seasonal, the late maturing, the floating rice and the flood retreating (the dry season).

Characteristic features of the areas in which they are cultivated are as follows:

(1) The early maturing

This is a weak photosensitive variety. It is also grown as dry season paddy rice. It is grown in sandy soil where soil fertility is low and where conditions of water utilization are relatively poor. Its crop yield is the lowest of all.

(2) The semi-seasonal

Like the early maturing, this is grown in sandy soil where soil fertility is low and where water is not well utilized. Crop yield exceeds that of the early maturing but is less than that of the seasonal.

(3) The seasonal

This variety is grown in areas of loamy soil of comparatively low altitudes, where supplies of irrigation water are more or less sufficient. Crop yield exceeds that of the semi-seasonal but is less than that of the late maturing.

(4) The late maturing

These are grown in areas of loamy—clayey soil of comparatively low altitudes where supplies of irrigation water can be obtained sufficiently over a long period. Crop yield is higher than that of the seasonal. These late maturing varieties are at times sub-divided into the ordinary late varieties and the extremely late varieties.

(5) The floating rice

This variety is grown in flood areas of low altitude where flood waters cover the ground 2 meters deep or more, sometimes 4-5 meters deep, and remain so for a comparatively long time. Sometimes this variety is sub-divided into seasonal and late maturing varieties, etc., depending upon the length of time they require to mature. The late maturing varieties are the most common. A correlation exists between the period of growth and the depth of flood water. Where flood water is 2-3 meters deep the variety grown is that which takes about six months to mature. Where flood water is 3-4 meters deep varieties requiring about seven months to mature is grown and where the flood water lies 4 meters deep or more the varieties that mature in about eight months is grown. Rice stalks grow at most about 20 cm a day, thus if flood water rises over this in a day, even the floating rice varieties are difficult to grow. Crop yield is generally large but the quality of the rice is bad. This variety is cultivated without transplanting.

(6) The flood retreating (the dry season)

Usually in around November, rice nursery beds are seeded. This is about the time flood waters start retreating. In December the seedlings are pulled out and transplanted. The early maturing variety is used for this, and is limited to areas where supplies of irrigation water are available even during the dry season.

We thus can see that the pattern of distribution of paddy fields according to the varieties of rice grown is largely governed by topographical and water utilization conditions, etc. It is believed that the longer it takes paddy rice to mature, the more soil nutrients the varieties require. The volume of soil nutrients that paddy fields can supply to the plant can be correlated with the soil texture. The general tendency is that the finer the grain size of the soil the more fertile it is. Such fine sedimentary soil settle in the lowlands where

Table III Natural conditions governing rice

Varieties	Submersion period	Altitude	Soil texture
Early maturing	short	high	coarse grained
Semi-seasonal	fairly short	fairly high	a little coarse
Seasonal	medium	medium	medium
Late maturing	long	fairly low	fine
Floating	medium-long	low	fine
Dry season	irrigation available only in dry season	—	

flood waters remain for a long time. Eventually, the interrelative connections that exist between the varieties of rice and natural conditions may be illustrated and are shown in Table III.

In general there is lack of facilities for irrigation and a general custom prevails among the natives to cultivate their paddy fields without using chemical fertilizers. Consequently, the general soil fertility is low and cultivation of double crops, that is the growing of the rainy season varieties and the dry season varieties, is not a common spectacle except in a few limited places where irrigation facilities are available or at places where double crop cultivation is carried out on an experimental scale.

Fig. 1 shows the length of time needed for these varieties of paddy rice to mature.

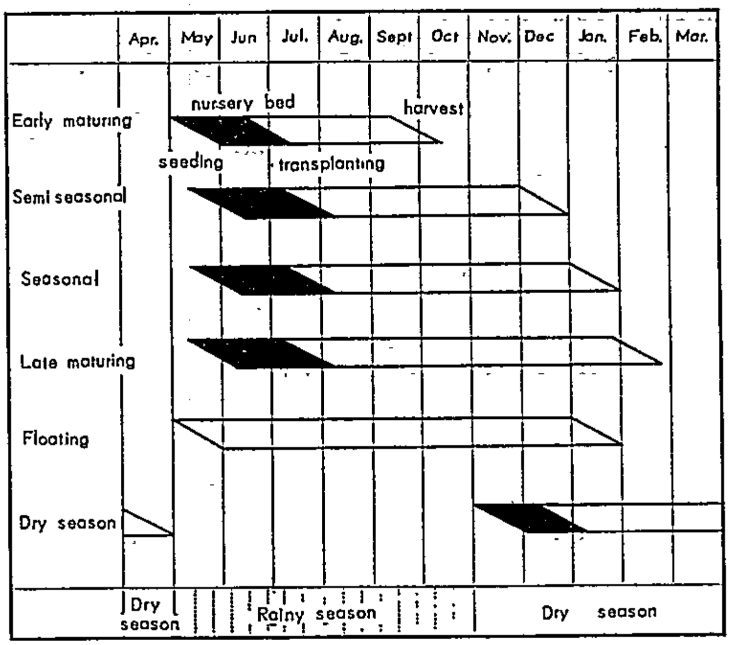

Fig. 1 Growing periods of paddy rice

4. Various problems of paddy cultivation with regard to irrigation and drainage

So far many people have pointed out that basically in Cambodia an important factor that deters the development of rice cultivation, except some exceptional areas, is the fact that nearly all the paddy fields do not have good water utilization facilities. The present absence of these facilities means that the production of rice is affected by weather conditions, that is by the annual precipitation and its distribution. Consequently, the state of rice production is very unstable as we may see by the following:

a. The rainfall and its distribution limit the process of seeding and transplanting. If the rainy season happens to start late there is a good chance that farmers will at times miss the opportune time to carry out seeding and transplanting.

b. If there is insufficient rainfall in the growing period, the drought that follows may decrease crop yields and may at times even stop the growth of the rice plants altogether.

c. If there is too much rain in the growing period, floods inundate the rice fields and may cause much damage, which could result not only in decreasing crop yields but even in reducing them to nothing. In the case of broadcasting, if the soil is too damp in the early stages of plant growth it could damage the budding and the growth of the plants and also cause a decrease in crop yield especially in places where it is difficult to drain off excess underground water.

d. In paddy fields situated at comparatively low altitudes where water is well retained, it is possible to grow varieties of rice that take a comparatively long time to grow but produce good yields. On the other hand, in paddy fields at relatively high altitudes where water is less well retained, farmers can only cultivate rice that take a shorter time to grow and produce a smaller yields. Farmers, therefore, are restricted in the choice of varieties they wish to grow.

e. If the present volume of rice production is to be increased it is absolutely necessary to change the present system of cultivation; that is, it will be important to make more use of fertilizers. To accomplish this, a rearrangement of fields would be necessary so that irrigation and drainage may be controlled at will.

f. At present rice crops are commonly grown only once a year, though climatic conditions may allow double cropping. Why it is not done is mainly because the soil fertility is generally low and because ample irrigation water is hard to get in the dry season. These two factors are related, but at any rate if water resources are prepared double cropping can be achieved.

5. Upland crop cultivation and water utilization

At present almost all the land that receives the benefit of irrigation water naturally or artificially is utilized as paddy fields. The remaining areas, as viewed from the point of water utilization, are upland crop growing fields. At present there are no irrigation projects being carried out worth noting except for the colmatage (mud irrigation) which is carried out in the Mekong stream area.

Upland farmlands may be divided into the following three types according to the conditions of land and water utilization:

(1) Those situated on the natural embankment of the Mekong and its tributaries, overrun by flood water in the rainy season

Flood water feeds the land with natural nutrients and keeps its productivity comparatively high. Maize, green beans, soy beans, tobacco and other upland crops are grown here. In some places double crops are grown, before and after the floods.

(2) Those that lie on the plateaus and hills outside the flood area

There being no floods there is no supply of natural nutrients here and thus the fertility of the land is low. Many varieties are cultivated here and almost all harvested only once a year.

In some parts of this area there are found special cases where irrigation and fertilizing are done by manual labor. They are by no means done satisfactorily, yet the resulting upland farming is considerably high level for this country. Pepper is cultivated in Kampot, oranges in Battambang and Kompong Cham and vegetables in other provinces.

(3) Those in terre-rouge and terre-noire

Terre-rouge is found widely distributed from Kompong Cham to Kratie. There are extensive rubber (*Hevea Brasiliensis*) plantations in this area which turn out large yields.

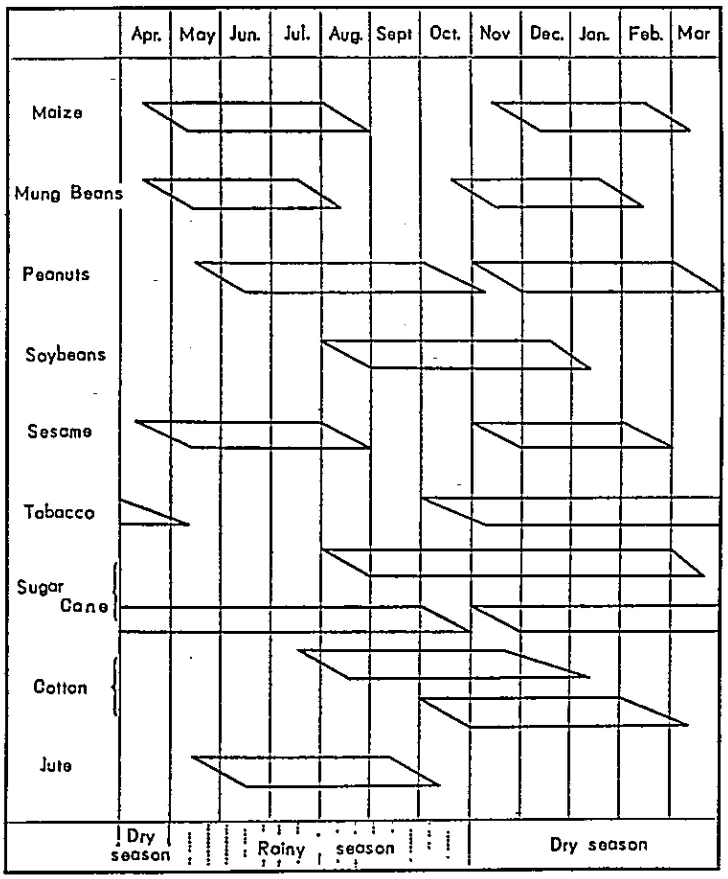

Fig. 2 Growing periods of the main upland crops

Terre-rouge is a good water retainer with other good physical properties. In its early stage of cultivation, terre-rouge maintains a high degree of fertility but it drops quickly within the short time of a few years when it grows ordinary upland crops. Terre-noire soil, on the other hand, derived from limestone, has good supplies of phosphoric acid and is a good water retainer, too. It is the kind of soil that is suitable for cultivation without the use of fertilizers. In Battambang area cotton has been grown since olden days in this soil. Areas of terre-noire are expected to be utilized to grow maize and other upland crops.

Such are the characteristic features of these three types of land. As to the general state of cultivation of upland crops in this area, even in the land of type (1), where conditions for water utilization are regarded as most favorable, crop yields are unstable because of flood damage in latter stages of growth to rainy season crops or because of drought damage in latter stages of growth to dry season crops. In the land of type (2), yields of upland crops are very low because of the low degree of soil fertility.

Fig. 2 shows the growing periods of the main crops in the upland fields.

6. Stabilizing and raising agricultural production by development of irrigation and drainage

We have studied the relation between agricultural production and water utilization in Cambodia. Now, after observing its present state of production we find its level by no means high nor stabilized. The reason why it is at such a low level may be attributed to various social and natural circumstances, but what directly affects its productivity and hinders its development is the underdeveloped state of cultivating techniques and the imperfection of water utilization means. The features most lacking which contribute to the relatively undeveloped state of cultivating techniques include selecting of crop varieties, planting and weeding techniques, eliminating plant diseases and pests, but the most decisive factor, with a few exceptions, is the not using of fertilizers.

Needless to say, stabilization of crop production is attained only when every agricultural technique is combined in harmony. Stabilization is not to be attained merely by changing a non-fertilizing cultivation method to a fertilizing cultivation method. In this context, an indispensable prerequisite is the preparing of conditions for good water utilization so that fertilizers can be most effectively utilized on the farmlands.

We must, however, be extremely careful and keep in mind the existing agricultural techniques in this country. The general level of production is low but there is a certain natural equilibrium maintained among all the factors that contribute toward production. A supplying of fertilizers or improving of water utilization facilities could at times upset this balance and bring about unexpected negative effects. Therefore, in planning new projects it is very important to study all possible angles of agricultural techniques.

A few suggestions shall be outlined as possible measures in stabilizing and increasing agricultural production in Cambodia.

(1) Reclaiming uncultivated land

Land presently under cultivation occupies only a little over 12% of the whole area of Cambodia. There are still large tracts of land waiting to be cleared and cultivated. The Cambodian government is encouraging the reclamation of uncultivated land so that it may be converted into farmlands but the undertaking, depending almost solely on manual labor, is progressing at a slow tempo. Introduction of mechanized land reclaiming methods is anticipated. Land reclaimed in this way is used mainly to grow upland crops but this tends to deprive the land of its productivity quickly, as explained before. Therefore, the government presently is stressing the reclaiming of cultivatable land in the terre-rouge and terre-noire areas. This undertaking, however, is limited in the acreage to be obtained and has the disadvantage of being far from main markets and seaports.

In Kampot Province, the most promising agricultural export crop, maize, is grown and here also is located the port of Sihanouk-Ville. In this province, therefore, land reclamation is of great significance but the efforts in this are making little headway because the soil is generally sandy. Here projects to bring irrigation water to upland farmlands are expected to bring good results.

(2) Stabilizing and increasing the level of production of cultivated land

a. Increasing the degree of land utilization, that is, improving irrigation facilities to make cultivation possible in the dry season and improving drainage facilities by building closed embankments to prevent flood water damage in the latter period of rainy season (for both paddy fields and upland farmlands)

b. Improving irrigation facilities to make possible an introduction of such rice varieties that takes a relatively long time to mature but turns out a large crop yield (for paddy fields)

c. Improving irrigation facilities to make flooding possible at an early stage for the seeding and transplanting of seedlings at an opportune time and for the acceleration of soil reduction (for paddy fields)

d. Improving water utilization facilities in the coastal areas to prevent saline damage (for paddy fields)

e. Improving drainage facilities in low swamp lands to prevent plant roots from retarded growth (for paddy fields)

f. Improving irrigation facilities to stabilize production of flood retreating varieties (for paddy fields)

g. Irrigating upland farmlands to stabilize and increase the productivity of upland crops and to serve as the basis for switching to a fertilizing method (for upland farmland)

h. Promoting colmatage which is very effective in increasing the fertility of upland farmlands and for the prevention of growth of weeds and damage from plant diseases and pests (for upland farmlands along the Mekong)

i. Improving irrigation and drainage facilities so that the paddy field-upland crop systems may be rotated, which is effective in maintaining the productivity of soil and in preventing the growth of weeds and damage from plant diseases and pests (for both paddy fields and upland farmlands)

j. An effective control of irrigation and drainage waters, land adjustment and redistribution of farmlands that will help in the introduction of mechanized farming (for both paddy fields and upland farmlands)

k. Setting up a system of cultivation techniques for the carrying out of agriclutural production of high level that will follow the improvements made in irrigation and drainage conditions (for both paddy fields and upland farmlands) including the following techniques:

Improving crop varieties

Improving cultivating techniques such as tillage, land leveling, seeding, transplanting, thinning, intertillage, etc.

Establishing a fertilizing technique

Establishing methods to prevent damage from weeds, plant diseases and pests

Improving the crop rotation system

Introducing mechanized farming

(3) Other necessary measures

a. Organizing systems for research and experiments, agricultural education and farm management

b. Setting up finances for carrying out various projects

c. Improving the system of distribution of farm products

II. Agricultural Land Utilization Scheme in Sambor, Cambodia

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1. Outline of agriculture in Sambor

Sambor District lies in Kratie Province, in the eastern part of Cambodia, near the border of South Vietnam. It is 340 km up the Mekong River from Phnom Penh, the capital. The areas referred to in this project take up about 67,000 ha of land in Kratie Province, extending over three *Sroks*, Kratie, Prek Prasap and Chhlong. These areas extend along the left bank of the Mekong, from Sambor Dam site to Prek Chhlong, and along the right bank of the Mekong from Sambor Dam site to Phum Kompong Kor, which lies across the river on the opposite of Chhlong. Of these areas, arable land is said to be about 18,000 ha, more than half of the total arable acreage of Kratie Province.

Table I compares the percentages of acreage of arable land, density of population and average sizes of farmland owned by farming households in Kratie Province with those of the whole of Cambodia and with those of Battambang Province, the agricultural center of this country.

We can see that of all the causes that hamper development of this area the outstanding one is the sparseness of population. In this area, only narrow strips along the Mekong have been cultivated by taking advantage of Mekong floods. There are extensive areas of swamp hinterlands at present uncultivated as natural conditions prevent advantageous water utilization, and sparsely wooded areas of little value which are also uncultivated. The total area of paddy fields of Kratie Province is 15,000 ha, a mere 0.7% of 2,296,000 ha, the total area of the country. In unhulled rice, the province turns out only 22,000 tons, a mere 0.8% of the country's total production of 2,760,000 tons.

As to upland crops grown in this area, we find small quantities mainly

Table I Land use in Kratie Province

	Paddy fields	Upland fields	Cultivated land	Population density	Mean land area per agricultural household
	ha	ha	%	person/km²	ha
Kratie Prov.	15,000	15,000	2.7	11.4	1.8*
Battambang Prov.	470,000	25,000	25.8	28.8	
Cambodia	2,296,000	300,000	16.6	31.7	3

* Figure based on oral communication

Note: After the *Report on agricultural statistics*, 1963~64 of maize, green beans (haricot vert), sesame, tobacco and sugar cane, which comprise an insignificant part of the total volume of supply to consumer areas as Kompong Cham, Phnom Penh, etc. In the future, Kratie Province is expected to become the chief supply source of vegetables, fruits and other products in Cambodia when its population increases, irrigation and drainge facilities improve, and fertilizers are used.

Along with Stung Treng, Mondulkiri and Rattanakiri, this area comprises one of the largest forestland areas in Cambodia.

Regarding transportation, there are state highways leading from Stung Treng to Phnom Penh via Kratie, Snoul, Mimot and Kompong Cham and roads running on the natural embankments of both sides of the Mekong for the use of trucks and carts in the dry season. The main role, however, is played by the Mekong River, where boats ply carrying rice, tobacco, vegetables, charcoal and other products down to Chhlong, Kompong Cham and Phnom Penh. Timber is carried out by trucks from the vicinity of Kratie and also from Snoul and Mimot to the Mekong, stream built into rafts and carried down to Kompong Cham and Phnom Penh. Roads allowing passage of large trucks in the dry season into the forest area are well taken care of by people engaged in the lumber business.

The average annual temperature is around 27°C and the annual precipitation about 1,800 mm.

2. Agriculture and land utilization

1. The present state of land utilization

The areas benefitted by Sambor Dam may be divided into the direct area and the indirect area. The former is the area extending about 40 km, less than 40 m above sea level which can be irrigated directly by water stored at Sambor Dam. The latter continues from the former downstream along both sides of the Mekong. Here substantial benefits may be anticipated for the land from irrigation by pumping from the main stream and the tributaries of the Mekong.

Table II shows the present state of land utilization of this area. In the area extending from the scheduled Sambor Dam site to Kratie, on the left bank of the Mekong, paddy fields (rainy season rice) dominate. Upland farmlands are found only in small sections on the natural embankment area of the Mekong. Here tobacco and maize are grown once a year, while banana plants, orange trees, and cocopalms are found grown in small patches around dwellings. As

Table II Land use in Sambor at present* (× 1,000 ha)

	Paddy field		Total of paddy field	Upland and orchard	Forest		Grass land (inundated)	Sum Total
	Rainy season	Dry season			Sparce	Jungle		
Directly benefited land	3.2	0.6	3.8	4.8	22.0	4.9	19.8	55.3
Indirectly benefited land	0.7	0.3	1.0	4.9	0.2	0.4	5.2	11.7
Total	3.9	0.9	4.8	9.7	22.2	5.3	25.0	67.0

* These are roughly estimated figures

we go downstream from Kratie to Prek Te and further down to Prek Chhlong we find upland farmland increasing in acreage. Fruit trees such as kapok, cocopalms are also found. Here paddy fields growing dry season rice are found. Beyond Prek Te, further upstream we come across more alluvial paddy fields than upland farmlands.

As we go south down along the right bank of the Mekong we also find the upland farmland area increasing until we reach the area opposite Chhlong, across the river, where upland farmland acreage exceeds paddy fields. Compared to the left bank area, we find slightly more dry season rice fields in the right bank area. There are some paddy fields irrigated by water drawn by small pumps (about 2-3 HP) from the ponds (*Baengs*) that are found in the lowlands of the flood area and from small rivers that do not dry up in the dry season.

In all, the area is extremely well utilized taking advantage of natural conditions. During the rainy season, using the floods, almost every inch of the land that can be utilized as paddy fields is cultivated, but in the dry season, neither land nor water is utilized to a great degree.

2. The present state of farm management

Farms in Sambor District may be classified roughly into five categories.

a. Farms that are found at altitude of 25-30 m above sea level, in fluvial sedimentation areas and in paddy field areas that lie along small rivers and streams, where rainy season paddy rice is cultivated by taking advantage of a 50 cm or so layer of flood water from the hills and from the rivers.
b. Farms that lie in the paddy field area of alluvial soil in the Mekong flood area, at its upper part, where rainy season paddy rice is cultivated by utilizing 50 cm or so deep ponded water in the rainy season.
c. Farms that cultivate dry season paddy rice by utilizing the ponds (*Baengs*) and small rivers that flow through the alluvial soil area of the Mekong flood area.
d. Upland farms scattered in narrow strips of land on the natural embankment area along the Mekong.
e. Farmers that own both upland farms of (d) category and paddy fields of categories (a), (b) or (c) mentioned above.

Large farming households in possession of paddy fields and/or upland fields own an average of 5-10 ha of land. Medium-sized farmers own 2-4 ha and small farmers about 1 ha.

Of these five types of farms the majority are of the (a) and (d) type household; the (b), (c) and (e) types being few. There are many farmers who live in villages along the Mekong and travel several kilometers to till their paddy fields in the fluvial sedimentation area. (Many construct temporary dwellings near their paddy fields during the rice growing period.) Land is generally left uncultivated except in the alluvial soil area where in the rainy season the Mekong floods every year bring fresh supplies of muddy soil rich in lime, phosphoric acid and other soil nutrients and except in comparatively high altitude fluvial sedimentation areas along rivers and streams.

(1) Paddy farmers

Whether they grow rainy or dry season rice, the farmers here cultivate their land only once a year. They use neither fertilizers nor chemicals to prevent plant damage. Crop yields differ according to the fertility of land, conditions of rainfall, etc. but on the whole the yield in unhulled rice is about 2.7-0.9 tons/ha. The average yield is about 1.8 tons/ha in unhulled rice (about 1.4 tons in hulled rice). The crop yield of dry season rice is believed to be somewhat less than that of rainy season rice, but how much is not clear. Each household owns an average about 2 ha of land, which means that in a normal year, yield per household averages 3.6 tons. Assuming that a household has an average number of 5 members, this comes to 0.9-1.1 tons of rice for family consumption in one season, about 0.54 tons for hired labor and ox cart rental (two oxen). A further deduction must be made for seeds, which leaves about 1.8 tons available for sale or barter. Rice is usually sold at around $2.9 per 0.04 tons (2 *tan*, 100 *Riels*). By selling the 1.8 tons each farming household gets about $130 cash income. Almost every farmer goes away for about two months every off-season to work as a laborer to fell and cut wood and bamboo for firewood and charcoal. This brings in an extra income of about $87, so in all, the gross income per household comes to around $220.

A household of five members spends about $220, so the actual balance comes to zero. Thus, farmers have the custom of helping their neighbors. Rice is borrowed and lent out in bad years and returned the following year or later after a good season. The same system is observed in labor. There is the custom of borrowing or lending labor and of offering joint labor in cooperative undertakings.

(2) Upland crop farmers

Upland crop farmers live in narrow strips of land, 2-3 km wide, on the natural embankment of the Mekong. Every year in the rainy season flood waters from the Prek Te, Prek Kampi, Prek Chhlong, Prek Sop and other Mekong tributaries bring muddy soil rich in nutrients to this area. The area is thus an alluvial soil region. Generally maize and sesame are planted here in the rainy season before the floods. In the dry season green beans (haricot

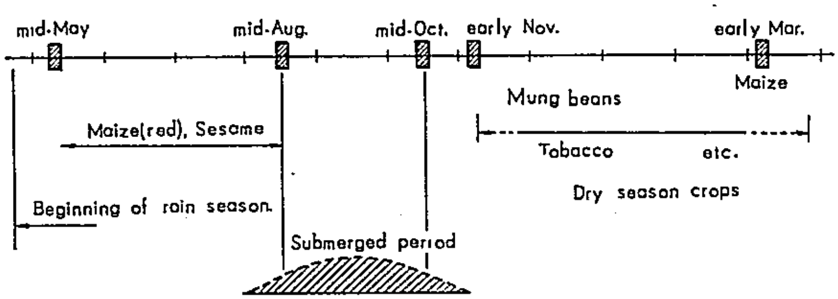


Fig. 1 Ordinary cropping schedule of farmers

vert), tobacco, maize, sesame, peanuts, cassava, watermelons, pumpkins, tomatoes, cucumbers, cabbages, sweet potatoes, etc. are planted. Other crops grown include sugar cane, cotton and fruits such as bananas, oranges, kapok, cocopalms, etc. The average acreage of cultivated land is about 2 ha, which more or less equals that of the paddy fields. Commonly farms rotate their crops as shown on Fig. 1.

Based on this cropping system, the budget of an average farm possessing 2 ha of land would be as shown on Table III.

Table III Areas planted of main crops and gross income

Season	Crops	Area planted	Yield per ha	Mean yield per ha	Production	Selling price	Gross income
		ha	kg	kg	kg	US$/kg	US$
Rainy season	Maize (red)	2.0	1,000~ 3,000	2,000	4,000	0.058	230
Dry season	Maize (white) (red)	1.0	800~ 2,500	1,000	1,000	〃	58
Dry season	Tobacco	0.5	300~ 1,000	(raw) 700 (dry) 100	(raw) 350 (dry) 50	(dry) 0.58~ 0.87	44
Dry season	Mung beans	0.5	500~ 1,500	700	350	0.174	58
Total							390

From Table III we can find that the gross income amounts to $390. Assuming that upland crop farmers get no extra income by side work since they are obliged to work their farms in the dry season, a household consisting of five members may spend about $320. The balance left would be $70. It would seem that upland crop farmers are better off than the paddy farmers who till the same acreage of land. This is not necessarily so since the latter are in a more advantageous position in that they hold stores of the staple food rice to tide over in case market prices are not stable or in case of famine.

3. A proposal on land utilization

To determine how land in this area should be utilized it will first be necessary to study the crops that have so far been introduced in this area and also crops possible to be introduced for cultivation. Also plans for agricultural products must be made to satisfy domestic demands, to process those products imported at present (necessitating, of course, the development of processing industries) and to promote exports. It will be necessary to further study agriculture in this area and in Cambodia, but if we were to make a recommendation, it would be that paddy field acreage in Kratie Province be increased by about 1.5 in order to satisfy the domestic demands of the present population of this province, because the percentage of paddy fields in this province is very low compared to other provinces. Future increase in land productivity may, of course, be expected but now we are basing our recommendation on the present level of production. There will be a further increase of acreage of paddy fields necessary when future increase of consumption of rice accompanying population increase is taken into consideration. If we are to consider not only the problem of securing adequate supplies of rice but also for increasing supplies of rice for export purposes, there must be had further paddy field acreage increases.

At the present stage an estimate of the future of upland farming of this area would involve increasing the production of maize which, as an export crop, is stable and also has good prospects to increase its export. Therefore, future development of this area should naturally be directed toward increasing the production of rice and maize. Consideration should also be directed to sugar cane and cotton, essential in changing from importing to domestic production, but we ran across doubts regarding increasing the production of sugar cane and decided that it needs further study. Therefore, our upland farming plan placed emphasis on the production of maize. Nevertheless, sugar cane production must be further studied carefully as a request will certainly arise for increased production as domestic consumption increases with the rise of the general standard of living and as the problem of exporting raw sugar arises.

As seen from the standpoint of production and circulation[1] maize is a crop whose demand as fodder will increase world-wide. Cambodia can afford to increase her maize production and its export considerably. Japan, for instance, imports about 2,500,000 tons of fodder maize annually. A look into Cambodia's past export records shows that she produced about 400,000 tons of maize during 1937-1938. She only managed to produce this volume under the protection of French policy but she did do it and it represented 64% of the total French

Table IV Projected land use

		Paddy field	Upland field	Total	Swamp	Sparse wood	Jungle	Sum total
(Left bank of the Mekong) Kratie, both banks of Prek Te, Srok Chhlong along the Mekong	direct	3.0	3.3	6.3	11.6	15.1	0.6	33.6
	indirect	0.7	2.5	3.2	3.6	0.1	0.3	7.2
(Right bank of the Mekong) Khum Taman, Kach Tasuy along the Mekong (Srok Prek Prassap)	direct	0.8	1.5	2.3	8.2	6.9	4.3	21.7
	indirect	0.3	2.4	2.7	1.6	0.1	0.1	4.5
Total	direct	3.8	4.8	8.6	19.8	22.0	4.9	55.3
	indirect	1.0	4.9	5.9	5.2	0.2	0.4	11.7
	total	4.8	9.7	14.5	25.0	22.2	5.3	67.0

1) Kato, Yasumaru, *Agricultural Situation in Cambodia*, Scientific Technique Bureau, Dept. of Natural Resources.

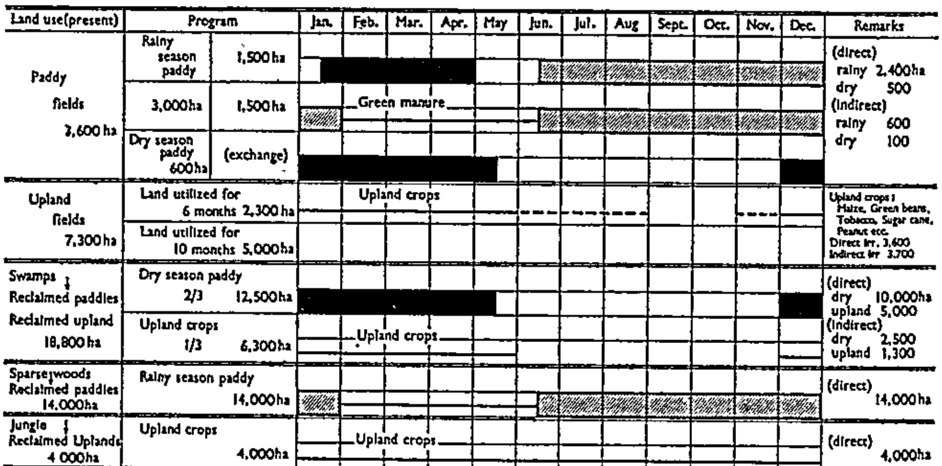
Indochina production, which far surpasses the 127,000 tons (1964 level).

In the future when plans are made to increase the volume of maize export, lowering the export price is the main point. This necessitates lowering the cost of production. Therefore, it is necessary to increase the yield per hectare and to further enlarge the cropping area. The land utilization plan shown in Table IV has considered the points enumerated above as well as the conditions such as topography, soil, irrigation and drainage.

Of the acreage mentioned above, those that are expected to receive the benefits of irrigation, excluding those topographically secluded or those destined for other purposes, are estimated to comprise about three quarters of the total acreage (the sparsely wooded area is estimated to be about two-thirds). A rough classification of land utilization set down in acreage for development is as follows:

(1,000 ha)		(Present land category)	(Planned land category)	Acreage (1,000 ha)
		Paddy fields	Paddy fields	3.6
		Upland fields	Upland fields	7.3
Paddy fields	30.1			
		Marshy land	Paddy fields	12.5
Upland fields	17.6		Upland fields	6.3
		Sparse woods	Paddy fields	14.0
		Jungle	Upland fields	4.0
Total	47.7		Total	47.7

Table V Cropping schedule



Total 47,700	Cultivated area per month*		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug	Sept.	Oct.	Nov.	Dec.	Remarks
		Rainy season paddy	15.5 (0)					8 5 (8 2)	17 0 (16.4)	17.0 (16.4)	17.0 (16.4)	17.0 (16 4)	17.0 (16 4)	17.0 (11.7)	( ) directly irrigated area
		Dry season paddy	13.9 (11.1)	14 6 (11.7)	14.6 (11.7)	14.6 (11.7)	8.1 (0.6)							13.1 (10.5)	
		Upland crops	17 6 (12.6)	17 6 (12.6)	17 6 (12.6)	17.6 (12.6)	17.6 (12.6)	9.0 (6.5)	9 0 (6.5)	9.0 (6.5)	4 0 (4.0)	4 0 (4 0)	9.0 (6.5)	17.6 (12.6)	

* Figures of cultivarted area per month are indciated 1,000 ha.

Dry season paddy   Rainy season paddy

The cropping areas and monthly irrigated areas are classified roughly in Table V.

In drawing up the above mentioned plan for land utilization, the following points from the standpoint of irrigation and land reclamation were considered:

a. Stabilizing rainy season paddy rice production: Our plan involves the irrigation of existing paddy fields so that irregular rainfall and unbalanced distribution may not make planting impossible nor delay transplanting time and also that droughts may not cause damage to the crop during its growth.
b. Reclaiming rainy season paddy fields: Our plan is to bring water to low productivity woodland areas and create rainy season paddy fields.
c. Stabilizing dry season paddy rice production: Our plan involves stabilizing water resources for dry season paddy fields that are now cultivated by utilizing the water from small streams, ponds and marshes.
d. Reclaiming dry season paddy fields: Our plan is to bring water into alluvial grassland (presently a flood area) lying along the Mekong River and to create dry season paddy fields there.
e. Introducing dry season paddy rice for double cropping: Our plan involves utilizing rainy season paddy fields in the dry season by securing sources of irrigation water.
f. Stabilizing upland crop production by upland field irrigation: Our plan involves increasing the land productivity, as well as raising the land utilization rate: stabilizing and increasing the productivity of upland farmlands by using ponded water. In this way the present land utilization rate could be increased, that is the present annual two-time land utilization — one crop before the floods in the rainy season and another crop in the dry season — may be changed to an annual three-time land utilization system — one crop in the rainy season and two crops in the dry season.
g. Reclaiming upland farmlands: Our plan involves creating new upland farmlands by irrigation in the alluvial flood areas along the Mekong River where topographical conditions allow.

WATER RESOURCE DEVELOPMENT PROJECTS

A. Developing and Planning Irrigation and Drainage Projects

I. Comprehensive Development of the Lower Mekong Basin

Kensaku Takeda

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1. General description of the Mekong River[1)]

The Mekong River starts on its long travels far up from the Tibetan plateau, the "roof of the Asian continent". It flows through Yunnan and the northern part of Burma, passes through the Thai-Laotian borders and crawls over the flatlands of Cambodia to empty into the South China Sea at the western end of South Vietnam. The total length of the river is about 4,200 km. It is the 10th largest international river in the world. (The catchment area is 800,000 km^2.)

The lower Mekong basin referred to in this report is the area in Laos, Thailand, Cambodia and Vietnam through which the Mekong flows. From the neighborhood of Vientiane, Laos, the river flows over a distance of about 2,700 km. The catchment area is about 610,000 km^2 where live about 24 million people. The boundary-point between China, Burma and Laos, where the main stream of the Mekong flows at 490 meters above sea level, divides the Mekong river basin into two sections for the basin development programme. The downstream from this point until the Pa Mong flows through ravines and the slope is rather small. There is hardly any flatland to be found in this region and except for Luang Prabang that lies along the main stream and a few towns in mountainous valleys. There is little land in this area suitable for people to live in groups. A plain below Pa Mong widens out on the southern bank of the Mekong River. This is the so-called Khorat Plateau. It lies 100-200 meters above sea level and slopes gently down toward the south-east. The Nam Chee and Nam Mune Rivers flow through this plain and join before they flow into the main Mekong River. To the north of the Mekong the Vientiane plain expands around the Nam Ngum River. The Mekong

1) Cf. regarding its hydrology, Takenouchi, Toshio, "Hydrological Investigation in the Lower Mekong Basin," pp. 55-66, and Kato, Tetsuo and Kawai, Takashi, "Hydrology and Meteorology in Cambodia," pp. 67-76.

soon meets the Annamese Cordiella mountain range and swerves its course southward, rushing down over the Khone Falls to enter Cambodia. On its right bank opens a plain, 100 meters or less above sea level and in the western part of this plain lies Lake Tonle Sap, also called *Grand Lac*. In the dry season the lake area is about 3,000 km² but in the rainy season it expands to 10,000 km², in order to become a part of the regulation reservoir of the Mekong. The basin below Sambor, Cambodia, is called the Mekong plains. Here from upstream the river brings sand and silt which settle and make shallows here and there. Near the river mouth is found a large delta of nearly 300 km in length.

2. Land utilization and irrigation in the Mekong area

An agricultural feature of this area is the vast acreages given to paddy cultivation. This tendency is not a phenomenon peculiar to the Mekong basin but quite common throughout the whole of the monsoon area of Southeast Asia. Economically, rice cultivation in the lower Mekong basin is of great value, greater than that of any other single crop grown there and shows that in land utilization, paddy cultivation best suits the land and water conditions of this area. It is because of this that rice cultivation is high in productivity and is stabilized in comparison with other forms of land utilization.

1. Land utilization

From the standpoint of land utilization this area may be roughly classified into four; the mountain and hill area, the highlands, the Mekong plains and the Mekong delta area.

(1) The mountain and hill area

This area lies 200 meters or more above sea level. The mountainous region extends from the northern part of Laos down south and divides into two parts. The eastern part extends on to the Annamese Cordiella mountain range and the western part on to the Dong Phya Yen and the Cardamones mountain ranges. Here in and between the forests are scattered small, narrow patches of land that have been cleared and are cultivated to grow rice and other upland crops for family consumption.

(2) The highlands

The representative highland area is the Khorat Plateau of Thailand. It rises 100-200 m above sea level. (Other highlands in the Annamese Cordiella Mountains, 600-1,000 m above sea level, are sometimes called the "elevated highlands"; *e. g.* the Bolven highland in Laos, and in Vietnam the Kontum, the Ban Me Thout and the Dalat highlands.) The Khorat Plateau is a structural plain consisting of Mesozonic sandstone. It has sandy soil which is not very fertile. The area is about 170,000 km²; 16% of it being arable land and the remainder open forests. A large part of the alluvial lands stretching along the Nam Mune and Nam Chee Rivers and their tributaries has been cultivated to grow rice. The highland is surrounded by mountain ranges (500-600 m above sea level) in the south and west, and then, compared to the surrounding areas, there is little rainfall even in the rainy season. There is a stretch of alluvial land to the east of this region, across the Mekong River, where rice is grown. The Vientiane plain of Laos is regarded as a part of the Khorat Plateau from the standpoint of land formation. The soil is also sandy. Both the Nam Ngum River and its tributary, the Nam Lic River, carry large volumes of water and the development of this resource is greatly anticipated.

(3) The Mekong plains

A large part of the Mekong plains is situated in Cambodia, along where the Mekong flows and begins to enlarge its width, near the vicinity of Kratie. Here the land along the Mekong River is cultivated only to a width of 1-2 km. Various upland crops are grown here. Beyond this area is forest land where trees grow in varying densities. The right bank area, beyond the hills, constitutes a basin which surrounds Lake Tonle Sap. Paddy fields encircle the lake. Geologically the basin is recently formed alluvial land, the result of river carried sediment filling up an ancient sea bed. The total area is 7,900,000 ha, of which about 400,000 ha is arable land, the remainder being woodland. The rice cultivation center of this area is the vicinity of Battambang. Water for irrigation is drawn from the rivers that empty into Lake Tonle Sap. One of the oldest established irrigation facilities of the lower Mekong basin, the reservoir of Barai Occidental and its irrigation canal system, one of the ruins of the famous Angkor Wat, is found on the shores of this lake. It was built about 1,000 years ago, subsequently repaired and now supplies water to irrigate about 12,000 ha of paddy fields near Siem Reap.

(4) The Mekong delta area

This is a vast alluvial area that starts spreading out into the lower Mekong basin below Kompong Cham. It is still spreading as every year in September-November the Mekong floods into the lower basin of 3-4 million hectares. The whole area assumes the appearance of a wide marshland. Flood water lies in various depths according to small topographical deviations of the land, and here and there the rice varieties most suitably grown are cultivated. The whole area consists of paddy fields except its southwestern part which is covered by mangroves and in the Joncs plains, aill-drained land.

2. Development through irrigation

The population of this area increases at an annual rate of about 3%. Agricultural products leaning heavily on rice take up a large part of the export volume at present, especially in Thailand and Cambodia, as reliable means of acquiring foreign exchange. There must be had further increased production of rice and production must also be stabilized if the present export capacity is to be maintained and yet enough supplies of food are to be secured in addition, for the increasing population. Experts calculate that by 1975 there will be a shortage of about 1.5-2.0 million tons of rice in the world. As this calculation is based on an ideal foreign trade to be carried out between countries where rice supplies exceed demand and where rice is needed, the actual shortage will be even larger and more acute.

Through irrigation, farmers will be able to grow crops other than rice in greater volume. It will make this area change from its present monoculture farming pattern into a multiculture one.

(1) Laos

Topographically, Laos is the region with most rainfall of the Mekong basin. Alluvial plains that have developed on the valley floors of the Mekong tributaries are suitable for farming but only a small part is being irrigated and only a few waterways are seen in and around Vientiane, Saravane, Sayabury and Luang Prabang. The total irrigated area is said to barely reach 850 ha. But it does not seem very difficult to build irrigation facilities in this area, such as reservoirs or diversions of water from the river. Beyond the natural embankment, a wide expanse of swamp hinterlands is left unutilized. Drainage could change such land to new tracts of farmland. Much is expected of this region in the future.

(2) Thailand

This region, the Khorat Plateau, situated in the northeastern part of Thailand, is thinly populated and the dryest region of the entire Mekong basin. Rivers are derived of flood water relatively quickly in the rainy season while the discharge is exceedingly low in the dry season. To overcome these difficulties, in 1951, an irrigation plan aided by the U.S.A. was carried out, providing water tanks for irrigation. By 1963 such tanks were set up at 133 sites (the overall storage capacity was 313 million cubic meters). At present, there are five more sites where tanks are being constructed. These tanks have been built on the smaller rivers. They are actually earth dams about 3-14 meters high but they do not necessarily serve their proposed purpose well, because at times it is difficult to store enough water and consequently sufficient irrigation water cannot be supplied. Sometimes storage water overflows because of too much rainfall and destroys the embankments. The actual spillway facilities of these dams can not cope with radical changes since the rainfall of this area was not studied well beforehand. This highland is more or less a gentle slope so that suitable dam sites for the construction of reservoirs are very limited. Moreover, even if such reservoirs are constructed they cannot be expected to have sufficient storage capacity. In both quality and quantity, boring tests and other investigations have revealed that underground water may not fulfill the need.

To improve irrigation in this area, it is, of course, necessary to build regionally small reservoirs or set up appropriate facilities to pump water from the main stream of the Mekong River according to available funds and technical capacity but fundamentally it must be based on plans to divert water from the Pa Mong reservoir.

(3) Cambodia

Cultivated land in Cambodia may be roughly classified in two categories, that is, (a) the alluvial land surrounding Lake Tonle Sap and (b) the alluvial land along the Mekong River and the Bassac River. Resources for irrigation water for (a) area are the rivers that flow into Lake Tonle Sap. Here projects at Bovel, Barai Occidental, etc. are functioning but in the area north to east of the lake the rivers are shallow and there is little rainfall. Consequently, rice cultivation is unstable. For irrigation water for (b) area farmers depend on the Mekong River and mainly flood waters are utilized. In the area below Kratie both banks of the Mekong River comprise the most fertile land of the Mekong basin. Here maize, tobacco, cotton, peanuts, soybeans and fruits are

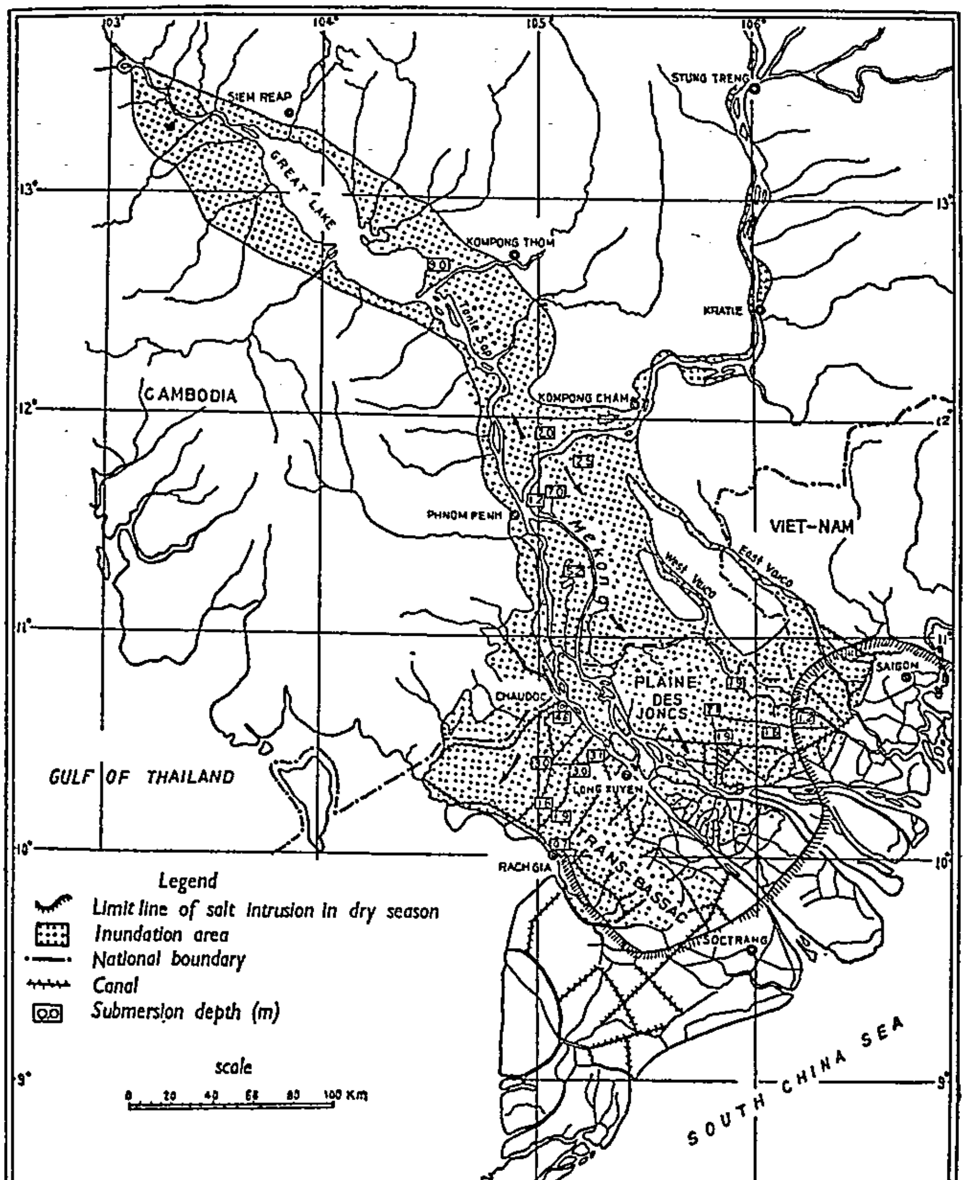

Fig. 1 Inundation areas of the lower Mekong basin

grown without irrigation. A separate report has been made on the general pattern of irrigation carried out in Cambodia so the description will be omitted here.

(4) Vietnam

Vietnam lies in the Mekong delta area. It is a very flat stretch of land, sloping at about 1/100,000 and averaging in altitude 1-2 meters above sea level. The tidal water level is about 1.8 meters. No project has been undertaken in this area so far that aims only at irrigation. Irrigation is carried out by making as much use as possible of canals that have been built for drainage or for diverting flood waters. As the land is at such a low altitude, almost level with the sea, drainage has to be well timed with the occurrence of low tides. In some parts of the area there are facilities that are similar to methods used in Japan. That is, a tract of land is surrounded with embankments equipped with canals and gates to take in irrigation water when the tide is high and drain it out when the tide is low. There are also agricultural development plans that combine the effects of embankments, pumps, gates and canals. These can be effective only when electricity can be had at low cost and this is what only an overall Mekong development project can bring. As to saline damage, it is frequently the case where the water of the delta area is made unusable by salt water that enters the rivers in the dry season when the discharge decreases. If the water resources of these rivers are developed it will increase the discharge in the dry season and work very effectively in preventing saline damage, and there would be more land to be utilized. I am of the opinion that by setting up pumping facilities and making better use of them a good part of the land can be further developed.

There is in Vietnam, beside the Mekong delta area, a highland region in the Annamese Cordiella mountain range in the upper stream of the Se San and Srepok Rivers. The comparatively high altitude of this area gives it a temperate zone climate enabling vegetables and coffee to be grown. If dairy farming is ever to be done in the Mekong basin it will be here.

3. Development of water resources and agriculture

Agriculture in the lower Mekong basin has been carried out for a long time in forms well adapted to Mekong's natural land and water conditions. A larger part is therefore carried out in the rainy season and except where natural conditions are especially favorable, cultivation is rarely done in the dry season. As paddy cultivation constitutes the main part, from its connection with land and water we can use the following classifications:

a. Areas where land is comparatively high in altitude and not directly affected by river flood waters
b. Areas where river flood waters cover the fields with a suitable depth of water
c. Areas where the depth of flood waters is greater than that of (b), that is about 4-5 meters but where the speed of flooding is below a certain

level

d. Lower altitude areas where the depth of flood waters is greater than that of (c)

The paddy fields of (a) category are the so-called rain-fed paddy fields. Cultivation, therefore, is largely affected by the distribution of rainfall and consequently production is very unstable.

Area (b) is comprised of valley plains and delta areas, where production is comparatively stable except in the border areas where floods may cause grave effects to the annual production.

Area (c) is the so-called area of floating rice varieties.

Area (d) is where ponded water lies so deep on the fields that it is even difficult to cultivate floating rice varieties. In the dry season, rice is planted as the flood waters recede.

Making changes in existing natural conditions, even by a small degree— enlarging areas for rice growing and setting up facilities to stabilize and increase agricultural production — constitutes irrigation and drainage projects. Agriculture here is based on existing natural conditions of irrigation and drainage and it is on this that the agricultural techniques, distribution of labor and other social patterns have been built. It has been so throughout its history and up to the present where we see them all more or less firmly established. The comprehensive water resource development plan of the Mekong has been studied and is about to be promoted to control flood waters, secure immense supplies of irrigation water in the dry season, generate low cost electricity, to develop industries and to raise the general standard of living of the local people. The project carries a very optimistic vision for the future but we must not overlook the fact that when the present natural state of the Mekong River undergoes a great change it will bring reactions that will show up in various parts and phases of the basin. The effects will first appear in agriculture and most seriously and regionally in the Mekong delta area. We already see such effects beginning to be manifested on the Chao Phraya plains of Thailand.

The project, on the other hand, will help to eliminate floods in the rainy season and to secure sufficient supplies of irrigation water in the dry season, but it may not be effective in stemming large scale plant diseases and damages from pests that its high temperatures and high humidity may bring. It is, of course, possible to revert to technical countermeasures such as chemicals to stave off the diseases and destroy insects. But at present would it be financially possible for the farmers and would they accept such changes without any serious opposition? To build such irrigation and drainage facilities, huge amounts of money will be needed and so the farmers will naturally expect considerably favorable effects from the projects and an improvement of agricultural production. Merely setting up these facilities and merely securing supplies of water will not affect production so favorably. There will also have to be introduction of new crop varieties, methods of fertilizing and other agricultural techniques. The traditional customs in the farming villages will have to undergo changes. Serious problems concerning the system of landownership will also arise.

Such great changes would mean a social upheaval in the farming societies. To carry them out smoothly without causing much trouble or friction, the changes must be gradual and arrived at in progressive degrees. Various effects and influences accompanying the projects and the changes made in natural conditions will have to be predicted and studied as much as possible in advance, otherwise not only will it be impossible to effect the objectives but adverse effects may result at times. The Mekong Committee, in starting out with these varied projects to develop the Mekong basin, has seen that for their realization, the plans must be composite development plans that cover all aspects concerning not only the construction of water utilization facilities but also the social and economic aspects.

II. Irrigation and Drainage Works in Cambodia

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Mr. Chau Seng, Minister of Agriculture and Forestry of Cambodia, said, "The basic difficulty of agriculture in Cambodia lies in water. In the rainy season we have floods when there is too much water. While in the dry season we do not have a single drop of water." If this difficulty is to be solved we shall have to wait until the comprehensive development plan of the lower Mekong basin is carried out but until then the only thing that can now be done is to set up more facilities for irrigation and drainage at strategic points as the Cambodian government is doing. In this report I will limit my description to irrigation and drainage works in Cambodia and report on their present state and on essential related problems.

1. Irrigation and drainage works

The facilities so far planned and constructed in agricultural districts of Cambodia may be classified in the following categories from the standpoint of irrigation and drainage facilities:

a. To prevent floods on the farmlands.
b. To carry out colmatage.
c. To prevent intrusion of salt water.
d. To store water in the flood periods to use for irrigation.
e. To draw water directly from the rivers for irrigation.
f. To store water drawn from the rivers for irrigation.
g. Others that make use of small capacity pumps.

I will now add my comments on each of these facilities, as each is characteristic in function and in the region in which they exist.[1)]

1. Flood protection

This is a method by which arable land is protected from flood damage by building closed embankments around the land. Control gates are provided in the embankments to adjust the inflow and outflow of water, and with it colmatage can be performed. There are also other ways by which embankments are built to control the floods. One is to dredge river beds and to use soil obtained to construct the embankments. This method is being employed in the Mekong transition area to the Mekong delta, where the Mekong joins the Tonle Sap River or branches out into the Bassac River. These constructions

1) See the map of the Mekong River area at the end of this report.

contribute largely toward stabilizing agricultural production. Following are descriptions of the main districts:

(1) Choeng Prey District

This district lies in the southern part of Kompong Cham Province. A project is now under way here to protect 5,000 ha of arable land from the Mekong floods. In 1949 embankments of the first and second section were completed and now protect 2,110 ha of land from the floods. The third section consisting of an 11 km long embankment to protect 1,700 ha of land is under construction. Also work is being carried out to raise the height of the embankments already made. It was said that once in five years the rice crop yields of this area had dropped to zero before these embankments were built, but rice production has now been stabilized and control gates built in the embankments have made it possible to control the water for colmatage.

(2) Kandal Stung District

A project was completed in this district to protect 2,000 ha of paddy fields near where the Bassac and the Prek Thonot Rivers meet. An embankment 14 km long surrounding the district provides the protection. It was built during 1959-1960 solely by manual labor which was contributed by the farmers in this locality.

(3) Veal Sam Nap District

A project is now under way in this district to provide for the protection of 25,000 ha of arable land. This is a part of the 60,000 ha wide, crescent-shaped, swamp hinterlands which lie where the Bassac River branching out of the Mekong curves southeast. The project involves improving conditions for better river navigation, dredging the river bed, building embankments with the dredged soil and raising the level of land by colmatage. France contributes her share in technical aid and at present land is being levelled and observations are being made on the water level.

2. Colmatage (Mud irrigation)

This is a method by which muddy water brings muddy soil to settle at a desired site. Its purpose is to give land the effects of fertilizers. It is carried out very skilfully by taking advantage of the periodical changes of flood water levels of the Mekong and the Bassac Rivers and making the best use of natural embankments and topographical features of the hinterland. The muddy water that has remained for a certain period in a given land is drained off down a natural slope. Water drawn from the Mekong is drained off into the Bassac River, and from the Bassac into the Prek Thonot River.

Such canals for colmatage were constructed at 57 sites during 1952-1954 in the places mentioned above (in Kandal Province and Kompong Cham Province). An aggregate area of 16,640 ha now receive their benefit. Most canals have no attached facilities but there are some that have concrete control gates where the roads intersect. No more canals were built after 1955, only some dredging was done in some of the main canals.

These facilities were built with joint technical cooperation by the U.S.A.

and Cambodia and were built for upland crop growing areas. Colmatage requires large volumes of water at a specific time, at a certain period, and handicaps people engaged in fishing. Appropriate adjustments are necessary between the two conflicting parties.

The Samrong Thom District is representative of those where colmatage was carried out. About 40 km away from Phnom Penh there is a control gate which also serves as a bridge for the road running on the right bank along the main stream of the Mekong River. There are three gates, 2 meters wide and 5 meters high, which control the inflow to the canal by means of flash board weirs. The benefitted area is the upland farmlands of 500 ha about 5 meters above sea level.

3. Prevention from salt water intrusion

An embankment built along the sea coast serves to prevent the intrusion of salt water and the water within the embankment is driven out by means of back-flow check pipes. In this way saline damage is prevented.

Facing the Gulf of Thailand there is a narrow tract of alluvial land lying along the sea coast, consisting of soil deposited by the small rivers originating in the Cardamones-Elephant mountain range. These small rivers rush down from the highlands 500-600 meters above sea level, then twist slowly through the flatland over a distance of about 15-20 km and finally reach the seashore. Monsoons blowing in from the southwest in the rainy season hit this mountain range and pelt this area with heavy rains. This causes frequent floods in the rainy season. While in the dry season the discharge of these small rivers drops immensely and permits salt water to back flow, causing saline damage. What must first be done to protect rice cultivation in this area is to plan measures to prevent salt water intrusion.

An example of measures taken is the Prey Nop District, an area of a lowland of 12,000 ha that extends from the mouth of the Kompong Smach River to the west side of the inlet. Experience has found that a simple low embankment serves the purpose well, a high embankment not being necessary because the tides are not so high. It is said that this project has made Kampot Province self-sufficient with the rice produced only in this district. The same method has also been adopted in Cheko District which has similar topographical features, to protect an area of 4,000 ha. This is an advantageous way to develop rice cultivation but there are still many improvements that have to be made technically in structural and management phases, such as making annual repairs of damage to embankments and tunnels by increased discharges in the rainy season.

4. Irrigation using water stored in the flood period

This method is to build embankments that cross small rivers to store water in the rainy season when the rivers increase their discharge. The water stored in this way is used in the dry season to irrigate paddy fields. The embankments are built taking advantage of the topographical features of the transition part

Table I Irrigation tanks in Cambodia

District	Province	Irrigated area	Storage capacity
Taing Kraing	Kg. Cham	250 ha	$2,000 \times 10^3 m^3$
Takeo Ville	Takeo	200	9,000
Bat Rokar	Takeo	1,000	9,000
Lomchang	Takeo	1,500	8,500
Snai Pol	Prey Veng	100	2,000
Kompong Sne	Prey Veng	4,000	100,000
Batheay	Kg. Cham	170	1,200
Thnal Bat	Kg. Cham	100	700
Trapeong Veng	Kg. Cham	100	700
Prey Kry	Kg. Chhnang	1,000	6,000
Chhuk Sar	Takeo	500	3,500
Lompau	Kampot	430	3,000
Veal Sas Khyal	Kg. Cham	357	2,500
St. Svay Ath	Pursat	55	400
O' Pak	Kratie	142	1,000
Trapeong Rumhuch	Takeo	214	1,500
O' Smach	Svay Rieng	300	2,000
Beng Trapeong	Kg. Speu	55	400

to the Mekong delta flood area. They differ in construction according to the characteristics of the land and consequently function in different ways.

The first types are found in Bat Rokar and Takeo Ville Districts. The ponded area lies at an altitude a little above the flood area of the Mekong River and a comparatively high embankment is built across the small rivers. The embankment is equipped with an overflow type spillway over which flood waters from the basin flow down. Irrigation canals are located along a relatively high land on both or one side of the embankment to let the water flow down naturally to paddy fields. The water is stored in very large volumes so that it may be used to irrigate the fields not only growing dry season rice varieties after the floods but possibly also in the early period of rainy season cultivation. This is an orthodox system of water storage limited only by topographically suitable sites. Many facilities built in the 1930's when Cambodia was a French Protectorate have been repaired and are still in use.

The second type may be seen in Kompong Sne and Snai Pol Districts, where embankments are stretching across the lowland of the Mekong flood area. When the river starts rising it does so on both sides of the embankments, but at times the flood waters rise more quickly on the Mekong River side of the embankment and pours into the storage area from its downstream side. The embankment at Kompong Sne has a concrete protection on the slopes of the downstream side to cope with this problem. When the waters retreat, the flood water remains in the storage area and is thus stored. These embankments are low and long and the spillways are the falling apron type made to withstand large volumes of inflow and outflow. The stored water is used not only to irrigate dry season rice fields. On the upper stream side of the embankment, the flood waters rise less quickly making it possible to grow more floating rice and on the downstream side of the embankment, the flood water retreats more quickly making it possible to grow more dry season rice (flood retreating varieties). Moreover, it is also possible to grow rice in the tank which can be utilized as the stored water is used. The tank is characteristically wide but there is one drawback—the necessity of using keelblocks and hand pumping facilities to raise water into the paddy fields since the water level of the pond is low.

The third type is found in operation in Chhuk Sar and O'Smach Districts. It is similar to the second type in that a low long embankment is built across the hollow part of small rivers and tributaries, but differs in that the water stored is that which flows in from the upstream side of the embankment. In some localities these tanks have helped increase surrounding areas to grow floating rice and dry season rice. There are other tanks where rice is grown in the tank itself. After 1956, under government guidance, plans have been made to build such tanks at 10 or more sites. During 1957-60 local farmers completed seven of them by manual labor. There are several more projects now being carried out under the sponsorship of the Takeo provincial government. These facilities are most appropriate, at least for the time being, for the natural conditions of the areas that surround the Mekong delta. Only local inhabitants really know from life-long experience the actual state of the floods in this area and, consequently, their opinion is highly valued and these projects require their participation. This again is another feature of these projects. Another interesting fact is that all the tanks that are to be built aim at storing about 7,000 m^3 of water per ha.

5. Irrigation with water drawn directly from rivers

By this system the natural flow of a river is diverted and water is brought into the fields through diversion canals. This system aims at securing adequate supplies of water in the early rainy season or to supplement the shortage of water during a sparse rainy season. Construction of these projects is limited to areas where the natural conditions permit it. Such conditions are that rivers that function as the supply source must have a specified amount of discharge through the year; it must be possible to draw water especially early in the rainy season; areas to be irrigated must be situated at suitable altitudes. Such conditions, therefore, allow these projects to be carried out only in the areas surrounding Lake Tonle Sap, in the fluvial plain of the upper part of the flood area, particularly along the rivers that flow into the lake from the south, owing to the conditions of the flow.

In these areas are the Moung Dauntri District where water is drawn from the Dauntri River, the Bamnak Kamrong District where it is drawn from the Bamnak River and the Bovel District where it is drawn from the Mongkol Borei River. All of these were developed in the 1930's when Cambodia was still a French Protectorate. In contrast, our attention is drawn to the projects in the Prey Chhor District of Kompong Cham Province where the planning and techniques are more advanced. Following are brief descriptions of the Bovel District and Prey Chhor District:

(1) Bovel District

The system adopted in Bovel District aims at irrigating an area of 45,000 ha that lies to the northwest of Battambang, the center of rice production. Around 1939 the French Colonial Government built facilities to serve 30,000 ha of land but the war and floods damaged them greatly. After independence, by 1955 the Cambodian government had repaired a part of the facilities that served about 10,000 ha of land, then later with a $110,000 U.S. aid she repaired more facilities and enlarged the benefitted area to 20,000 ha. Cambodian technicians have broken the old diversion weirs and remodelled them into modern movable concrete ones (the gates were made in the U.S.A.). The work took them from August, 1963, to May, 1964. To enlarge the benefitted area to 45,000 ha, main canals and roads are now under construction at an estimated cost of $357,000.

(2) Prey Chhor District

The area is 6,000 ha of the comparatively well-developed rural district in the southern part of Kompong Cham Province. The surveying was done from 1952-1957 and the work was carried out from January, 1958, to July, 1960. This is said to be the first project that was planned and constructed solely by a Cambodian team of technicians.

Table II Project costs per hectare

District	Benefitted area	Total project cost	Project cost per hectare
Barai Occidental	12,000 ha	US$ 1,015,000	US$ 84.6
Prey Chhor	6,000	338,000	57.4
Prey Nop	12,000	334,000	27.8

6. Irrigation with water drawn from rivers and stored

Water is drawn from swollen rivers in the rainy season, stored in tanks, then used as a supplement in the rainy season and to irrigate paddy fields in the dry season.

In historical significance, in magnitude and in technical features, Barai Occidental District occupies a particularly important position in irrigation and drainage of this country.

The prototype of this irrigation system dates far back to the days of Angkor, 1,000 years ago. Barai Occidental was one of the large man made reservoirs built at sites now lying to the east and west of Angkor Thom, the then capital city, to supply water to the inhabitants of the city and to the farmlands that supported the nation. The site is used at present for a new project built around the old reservoir.

The present project has a movable diversion weir by which a maximum

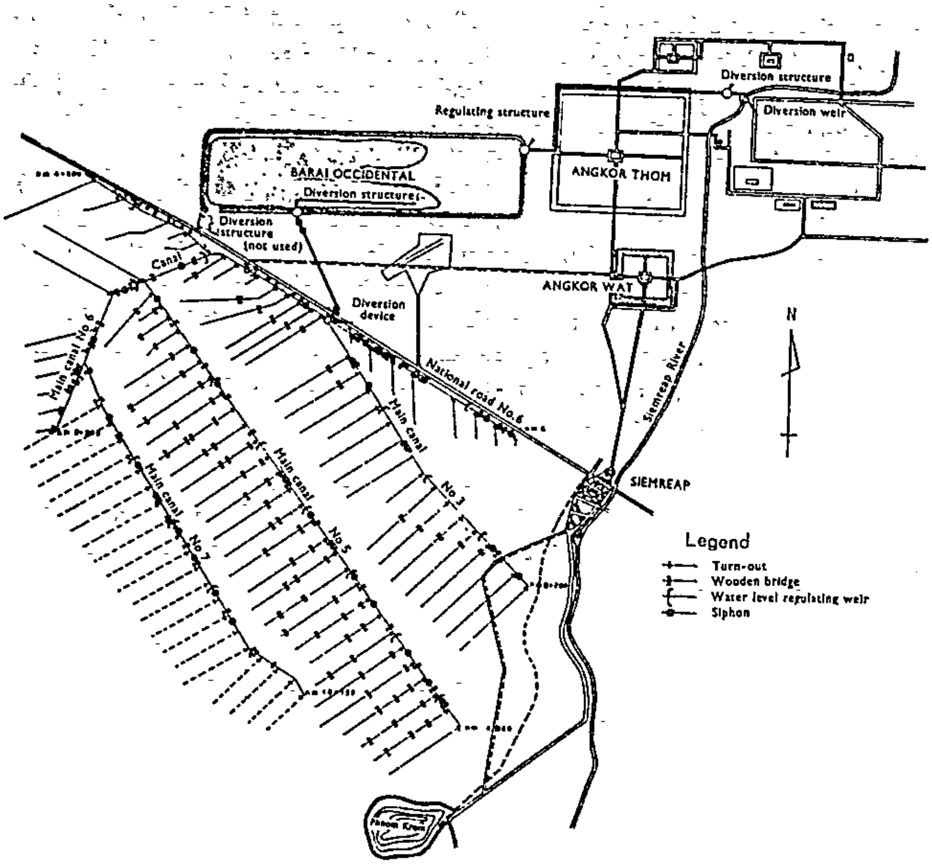

Fig. 1 Irrigation system of Barai Occidental

of 15 m/sec of water is drawn from the Siem Reap River that flows east of the ancient capital, Angkor Thom. Water is taken into the moats lying to the north and west of Angkor Thom, then drawn into the reservoir from its northeast corner. The reservoir is rectangular, 2.2 km from north to south and 8 km from east to west. It was built on a level piece of ground which had been raised by heaping earth. Hitherto, the level of the ponded water was 22 m above sea level and the storage capacity was 7,000,000 m^3. The present project has raised the average height of the embankments to about 12 m and increased to 55,000,000 m^3 the effective storage capacity at sea level +25 m. The water is used to irrigate paddy fields totalling 12,000 ha that lie between national highway No. 6 which runs past the western outskirts of Siem Reap and the border of the flood area of Lake Tonle Sap.

Main components include a movable diversion weir (which has a floating type automatic shutter weir), two control gates, a head intake from the reservoir, 56 km of main canals, 155 km of sub-canals, 20 diversion checks (water level regulating weirs), 88 intakes to the sub-canals, syphons at 38 points, 124 bridges and roads for management. Except for those canals that are a part of the main construction, all the others are earthen. The project required $1 million for construction, and a large part of it, $977,000 was provided by U.S. aid funds. This plan for improvements was made in the 1930's. In 1937-1945 some construction was done temporarily. Again after the end of the war the plan was resumed seriously as one of the cooperative works between the U.S.A. and Cambodia. The present facilities were built during 1952-1957.

This system of irrigation aims at stabilizing rice cultivation in the rainy and the dry seasons. The realization of the benefits from this system is greatly anticipated as the Cambodian government places much importance on its utilization during the dry season. In April, 1964, the government set up a committee for further development of this district. The committee was divided into sub-committees for statistics, propagation, agricultural administration and irrigation and drainage for the purpose of carrying out investigation, research and to study proper measures.

7. Other systems of irrigation

Apart from the construction of irrigation facilities by the government or by government agencies there are also irrigation facilities carried out independently by civilians, but their participation in the field of irrigation is little.

Rubber plantations have comparatively large scale irrigation facilities. Some fruit plantations draw irrigation water from wells or streams by means of diesel pumps. Some upland farmlands located on natural embankments have small scale embankments and draw irrigation water by pumps.

Some individual farms use hand-operated pumping devices and keelblocks. In Siem Reap Province water-wheels are used and in Kompong Cham Province sweep-buckets.

2. How irrigation and drainage projects are carried out

Irrigation and drainage projects necessitate large amounts of money for their construction and maneuverings to adjust the many and diverse interests of the people involved. Consequently, they must be executed directly by strong policies of the government or of the provinces concerned.

The government division in charge of irrigation and drainage projects is the Division of Agricultural Engineering (Division du Genie Rural) of the Agricultural Affairs Bureau of the Ministry of Agriculture and Forestry. It is responsible for all the phases concerning promotion of irrigation and drainage projects such as investigation, planning, enforcing and management. The Division du Genie Rural is an independent organ within the Agricultural Affairs Bureau. It was brought to its present form of organization in 1959 after frequent reorganizings of the governmental organs. In 1956 this division took exclusive charge of irrigation and drainage facilities. Until then the Transportation and Navigation Bureau shared the responsibility.

Projects under government jurisdiction are divided into government projects and provincial projects. Investigation and planning is done principally and directly by the government. Large projects (covering areas exceeding 500 ha) are carried out directly by the government. Those of smaller scale are carried out by the provincial government concerned in order of their urgency. In judging the economy of the projects as the government projects, the government undertakes the limit ceiling production cost as set at $85.70 or less per hectare. When a project exceeding this limit is carried out, the farmers who are to receive its benefit are required to help with manual labor to make up for the deficit. There is also a system by which the head of a provincial government may request the central government for technical and financial aid in a project he plans to carry out independently.

3. Development of construction of irrigation and drainage facilities

I will now summarize the development of the projects mentioned and dwell on them in connection with the history of this country.

First of all, there is the first period that terminates in the year 1951 including the civilization of Angkor (6th to 12th century), the decline and fall of the Khmer Monarchy, its emergence as a French Protectorate (1863), the occupation by the Japanese armed forces, the return of French rule, the provisional declaration of independence (1945) and its subsequent progress toward a complete independence. The present irrigation and drainage facilities were constructed by the Rice Cultivation Bureau of the French Protectorate Government in the 1930's.

From 1951 to 1955 Cambodia became a completely independent de facto state (1953) and with the support of the Geneva Armistice Treaty (1954) she started consolidating her internal situation. In September, 1951, the U.S.A.-Cambodian Economic Aid Agreement was concluded. This started a new epoch in the planning of projects with United States Operation Mission (USOM, now AID) funds and guidance.

The period that follows started after the 1955 dry season. It was in this period that the mechanism of the present government was established and new undertakings led by the Cambodian government started unfolding. There was a long term project which was extended to the end of 1955. In December, 1959, a five-year project for economic development was made public. It is now underway.

It may be said that it was only after the 1955 dry season that developments in irrigation and drainage in Cambodia actually started. The Committee for Coordination of Investigation of the Lower Mekong Basin (the Mekong Committee) started in October, 1957. As regards the relations between Japan and Cambodia there is a friendship treaty which was concluded in December, 1955. In June, 1959 the Agreement of Economic and Technical Cooperation between Japan and Cambodia was concluded.

Table III Principal irrigation and drainage projects

Year	Flood protection	Colmatage	Salt water intrusion protection	Irrigation by ponds	Irrigation by river water	Remarks
before 1951	Choeng Prey: Embankment 1 section 1,060 ha 2 section 1,500 ha		Prey Nop: closed embankment 1 section 1,300 ha 2 section 1,000 ha 3 section 700 ha 4 section 1,400 ha 5 section 1,200 ha	Taing Kraing Takeo Ville Bat Rokar Lomchang Snai Pol Kompong Cham	Bovel: 20,000 ha Bamnak Kamrong: 2,000 ha Khya: 400 ha	
1951～1955		Ⓐ Kandal, Kompong Cham: Construction of 57 canals 16,640 ha	Prey Nop 1,2,3,4,5 section: Improvement of closed embankment	Batheay Thnal Bat Trapeong Veng	Bovel: Enlargement of area by diversion weir 10,000 ha Moung Dauntri: 1,000 ha	Five-year Irrigation Plan launched in 1952 (budget: $ 28 million)
1955～1961	* Kandal Stung: 2,000 ha	Samrong Trom, Koki Thom: Improvement of canals 1,940 m	Ⓐ Prey Nop: Improvement of embankment to enlarge the protected area, Construction of check pipe, 19 Improvement of check pipe, 10	Prey Kry Lomchang: Improvement Ⓐ Kg. Sne: Improvement Lomchang: Enlargement * Chhuk Sar * Lompau * Veal Sas Khyal * Svay Ath * O' Pak * Trapeong Rumhuch * O' Smach * Beng Trapeong	Ⓐ Bovel: Improvement Ⓐ Prey Chhor: 4,000ha Ⓐ Barai Occidental: 1,300 ha Khya: Construction of a weir, Enlargement of area, 600 ha * Chrap: 300 ha	Two-year Plan for National Reconstruction launched in 1955 Five-year Plan for Economic and Social Development launched in 1959
1961～	Choeng Prey: Enlargement Ⓟ 1,700 ha Barai: 20,000 ha	Ⓟ Veal Sam Nap: Colmatage flood protection 25,000 ha	Cheko: 4,000 ha	Tonle Bati O-Ampean	Ⓐ Bovel: Improvement of weirs, Enlargement of area, 45,000 ha Banam: 100,000 ha	

Note: Ⓐ Funds obtained from U.S. Aid Funds Ⓟ Planned, but not started as of Nov. 1962
* Constructed by farmers' own labors
This table was compiled from date presented by the Genie Rural, and from additional date presented in 1962

4. Points of interest and the future direction of development

Most of the facilities that have been built so far are being worked to full capacity to supplement the shortage of water in the rainy season and to irrigate the paddy fields that grow flood retreating rice varieties. Favored by sunlight and high temperatures it should be possible with these facilities to grow double crops, at least in the rainy and dry season.

From the standpoint of national economy, upland crops beside rice that will be profitable export products are maize and sugar cane. To increase the production of these two upland crops, irrigation is becoming increasingly important but so far little has been done in this field.

In order to solve fundamental problems of irrigation and drainage in this area we shall have to wait until the general Mekong development plan is perfected. This is going to take some time to realize but now that the long period of waiting is over, Cambodia can no longer remain in her present state. There will certainly be many changes and her future looks bright. Following are listed some of our recommendations:

(1) Promoting development of the tributaries

It is a great advantage for this country that it has the comprehensive development plan of the Mekong to depend upon. The Prek Thonot and Battambang projects with multipurpose dams for modern water utilization are on their way to realization, and the Sambor project is in a concrete planning stage. Construction of these basic main facilities will certainly bring large changes to the agriculture of this country.

(2) Enlarging the existing method of development

Building facilities to prevent intrusion of salt water into coastal plains, closed embankments to prevent floods, reservoirs—all these undertakings will grow in size and scale as suitable sites increase and techniques improve. To improve the local conditions of the complicated floods in the transition part of the Mekong delta would be impossible unless it is done by native technicians who are familiar with the actual conditions. In this respect the activities of Cambodian technicians especially are expected to increase.

(3) Development of new methods

There is a plan to establish an experimental farm for the National University of Agriculture. It will be surrounded by embankments and divided into two sections: One set aside as a pond area to take in flood water in the rainy season, the other to be a farmland protected from the floods which will receive supplies of water throughout the year. The plan envisages using a part of the marshland and hills lying behind the Bassac River, west of Phnom Penh. It is a new development and great results are anticipated.

(4) Utilization of pumps

The using of pumps to draw water and supply it to arable land depending only on rain water in the rainy season or to draw it from water sources found in various parts of the country in the dry season. Probably this method will be adopted step by step in the future and develop as soon as the present state of securing of machines, electricity and oil improves. It will help develop the land at higher altitudes that have not been yet developed much and will probably make way for general utilization of underground water.

(5) Problems outside irrigation and drainage techniques

Construction of irrigation and drainage facilities will have no meaning at all unless related to agricultural production, in which the cooperation of the farmers is necessary. The Bovel and Barai Occidental projects are good examples of this. It will require time and it depends on the outcome of solutions to related problems. In constructing irrigation and drainage facilities our attention should be directed not only to the main basic facilities but also to the terminal facilities directly connected with the arable land itself.

(6) Anticipating Cambodia's own technicians and techniques

Until 1950 Cambodia depended solely on French techniques for the construction of irrigation and drainage facilities and after 1951 new techniques brought in by USOM, for instance the new technique in colmatage observed in the planning and carrying out of the main irrigation systems, have helped raise Cambodia's general technical level. But, on the other hand, it should not be overlooked that there once existed in Cambodia the civilization of Angkor and that the local people are proud that they are of the same Khmers who built that high civilization. It is shown in the enthusiastic attitude the people display toward the projects of Barai Occidental and Bovel after USOM left and in our discussions with government technicians.

In planning construction of irrigation and drainage facilities it is essential to see that they harmonize well with the local and natural conditions. Data to serve as the bases for plans are still lacking and it means that we must look forward all the more to the advancement of characteristic techniques of the Cambodians and use of local technicians who know very well the actual state of local affairs and the conditions.

III. Historical Development of Irrigation and Drainage in the Chao Phraya Delta

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1. Introduction

The Chao Phraya Delta forms a rough triangle having Chainat at its apex and the sea coast line at its base, and it is a large flatland (about 21,600 km^2 in area) with little gradient. This delta is a kind of composite delta made over ages by the several rivers such as the Chao Phraya River flowing through its center, the Maeklong River coming from the west and the Bang Pakong River from the east.

The most outstanding characteristic of agriculture of this area is the prevalence of single rice cultivation. The cultivation of other crops is negligible. The major portion of the rice, the largest export item of Thailand, is produced in this delta area, called Thailand's rice granary. This is the most densely populated area and historically, the place where the Thai actively engaged themselves to develop their country. It was because of their great efforts to develop agricultural production in this area that Thailand has quickly become a modernized country.

Among a number of natural conditions that control the production of rice in the Chao Phraya Delta the most important one, I believe, is that governing water supply. It should not be supplied in excess of, nor less than the demand.

Annual precipitation generally necessary in Thailand to grow rice is estimated to be about 1,800 mm, but in Bangkok there falls only about 1,400 mm and in Ayutthaya as little as 850 mm. Clearly it is impossible to grow rice here if the cultivation depended only on rainfall. The deficit, therefore, has to be supplemented by rivers with their flood water. To put it differently, it would be impossible to grow rice in this area if there were no natural river floods.[1] Rains and floods are brought to this area by southwest monsoons and typhoons so that they vary greatly quantitatively and seasonally. With climatic conditions being so irregular it is quite natural that rational methods of water utilization or of irrigation are very important in rice production. Without proper irrigation facilities it is difficult to grow rice and developing such facilities is a must for the development of agriculture. Thus in Thailand, whose economy depends overwhelmingly on rice, the state of development of irrigation facilities may indicate the extent of her productive development. On the other hand, it may be said that the state of economic development

1) De La Loubere, *Du Royaume Siam*, Tome Première, Paris, 1691, pp. 53-54.

of Thailand, as whole, governs development of irrigation.

In this report, based on the natural conditions of this area that have significantly influenced the history of Thai society, I will describe the history of irrigation and its relations with the process of development of her economy.

2. Topographical features[2] and land utilization in the Chao Phraya Delta

In the Chao Phraya Delta the land is utilized by making use of the floods and the type of the floods is determined by the topographical constituents of the delta. Thus we will study land utilization in this area according to the topographical constituents, that is, the debris fan area, the upper delta and the lower delta areas.

1. The debris fan area

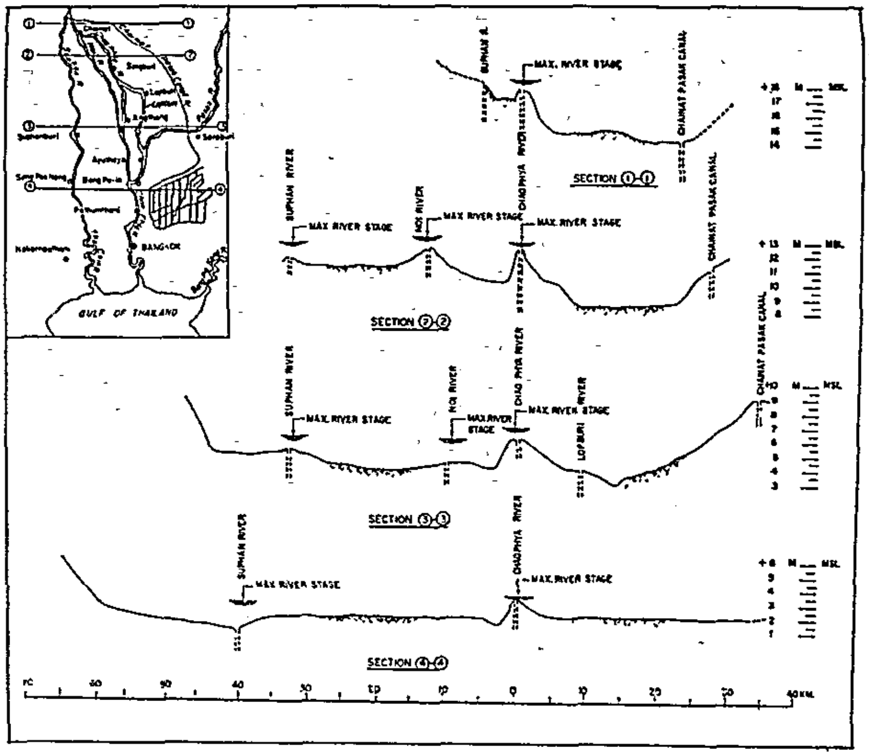
The development of debris fan areas in the Chao Phraya Delta is very much limited only to the narrow areas that border the hills, where only a little is to be found. The reasons for this are that the soil in the upper stream area is laterite and fine soil particles, and that the existence of a basin above Chainat, the apex of the delta, also prevents sand and gravel from being carried down the river to form a debris fan area.

2. The upper delta area

The most characteristic feature of the upper delta area is the existence of natural embankments and swamp hinterlands. We find several rows of natural embankments running down southward from Chainat; the largest one, about 145 km long and approximately 5 km wide in the upper delta area and 8-10 km in the lower area, extends down to Ayutthaya. There are also large natural embankments formed along the Noi and the Suphan Rivers. Between these natural embankments lie the extensive swamp hinterlands, through which interlace a number of canals tracing old river beds (see Fig. 1).

When the flood season comes, rivers flow over these natural embankments into the swamp hinterlands and form huge natural reservoirs. On the natural embankments water can be stored in only a few places and only for a short time. Villages lie here in a straight line as well as schools, temples, markets, government offices and rice polishing mills. The soil is fine sand—silt. Around farmers' dwellings vegetables are grown and trees planted for firewood for home consumption. As we travel out from the natural embankments toward the swamp hinterlands, we find the soil getting finer and the flood water inundating for a longer time and deeper. In the swamp hinterlands the soil is heavily clayey, flood water stays for five to six months and covers the land to a depth of 3-4 meters. Here mainly a single rice cropping is cultivated and no other

2) My thanks to Mr. Masahiko Ohya who furnished me with information on the topography of the delta.



Source: United Nations, "Utilization and Development of Delta Areas", *Proceedings of the Regional Symposium on Flood Control, Reclamation*, Water Resources Series No.25, p.27.

Fig. 1 Cross sections of the Chao Phraya delta area

crops are grown. Many generations of experience have given the farmers here a knowledge of rational selection of the most suitable varieties of rice that best fits the natural conditions of this area. Where flood water remains for a shorter period in shallower depth, the early maturing varieties are grown. As we approach the swamp hinterlands the medium maturing or late maturing varieties are selected and grown, and where the water lies deepest the floating varieties are found.

Rice cultivation in the swamp hinterlands is done by broadcasting as flood water lies deep. Unlike the method of transplanting, broadcasting does not require water to be put in paddy fields and the trouble of levelling the ground is omitted. As far as rice cultivation is concerned, the farmers have nothing to do after the floods come when rice stalks start growing, as the deep water exterminates the weeds and the floods supply sufficient water. The consequent crop yield is comparatively stable and the farmers can lead easy lives. In other words the labor productivity is high. The low land productivity of broadcasting is sufficiently compensated for by larger areas of farmland held by the farmers.[3] A rational method of farming is carried out here, taking advantage of the floods.

Until the 19th century, Thai livelihood had been based and had developed on the production of rice of the upper delta area. The ancient capital, Ayutthaya, lay at the end of a large natural embankment that runs along the Chao Phraya River with the provinces of Anthong, Lopburi and Suphanburi surrounding it. Her king's influence saturated these provinces,[4] which more or less correspond to the present upper delta area.

Natural conditions may be given as reasons. This area depended on flood water as well as rain water, consequently the water supply situation was far more stable than that of the surrounding areas where rice cultivation depended mainly on rainfall. Naturally rice production was more stabilized and this can be explained by the old system of collecting land revenue (*Kha Na*).[5]

To collect land revenue the paddy fields were divided into two categories, called *Na Khu Kho* and *Na Fang Loi*. Farmers of the *Na Khu Kho* category were taxed for the total area of land they occupied and those of the *Na Fang Loi* category were taxed for the area of land they actually cultivated. This was because the paddy yields in the *Na Khu Kho* category were comparatively stable since their cultivation also depended on the floods for water supply whereas the paddy yields in the *Na Fang Loi* category were unstable since they depended mainly on rainfall as the main source of water supply. The paddy fields of the *Na Khu Kho* category were concentrated in Ayutthaya and its neighboring provinces. This tax collecting system was revised in 1905[6] in order to increase revenue to make modernization possible. The development of irrigation works from the 19th century on had increased rice production and expanded its area. The land revenue system now having been revised, *Na Khu Kho* now stood for mature paddy fields that had been cultivated for a long time with stabilized crop yields while *Na Fang Loi* stood for paddy fields with unstable crop yields such as recently reclaimed land that had been only partially tilled or land on mountain slopes.[7]

With the development of the national economy and land reclamation in the vast lower delta, the upper delta area began losing importance. Especially after the Second World War when the Chainat Dam and other irrigation facilities were set up, the pattern of floods in the natural embankments and swamp hinterlands changed and here rice cultivation began to lose stability.

3. The lower delta area

Probably the flat lower delta area stretching from Ayutthaya to the seacoast

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3) Dilock, Pring, *Die Landwirtschaft in Siam*, Tubingen, 1907, S. 98, S. 137.
4) Lingat R., *Prawatisat Kotmai Thai Kotmai Thidin*, Bangkok, 1940, p. 33.
5) Prakat Goen Khana Tradaeng Prot Kai Tang Khang, 1864. Sathian Lailak, *Prachum Kotmai Pracham Sok*, vol. 7, p. 120.
6) Prakat Kae Withi Leo Phikat Kep Goen Khana, 1905. *Prachum Kotmai Pracham Sok*, vol. 20, p. 163.
7) Dilock, Pring, *op. cit.*, S. 84.

was a sea bed 500-600 years ago.

Today, from beyond the upper delta area flood water flows into numerous canals interlacing the plain and covers the flat lower delta area with a shallow and wide layer of water. The land inclines a little toward the sea and allows the flood water to remain for a long time without flowing immediately into the sea. Rice crops mature during this period.

There being no swamp hinterlands it would have been impossible for flood water to cover the whole of this flatland evenly and widely, had there been built no network of canals. Consequently it would not have been possible to cultivate rice here except in some narrow limited parts. Moreover traffic ways could not have been built, making it very inconvenient to live. This was the situation until the middle of the 19th century. Floods had rushed down from the upper delta area, and were not able to cover the whole of the lower delta area and greatly handicapped rice cultivation in many places.[8]

To develop this vast plain a sufficient number of canals had to be built and much labor and money put into it, so the construction had to wait until the Thai national economy had made further developments. A large part of the present network of canals was built during the latter half of the 19th and into the 20th century. This corresponds with the development of the Thai national economy, the details of which will be dealt with in the following chapter.

3. The history of irrigation

I will describe the history of irrigation in Thailand by arbitrarily dividing it into four periods: before 1856, 1856 (Bowring Treaty)-1902, 1902 (Van der Heide)-1945, 1945-present.

1. Before 1856

This first period was when Thailand was an ancient state, and her society was supported by peasant corvee labor (*Khau Duan Ok Duan*).

No one knows when the history of irrigation of the Chao Phraya Delta began. Probably it is as old as the history of the people who began to inhabit this region. To make rice cultivation possible and to construct traffic ways—the means by which peasants carried tributes and taxes—canals were built and repaired,[9] but how were laborers pressed into service and how were they organized to carry out these civil engineering works?

From the Ayutthaya Period (1350-1767) to the beginning of the Ratanakosin Period (1782—) it was with the labor of the peasants that built these canals.[10] But actually how was the labor assembled? It is not known but probably this is due to the fact that hardly any study has yet been made on

8) Bowring, Sir John, *The Kingdom and People of Siam*, vol. 1, 1857, p. 8.

9) Wales, H. G. Q., *Ancient Siamese Government and Administration*, London, 1934, pp. 229-230.

10) Chao Phraya Wongsanupraphat, *Prawati Krasuang Kaset-Trathikan*, Bangkok, 1910, p. 126.

how villages (*Mu Ban*) were established and what kind of relationship existed between them and the bureaucrats in those days.[11] There exist very few records on irrigation projects of the Ayutthaya Period.[12] Small scale local works—it must have been these small projects that made up the majority of the irrigation works in those days—were not recorded in the chronicles of the kingdom, but some references to several canal projects are found in the chronicles of the Ayutthaya kingdom (*Phraracha Phongsawadan Krung Si Ayutthaya*).[13] According to these records, the canals were built to improve transportation. For example, a curve in a river was cut away to make it straight or canals sedimented by mud were dredged—such were the objects of these works. In those days when economic development was at a standstill and self-sustaining economy was prevalent, there was no need for the Thai society to build large canals for agricultural production.

Canal building continued into the Ratanakosin Period. A remarkable case was the building in 1831 of the Bang Khun Thian Canal.[14] A Chinese, Phraya Chodi Krat Seti, undertook the construction, employing Chinese coolies to complete the work. This was probably among the first works in which Chinese coolies were engaged for canal building. It was around this period that immigrant Chinese began replacing native peasant corvee labor, even in irrigation projects, which were accordingly performed more effectively. Incidentally they played very important roles in Thailand's modern history. Thus native peasant laborers were relieved of hard work but were compelled to pay capitation taxes (*Kha Rachakan*) instead. They had to grow more rice to sell so that they could pay their capitation tax.

The appearance of Chinese coolies on the stage of Thai history shows that a social specialization had already been developed to some extent though it took on a peculiar form of using foreign immigrant laborers. It shows, as I will relate later, that already in this period preparations were made that resulted in her amazing development of production in the latter half of the 19th century.

2. 1856[15]-1902

The second period was the opening of her country to European trade when her national economy developed rapidly and old social institutions started disintegrating rapidly.

By the time she entered the latter half of the 19th century Thailand could no longer keep her country closed to foreign trade with Europe, and in 1856

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11) Villages in Thailand are basically and generally characterized as "loosely structured", but the definition can not be applied with justification to the village societies of olden days for there have been great social and economic changes since the 19th century that must have greatly influenced village societies. A corroborative study into historical characteristics of the village structure would be valuable.

12) Chao Phraya Wongsanupraphat, *op. cit.*, pp. 125-161.

13) Krom Tamra Krasuang Suksathikan, Phraracha Phongsawadan Krung Si Ayutthaya, 1922, pp. 19, 622-624.

14) Chao Phraya Thiphakrawong, *Phraracha Phongsawadan Krung Ratanakosin Rachakanthisam*, Bangkok, 1934, pp. 107-108.

she concluded a commerce and friendship treaty through Bowring, a British envoy. The treaty went into effect immediately and similar treaties followed with other European countries in succession and her ports were opened to foreign trade. This was when these European powers were defeating the countries of Southeast Asia, pushing their colonization policies. Their demand for food, that is, for rice, was increasing and Thailand was destined to play the role of a rice supplier. It was this huge and continuous foreign demand for rice, not a spontaneous development of her national economy that started developing rice cultivation in the lower delta area. The objective was attained not by raising the productivity of land but by extension of arable land, to which the development of irrigation projects greatly contributed. To grow more rice for foreign trade many large canals were built and repaired. An unprecedented era appeared in the Thai history of land reclamation.

There are several interesting remarks to be observed in the laws and proclamations of those days concerning construction and maintenance of canals, a few of which follow:

(1) The Mahasawat Canal[16]

A new canal was built to connect Nonburi Province with Nakhon Chaisri Province, and 2,600 ha of wasteland on both sides of the canal was partitioned into 50 sections. One or more sections were given to a prince (or princess), who compelled peasants (*Bao, Phrai*) to till the land or farmers to tenant the fields.

(2) The Phasi Charoen Canal[17]

Pho Yim and Phra Phasi Sombati Boribun[18] made two proposals for the purpose of securing funds to build this canal.

a. To collect transit taxes from boats that ply the canal and levy taxes on the paddy fields and upland farmlands existing on both sides of the canal.

b. To set up gambling houses and raise money from the profits obtained.

(3) The Niyom Yatra Canal[19]

This canal was built by a governor of the province of Samut Prakan. Peasants cooperated by contributing money to its construction and were allowed to occupy and cultivate 1,600 ha of the reclaimed land. The provincial government exempted them from payment of land revenue for three years and according to the law issued certificates of occupation (*Chanot Tra Chong*) to them.

15) I have based my division on the year when the Bowring Treaty was concluded, though social and economic changes the treaty brought about became evident in later years. My division has been based on politics.

16) This is an example of possession of land by a member of the royal family. It represents an origin of absentee land ownership. Prakat Rang Phrarachahataleka Phrarachathan Na Phra Chao Lukthoe, 1861. Sathian Lailak, *Prachum Kotmai Pracham Sok*, vol. 6, p. 273.

17) Prakat Khut Khlong Phasi Charoen, 1865. Sathian Lailak, *Prachum Kotmai Pracham Sok*, vol. 7, p. 154.

18) Pho Yim was presumably a Chinese tax collector. *Phasi* means tax.

19) Instances of land occupation by the cultivators (later coming into their possession). Prakat Krom Na, 1890. Sathian Lailak, *Prachum Kotmai Pracham Sok*, vol. 12, p. 18.

(4) The Rangsit Canal[20]

A permit was given to the Siam Canals Land and Irrigation Company[21] allowing it to construct the canal and take possession of 800 m of land on either side of the canal. It is to be remarked that the construction of this canal was undertaken speculatively by a private company. The Rangsit area was a swamp which had been a lagoon. It was a wasteland where hardly any one lived, and in the last stage of development of the lower delta area this area was taken up and a network of canals was built by a private company. With the water utilization situation improving, tens of thousands of peasants came to settle,[22] and with the construction of this network of canals a large-scale absentee landownership system came into being. It was to present serious social problems in later days.

This brief description leads us to some clues of some important historical facts, of which, one was the right of migration. In former days peasants were virtually deprived of this right as the old Siamese social system aimed at securing forced labor, but we see many of them moving in and settling in the lower delta area as irrigation works there started developing. We find them occupying and cultivating the land, and their right of migration being fully realized. This was the beginning of the disintegration of the old society which was based on corvee labor.

Actually, various important social reformations were made during the 19th to the 20th century. The form of forced labor changed to a capitation tax, slaves (*That*) were freed, the contract tax collection system (*Pramun Goen Luang Rap-Phukkhat*) was doomed and great reforms came about in the administration system. To put it simply, Thai society had started a rapid march toward modernization under the leadership of the nobles grouped around the king.[23] The modernization, however, had to be piecemeal and unexhaustive on account of the insufficiency of social specialization described before. And it was this piecemeal process of modernization that eventually blocked the way toward further development of agricultural production, which was achieved by the irrigation works.

3. 1902-1945

The third period was when her national economy, which had been developing since the latter half of the 19th century, began stagnating. In this period, her national economy took on a pattern of exporting primary materials and importing industrial goods.

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20) Nangsu Anuyat Khut Khlong Krasuang Kaset-Trathikan, 1891. Sathian Lailak, *Prachum Kotmai Pracham Sok*, vol. 12, p. 217.

21) Sanya Phrarachathan Phrabromrachanuyat Khut Khlong, 1888. Sathian Lailak, *Prachum Kotmai Pracham Sok*, vol. 11, p. 237. Chao Phraya Wongsanupraphat, *op. cit.*, p. 38.

22) Chao Phraya Wongsanupraphat, *op. cit.* p. 154.

23) There are still many points to be clarified regarding the material bases of the nobles of those days and it is important to study the relationship they had with the new merchant class, the Chinese merchants.

As we have seen, irrigation works had been developed largely in the lower delta area, and as a result arable land increased greatly. With this increase it became difficult to utilize irrigation water. Lacking proper care and attention, some of the canals became clogged with mud, rendering them useless. In coastal areas saline damage also grew. In view of this, and to stabilize agricultural production, the Thai government decided on a new series of irrigation plans and in 1902 invited a Dutchman, Van der Heide, and set up an Irrigation Department.

He surveyed in detail the natural conditions and agriculture of the Chao Phraya Delta and in 1903 submitted to the government his comprehensive irrigation plan which covered the whole of the delta.[24] The two main points of his plan were:

a. Repairing existing canals and making improvements by setting up water gates.

b. Constructing a dam at Chainat, the apex of the delta, and utilizing it as the base to build a network of canals to supply water to the whole delta area.

His plan was to benefit the area by stabilizing its agricultural production and enlarging arable land areas—which is a natural consequence of the plan—and bring various other benefits and work favorable to all phases of Thai national economy. The plan was studied as to its economy and feasibility. The outlined investment was stressed to be very advantageous but the British financial adviser who wielded much influence in the Thai government at the time strongly opposed it. He insisted that it was sufficient to repair and maintain only the existing canals.[25] The Thai government eventually followed his advice. Later, Van der Heide submitted another plan, smaller in scale to the government, but it too was rejected. He had to be satisfied with repairing the existing canals before he left for home in 1909. In 1912 the Irrigation Department was abolished and its work was transferred to the Ministry of Transportation.

Van der Heide's grand vision quite naturally failed to be realized because he had disregarded the actual stage of economic development of Thailand and the international circumstances she was surrounded with at the time. Her national economy had to be more developed if the revenue outlined in his proposed irrigation plan was to be secured. A multiple change based on the development of agricultural production was a prerequisite for the national economy. Britain, on the other hand, who was able to exert a great influence on the Thai government politically and economically, desired stability of the Thai society. It was quite natural that the British disapproved of the Van der Heide plan which necessitated huge financial investments. The European powers and their colonial governments' demand for rice were more or less satisfied by supplies from Burma.

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24) Van der Heide, J. H., *General Report on Irrigation and Drainage in the Lower Menam Valley*, Bangkok, 1903.

25) Iagram, J. C., *Economic Change in Thailand since 1850*, Stanford, 1954, pp. 197-198.

Nevertheless, it was an unwise policy to leave the matter as it was. Something had to be done to save the area from damages inflicted annually on rice production both by floods and droughts that followed irregular rainfalls. The Thai government decided to call a foreign technician and an Englishman, Sir Thomas Ward, was invited. In 1915 he sent in a report to the Thai government.[26] He thought of a plan that would cover the whole Chao Phraya Delta, but on second thought he concluded that such a large scale plan would not be in line with the then state of national economy and submitted several smaller scale plans. His plans were adopted and in 1916 the South Pasak project was carried out and in the 20's the Suphan and the Chiengrak-Klong Darn projects. But progress was very slow because of financial difficulties.

That the irrigation works of pre-war Thailand did not develop smoothly was due to the fact that her national economy failed to progress as planned in the process of changing over to a multi-purpose pattern. This is evident in the long period of stagnancy of her rice production. Farmers complained of shortage of water especially in the areas surrounding the delta and in the lower delta area, and money put in the irrigation facilities did not bear satisfactory results as were first planned.

4. 1945-present

The fourth period is when changes of international circumstances after World War II put her national economy on the road to development again.

After the end of World War II international conditions surrounding Thailand underwent great changes. Thailand was requested to increase her rice export volume. Internationally it was an absolute necessity so that the world could tide over the critical post-war shortage of food. International study was given to the possibility of increasing rice production in the Chao Phraya Delta. In 1948 an FAO mission visited Thailand and made recommendations on measures to expand her agricultural production.[27] In its recommendation the mission stressed the importance of the Chao Phraya Project and in 1950 the World Bank sanctioned this plan with a loan of about eighteen million dollars. The project went into effect in 1952. It consisted of the three following points.

a. Building a dam at Chainat, the apex of the delta.

b. Using the tributaries and distributaries of the Chao Phraya River as main canals, and dividing the whole benefitted area into several sections.

c. Leaving the swamp hinterlands between the natural embankments as they are and using them as huge natural reservoirs to regulate the floods in the lower delta area.

The Chainat Dam was completed in 1957. Along with the construction of the main canals small ditches and dikes were made to draw water into each

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26) Irrigation Department, *Project Estimate for Works of Irrigation, Drainage and Navigation to develop the Plain of Central Siam*, vol. 1 - 4, Bangkok, 1915.

27) FAO, *A Report of the Mission for Siam*, Washington, 1948.

plot of farmland (Ditch and Dike Project). It was now possible for the Chao Phraya Delta area to develop its agriculture to a great extent.

Following this, construction work began on the Yanhee Project. Its main object is in developing electric generating facilities. It also has the function of regulating the discharge of the Chao Phraya River further upstream from Chainat. Much is expected of it in increasing the effects of the Chainat Dam. As the works progressed, the water supply situation became increasingly stable in the lower delta area and in the surrounding higher areas. Consequently, the rice cultivation was stabilized. On the other hand, flood situations in the upper delta area, the basis for Thai economy, changed and rice production in this area is losing stability. Rivers now carry less soil from the upstream area and natural fertilizers are decreasing in supply. A renovation in agricultural techniques is needed.

As mentioned before it was the assistance of foreign powers, urged by international circumstances, that developed the Chao Phraya and Yanhee Projects. On Thailand's side there were the following circumstances in existence which had consolidated her economy to place it on a sound basis enabling her to use foreign aid effectively.

a. She was a rice exporting country during the post-war world-wide food crisis and amassed a large stockpile of foreign currency and built up her economic strength. Her export of other primary goods beside rice went on smoothly in large volumes.

b. She has been an independent country since before the war and experienced no social disorder in the post-war days. Her adminstrative set-up functioned comparatively well.

c. She had had much experience in irrigation works.

4. Conclusion

We have studied the history of irrigation in Thailand in connection with the process of her economic development. Irrational though her old system of agriculture seems it had its historical bases. Her agricultural techniques were low level but were rational, and being rational have made it possible for her to cultivate rice up to the present day. Although the relationship between natural conditions and society seems to be unchanging, in reality it has changed through the course of history.

At present the agriculture of the Chao Phraya Delta is making rapid progress and change. The population is rapidly increasing, uncultivated land is decreasing and the economy is shifting speedily toward commercialization. It was necessary that the farmers should prosper, they being necessarily the source of wealth for the development of industries and the market for industrial goods. Consequently, the government made all haste to develop her agriculture. Such was the social background that existed and motivated the development of the Chao Phraya and other irrigation projects.

But rapid and sudden changes of agricultural techniques were detrimental to the existing rationality and tended, on the contrary, to lower the level of agricultural production. This is evident in the upper delta area. Here rice cultivation had been very stable but the change made rice yields unstable. Consequently, there is now an overall demand for renovation of techniques. Now, agricultural techniques are combined and consolidated so that no partial change is permissible. If a new technique is to be introduced and if it is to fit in well with present-day social changes, consideration must first be given to the rational system of agriculture now existing.

Upon realization of a Chao Phraya Delta plan and the Yanhee Project, what will be the outcome of production? And based on this development what multiple changes will the economy of Thailand have to undergo? Will a sound pattern emerge? We look forward to this with great anticipation.

IV. Rice Culture and Irrigation Systems in the Philippines

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I am by no means exaggerating if I say that in Japan the study of water of the Philippines has not yet been taken up seriously. In a sense the problem of water in the Philippines has many things in common with those of Japan but in another sense it does not. It is my intention to clarify this and present to my readers a true picture of the water problem of the Philippines. Even in the Philippines the study of irrigation water has progressed little and lags behind Japan. As I will show later, this problem is a very important one because at present only 18% of their paddy fields are irrigated as compared to Japan's 95%.

1. The importance of irrigation water in the Philippines

Paddy cultivation occupies 48.2% of the total cultivated area and its production is 39.0% of the total volume of production. The second largest crop, maize is only 30.5% in area and 7.3% in production. Other crops are negligible, less than 5% in either cultivated area or production. There is irrigated a wide variety of upland farmlands where such crops as coconuts, abaca, sweet potatoes, maize, vegetables, fruits are grown but the method of irrigation is quite different from that used for paddy fields.

The most advanced area in irrigation lies in Central Luzon, where 45% of its total cultivated area is irrigated artificially, this is far below Korea where the average irrigated level is 53%. Although climatic conditions in the Philippines readily permit growing double or even triple rice crops, her limited and as yet, underdeveloped irrigation facilities keep single crop farming prevalent. Indeed very little double crop paddy cultivation is seen, to say nothing of secondary croppings. Even in Central Luzon where rice cultivation is most advanced only 9% of the farmers engage themselves in double crop rice cultivation.

Generally paddy rice has been cultivated in the rainy season by depending solely on rain water. To state it simply no fertilizers were used, weeds were left to grow and nothing was done to prevent plant diseases or stave off pests. Thus it will be necessary to improve the above conditions also, otherwise irrigation water cannot be utilized to the fullest.

2. Irrigation water and paddy cultivation

1. Land classification by rainfall

There are dry and rainy seasons in the Philippines but a clear delineation is seen only in the islands of the western part facing the South China Sea. On the other side, in the Pacific coast area there is much rainfall from November to January, and here they have a rainy season but no dry season. Generally, the rains come regularly and cover the area evenly throughout the year. Therefore, it is in the areas where rainy and dry seasons are clearly delineated that the problem of water is most important. To study this problem studies must be made on the distribution of rainfall.

The areas of the Philippines may be classified into four categories by climate (rainfall).

(1) Type I (Western Type) where the dry season (November to April) and the rainy season (May to October) are clearly defined

(2) Type II (Eastern Type) of maximum rinfall from November to January and where there is no dry season

(3) Type III (Transitional Type) where separation of the seasons is obscure, generally dry during November-December and much rainfall during January-October

(4) Type IV (Transitional Type) where annual distribution of rainfall is even

Type I regions are found facing the South China Sea, and the most representative ones in Central Luzon are Pampanga, Bulacan and Pangasiman. Vividly contrasting are the districts of Borongan of Samar and Daet of Camarines Norte where the pattern of the rainy season is the exact reverse of the climate for type I, that is, there is much rain in winter but no dry season like the type III pattern. Butan of Agusan, where annually there is a comparatively even distribution of rainfall, has a climate quite similar to type IV. In the Philippines where rice production depends almost solely on rainfall, its regional peculiarities greatly affect the rice transplanting and harvesting periods.

2. Rainfall and rice cropping systems

The general relation between these types of climate and systems of rice cropping is as follows:

(1) Type I

The dry and rainy seasons are clearly delineated. Rice plants are almost all cultivated during June-September, avoiding the dry season, while upland rice is cultivated during April-June, earlier than paddy.

(2) Type II

Except for the areas of the type I climate, the cultivationg period in the areas of this type of climate is the most complicated. It concentrates more or less in the wet October-January period. Upland rice is transplanted at a somewhat earlier date. In some areas rice cropping systems similar to those of type I are found. This is probably due to the absence of an extremely dry season.

(3) Type III, type IV

Rice cultivation is done in various periods but the general tendency is that more of it is done during the rainy May-September season than during the rainy October-January season. Comparing cultivation of upland rice with that of paddy, the former is generally done earlier than the latter and far more so during the season from spring to summer, that is, during April-July (sometimes in August). Pragad rice, using irrigation, is cultivated in the dry season even in the areas of the type I climate.

3. Effects of typhoons

Typhoons strongly affect especially the northern half of the Philippines and the relationship of their frequency to the growing period of paddy is an important problem. To grow rice, typhoons must be avoided as much as possible and to do so varieties that take 150-160 days to mature are seeded before April 19, those that take 113-120 days by May 31 and those that take 130-140 days before May 12, in this way avoiding the October typhoon period. The worst typhoon period is from October 13 to 27, followed by the September 28 to October 12 period. There are no typhoons at all from December to mid-April of the following year.

3. Irrigation in the Philippines

There were hardly any irrigation works worth mentioning in the Philippines before the Spanish colonial days. Only very simple irrigation methods were carried out on the mountain terraces of the Ifugaos and a few other places in the Mountain Province of Northern Luzon butt hey were of a much different pattern than that of modern irrigation.

Irrigation works of the Spanish colonial days were carried out by friars in and around Manila, for example at Laguana, Carite, Bulacan, Bataan, Rizal and Isabela. They built stone dams, tile drainage and open drainage conduits, which in time became clogged with sand and mud and thier maintenance had to be delivered over to government authorities, who in turn gave it to the farmers.

By the time the U. S. A. colonized the country her civil engineering techniques were quite advanced and from this period the irrigation works grew larger in scale. 23,935 ha of irrigated land in the Spanish colonial days increased to 86,130 ha during the American colonial days. During U. S. occupation, irrigation facilities were set up at Tarlac, Pampanga, Bulacan and Nueva Ecija of Central Luzon, La Union, Ilocos Sur, Ilocos Norte of Northern Luzon and Antique and Iloilo of Paray Island. No other irrigation facilities were built.

During the Japanese occupation irrigation works were set up at Rizal, Nueva Ecija, Suriaya and Quezon, covering a total area of 1,270 ha.

Great developments were made in irrigation after the Philippines gained

Table I Irrigation system

	1960 ha	1960 %	1965 ha	1965 %
1. National Gravity Irrigation System	260,860	36.6	318,711	34.1
2. Communal Irrigation System (Government Assisted)	83,533	11.7	153,734	16.4
3. Communal Irrigation System (Private)	333,602	47.0	373,602	40.4
4. Irrigation Pumps	10,500	1.4	60,000	6.4
5. Friar Land Irrigation System	24,000	3.3	25,221	2.7
6. Municipal Irrigation System	—	—	4,000	0.4
Total	712,495	100.0	935,268	100.0

Source: The Irrigation Program of the Philippines, 1965

independence. The National Gravity Irrigation System had already started operating from 1922. It was controlled by the President of the Philippines. Irrigation works of communals or pump irrigation facilities were carried out jointly by groups of farmers and land owners or by cooperatives but they did not succeed because the people who were responsible neglected the work of improving and repairing the facilities, were slow in cooperation or neglected to pay for the expenses of maintenance and control.

At present the National Irrigation System has plans for irrigation works in 77 sites in all, the total irrigated area being 317,431 ha and the total cost $72,807,100. 18 of these projects are in Central Luzon and many of them are large.

We find the amount of money invested in the National Irrigation System, one of the basic investments of the nation, increases over the years showing that her irrigation policy has made a steady development. The Philippine government estimates about $500 per ha in investment for new projects. This more or less corresponds to the amount estimated in Thailand and Malaya, respectively $500-$625 and $400-$450. The pump irrigation system has been in existence for over 60 years, and from 1949 the Irrigation Pump Administration of the Department of Agriculture and National Resources took over to promote the development.

4. Irrigation system

1. Paddy cultivation and regional characteristics of irrigation systems

Regionally the Philippines may be largely divided into nine districts, (1) Ilocos, (2) Cagayan valley, (3) Central Luzon, (4) Southern Tagalog, (5) Bicol, (6) Eastern Visayas, (7) Western Visayas, (8) Northern and Eastern Mindanao and (9) Southern and Western Mindanao. The actual state of rice cultivation and irrigation of each district is shown in Fig. 1.

We will compare Bicol and Central Luzon where there is the highest percentage of irrigated areas. The first crop irrigated area of Central Luzon is 34.3% in contrast to 26.8% of Bicol, but in the second crop irrigated area Bicol with high percentage of 18.2% far exceeds Central Luzon with 10.6%.

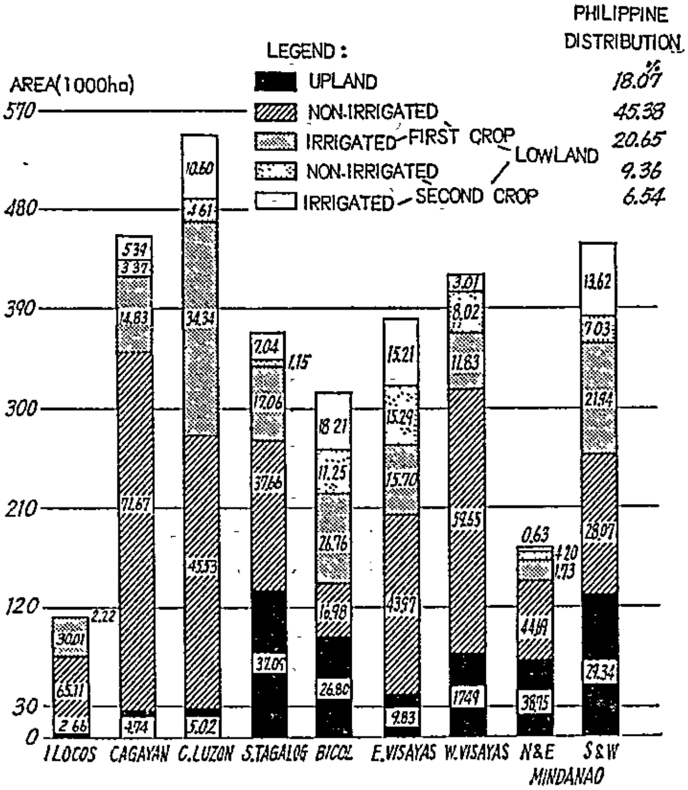

Fig. 1 Regional distribution of paddy fields

The regional differences between Bicol and Central Luzon are evident despite their similar climatic conditions (especially in rainfall). That is, the percentage of paddy cultivation is the largest in both districts. Central Luzon has a type I climate, dry from November to April and wet from May to October, whereas Bicol district has a type II climate with maximum rainfall during November-January and no dry season, which is regarded favorable for its double rice cultivation. In upland farmland area Central Luzon has only 5.0% in contrast to Bicol's 26.8%. In average crop yield per unit area both districts are in the group of districts with the highest level and the rate of increase is higher than any other district group. In areal expansion of cultivated land Central Luzon is somewhat at a standstill while Bicol shows an increase. In Central Luzon more stress is placed on increasing the crop yield per unit area rather than on increasing the areas of cultivated land. (Fig. 2)

2. Types of irrigation systems

A picture of irrigation of the whole of the Philippines may be had by studying its development in Central Luzon, where irrigation systems are the most advanced. The irrigation systems in Central Luzon may be divided into the following five categories:

a. National Gravity Irrigation System: maintained and controlled by

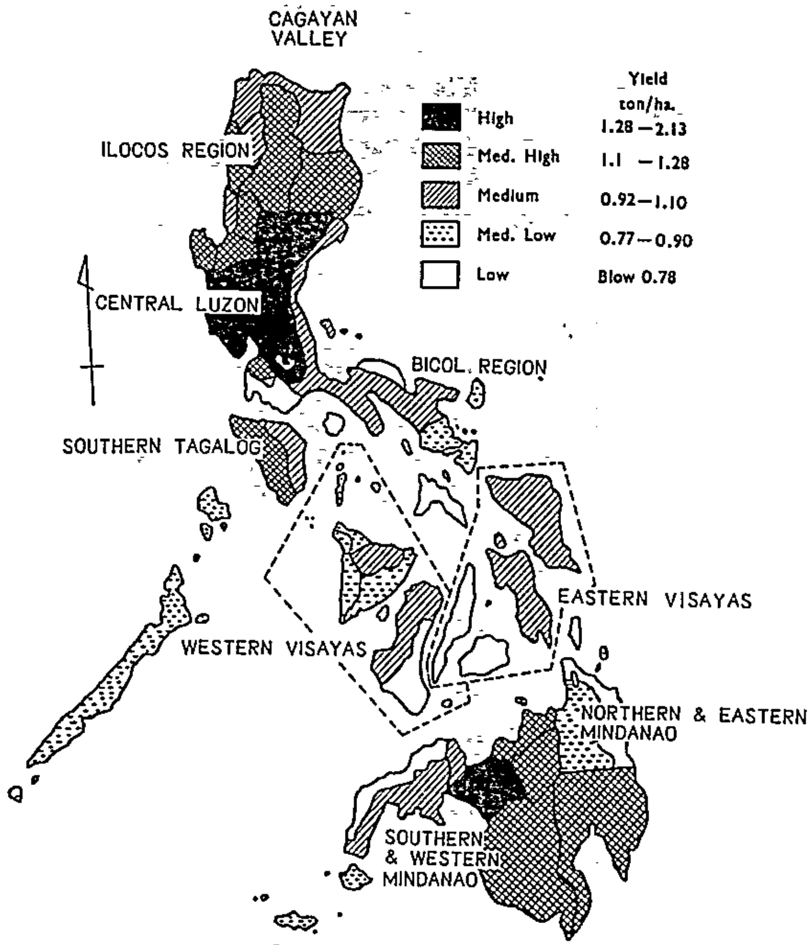

Fig. 2 Distribution of rice yields among Philippine Provinces (Three year average, 1956-57 to 1958-59).

Source: Division of Agricultural Economics, Dept. Agriculture and Natural Resources

Table II Irrigated areas in Central Luzon

	National		Communal		Friar Land		ISU		Private Area
	No.	Area	No.	Area	No.	Area	No.	Area	
		ha		ha		ha		ha	ha
1. Bulacan	2	29,480	—	—	2	1,137	1	359	2,416
2. Nueva Ecija	8	50,690	2	5,050	—	—	15	3,061	92,438
3. Pampanga	1	6,000	3	1,800	—	—	3	4,626	3,067
4. Tarlac	3	19,270	2	1,750	—	—	4	1,125	8,457
5. Pangasinan	4	30,300	5	11,120	—	—	2	717	8,130
Total	18	135,740	12	19,720	2	1,137	25	9,888	114,508

Source: Report on the Water Resources of Central Luzon, 1961 the Bureau of Public Works

b. Communal Gravity Irrigation System: carried out by autonomous public bodies with assistance from the government

c. Friar Land Estates Irrigation System: The Bureau of Land administrates the lands that were formerly "Friar Land Estates".

d. Pump Irrigation System Financed by the Irrigation Service Unit: Projects financed and built by ISU, cost to be paid back within ten years; facilities for drawing water from rivers and deep wells are also included.

e. Private Irrigation System: Individually or communally held rights of water utilization.

Table II shows the area of cultivated land of each district and each system of irrigation. We find large differences according to the district but, generally speaking, national and private systems are outstanding in number, the remainder being only a small percentage.

As to the extent of utilization of surface water and underground water, in the Central Luzon area we find more underground water used, a tendency outstanding in Bulacan and Pampanga, where many artesian wells are to be found.

V. Agricultural Development in East Pakistan

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1. Natural conditions in East Pakistan

East Pakistan is located on a large delta constructed by large rivers originating in China and India and lies behind the Bay of Bengal. The country is affected greatly by sea tides. Technically, politically and economically it is very difficult for her to exercise independent control over these large rivers. She faces many difficult problems which cannot be solved unless all the nations of the world in the name of humanity extend generous help to her by assembling their best knowledge and techniques. By this we mean that to develop this delta area is a humanitarian problem for the 20th century.

1. Topography (Rivers)

East Pakistan is a flood plain, a delta country. In general, even as far as 300 km inland from the Bay of Bengal the land rises only about 17 m above sea level, but in the eastern part lies the Chittagong-Tipperah Terrace, resembling hill tracts, and in the north-eastern part is Sylhet, a somewhat hilly land. Consequently the tides of the Bay of Bengal affect areas even further upstream than 300 km. Rivers carry huge volumes of silt to settle in the lower basin and build up alluvial land, thus naturally enlarging the area of the country. Sedimentary soil and sand brought by the rivers block the natural flow of the rivers and make many distributaries which render the topography of the delta all the more complicated. A scale map of 1/50,000 would show networks of numerous small rivers and square ponds.

The characteristic features of the three large rivers of this country are shown in Table I. A thorough knowledge of these features must be available and grasped accurately if plans for the agricultural development of East Pakistan are to be made. A thorough consideration of these three points is especially necessary: with them, our comments and opinions:

(1) Analysis of tidal action

a. The uppermost tidal points in these rivers shift a little upstream in the rainy season from the tidal points of the dry season, but the shift is generally very little.

Table I Three main rivers

	Ganges	Brahmaputra	Meghna
Catchment area	920,000 km^2	580,000	70,000
Length	2,600 km	2,900	—
Slope	1/20,000	1/15,000	1/25,000
Assumed maximum discharge	42,000~55,000 m^3/s at Hardinge Bridge	50,000~70,000 at Sirajganj	83,000 at Chandpur 11,000 at Bhairab
Average discharge	16,000 m^3/s	20,000	4,700
Minimum discharge	1,800 m^3/s at Hardinge Bridge	6,000 at Bahadurabad	2,000 at Bhairab
Maximum discharge	water surface 3.5 m/s average 3.0	2.6 1.6	— 0.8
Suspended sediments (by weight)	max. 0.1 % min. 0.005	0.13 0.012	— —

b. The amplitude of tidal action increases when the discharge of the rivers decreases.

c. The amplitude of tidal action changes according to the distance from the river mouth. The changes show a tendency to constrict into a curve. There are a few further changes.

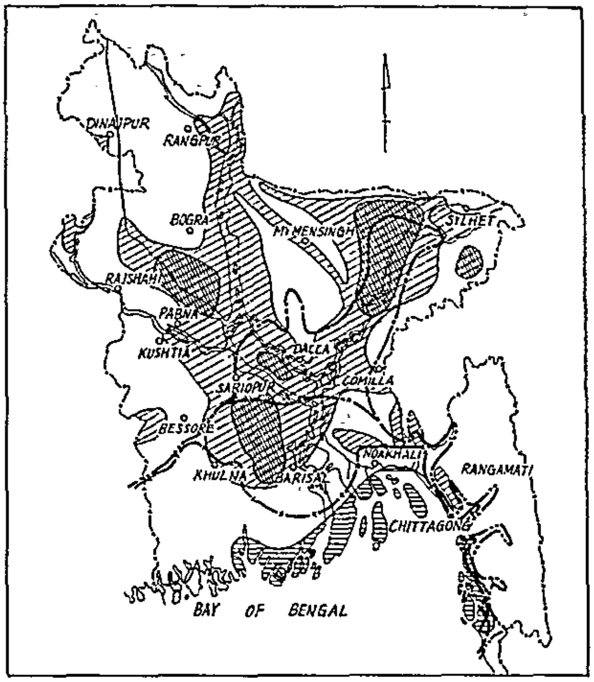
d. *The speeds at which the highest point of the water level and the lowest* travel are generally regarded to equal the speed at which waves travel ($\sqrt{gh}$). The average value of h may be generally applied at the estuaries but it has actually been found inapplicable in the vicinity of mid-stream islands and in the separation distributaries.

e. The maximum and minimum of the water level cannot be obtained through a non-uniform flow calculation, that is, from the backwater curves.

f. The amplitude of the tidal action decreases suddenly at the points where the river beds elevate and form rapids in the shallows.

(2) The volume of suspended colloid and sedimentary action

These important factors of alluvium and accumulation must be studied separately for each river system. Though general information of the river systems here is available, there is not enough accurate data available to help us make workable plans. Areas immediately adjacent to the banks of the rivers are generally elevated and become lower the further and inland, we go in the lowest parts even in the dry season, marshes and beels are found, which



LEGEND
DEPTH OF FLOOD WATER EXCEEDING 15'FT
DEPTH OF FLOOD WATER LESS THAN 15'FT
AREAS AFFECTED BY STORM SURGES IN 1960 & 61
LIMIT OF TIDE WITH REVERSAL OF FLOW
LIMIT OF BACK WATER EFFECT OF TIDE
LIMIT OF SALINITY

Fig. 1 Effect of tidal action and salinity

present great obstacles to agricultural development. Traditionally as a countermeasure a silting method has been adopted by which water is drawn from the rivers in the rainy season through canals into these beels where the suspended colloid settles. If, however, plans are made and canals are constructed without investigating well the nature of the soil of the river beds, silt will clog up the canals in one rainy season and render them useless. Unfortunately, very few reports and little data are available on effects of silting. In the design of canals, this silting method should be taken into account from the standpoint of agricultural development, not merely as a means of irrigation.

(3) On salinity

Prevention from saline damage should be solved from the standpoint of civil engineering by the Coastal Embankment Projects. On the other hand, research should be conducted to find suitable crops able to grow in saline soil. Given the values of the salinity distribution at the estuaries where the salt water flows in, and given the discharge of the river, Arons & Stommel's theory as propounded in "The Problem on the Diffusion within a Continuous Body" may be applied but the hypothesis is too rough to reflect the actual state with accuracy.

We will present here some data obtained from measurements of the tidal levels and on the effects of the salt water intrusion (Fig. 1).

The three problems mentioned above are still far from being satisfactorily solved, and to produce satisfactory answers it will be necessary to take actual measurements wherever possible.

2. The soil of the delta

The soil as viewed from the alluvial conditions of the rivers may be classified as follows:

(1) Marine sediments

The southernmost part of the lowland that faces the Bay of Bengal is covered by this type of soil, having been continuously accumulated by the sea. The coastal forest area known as the Sundarbans is representative of this type of land. Land facing the Bay of Bengal is unsuitable for agriculture unless embankments are built taking into consideration the nature of the sea water, the level of the tides and the lowness of the land.

(2) Ganges alluvium

As we go further west the soil gets increasingly better and weathered; the result of the eastward movement of the Ganges River. It has a pH value of 6-8. The new soil in the eastern part of the region contains abundant free carbonates derived from sedimenting silt in the upper layers. The Ganges River contains many soluble solids and the water has a characteristically high nutritious quality.

(3) Brahmaputra alluvium

This type of soil covers the districts of Sylhet, Tipperah, Mymensingh and Dacca. The flood area of the Meghna River which comprises the whole of Sylhet and a large part of Mymensingh has a low pH and is leached, thus crops do not grow well. The soil in the northern part of Mymensingh and in the lowland section of Sylhet is made up of the sediments of comparatively hard rocks of the Jaintia, Caro and Khasi hills. In chemical properties Brahmaputra alluvium is not inferior to the Ganges alluvium.

(4) Tista alluvium

The Tista River flows through hilly territory and deposits a coarse alluvial soil with high water permeability and of reddish color.

(5) Red soil

This is a tropical lateritic soil and its pH value is below 5.5. A very fertile land may be made out of this soil by irrigating it, supplying it with green manure and lime to improve and to form a granular structure.

(6) Peat belt

This soil was discovered in 1953 and is interesting as an object for study. It is a shallow layer of about 0.3-3.6 meters. The total dry weight of the peat is estimated to be around 14 billion tons. It is a considerably weathered soil.

2. Agriculture in East Pakistan

1. A general outlook

The basis of East Pakistan's economy lies in her agriculture and she is expected to stress more developing her agriculture in her economic policy. More than 80% of the population is engaged in agriculture but there are in her villages a considerable number of poor families which own no land, although inadequate censuses keep us from knowing the real figures. In the 10 years after independence, her population increased by about 20 million due to refugees from India and to improved medical care, all of which worsened the country's food situation. The market price of rice is exceedingly high in comparison to the income of the inhabitant.

In our eyes agricultural cultivation as now carried out can use many improvements. But her delta agriculture has been built by a long history and long experience. It is a pattern of agriculture accepting the prevailing conditions of nature and Nature assures the farmers only the lowest limits for their livelihood. They live on a thin marginal line harrassed by too much water in the summer, too little of it in the winter and terrified by the cyclones at the beginning of the rainy season. On an average they till less than 2 ha of land and earn an average annual gross income of $560. An average family consists of eight members. This is more or less the picture of an average farmer's family in the Bengal district.

Table II shows the extent to which land is utilized but the data are somewhat vague as it shows East Pakistan's total area as 14.3 million ha, and tells us that arable land comprises roughly 70% of the total. It is difficult to tell where arable land begins and where rivers and swamps do, but more or less the actual state of this area is that 71% of the cultivated area is paddy fields, about 7.7% jute fields and the remaining area has other agricultural products such as pulses, rape, sugar cane, wheat, barley, tobacco, tea, and other crops.

Table II Land classification

Forests	River land	Uncultivated land	Fallow land	Planted areas	Total
1.25	.65	1.90	1.82	8.30	13.92

* Figures are in millions of hectares
Source: Statistic data, Directorate of Agriculture of East Pakistan, 1951~52

2. Rice cultivation

Many varieties of rice are grown in East Pakistan, such as those growing even in water 5 meters deep, able to withstand the arid climate, bearing long and large grains, bearing small grains and able to be cultivated in autumn, winter, spring or summer.

The varieties may be roughly divided into the following groups:

Group I - - - *Aus* (Autumn rice) { Highland *Aus* / Lowland *Aus* }

Group II - - - *Amon* (Winter rice) { Lowland *Amon* (Broadcast or Floating *Amon*) / Transplanted }

Group III - - *Boro* (Summer rice or Spring rice)

Of the total percentage of the area cultivated, the *Amon*, *Aus* and *Boro* varieties occupy respectively 66%, 28% and 6% but they differ considerably in the various regions. In general the varieties most widely grown are the *Amon*. In yield per unit area the *Boro* varieties surpasses the others. The *Boro* is transplanted at present in the dry season in only the swamp areas and adjacent land because it is only there that water can be obtained for irrigation. If irrigation water can be had in the dry season by pumping or from head works, the cultivation of the *Boro* varieties is expected to be expanded within a short time, since natural conditions favor its cultivation even in the dry season (winter). Not only is it easy to cultivate but is also resistant to plant diseases and pests, and fertilizers do certainly work effectively with these varieties.

The paddy fields are tilled mainly by oxen that pull long heavy wooden plows with an iron edge. As the plow is usually heavy it is pulled by two oxen but even then the surface of the ground can only be stirred to a depth of 3-5 cm, which is by no means sufficient. Lately tractors supplied under U. S. aid have come into limited use on government and college farmlands but they often break down, the drivers still being unused to the machines. The Directorate of Agricultural of the East Pakistani government has shown interest in Japanese tillers and after experimenting with them, bought from several manufacturers (Sato, Kubota, Yammar, etc.) and is now promoting their use, but a general adoption of machines still seems remote, as here there is a surplus of human labor.

East Pakistan's present agri-pattern is of a single rice cultivation, chiefly in the rainy season, though climatic conditions would make it very easy to grow double crops or even triple crops on a greater part of the land. The main reason why it is not yet being done is because water cannot yet be controlled.

The average yield of paddy rice is about 1 ton per ha. This is very small as compared to Japan's 4 tons per ha. If even 10% of the present acreage of the paddy fields, with present agricultural techniques, grew double crops it would immediately be possible to solve the present acute shortage of food. It may not at once be possible to control the water of the delta area thoroughly, but artificial control of an area of about 10% of the present cultivated land should be quite possible. It is more important to make a workable plan to cover 500-5,000 ha of land and be able to carry it out instead of experimenting with too large a project.

3. Upland farming

East Pakistan's largest agricultural export item is jute. About 6 million bales (1 bale: 200 kg) are produced annually, a large part of the world's total production. Here jute is called the "golden fiber", an agricultural product she is proud of. Lately the market price is declining because of chemical fibers. Jute is grown in the flood areas of the rivers flowing through the delta. Other upland farm crops are the pulses, rape, sugar cane, wheat, barley, tobacco, tea, etc. There are many tanks standing around villages and by using the water stored in them, chillies, onions, and soybeans are cultivated in the winter.

3. Direction of agricultural development

In a country like East Pakistan where the land is mostly flat and wide and where numerous rivers flow irregular courses, it may be said that the direction of agricultural development is determined by how the rivers are controlled. It is true that at present her agriculture utilizes the rivers for irrigation, for fertilizing and for transportation. Thus her agriculture is very closely connected with the rivers but very unstably, as the rivers are merely utilized in their natural state.

How then, given such natural conditions, should agricultural development mainly paddy cultivation) of this delta area be promoted? As an answer we feel that to arrive at a high technical level of paddy cultivation it is necessary to bring in drastic means of irrigation water control, and this leads to two general methods.

In view of its topography one is to plan mainly for winter season irrigation chiefly for the cultivation of the *Boro* varieties in areas irrigable by using pumping and barrage facilities. Japanese paddy cultivation techniques could be introduced comparatively easily. Due to natural conditions, such areas are limited to specific regions. If plans are made for larger areas the accompanying irrigation and drainage facilities will necessarily have to be larger in scale, this in turn necessitating larger investments and demands for higher levels of civil engineering techniques. It is, therefore, desirable to plan for a comparatively smaller area (100-5,000 ha). Development in this direction will change the present agri-pattern which is based on the increased discharge of the rivers in the rainy season, and it means a revolution in her agricultural history. The effect would very greatly influence not only the farmers concerned but also the whole social life of the East Pakistanis. Small scale projects should, therefore, be carried out only where the invested money would bring immediate and large effects. We, as Japanese experts, unfolded our plan to the government and stressed that the government should carry out small scale irrigation and drainage projects running parallel to the master plan for water utilization and yet directly connected with an increase in production. Our plan was recommended to the Water and Power Development Authority (WAPDA) and to the provincial minister of agriculture, and as a consequence a Small Scheme Directorate was set up in the WAPDA, to which we served as consultants.

The other is to tackle the flood problem of the delta area. All the rivers in East Pakistan should be considered a single body and be placed under one master plan for flood control. It is not going to be easy to control these numerous large and small rivers which formed this delta over long centuries and which flow at random throughout it. In general, the rivers subject to large changes in discharge are controlled by flood control dams constructed in their upstream areas. Similar dams for generating electric power also help in regional development but in the case of East Pakistan this is limited only to the Chittagong Hill Tracts. As most of the large rivers that flow through this delta pass through

India it is impossible to control the discharge in the rainy season at their sources.

A master plan should be drawn up from the standpoint of improving the prevailing situation, a plan to lessen the immediate damage from the rivers and enlarge the field of water utilization. To make this all-encompassing master plan it should be based on precise hydrological data, which FAO technical teams are now hurriedly collecting and compiling.

4. Governmental measures

The agricultural bureaus of the provincial governments draw up concrete plans regarding the direction of the development of agriculture of East Pakistan. Of these, those requiring large outlays of government funds, especially foreign funds, are handled by the WAPDA.

East Pakistan's main agricultural policies follow:

a. To put into effect proposals of aid from foreign countries in technical and economic cooperation in the form of loans, credits, proposals and gifts. The WAPDA is chiefly responsible for the building of various facilities for agricultural development.

b. To experiment with market price regulating of rice and wheat and with supplementing the pressing shortage of food by making government organizations store 300,000 tons of rice and wheat, respectively.

c. To establish a subsidy system to subsidize 60% of the outlay for fertilizers, 100% for preventing plant diseases and pests (chemicals are applied directly), 20% for minor irrigation facilities and 10% for mechanization and seeds. The system, however, is not working at full capacity due to lack of proper terminal set-ups.

d. To improve guidance organizations to propagate agricultural techniques and educate the farmers by a "tell-show-do" method, one of which is the setting up of agricultural technique centers.

e. To establish agricultural cooperative associations. First of all, the Pakistan Academy for Rural Development (PARD) at Comilla, is being enlarged and strengthened to start educating future leaders of farming villages.

The preparatory work to lay the bases of East Pakistan's agricultural development is still in its planning stages as it started only recently. While we were engaged in technical cooperative work there were several Japanese paddy experts at the Agricultural Training Center of East Pakistan engaged in the work of guidance in agricultural techniques. They complained that what was most inconvenient to them in carrying out their program was mainly due to the incompleteness of the testing fields, especially the difficulty of water control due to lack of irrigation facilities. They insisted strongly that before any other thing is done the farmers should be educated and given technical guidance in irrigation and drainage.

B. Several Reports of Water Resource Development Projects

I. Nam Kam Development Project in Thailand

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As members of the Mekong River Nam Kam Investigation Team sponsored by the Japanese Government, we were dispatched to Thailand to carry out investigations on the agriculture of the Nam Kam Basin Comprehensive Development Project in northeastern Thailand. In December, 1962, we prepared the reports "Comprehensive Development of the Nam Kam Basin" and "Preliminary Designs of the Nam Pung Irrigation Project". We shall describe the circumstances of the investigation and outline these development projects.

1. Nam Kam Development Project

For three years in succession, from 1959 to 1961, the Japanese Government sent her reconnaissance and survey teams to Thailand to investigate the main tributaries of the Mekong River. In September, 1961, she submitted to the ECAFE Mekong Committee the "Comprehensive Reconnaissance Report on the Major Tributaries of the Lower Mekong Basin" with the recommendations that at first a pilot project in the Mekong tributaries should be decided for a procedure of an early development of the Lower Mekong basin, and that the pilot project should be surveyed by an investigation team, and for this pilot project the Nam Kam basin is most suitable.

For this purpose, in 1961 the Japanese government dispatched to Thailand an investigation team consisting mainly of engineers from the Electric Power Development Co., Ltd. (EPDC) and from the Ministry of Agriculture and Forestry. The team was commissioned to make on-the-spot surveys with regard to hydroelectric power development, agricultural development and flood control in the Nam Kam basin. In December, 1962, the team submitted to the ECAFE Mekong Committee, the reports, "Comprehensive Development of the Nam Kam Basin" and "Preliminary Designs of the Nam Pung Irrigation Project".

On the basis of these, the Thai government decided on an early execution of the development plans by using the Thailand Special Yen Funds that had been granted by the Japanese government and in December, 1962, she requested the EPDC to prepare a definitive report with concrete and precise blueprints. The Christian Nielsen Thailand Co. was contracted to construct the dam and the hydroelectric power generating stations. The EPDC was commissioned to supervise the work (the contract was made in December, 1964) as consultant. Construction is now under way and will be completed by October, 1965. The irrigation works of the projects have not yet progressed to the stage of execution.

2. The comprehensive development of Nam Kam basin

1. Outline of the Nam Kam basin

The Nam Kam basin is located in the northeastern part of the Khorat Plateau. The Nam Pung River originates in the hill tracts, about 500 m above sea level, west of this basin area, and flows northeast into Nong Han Lake. Rivers flowing on the right of the Nam Kam River also flow northeast down from the southwestern hill tracts into the main stream of the Nam Kam River. Rivers on the left of the Nam Kam River originate in the northern hill tracts, about 200 m in altitude, and crawl southeast also into the main stream of the Nam Kam River.

The main stream of the Nam Kam River starts out from Nong Han Lake and as it passes through the Nam Kam gate twists slowly on over a distance of about 133 km to That Phanom, where it joins the main stream of the Mekong River.

Nong Han Lake has a catchment area of 1,561 km^2, more than 45% of the catchment area of the Nam Kam River, 3,440 km^2. Under normal conditions the lake has about 100 km^2 in water surface area, with the water level 156.5 m above sea level and maximum depth 3.50 m. During abnormal flood periods the lake acts to control flood discharge into the Nam Kam River main stream. According to the records, the lake attained a maximum depth of 5.70 m when the water level reached a maximum height of 158.72 m above sea level and expanded out to about 166 km^2 in area, 17 km long from north to south and about 14 km wide from east to west. It abounds with many varieties and yields much fish. The Department of Fisheries has installed a control gate at the lake outlet to maintain the water level in the dry season and to preserve its fishery resources and to help develop fishing industries. (Refer to Figs. 1 and 4, and the maps in the appendix)

On the western shore of the lake stands the city of Sakol Nakorn (population

16,500; 153,600 including the suburbs) the center of political and economic activities of this region. A state highway runs through Sakol Nakorn along the main stream of the Nam Kam River up to That Phanom (population about 11,000; 68,900 including the suburbs). Along the highway are found comparatively large numbers of dwellings and paddy fields. The area along the Mekong River, from where it joins the Nam Kam River, lies outside the Nam Kam River basin. About 55 km upstream of the above confluence of the river is the city of Nakorn Phanom (population 12,000; 62,500 including the suburbs) and about 45 km downstream is Mukdahan (population 12,000; 70,200 including the suburbs), facing Thakhek and Savannakhet, two large towns of Laos across the river.

Geologically, the Nam Kam River basin is a large land block jutting to the southeast. The bed rock consists of Khorat Series, belonging to Triassic-Jurassic periods, composed mainly of sandstone and conglomerates of terrigenous deposit. The bed rock of the upper reaches of the Nam Pung River, at the proposed dam site, is presumably Khorat Series of comparatively recent geological period, which has formed horizontally into extremely gentle folds. Covering the bed rock is yellow and yellowish-brown sandy soil. In the flat section were observed small blocks of laterite which have undergone lateritization.

The climate of this region is similar to that of the tropical plains. Rainfall, compared with tropical rain forest areas where tropical vegetation grows densely, is comparatively little and seasonal changes are observed. In the summer (June to September), southwest monsoons cause days of continuous rainfall. But in the winter (November to April), dry northeast monsoons blow bringing hardly any rain, the temperature falls during the night creating a desert climate. Because of this phenomenon one will see an intergrowth of tropical trees and grasses. The annual precipitation is about 1,500 mm. The temperature seldom falls below 10°C and the lowest recorded was about 5°C, differing comparatively little through a year, but since the climate is a continental type the difference between the maximum and minimum temperatures in a day is quite great.

Table I Average monthly precipitation and temperature in Sakol Nakorn

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Precipitation (mm)	0.0	14.8	12.1	30.3	221.1	101.8	166.9	189.7	392.5	1.0	0.0	0.0
Temperature (°C)	21.8	23.9	27.5	29.3	28.8	28.3	27.9	27.7	27.3	26.2	23.6	21.7

Note: Precipitation figures, from Nov. 1958 to Oct. 1959 were used
Temperatures are mean of ten years (1947 to 1958)

2. The basic idea of the plan

About 30 km southwest of Sakol Nakorn, in the upstream area of the Nam Pung River, a tributary of the Nam Kam River, there are several waterfalls forming a series of rapids. At this site the available head is approximately

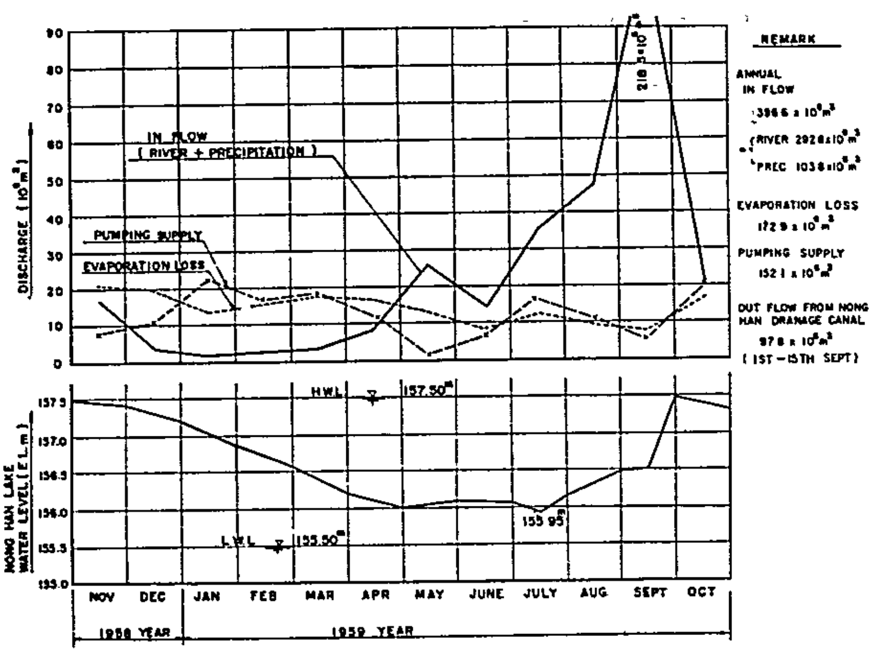

Fig. 1 Annual variation of water level of Lake Nong Han

60 meters. A rock fill dam, about 40 m above foundation rock, should be built on the rocks that appear in the upstream of the fall and the Nam Pung reservoir with an effective storage capacity of 122 million m³ would be created. The dam will store run-off from a catchment area of 296 km².

Diverting the water from this reservoir an electric power generating station with a maximum 6,000 kw output should be constructed to supply electricity not only to Sakol Nakorn City but also as far as to Nakorn Phanom, That

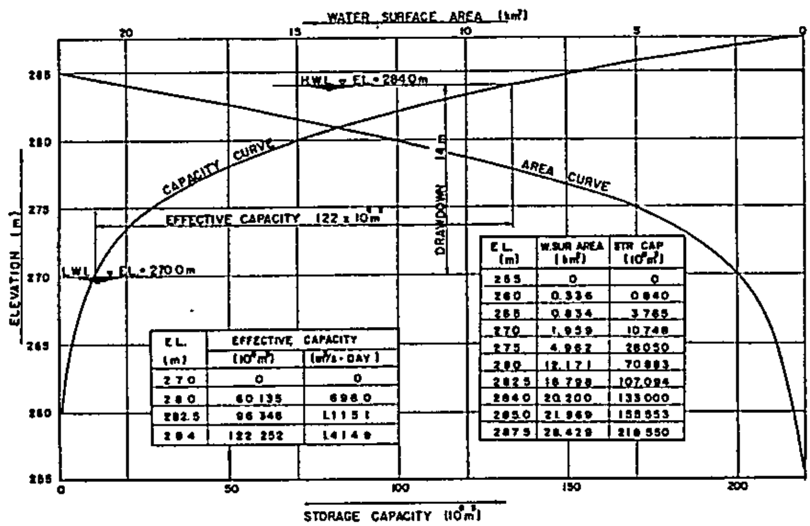

Fig. 2 Water storage capacity and water surface area of the Nam Pung reservoir

Phanom, Mukdahan and other cities that lie in the main stream area of the Mekong River.

At the Nam Pung bridge site in the lower basin, the water released through the electric power generating station is drawn to irrigate 10,000 ha of arable land on both sides of the Nam Pung River. It is estimated that Nong Han Lake will store about 196 million m³ of water when the effective depth of the lake is 2.0 meters. Under present conditions this lake serves as a flood storage basin in the rainy seasons but floods occur frequently in the vicinity around the lake every year because the Nam Kam River main stream can not hold a sufficient amount.

It would be possible to use this lake as a reservoir in its present state and if pumping stations are built on the lake shore it would be possible to pump up the water for irrigation. By this method about 4,500 ha of land could be developed. With the addition of the irrigated area along the Nam Pung River a total of 14,500 ha of land could be developed. The Nam Pung reservoir will contribute also to decrease flood damage in the lower area around Lake Nong Han and the main stream of the Nam Kam River. As the main stream of the Nam Kam River downstream of Nam Kam gate allows passage of only about 35 m³/s of flood discharge it will have to be enlarged to allow a minimum

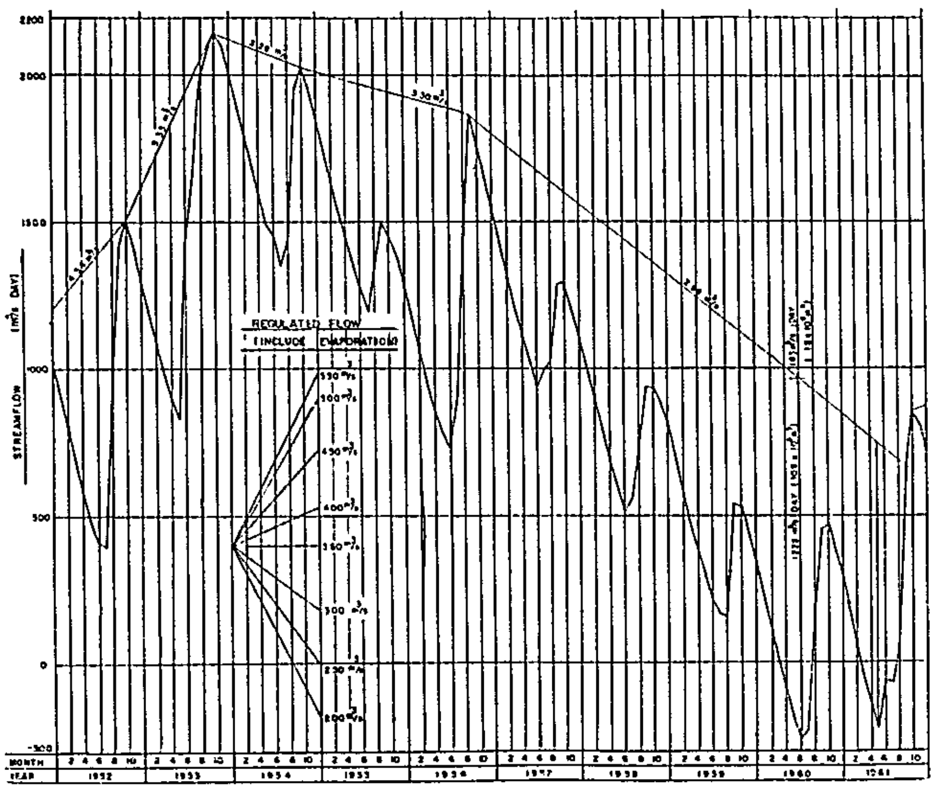

Fig. 3 Inflow diagram of Nam Pung reservoir

passage of about 155 m^3/s of water during the flood periods if the lower basin is to be protected. In order to maintain the water level of Nong Han Lake below 157.5 meters during the flood period it would be better to construct a drainage canal about 7.3 km long north of Nong Han Lake and let the flood flow directly into Huai Nam Un, a small tributary of the Nam Song Kram River, that flows almost parallel to the north of the Nam Kam River, instead of improving the main stream of the Nam Kam River. Also the drainage canal should be used for pumping irrigation water for the Nong Han West area and the Nong Han North area. (Figs. 1, 2, 3)

3. Specifications of the electric generating station
   Location: On the Nam Pung River, a tributary of the Nam Kam River in the Mekong River Basin
   Method of electric generating: With regulating reservoir
   Type of dam: Center impervious earth core rock fill dam
   Catchment area: 296.0 km^2
   Pondage area: 21.97 km^2
   Normal high water level: 284.0 m
   Minimum water level: 270.0 m
   Gross storage capacity: 155.55 million m^3
   Effective storage capacity: 122.25 million m^3
   Maximum dam height above foundation: 40 m
   Crest length: 1,719 m
   Crest width: 10 m
   Slope upstream: 1:1.75
   downstream: 1:1.5
   Dam volume (total): 730,000 m^3
   Maximum available discharge: 8.8 m^3/s
   Installed capacity: 6,000 kw
   Annual output: 15 million kw-h
   Date of operation: September, 1966
   Total cost of construction: 5,211,000 dollars

3. Agricultural development plan

1. The irrigable area
   (1) Topography

The western part adjacent to the Nam Kam Project area, which is 500 meters or so in elevation, is called the Nong Han terrace. Two rivers, the Nam Pung and the Nam Kam originate here. The topography is flat, undulating little. The right bank area of the Lower Basin area of the Nam Pung River slopes generally at 1/1,500 towards the east-southwest. The area along the Nam Kam River has a slope of 1/1,200. Similarly the left bank area has a slope of 1/600-1/1,500 towards Nong Han Lake. The Nong Han West area slopes at 1/1,200-1/1,600 towards the lake, and the Nong Han

North area slopes at 1/700-1/1,200 towards the lake.

(2) Soil

The geology of this region consists of a formation of Mesozoic psammite which is covered by a thin layer of fine sandy loam derived from the psammite. Soils covering this region are generally sandy loam brown in color, sterile and with little humus.

(3) Water quality

The quality of the water of this region is as shown on Table II, and can be used for irrigation.

Table II Chemical analyses of the river water (mg/liter)

	Date	Ca	Mg	Na	K	HCO_3	SO_4	Cl	SiO_2	Fe	PO_4	NO_3-N	NH_4-N	Albuminoid N	$KMnO_4$ consumption	Evaporation residue	Floating matters	Turbidity*	pH	Hardness of water**
Chiang Saen	Average, July 1956~June 1957	32.1	5.9	8.4	1.7	116.9	17.1	6.9	14.4	0.00	0.01	0.02	0.04	0.08	7.1	145.3	186.2	145.1	6.9	104.5
Nong Khai	〃	31.1	5.7	7.7	1.6	115.6	14.7	6.2	15.0	0.00	0.00	0.04	0.04	0.09	7.7	139.2	174.1	134.5	6.9	101.0
Mukdahan	〃	26.8	4.9	7.5	1.4	100.3	12.2	6.6	13.8	0.00	0.00	0.04	0.04	0.10	5.1	124.3	99.9	57.1	6.9	87.3
Sakol Nakorn	〃	3.0	0.7	5.8	1.4	15.5	0.3	9.5	6.3	0.12	0.00	0.06	0.06	0.10	7.2	51.1	35.6	58.4	6.1	10.4

* Turbidity 1 is indicated by the turbidity of 1 mg/*l* of porcelain clay

** Hardness of water is indicated by $CaCO_3$ mg/*l*

After J. Kobayashi, Chemical studies on the rivers of Southeast Asian countries (in Japanese)

(4) Underground water

There are some tracts of cultivated land around Nong Han Lake that are located very close to level of the lake surface. On the other hand, past records (1950-1961) show that the lake level fluctuated approximately by 4 meters. They allow us to conclude that the level of underground water must have also fluctuated enormously during a year or between years in the area surrounding the lake.

In the Nong Han Lake flood control plans the highest water level is to be 158.17 m, thus the elevation of the permanent upland field is generally planned to be more than 160 m for safety, judging from past records of underground water level and by technical observation.

The water table in the dry season seems to be approximately 3-5 m lower than that in the rainy season. If, therefore, short-period upland crops of shallow root zones are cultivated in the dry season, there would be no particular problem with respect to the elevation of paddy fields where dry-season upland crops are grown as second crops.

(5) The present state of farm management

Farm management in Thailand is small and poor. Cultivated acreage per household is about 3 ha, of which about 2.8 ha is paddy field. In addition to rice there are cultivated peanuts, sesame, beans, cassava, castor oil plants, kapok, maize, sugar cane, tobacco and cotton. There are only small quantities of daily products and meat produced. Large livestok are chiefly water-buffalo and cattle. Recently chicken raising has made remarkable progress in the suburbs of the cities.

Chemical fertilizers used in Thailand are all imported. Therefore, the market price of ammonium sulfate ($(NH_4)_2SO_4$), potassium chloride (KCl), Thomas slag (P_2O_5) and urea ($CO(NH_2)_2$) are expensive to use in paddy cultivation. For instance, the market price of ammonium sulfate at Sakol Nakorn is $0.12-0.14 per kg.

2. The agricultural development plan

The plan proposes to develop 14,500 ha of land. Table III shows the classification of the land at present in certain areas.

In this plan, the policy of developing and improving this region is, in principle, to shift the existing single paddy cropping in the rainy season to an all-year round cropping. Also upland crops that bring in as much profit as possible will be introduced in places suitable for upland farming of relatively high elevation. Where rice is grown at present there are many sites that under natural conditions become swampy in the rainy season and many others that are not suitable for all-year upland farming. Accordingly these should be continued to be managed as paddy fields. By constructing new irrigation facilities, the water required can be secured throughout the necessary period, thus enabling the farmers to have an optimum time for transplanting, to stabilize their one cropping of rice a year and to contemplate two croppings of rice a year.

For these purposes another large drainage canal should be built on the northern shore of Nong Han Lake to control the flood waters which inundate areas surrounding Nong Han Lake and along the Nam Kam River. By con-

Table III Land use in project area at present

District	Benefitted area (ha)			
	Paddy fields	Upland fields	Forest, Others	Total
Lower Nam Pung	9,000	0	1,000	10,000
Lake Nong Han west	2,500	0	0	2,500
Lake Nong Han north	1,500	0	500	2,000
Total	13,000	0	1,500	14,500

Table IV Projected land use

	Total cultivated area (ha)			First crop (ha)			Second crop (ha)				
									Break down of upland fields		
	Paddy fields	Up-land fields	Total	Paddy fields	Perma-nent fields	Total	Paddy fields	Up-land fields	Perma-nent fields	Dry season fields	Fallow land
Lower Nam Pung	9,000	1,000	10,000	9,000	1,000	10,000	3,000	4,000	1,000	3,000	3,000
Lake Nong Han west	1,000	1,500	2,500	1,000	1,500	2,500	400	1,800	1,500	300	300
Lake Nong Han north	1,000	1,000	2,000	1,000	1,000	2,000	400	1,400	1,000	400	200
Total	11,000	3,500	14,500	11,000	3,500	14,500	3,800	7,200	3,500	3,700	3,500

trolling its level, the flood water can be prevented from causing damage to the paddy fields. This means it will be essential to select suitable rice varieties and improve them.

Concerning the introduction of upland crops in order to improve farms in this district, two methods can be used. One is the planting of second crops in paddy fields and the other is the establishing of permanent upland fields. By securing sufficient irrigation water, the lands that have been left uncultivated in the dry season will have a high productivity. The exceedingly high water table of the paddy fields in the rainy season drops about 3-5 m in the dry season, and, therefore, will not affect upland crops which are planted as second crops. As for permanent upland fields, selection has been made of relatively high cultivated lands and reclaimed forest lands where ground water will not reach the root zone of crops even in the rainy season, and sufficient irrigation water can be secured throughout the year.

In the case of upland fields, profit can be made even if relatively high priced fertilizers are applied because high productivity can be expected. Table IV shows the areas of cultivated land after completion of this plan.

Comparing Tables III and IV, the following become clear:

a. No changes will be made in the paddy field category of the Lower Basin area of the Nam Pung River before or after the execution of the plan ;1,000 ha of forest lands will be reclaimed where upland farmlands will be created at an elevation of about 163-165 m.

b. In the Nong Han West area, 1,500 ha of relatively high land generally 162 m in elevation, out of 2,500 ha of existing paddy fields, will be converted into upland field, and the remaining 1,000 ha left as paddy fields.

c. In the Nong Han North area, 500 ha of paddy fields, 160-162.5 m in elevation, out of 1,500 ha of existing paddy fields will be converted into upland fields. Further, the present forest lands of 500 ha (160-162.5 m in elevation) will be reclaimed into upland fields. As a result there will be 1,000 ha of upland fields and 1,000 ha of paddy fields.

Thus, after the completion, the total area of arable land will be 14,500 ha, consisting of 11,000 ha of paddy fields and 3,500 ha of upland fields.

As for the farming of the 11,000 ha of paddy fields, an about 1/3 of the acreage of each of the three areas (totaling 3,800 ha) a second rice will be grown immediately after harvesting the first rice crop; another 1/3 (3,700 ha) will be used for short-period upland crops[1]; and the remaining 1/3 (3,500 ha) will be left fallow. As for the paddy fields, in order to maintain soil fertility and increase farm income, this rotation will be carried out in turn starting with the period of the second rice crop. For this purpose it is especially necessary to introduce varieties of rice with a normal total growing period of 175 days (nursery period of 35 days and irrigation period of 120 days) for the first crop, and similarly, varieties with a normal total growing period of 150 days (nursery period of 30 days and irrigation period of 100 days) for the second crop.

Since the whole area is favored throughout the year by high temperatures and much sunshine it will be possible to develop diversified farming, if proper irrigation is practiced.

3. Irrigation plan

(1) An outline of the plan

(i) Lower Basin area of the Nam Pung River

As for intake facilities, head works are to be constructed on the Nam Pung River and the First Nong Han pumping station is to be installed on the southern shore of Nong Han Lake. Arable land will be divided into two parts; one where water will be drawn in from the head works (including the arable land to be irrigated by pumping from the lake whenever any shortage of river water occurs), the other depending exclusively on pumping water for irrigation.

Generally, the former is the area which will be irrigated by the natural flow of the Nam Pung River and the water to be discharged from the Nam Pung dam. The benefitted area will be 7,273.6 ha of paddy fields and 785.2 ha of upland fields, a total 8,022.8 ha. The latter is the area not depending on water drawn from the head works but on water pumped up from the first Nong Han pumping station. The benefitted area will be 1,762.4 ha of paddy fields and 214.8 ha of upland fields, totaling 1,977.2 ha.

Of the acreage to be irrigated with water taken from the head works, 214.8 ha of upland field connot be irrigated naturally because of higher elevation, so the plan is to irrigate that land by pumping water in the second stage by the Ban Lat Du pumping station.

(ii) Nong Han West Area

This area is to be irrigated with water drawn from the lake by the second Nong Han pumping station. This station will be installed in the western part of Ban Thung Mon on the left bank of the large drainage canal which will be excavated for flood control in the northern part of Nong Han Lake.

(iii) Nong Han North area

1) Accordingly the upland cropping area at this time will total 7,200 ha including 3,500 ha of permanent upland fields.

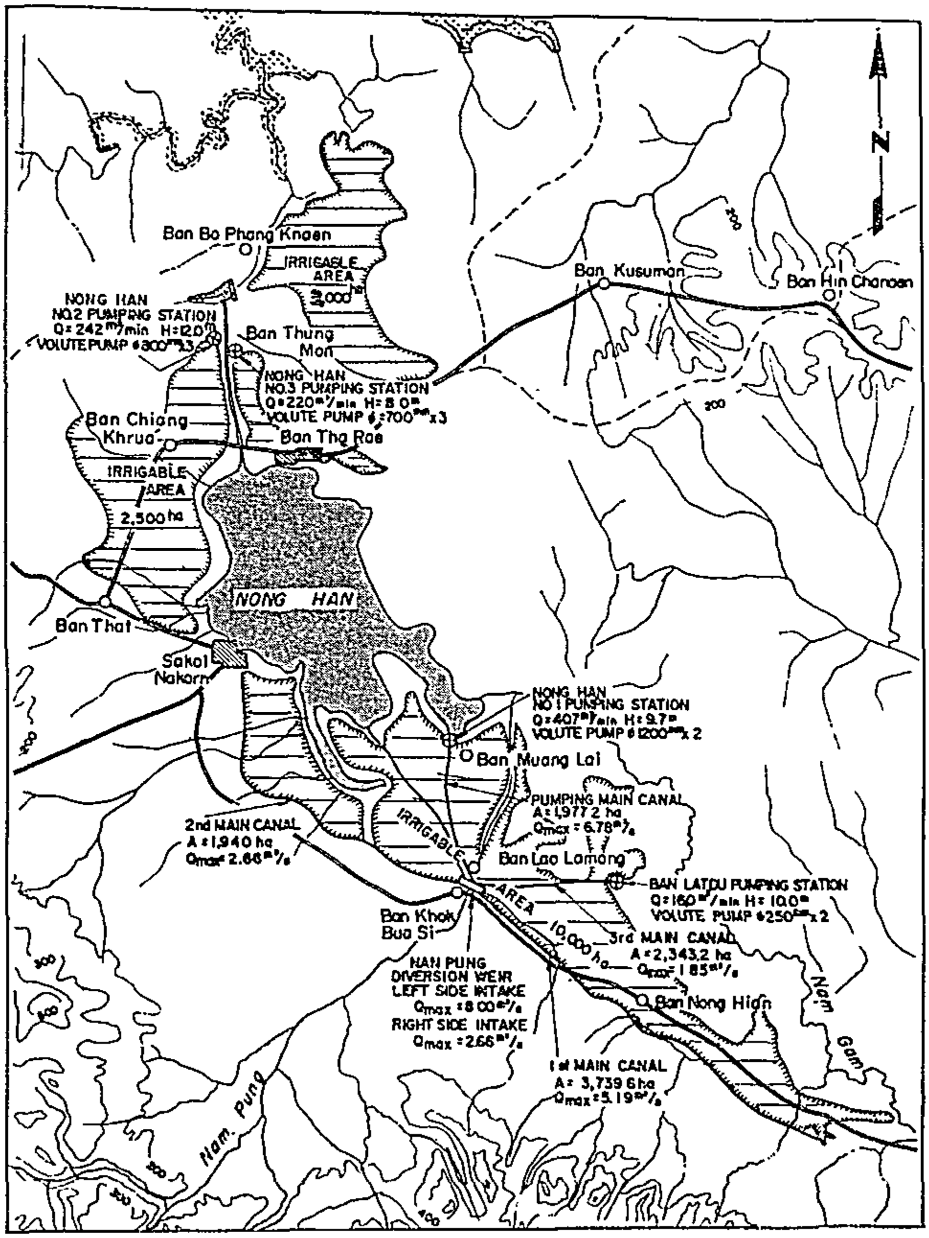

Fig. 4 General plan of Nam Kam Project

Similar to the Nong Han West area the third Nong Han pumping station is to be installed in the neighborhood of Ban Phon Sawang on the right bank of the drainage canal to pump up the lake water.

(2) Water requirements

Water requirements were calculated for the paddy fields and for the upland fields.

(i) Irrigation period

The standard method that will be applied for the first paddy rice cropping should be—sowing the seeds in beds on June 10, transplanting the seedlings (35 days growth) on July 15, irrigating the paddy for 120 days thereafter and harvesting the rice 140 days after the transplanting (on December 3). The second paddy rice cropping should be—sowing the seeds in beds on December 10, transplanting the seedlings (30 days growth) on January 4, irrigating the paddy for 100 days thereafter and harvesting the rice 120 days after the transplanting. Puddling operations will be completed within 40 days in each area and in the first half of this period (20 days), with puddling operations for about two thirds of the total irrigated area.

Upland fields will be irrigated throughout the whole year.

(ii) Unit water requirements

As water requirements for paddy fields vary according to topographical conditions, soil texture, the level of the underground water, the conditions of the climate and the growth period, they should be determined by data obtained from 3 to 5 years. But during this survey no data could be obtained because of the very short stay. Therefore, we determined the unit water requirements for paddy as 10 mm/day and for puddling, 150 mm which have been used in a plan for irrigation in the northeastern part of Thailand.

The area for nursery beds was determined as 1/20 of the field area to be transplanted and water needed to prepare the nursery beds was estimated as 150 mm and for subsequent supplementary supplies as 10 mm/day.

Water requirements for the upland crops were calculated by the Blaney-Criddle formula, the results are on Table V.

Table V Water requirements in upland fields (mm)

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Monthly consumptive use	153	130	132	151	131	92	85	86	102	137	149	142
Mean of consumptive use in 5-day periods	24.7	23.2	21.3	25.2	21.1	15.3	13.7	13.9	17.0	22.1	24.8	22.9

Note: K=0.75 was used in the Blaney-Criddle formula

(iii) Net water requirements

The net water requirements was obtained by multiplying the unit water requirements by the acreage of the respective areas concerned. Table VI shows the values of each area by periods.

(iv) Basic year for planning

The net water requirements that was needed during the wet June-November season amounted to 63.7% of that for the whole year, and the net water requirements needed for the paddy fields in the rainy season amounted to 83.6%. The irrigation plan will, therefore, lay more stress on paddy cultivation of the rainy season. In other words the basic year of this plan was determined by the effective rainfall for the paddy fields in the rainy season and the discharge of the Nam Pung River at the head works site in the same season. An objective

Table VI Net water requirements

	Period	Net water requirement (10^3m^3)		
		Paddy fields	Upland fields	Total
Lower Nam Pung area	Jun.~Nov.	125,357	13,349	138,706
	Dec.~May	35,364	32,386	67,550
	Total	160,721	45,535	206,256
Lake Nong Han west	Jun.~Nov.	13,358	9,985	23,343
	Dec.~May	4,526	15,005	19,531
	Total.	17,884	24,991	42,874
Lake Nong Han north	Jun.~Nov.	13,358	6,506	19,864
	Dec.~May	4,526	11,747	16,273
	Total	17,884	18,253	36,137
Total	Jun.~Nov.	152,073	29,840	181,913
	Dec.~May	44,416	58,938	103,354
	Total	196,489	88,778	285,267

of this plan is to supply water to supplement the shortages that occur about once every five years.

The year 1959 was used as the basic year for this plan since during the past 12 years this year rated next to the lowest in annual effective rainfall and effective rainfall of the rainy season, and also the discharge of the Nam Pung River was next to the lowest.

(v) Calculation of amount of irrigation water supplied in the basic year for planning

Every five days, from November, 1958, to October, 1959, required water supplies were calculated. We took for upland fields 60% as irrigation efficiency including loss of water in canals, and for paddy fields 20% accounted for the loss in the canals.

The discharge from the dam was obtained by taking into consideration 1.7 m^3/s of water that would be required regularly to generate electricity for general consumption and a supplementary discharge required to generate electricity that will be consumed in pumping water for irrigation. The calculations and their results would take up too much space and are thus not given here.

4. Main construction plan

(1) Outline

Head works are to be built in the Lower Basin of the Nam Pung River, about 700 m below the Nam Pung bridge. Water is to be taken in from both sides of the river.

The intake canal on the right bank will be connected to the first and third main canals. It is also to be connected to the main pumping canal, about 200 m below the head works, to draw water from the first Nong Han pumping station in case the discharge of the river is short of supply. The intake gate on the left bank is connected to the second main canal.

The first Nong Han pumping station is to be built halfway between Ban Tha Wat and Ban Yang At near Nong Han Lake, and the Ban Lat Du pumping sation is to be built at the terminal of the third main canal. For the Nong Han West and Nong Han North areas, the second and the third Nong Han pumping station are to be constructed on the left and right banks of the large drainage canal that will lead northeast from the northern tip of Nong Han Lake to control the flood waters of the lake.

(2) Head works

A movable weir type, not a fixed weir type, will be set up to allow abnormal flood waters to pass in the rainy season. For the purpose of regulating the released discharge from the power house, the highest intake water level is 0.5 m above the estimated intake water level. By increasing its level by 0.5 m about 100,000 m^3 of water can be regulated in one day. The estimated intake water level of the head works will be 163.7 m and the regulated water level 164.2 m. The maximum volume of water intake will be 163.7 m and the regulated water level 164.2 m. The maximum volume of water intake will be 8.0 m^3/s on the right bank, and 2.66 m^3/s on the left bank.

Weir length: 37.5 m

Gates: 3

Gates (width × height): 10 × 3.4 m

Lift method: Oil pressure method

(3) Pumps

Specifications of the pumps are given in Table VII.

Table VII Pumping facilities

Pumping Station	Designed pumpage	Maximum total lift	Pump dia.	Number of pumps	Motor	Number of motors	Total power	Mean power per m^3 of water
	m^3/min.	m	mm		v		kw	kw-h
Nong Han 1	407	9.7	1,200	2	6,000	2	1,000	36.73×10^{-3}
〃 2	242	12.0	800	3	6,000	3	750	46.71×10^{-3}
〃 3	220	8.0	700	3	6,000	3	450	30.10×10^{-3}
Ban Lat Du	16	10.0	250	2	400	2	50	52.08×10^{-3}
Total							2,250	

(4) Canals

Generally the canals in excavated sections will be earth canals, and the embankments will have asphalt lining and in cross-section will be trapezoidal. The longitudinal gradient of canals is within the range of 1/2,000 to 1/6,500. The length of canals in each area is shown in Table VIII.

Table VIII Canals of Nam Pung project area

	Main canal	Lateral canal	Total
Lower Nam Pung	53 km	67 km	120 km
Nong Han west	27	17	44
Nong Han north	23	13	36
Total	103	97	200

Table IX Construction costs of Nam Pung project

	Total construction cost
Lower Nam Pung	$ 10,239,078
Nong Han west	2,757,092
Nong Han north	1,939,411
Total	14,935,581

(5) The cost of construction

The total cost of construction is estimated as shown in Table IX.

(6) Benefits of the project

Details on the benefits of this project will be described later by Mr. Gakuji Kimura (pp. 221-232).

4. Conclusion

It is very important for the development of this area that the irrigation be carried out according to this plan. It is necessary furthermore for the realization of the expected production of the arable land to establish farming plans including arrangements for drainage canals, terminal irrigation canals, farm roads, studies of optimum land allotment, and efficient placement of farm villages. It is desirable that all these points be planned rationally and executed together with the main construction works.

It is also necessary to study and make agricultural tests and experiments to improve the varieties of the crops to be introduced, to better the methods of fertilizing, to provide for proper farm management with proper use of labor. The results of these studies and tests should be demonstrated to the farmers since this will increase the benefits of the project. But as it is going to take many years to realize this, we recommend the early establishment of agricultural experiment stations and extension services. It will be important to stations and extension services. It will be important to educate agricultural technicians so that they may improve and propagate better farming techniques, guide the farmers and act as consultants.

II. Pattani Development Project in Southern Thailand

Akiyoshi NODA

Foreign Activities Dept., Electric Power Development Co., Ltd.

The Electric Power Development Co., Ltd. (EPDC) has been engaged in carrying out engineering consultations on investigating, planning, designing, supervising and providing technical assistance relating to electric power development and large scale civil engineering works in South America, Southeast Asia, etc. It has sent investigation teams to several development projects in Thailand. The Nam Pung dam which belongs to a part of the Mekong River Comprehensive Development Project is now under construction under consultants of the EPDC.

In June, 1964, we were sent for one and a half months to the southern tip of Thailand, to the Pattani River basin, to undertake reconnaissance to prepare for setting up an agricultural development plan, which was to be a part of the Agreement for Technical Assistance concerning development of hydraulic power, agriculture and flood control there. The agreement was concluded between the National Energy Authority (NEA) of Thailand and the EPDC.

1. General description of Southern Thailand

1. Location

Southern Thailand extends from the central to the northern part of the Malay Peninsula, touching Burma to the west and Malaysia to the south. It is an area of about 70,000 km^2, roughly amounting to 14% of the total area of Thailand.

Three of the southern provinces, Yala, Pattani and Narathiwat form the vital points of development of southern Thailand and play very important roles in its progress, and thus make up the area of the Pattani Project. The Pattani River, about 210 km long and with 4,200 km^2 of catchment area, originates in the mountains of the Thailand-Malaysia border. It slopes at a degree of 1/450 in its upstream, 1/2000-1/3000 in its middle and lower stream basin and flows up north through the middle of Yala and Pattani Provinces into the Gulf of Thailand. (Figs. 1 & 2)

2. Topography and Geology

Topographically, the area of the three provinces of Yala, Pattani and Narathiwat may be roughly divided into the mountain, the hilly and the coastal areas. The flat coastal area consists of Cainozoic soil, covers the largest area, and a large part of it is utilized as farmlands. The mountain area that extends along the Malaysian border is made up chiefly of the Paleozoic soil and is covered with thick forests. The hilly area lying between the mountain area and

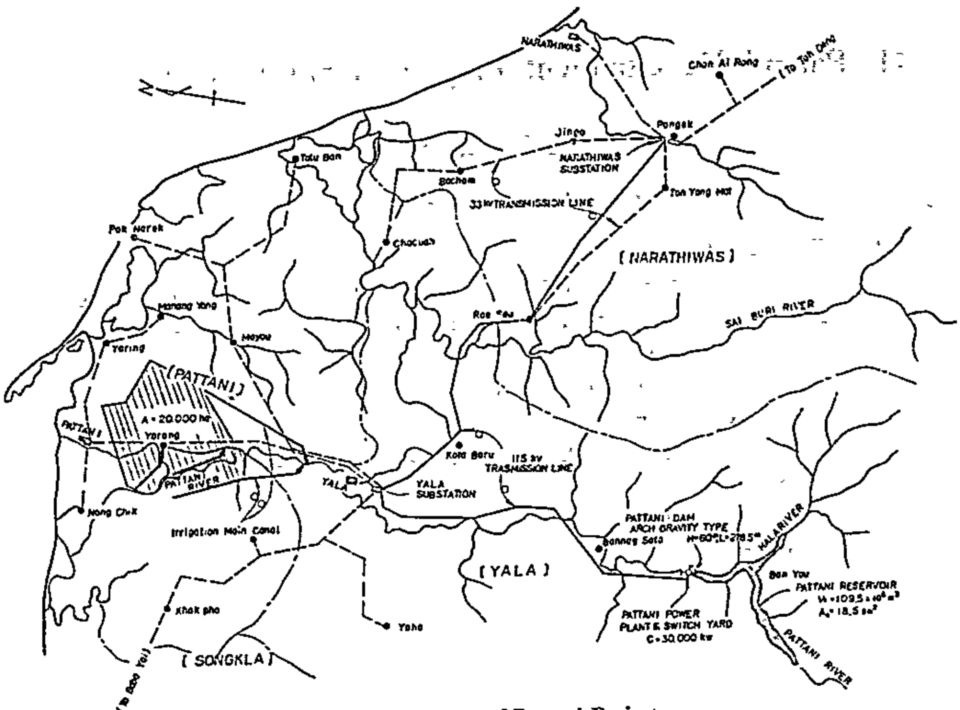

Fig. 1 General map of Pattani Project area

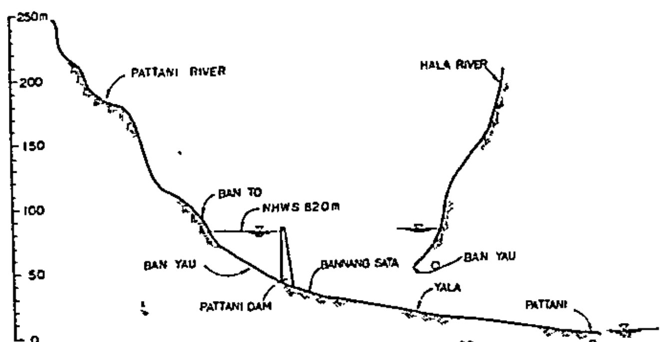

Fig. 2 Longitudinal section of Pattani River

the coastal area is made up of the Mesozoic soil and is mainly utilized for rubber and fruit plantations.

3. Climate

This area belongs to the tropical climate zone. The temperature remains almost constant throughout the year. As shown in Fig. 3, its monthly average temperature is highest, 28.0°C in May and lowest, 25.7°C in December.

The annual precipitation reaches often more than 2,000 mm under the influence of the monsoons and typhoons, but the greater amount of it is concentrated in May and the months from September through December.

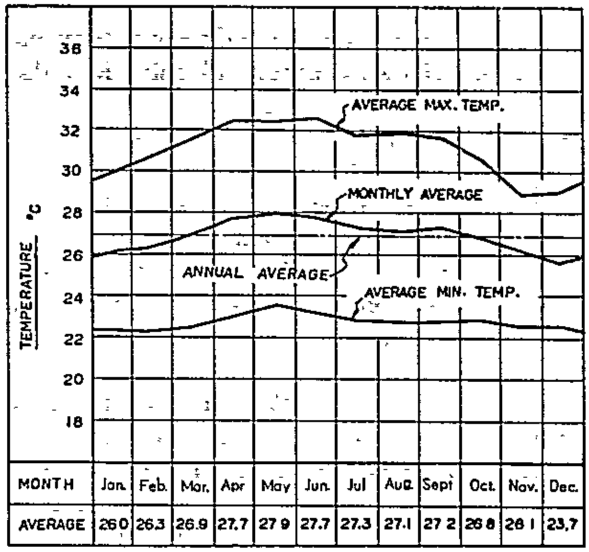

Fig. 3 Monthly mean temperatures (Narathiwat, 1943-1960)

4. Population and state of employment

Table I shows the population, number of farming households and agricultural population of the three provinces. We can see that more than 70% of the population is engaged in agriculture.

5. Description of main industries

(1) Agriculture and forestry

The characteristic features of agriculture of southern Thailand, in contrast to northeastern, northern and central Thailand where agriculture centers on cultivation of paddy rice, may be said to be the cultivation of rubber and fruits. Income from these two products, in southern Thailand, comprises about 62% of the total agricultural income. It is second to southwestern Thailand which has the highest percentage. The percentage of agricultural land in southern Thailand is 15.7% of the total area, being smaller than that of other districts of Thailand. On the other hand, the rubber and fruit plantations take 42.4% of the total. This is high as compared with other districts and well represents the features of agricultural management in southern

Table. I Farming households and population

	Population	Male	Female	Households	Farming households	Farming population
Thailand	26,257,916	13,154,149	13,103,767	4,616,654	3,410,309 (%) 73.9	19,589,805 (%) 76.4
Yala Prov.	149,348	76,747	72,601	30,384	21,891 72.0	106,220 71.1
Pattani Prov.	281,587	141,727	139,860	59,239	45,673 77.1	219,537 78.0
Narathiwat Prov.	266,038	134,295	131,743	55,817	39,228 70.3	188,390 70.8

(*Statistical Yearbook, Thailand*, No. 24, 1963)

Thailand.

In the lowland along the coast, the main agricultural management form is rice cultivation, in the hilly area rubber and fruit and in the mountain area, forestry.

(i) Rubber

The rubber production of the three provinces is 84,000 tons, which is roughly equivalent to 50% of Thailand's total rubber export. Rubber plays a very important role in Thailand's foreign trade.

Rubber plantations in southern Thailand, with the exception of a few, are in general small. An average plantation is hardly more than 0.5 ha wide. The processing techniques of raw rubber sheets at farming households are by no means excellent.

To keep her trade position in the fluctuating world market rubber prices and from losing out to the synthetic rubber industries, the government has experimental stations, where young plants are reared and through which planters are encouraged to replant old trees. The government also gives monetary aid toward increasing the productivity of rubber. Table III shows the cultivated area and the production of rubber in these three provinces.

Table II Principal export commodities of Thailand (1962)

Commodity	Export revenue (millions)	Quantity (tons)
1. Rice	155.5	1,271,023
2. Rubber	101.3	194,179
3. Tin	32.9	19,841

(*Statistical Yearbook*, No. 24, 1963)

Table III Rubber production (after Kitamura)

	Yala	Pattani	Narathiwat	Thailand
Cultivated area (ha)	64,093	49,740	85,340	199,170
Production (tons)	26,915	20,899	35,862	170,848

(ii) Fruit

Fruit such as durians, coconuts, pineapples, bananas, etc., the agricultural products of southern Thailand, grow in such a favorable climate abundantly in species and in volume. Bangkok is the chief market.

(iii) Paddy rice

Paddy fields in southern Thailand comprise about 42% of its total agricultural area. The percentage is exceedingly low compared with other districts of the country. Thus southern Thailand is a rice consumer area. Here a single rice cultivation is carried out by making use of the rain water in the rainy season. A varieties commonly called the "heavy type" with a comparatively long growing period, sown in August, transplanted in September-October and harvested in February is generally grown. Irrigation and drainage facilities are insufficient in this area, and the rice cultivation has suffered from delays of transplanting, droughts, and floods in the rainy season.

The average yield of paddy rice here is about 140 kg/10 a. This more or less approaches the national average but the soil productivity of this area has consequently sunk to a low level because of employment of natural cultivation techniques without fertilizers. In some parts of Yala and Pattani Provinces, double rice cropping is being carried out on experimental bases with very good results. The varieties of rice used in this double cropping is the so-called "light type", which needs a short period to mature. Sown in late March, transplanted in early May, it is harvested in September.

(iv) Upland crops

The upland farmlands occupy a very small percentage of the total agricultural area, and the harvests are all used for home consumption. The main crops are maize, potatoes, ground nuts and beans. At agricultural experimental stations, efforts are being made to popularize the cultivation of coffee and pepper which reap high profits.

(2) Stock breeding

The middle-class farmers of this area keep, on an average, only one or two water buffaloes or cows for farm labor, a few pigs, some chickens and some ducks. Accordingly, all dairy foods have to be purchased from other parts of the country. Following the policy of the central government, the provincial offices are making efforts to promote more stock breeding. It is very difficult to grow fodder for domestic animals because of the damp climate in southern Thailand.

(3) Mining and other industries

There are deposits of tin, pyrite and wolfram in the vicinity of Ban To and Bannang Sata of Yala Province. Mining is one of the main industries of southern Tailand.

There are no other industries worth mentioning at present except for a few small food, drinks and rubber processing industries.

2. The Pattani Development Project

1. Outline

In the Pattani Development Project, a reservoir with an effective storage capacity of 100 million m^3 is provided in the upstream of the Pattani River. By the construction of this reservoir, the floods may be controlled, irrigation water for about 20,000 ha of arable land in Yala and Pattani Provinces may be secured and 86.3×10^6 kw-h of electricity may be supplied annually to the three provinces, which would stabilize and improve the livelihood of the inhabitants and contribute toward development of industries (refer to Fig. 1).

2. The dam and reservoir plan

The Pattani Dam site which is about 11 km upstream from Bannang Sata, about 40 m above sea level, lies at the narrowest point of the Pattani

River. Under several layers of sand and gravel of several meters, the bed rock of the proposed dam site is composed of quartzite and silicious sand stone of the psammite group and phyllite and altered slate of the pelite group.

Selection of the type—a gravity, a fill type or an arch-gravity dam—was studied mainly from the points of the foundation, the construction material and the cost of construction. With regard to the point of fixing, comparative studies of high water levels were made to keep the cost of construction per kw-h of generated electricity as low as possible. Taking all these questions into account and studying them together, a decision was reached to build the most economical dam and reservoir with the following specifications.

Type: Arch-gravity type
Height × length : 60 m × 278.5 m
Width of crest : 5.5 m
Estimated flood discharge : 3,000 m^3/sec
Catchment area : 2,100 km^2
Pondage area : 18.5 km^2
Effective storage capacity : 109 × 10^6 m^3
Average discharge : 20.0 m^3/sec
Effective head : 35.2 m

Fig. 4 shows the mass-curve of the reservoir. Rainwater in October-December will be stored to be utilized in the dry January-September season. Natural flow of the Pattani River could then be regulated and sufficient water could be secured to irrigate 20,000 ha of land of the downstream area even in the dry season.

Adding the Second Pattani and the Hala reservoirs scheduled to be constructed in the near future, the mass-curve of the Pattani Dam is shown in solid lines in Fig. 4. When these two reservoirs start functioning together, more

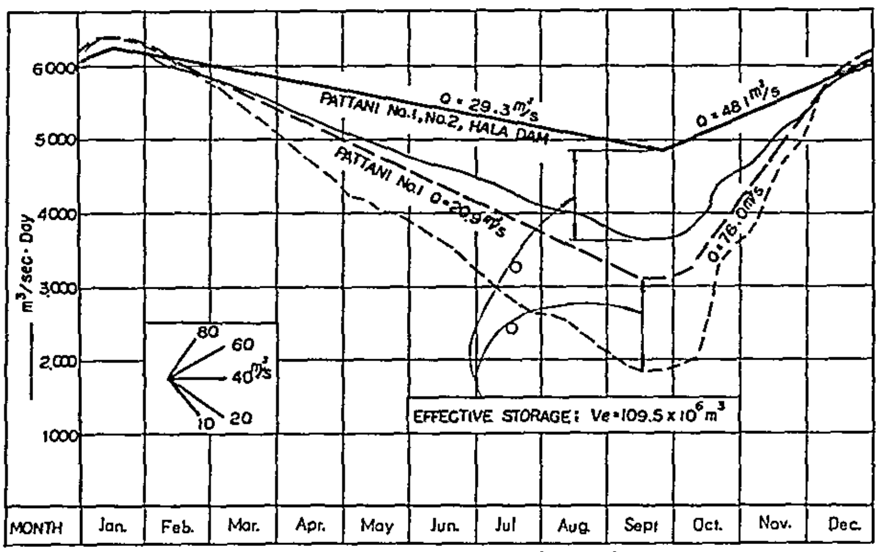

Fig. 4 Mass curve of Pattani dam site

and larger composite effects of the utilization of the water resources and of flood control is expected.

3. Plan for generating electricity

In 1962 about 4,800 kw of electricity was consumed in these three provinces. An increase in the demand for electricity by households and industries is expected in the near future, so we decided to make preparations for electric generating facilities with capacities of up to 18,000 kw by 1974 and 30,000 kw by 1979. To minimize the initial amount of investment, two 10,000 kw generators will be set up first. They will produce a firm energy of 53.9×10^6 kw-h and the peak energy will be 29.1×10^6 kw-h. With further increase of demand, facilities to generate 30,000 kw will be set up eventually to produce a firm energy of 63.6×10^6 kw-h and a peak of 22.7×10^6 kw-h.

A network of transmission lines from the Pattani station will send electricity of 115 kv to substations at Yala and Narathiwat where it will be transformed to 33 kv for the ultimate consumers.

4. The flood control plan

The Pattani River flows through the coastal plains at a gentle slope. In parts the river bed is higher than the surrounding arable land which are subjected every year to damage from floods from the river. It was estimated that the capacity of the Pattani River was about 390 m^3/sec in this vicinity, the maximum flood discharge at the dam site 460 m^3/sec and the collectable water in the remaining basin 1,700 km^2 up to Yala was 60 m^3/sec. Therefore, the maximum flood discharge at the planned site was estimated as 520 m^3/sec. If the Pattani Dam is built with a regulating capacity of 160 m^3/sec of water, it would greatly lessen flood damage in the arable lands of the down stream area.

3. The agricultural development plan

1. The direction of agricultural development

As population increases in this region, where there is little room for creation of more paddy fields, the food situation will grow worse. An increasing of production of paddy rice and other agricultural products is, therefore, a big problem in the development of this region. As there is no more room in this region to make new arable land, the direction will consequently have to lie in intensive utilization of the present limited areas of cultivated land. To improve and develop the limited land resources, a second paddy and profitable upland crop cultivation must be brought into augment the present single crop method and in addition a more stabilized method of single rice cultivation. Cultivation of fodder and manure crops is believed to be an effective means to prepare for a future stock breeding and to improve soil conditions.

The most basic requirement in this undertaking to stabilize agricultural production in both the rainy and dry seasons, in order to make most effective use of Pattani Dam such as its constant discharge and its flood control measures, is to provide an essential base such as the completion of irrigation and drainage facilities.

2. A general description of the agricultural development area

The total benefitted area of the Pattani Development Project is 20,000 ha, consisting of 18,700 ha of laddy fields on both sides of the Pattani River and 1,300 ha of wasteland on the left bank side, spreading out in a fan shape from Yala City toward Pattani City. The wasteland is scheduled to be converted into arable land. The paddy fields are made up mainly of loamy and clayey soil which hardly contains any NH_4-N, NO_3-N, P_2O_5, K_2O, MgO, or Mn_2O_3. The chemical property of the soil is very poor.

As mentioned before, the annual precipitation is by no means small as compared to that of Japan, but in this region there is hardly any rainfall in the dry season. This is the cause of very great damages arising from delays in rice transplanting and droughts due to shortage of water during its growing period. The paddy fields, on the other hand, are inflicted with heavy damage in the rainy season by the high intensive rainfall, the fields flooded over annually with water 0.5-1.0 m deep. Damage from plan diseases and pests is also very great, depending on the year. In Tables IV and V, records are given of the weather and the damages wrought in the arable lands along the Pattani River.

As we have seen, agricultural management in southern Thailand is represented by rubber and fruit cultivation and only 42% of the total arable land is utilized as paddy fields. But it is a feature of this proposed project that a large part of agricultural development area is located in the coastal plain where paddy rice is cultivated. Table VI compares the cultivated area and

Table IV Meteorological records

	Monthly precipitation (mm)			Temperature (°C)	Evaporation (mm)
	Bannang Sata 1952~60	Yarang 1952~53 1961~63	Pattani 1952~63	Yala	Bannang Sata 1962~63
Jan.	105.2	167.4	79.0	27	71
Feb.	38.5	16.1	2.9	27	92
Mar.	81.5	20.7	15.6	27.5	131
Apr.	111.0	18.5	42.5	28	147
May	206.1	81.0	92.0	28.5	136
June	137.4	36.6	87.7	28	120
July	131.0	100.6	82.0	28	127
Aug.	138.5	114.8	97.2	28	106
Sept.	176.3	127.3	72.8	28	105
Oct.	283.7	203.2	230.6	27.5	101
Nov.	276.8	282.7	399.6	26.5	78
Dec.	215.7	226.1	234.4	26	66
Total	1,901.7	1,395.0	1,436.3	mean 27.5	1,208

Table V Damages in cultivated land along the Pattani River

	Cultivated area	Area damaged	
		Area	Percentage
	ha	ha	%
1955	20,311	2,778	13.7
56	19,204	3,091	16.1
57	17,865	5,064	28.3
58	12,721	6,762	53.2
59	10,371	4,101	39.5
60	9,208	338	3.7
61	13,744	144	0.9
62	15,262	398	2.6

Table VI Principal crops in Pattani and Yala Provinces*

	Cultivated area (ha)		Average yield (Yala and Pattani)	
	Yala	Pattani		
Rice (first)	12,517	53,854	1,630	kg/ha
Rice (second)	50	40	1,440	〃
Maize	4	52	1,750～ 3,000	〃
Sugar Cane	182	73	6,300～ 9,400	〃
Sweet potato	12	179	6,560～ 7,190	〃
Cassava	198	129	5,600～ 7,800	〃
Water melon	33	75	6,000～11,000	〃
Peanut	6	32	1,160～ 2,190	〃
Long bean	180	—	1,900	〃
Egg plant	260	—	2,500～ 4,000	〃
Coffee	80	65	2,800	〃
Tobacco	4	44	600～900	〃
Pepper	190	—	2,500	〃
Kapok	100	—	1,900	〃
Rubber	75,130	29,372	1,100	〃
Coconut	570	13,736	7,810	fruit/ha
Pineapple	400	163	7,810	kg/ha
Banana	290	460	4,700～ 5,000	kg/ha
Rambutan	295	690	3,000～ 4,000	fruit/tree
Mango	30	116	600～900	kg/ha
Papaya	16	15	18,500	fruit/ha
Orange	45	135	25,000～47,000	kg/ha

* Figures based on oral communication, July, 1965

the average yield of the main crops grown in Pattani and Yala Provinces.

3. Irrigation plan

(1) The basic precipitation for planning

We took 1,200 mm as representative of the basic design precipitation for this plan with the probability of occurrence once in every 5 years. It was derived from the figures of precipitation recorded in 1952 to 1955 and 1961 to 1963 at Yarang, the central part of the planned area. As to monthly distribution of precipitation, that of 1961, which most approximated the basic precipitation for planning, was adopted.

Table VII Monthly precipitation in Yarang (1961)

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Precipitation (mm)	41.0	17.5	5.7	0	54.4	11.0	38.7	49.0	165.9	217.0	326.6	287.4	1,214.2

(2) Available discharge of the Pattani River

The average discharge at Pattani Dam in the upstream is about 20 m^3/sec. Adding 3 m^3/sec in the remaining basin 1,670 km^2 up to the intake site of irrigation water, the resulting total, 23 m^3/sec was determined to represent the volume of available water.

4. Unit water requirement

There were no records available to ascertain the water requirement in depth of the planned area, so we estimated 10 mm/day as feasible to represent the unit water requirement of the paddy fields composed mainly of clayey soil.

As for the unit water requirement for upland crops, we used the Blaney-Criddle formula—that the average evapotranspiration is 4.2 mm/day in the dry season—and assumed that the irrigation efficiency would be 70%. The resulting answer, 6.0 mm/day was adopted. We assumed that the effective rainfall would be 70% of the basic design precipitation and the conveyance efficiency of the canals would be 80%. The relation between the irrigation period and the unit water requirement is shown in Table VIII. The maximum gross water requirement of about 21 m^3/sec would be necessary in June.

Table VIII Water requirements and irrigation period of paddy and upland fields

	Unit water requirement	Irrigation period		Remarks
		First crop	Second crop	
Puddling	150 mm	mid-Sept.~ mid-Oct.	early Apr.~ early May	Nursery bed area is one-twentieth of paddy fields
Paddy fields	10 mm/day	mid-Aug.~ mid-Feb.	early Mar.~ early Aug.	40 days in nursery bed
Upland fields	6 mm/day	—	mid Feb.~ early Aug.	

5. Irrigation facilities

Main intake facilities will be built on the left and right banks of the Pattani River, at a point about 5 km downstream from Yala City. From the right bankside 13.3 m^3/sec of water will be taken in and from the left bankside 5.3 m^3/sec will be drawn to be carried to the irrigated areas with trapezoid earth canals. The total length of the main canal is estimated to be about 70 km.

6. Agricultural benefits

In calculating agricultural benefits we assumed the following cropping patterns: In the rainy season, the entire cultivated area will be planted with paddy rice. After harvesting the first rice, 40% of the fields will be used to raise a second rice crop, 30% to grow groundnuts, tobacco and other upland crops and the remaining 30% will be fallow and used to grow green manure crops to improve soil fertility.

On this basis outlined above, a gross revenue of about 270 × 10^3 dollars is expected for every 1,000 ha of arable land. Assuming the ratio of net revenue of 18,700 ha of the irrigated area to be 58% and that of the reclaimed 1,300 ha of land 51%, the annual net benefits of this agricultural development plan would be such as described on Table IX.

Table IX Agriculture revenue (in U.S. dollars)

	Annual gross revenue	Net revenue (%)	Annual net revenue	Operating and maintenance costs	Annual net profit
ha	thousands		thousands		thousands
Cultivated land (18,700)	3,641	58	2,112	112	1,999
Newly reclaimed land (1,300)	354	51	181	8	173
Total	3,995		2,293	120	2,173

The annual gross revenue of the total area is 3,995 × 10^3 dollars. Necessary annual expenditures, including management and maintenance expenses, is 1,822 × 10^3 dollars. The annual net benefits will be 2,173 × 10^3 dollars. Thus agricultural benefits justify the agricultural development which would play an important role in the comprehensive Pattani Development Project.

4. Conclusion

Lately in Thailand all the water resource development projects have become multipurpose, including water supply, irrigation, and hydraulic power generation, etc. Of late, investment in the agricultural field has come to be regarded with increased importance. For instance, the World Bank has again recognized the need for more investments in the agricultural field, or the Asian Agricultural Development Funds has been conceived. In Southeast Asian countries, development and promotion of agriculture, their most important resource today, contributes largely to stabilizing and improving the livelihood of their peoples. In this way, by preparing the bases for an enlarged agricultural production, Southeast Asian countries can accumulate capital and strengthen their economic potentialities thus laying the foundation for industrialization.

III. Economic Evaluation of Irrigation Development Projects in Thailand

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When an agricultural development project is to be carried out, whether it is for the development of irrigation or drainage, the first requisite is to check and evaluate its economic efficiency. Development projects that are not economically efficient have very little chance of being realized but when developing countries are dealt with, especially the countries in Southeast Asia, we should not hastily jump to a conclusion that there is no prospect of a certain project to be realized just because it is not economically efficient. Very often there are political demands integrated for its promotion. Nevertheless, we should not always affirm that development projects should be promoted by any means, to the extent of disregarding their non-economic nature.

In this connection, I would like to analyze two examples, the Nam Kam and the Lam Pao development projects. These two projects had given us considerable advanced studies on their economic efficiency where data had been available. Since these two projects are not yet completed, my study at this stage will have to be limited only to the benefits outlined in the planning. As no such studies have yet been made actually or sufficiently in Thailand, I believe my study has some meaning. Nearly all the irrigation projects that have been planned by the Thai government are, with a few exceptions, comparatively small in scale and lack essential data necessary my purpose, so they have been purposely left out of the scope of my studies.

From what little data I have so far been able to collect, it may be true that these development projects have not reached the level of effects originally planned. I should like to express my opinion on the reasons in the last part of this report, and first deal with the two projects, the Nam Kam and the Lam Pao projects.

1. Nam Kam Project[1]

For an economic evaluation of this development project I applied the present rate of electricity to evaluate the rate of electricity for general consumption and estimated the agricultural income to be 30% below the price level of the Bangkok market. In determining the allocation of common expenses I considered 6,100 ha out of 10,000 ha, the Nam Pung irrigated area, as the naturally irrigated area that results from constructing the dam. Funds for

1) Details of this project are given on pp. 193-207 of this report.

the construction were calculated at an interest rate of 6% per annum including the time required for the construction. If other sources with lower rates of interest are used, the prevailing rate of electricity could be made lower. A general breakdown of expenditures is found in Table I.

Table I Construction costs

	Cost ($)
Dams	3,142,360
Canals	1,276,970
Power and Substation	1,254,990
Transmission lines	855,420
Power station	6,529,750
Lower Nam Pung area	8,105,360
Non Hang Lake area	4,349,303
Irrigation	12,454,663
Canals	2,057,000
Dams	443,000
Flood control	2,500,000
Total	21,484,403

The total outlay of money for the Nam Kam development project plus 6% interest per annum is shown on Table II. Expenditures involved in flood control are not given separately as the necessary data were not available. From Table II we may see that of the total outlay for construction, $20,275,493 (excluding the outlay to build the flood control facilities), $11,618,036, roughly 57.3% of the total is in dollar funds and $ 8,657,457, 42.7% of the total is in baht funds.

Table II Necessary investment including interest (US $)

	Total construction cost	Foreign	Local
Common facilities	3,294,931	1,601,336	1,693,595
Canals	1,343,217	676,578	666,639
Power station	729,256	641,724	87,532
Substation	569,972	579,244	9,272
Transmission lines	885,583	486,979	398,604
Power facilities	3,528,028	2,324,527	1,203,503
Lower Nam Pung area	8,756,031	4,993,564	3,762,467
Nong Han Lake area	4,696,503	2,698,611	1,997,892
Irrigation facilities	13,452,534	7,692,175	5,760,359
Total	20,275,493	11,618,036	8,657,457
Flood control facilities	2,604,520		
Sum Total	22,880,013		

(1 Baht=$ 0.048)

Let us now study the allocation of expenditures for facilities used in common, such as the dam and the spillway which are used both to generate electricity and for irrigation. The percentage of expenses allotted to each facility is 54.99% and 45.01% respectively. Table III shows the amount of money necessary to construct these common facilities and the annual expenses allocated to each facility as mentioned above.

Table III Cost of common facilities and amortization

	Construction cost	Amortization
Power	$ 1,811,884	$ 162,622
Irrigation	1,483,047	133,111
Total	3,294,931	295,733

Table IV shows the money needed to construct electric generating facilities, to which has been added the amount allocated to this facility.

Table IV Cost of power station

Dam (allocated)	$ 1,811,884
Canal	1,343,217
Generating Statin	729,256
Generating equipment	3,884,357
Substation	569,972
Transmission line	885,583
Total	5,339,912

Regarding the cost of construction of irrigation facilities, see the separate report "Nam Kam Project in Thailand" (p. 193) wherein reference has been

Table V Calculation of benefit-cost ratio

Expenses			Income	
Employed	$ 55,968		Gross agricultural prodaction	$ 2,497,920
Self employed	429,648			
Labor Costs		485,616		
Fertilizer, feed, etc.		21,648		
Farm machines and implements, house		90,288		
Rental value, interests, taxes		6,144		
(Total)		(603,696)		
Water charge		1,382,016		
(Total)		(1,985,712)		
Excess profit		512,208		
Sum Total		2,497,920		2,497,920

made to the matter.

We will now proceed to an economic evaluation of the irrigation development project.

The amount of money invested in irrigation, including the amount allocated for common use of the dam, is $14,875,824. To this was added an amount necessary for depreciation, working and maintenance expenses, interest at 6% per annum and the amount of increasing expenses of farming households, and on the benefit side we estimated the gross increased production of farming households at 30% below the Bangkok wholesale market price level and obtained Table V which illustrates the contrast in expenses and benefits in the fiscal year of 1970. From Table V we calculated the ratio of expense and benefit as 1,258 and the excess benefit as 25.8%. Thus, we find that the projects financed with funds at an interest rate of 6% per *annum* are profitable.

Table VI shows the earnings and expenses of money involved in the management of irrigation development projects.

Table VI An estimate of the irrigation project

Output		Earnings	
Operation and maintenance	$ 191,952	Farm gross income	$ 2,497,920
Amortization	297,504	Labor costs	−485,616
Interest	892,560	Fertilizers, feed etc.	−21,648
(Total)	(1,382,016)		
Surplus	512,208	Farm machines and implements, house	−90,288
		Rental value, interests, taxes	−6,144
		(Total)	(−603,696)
Sum Total	1,894,224	Sum Total	1,894,224

The balance, after deducting from the gross agricultural production expenses involved in farm management and utilization of irrigation and other facilities (including a 6% per annum interest and an amount set aside for depreciation) is $512,208 which is 3.44% of $14,875,824, the total cost of production. Appropriating this as repayment, it has been found that the total debt could be paid back in 29 years. If funds to finance the construction could be obtained at an interest rate lower than 6%, it is quite evident that repayment can be made in a shorter length of time.

2. Lam Pao Project

It was planned that the funds necessary to carry out the Lam Pao project, roughly $6,720,000, were to be collected from the country itself and foreign countries. According to the plan $4,800,000 was to be obtained from foreign countries at an interest rate of 8% per annum and $1,920,000 from within the country at 3% per annum. Interest during the period of construction, planned for 3 years, is about $432,000 (foreign and domestic funds share this amount of interest at a rate of about 50/50) and will be added to the principal. Expenses for management and maintenance of the project are estimated at $0.54 per year, so it will come to total $86,400 or $2,592,000 in 30 years. Table VII shows the results of a trial calculation made on the annual expenses needed for redemption over a period of 30 years in equal amounts annually under the conditions mentioned above.

Table VII Annual costs

	Local monies	Foreign monies	Total
Interest	$ 3,772,320	$ 2,878,080	$ 6,650,400
Principal	1,920,000	4,800,000	6,720,000
(Total)	5,692,320	7,678,080	13,370,400
Annual amortization	189,744	255,456	445,680
Annual operation and maintenance			86,400
Total annual cost			532,080

Table VIII Project budget summary (annual)

	Without project	With project	Increase due to project
Irrigable areas (ha)	$ 112,000	$ 160,000	$ 48,000
Number of farms	2,555	3,635	1,080
Investment assets	1,395,000	6,425,000	5,030,000
Farm produce sold	285,000	2,979,000	2,694,000
Produce consumed on farm	219,000	350,000	131,000
Non-farm income	139,000	92,000	-47,000
(Gross family income)	643,000	3,421,000	2,778,000
Farm operating expenses	193,000	829,000	636,000
(Net family income)	451,000	2,593,000	2,142,000
Produce consumed	219,000	351,000	131,000
Minimum family living costs	232,000	329,000	98,000
Homestead improvement	0	438,000	438,000
Family living allowance	0	876,000	876,000
(Available for amortization)	0	599,000	599,000

According to the planned income and expenses (Table VIII) the amount that can be set aside annually for amortization is $599,000. Now, assuming that in a 30-year redemption period it would be possible to receive the total value of the planned effects from the 10th year onward and that during the first 10 years the effects, starting from zero, increase and reach this level in a straight line, the aggregate amount for depreciation will become $14,913,600 in 30 years. The project further anticipates rice production to increase by 25,780 tons per year, all of which is scheduled to be exported. This will enable the tax office to earn $41.30 (average premium $32.60, export duty $6.60, corporation tax $1.60, and local tax $0.50) for every ton of rice exported. In

30 years this will amount to $22,560,000. After making the calculations described above, we find that the ratio between the capacity to repay the funds and the actual amount necessary to be refunded is 3:1. If the cost of construction and the expenses needed to run and maintain the project are to be paid by the farmers without interest, over a period of 40 years, in equal amounts, the annual expenses planned should be $254,400, that is, $168,000 to refund the principal and $86,400 for working and maintenance expenses. This is equivalent to about 40% of the amount that can be appropriated annually for depreciation.

Let us now consider the benefits and begin with irrigation.

The direct annual agricultural benefit is obtained by adding two figures—the amount after deducting from the increase of the gross agricultural income the annual increase of agricultural management expenses during the 30-year (average 25-year) redemption period and the amount of the annual increase of property during this period. The amount, as was derived on Table VIII, is as follows:

$$(2{,}133{,}360 \times \frac{25}{30}) + (5{,}009{,}568 \div 30) = \$1{,}944{,}960$$

Now, there is included in this project an area of 2,508 ha (580 households) of arable land, which is set aside as the site for the reservoir. The loss of this area is 20% of the present amount of benefits and amounts to $99,024 a year. Accordingly, the planned annual increase of direct benefit comes to $1,845,936. Tax on the net increase of production, that is, on the planned increase of production, 25,780 mt, minus the loss in production due to building of the reservoir mentioned above, 2,240 mt, comes to $41.30 per mt. In other words, the annual tax yields will increase by $971,712. Though to calculation was made on indirect benefits obtainable from irrigation, considering the transportation, processing and handling of the products it has been estimated at around 50% of the direct benefit. Public benefits are usually about 10% of the direct benefits. All these points considered, the increase of benefits will be as shown in Table IX. Eventually, the cost-benefits ratio will be:

(i) Overall cost-benefits ratio

$$\frac{\text{Annual benefits (total benefits)}}{\text{Annual redemption \& working expenses}} = \frac{4{,}509{,}256}{532{,}080} = 8.47$$

(ii) Cost-benefits ratio of the direct benefits

$$\frac{\text{Annual benefits (direct benefits)}}{\text{Annual redemption \& working expenses}} = \frac{2{,}817{,}648}{53{,}080} = 5.30$$

Table IX Annual benefits from irrigation ($ US)

	Direct benefits	Indirect benefits	Public benefits	Total
Project	1,845,936	922,992		2,768,928
Nation	971,712	485,856	281,760	1,739,328
Total	2,817,648	1,408,848	281,760	4,508,256

3. Evaluation of economic efficiency

Comparing the Nam Kam and Lam Pao projects, we find that there are some differences between the two in benefits calculated, as shown in Table X. Since the calculated benefits would most probably be re-evaluated when the projects are effected it may not be proper to discuss them at this stage. Nevertheless, we consider it necessary to dwell on the points since there seems to be quite a large difference in the way the benefits of both projects have been calculated, because some of the values concern the basic problems of agricultural management and for this reason some of the values have been overestimated.

Table X Benefits in Nam Kam and Lam Pao projects

	Nam Kam projects	Lam Pao projects
Benefit-cost ratio	1.258	5.3
Surplus benefit ratio	25.8%	43.0%

In calculating the cost-benefits ratio the gross agricultural production of the Nam Kam project has been estimated at \$2,497,920. The figure has been divided by the sum of labor costs and water utilization expenses, that is by farm management expenses. Mathematically expressed, it is:

$$\frac{\text{Gross agricultural production}}{\text{Farm management expenses}} = \frac{2,497,920}{1,985,712} = 1.258$$

On the other hand, the annual increase of farm management expenses of the Lam Pao project for a 30-year (average 25 years) redemption period has been deducted from the gross increase of agricultural income. To this has been added the annual increase of property this year. From this has been deducted the loss of benefits of this region and the resulting answer has been determined to represent the value of direct benefits of the project. That is,

$$(2,133,360 \times \frac{25}{30}) - (5,009,568 \div 30) = \$1,944,960$$

$$1,944,960 - 99,024 = \$1,845,936.$$

The tax yields have been estimated at \$971,712, taking the tax at \$41.30 per mt of the net increase of rice production. The cost-benefits ratio of the direct benefit would then be:

$$\frac{2,817,648}{532,080} = 5.30$$

Comparing these two projects, we find that in the Lam Pao project the increase of assets has been added to the direct benefits, while in the Nam Kam project this point has been given less consideration. In the Nam Kam project the labor expenses have been added to the farm management expenses but this point has not been considered in the Lam Pao project. These are some of the reasons that may explain why there are such large differences seen in the cost-benefits ratios of the two projects.

Table XI Expected crop yields from Nam Kam project

	With Project		Without Project	Remarks
	kg/ha	$/ha	kg/ha	
Rice	1,750	59.0	1,160	1. Rice price before project=$39.1/ha
Sugar cane	42,000	200.0	—	2. Increased production (first cropping paddy
Peanut	3,000	289.1	—	rice)
Sesame	950	137.3	—	590 kg/ha=$19.9/ha
Kenaf	2,250	195.2	—	3. Second cropping paddy rice and upland
Maize	3,000	130.1	—	crops production due to project are estimated
Cotton	1,400	175.4	—	as increased production only
Kapok	6,300	546.5	—	
Castor beans	1,560	150.4	—	
Tobacco	1,360	589.9	—	
Pasture grass	—	69.4	—	
Vegetables	—	82.9	—	

Table XII Comparison of crop production with irrigation and fertilizer, and without irrigation

Crops	Area (ha)		Area	Yield	Price	Price	Total
	Rainy season	Dry season	(Total) (ha)	mt/ha	$/mt	$/ha	$
Rice	11,200	48,000	16,000	2.31	33.6	77.8	12,432,000
			9,600	*1.17*	*33.6*	*39.3*	*376,992*
Sugar cane	2,460	2,460	2,460	42.2	4.8	202.6	486,000
			480	*18.8*	*4.8*	*90.0*	*43,200*
Peanut	160	800	960	7.06	96	678.2	650,880
			160	*8.13*	*96*	*78.0*	*12,480*
Sesame	160	320	480	0.56	144	81.1	38,880
			80	*0.56*	*144*	*81.0*	*6,480*
Kenaf	320	640	960	2.25	33.6	74.9	72,000
			320	*1.69*	*33.6*	*57.0*	*12,240*
Maize	800	2,460	3,200	3.75	43.2	162.2	566,400
			320	*1.49*	*43.2*	*67.2*	*21,504*
Cotton (lint)	160	480	640	0.56	192	108.0	69,120
			80	*0.31*	*192*	*33.6*	*2,688*
Cotton (seed)	—	—	—	0.94	19.2	18.2	11,520
			—	*0.43*	*19.2*	*3.3*	*288*
Tobacco	160	800	960	1.37	36	51.8	47,040
			80	*0.75*	*36*	*27.0*	*2,160*
Mung beans	320	480	800	1.25	96	120.0	96,000
			80	*0.75*	*96*	*72.0*	*5,760*

Note: Roman type figures indicate crop production with irrigation and drainage, and *Italic type figures*, without irrigation.

Let us now study the next most important problem, that of gross agricultural production. The calculated values of gross agricultural production of the Nam Kam and Lam Pao projects are found in Tables XI and XII. We can see from these tables that the increase in the volume of production per unit area is set at a comparatively higher level in the Lam Pao project than that of the Nam Kam project. On scrutinizing we find that it is mainly due to the effects of fertilizing. In the Lam Pao project it has been planned to fertilize as well as irrigate the land but in the Nam Kam Project no consideration has been given to fertilizers for the time being. It is a generally recognized fact that for such land of poor soil fertility, far better effects could be had if fertilizers are used simultaneously with irrigation water instead of merely irrigating the land. This was admitted in the Nam Kam project but no endeavors have been made to use fertilizers at least as far as rice cultivating was concerned. This is because the market price of fertilizers is high and it does not pay for the farmers to use fertilizers at present and also because of reasons concerning crop varieties, etc., at the present, therefore fertilizers have not brought about the anticipated results. There is much criticism about this but it probably could not have been helped.

Another matter concerns distribution. In remote areas such as Lam Pao and Nam Kam, sufficient means for transporting agricultural products are not always available and from the standpoint of transportation costs, for crops that take up much space, except those that can be processed locally, it does not generally pay to cultivate them. Nevertheless, both the Nam Kam and the Lam Pao projects have adopted wide cultivation of such agricultural crops. This is the reason why the values of gross agricultural production have been set very high.

Related to the problem of distribution is the problem of cropping. Table XIII shows the plan in the Nam Kam project. As Table XI and XIII show, paddy cultivation is at present confined only to a single cropping method in the rainy season in spite of conditions existing that would enable single cropping even in the dry season, thus double rice cropping. The present pattern of paddy cultivation is: May/June the nursery bed period, June/July the transplanting period, one month after mid-November the harvesting period with three rice varieties, namely the early maturing, the medium maturing and the late maturing, then the early maturing varieties are harvested 80 days after transplanting, the medium maturing varieties 120 days after and the late maturing varieties 150 days after. When the projects were drawn up, a rotating cultivation system was planned. The rotation system was to cultivate first and second rice crops as shown in Fig. 1, then after the second cropping and before the first cropping, that is, during the 2-month idle period (May and June) by cultivating green manure crops to nourish the land.

Upland farm crops were divided into those for permanent upland fields and those for dry season upland farms that utilize paddy fields. Upland farmlands for permanent crops were selected at high altitudes so that crop roots would not be submerged by water in the rainy season and crops were selected

Table XIII Cropping schedule and yields in the lower Nam Pung project area

		Crop	Area (ha)	Income ($/ha)	Gross income ($)	Net income($) Paddy 8% Upland 7%
Paddy		First	9,000	19.9	179,100	143,280
		Second	3,000	59.0	177,000	141,600
		Total.	12,000	—	356,100	284,880
Upland	Dry season upland fields	Tobacco	200	589.9	117,980	
		Maize	400	130.1	52,040	
		Rubber	630	137.3	86,499	
		Castor beans	630	150.4	94,752	
		Peanut	630	289.1	182,133	
		Kenaf	420	195.2	81,984	
		Vegetables	90	82.9	7,461	
		Total	3,000	—	622,849	
	Permanent upland fields	Cotton	800	175.4	140,320	
		Sugar cane	120	200.0	24,000	
		Pasture grass	40	69.4	2,776	
		Kapok	40	546.5	21,860	
		Total	1,000	—	188,956	
		Tobacco	60	589.9	35,394	
		Maize	110	130.1	14,311	
		Sesame	170	137.3	23,341	
		Castor beans	170	150.4	25,568	
		Peanut	170	289.1	49,147	
		Kenaf	100	195.2	19,520	
		Vegetables	20	82.9	1,658	
		Total	800	—	168,939	
	Total (upland)		4,800	—	980,744	686,521

which dig deep with their roots and which do not mature very fast. According to the plan, 2,900 ha of cotton will be grown in 3,500 ha of permanent upland farmlands in order to prepare for cotton spinning, a future agricultural processing industry, and in 100 ha, pasture grass will be brought in to be the stepping stones to future dairy farming in the northeastern region. 100 ha of kapok fields and 400 ha of sweet potato fields have also been planned. Pasture grass, sweet potatoes and kapok will be grown throughout the year and cotton from May to December. As the January to April period overlaps the second cropping period of paddy fields, it has been planned to introduce the early maturing upland farm crops like dry season upland farm crops. As to the dry season upland farm crops to be cultivated in the paddy fields as second

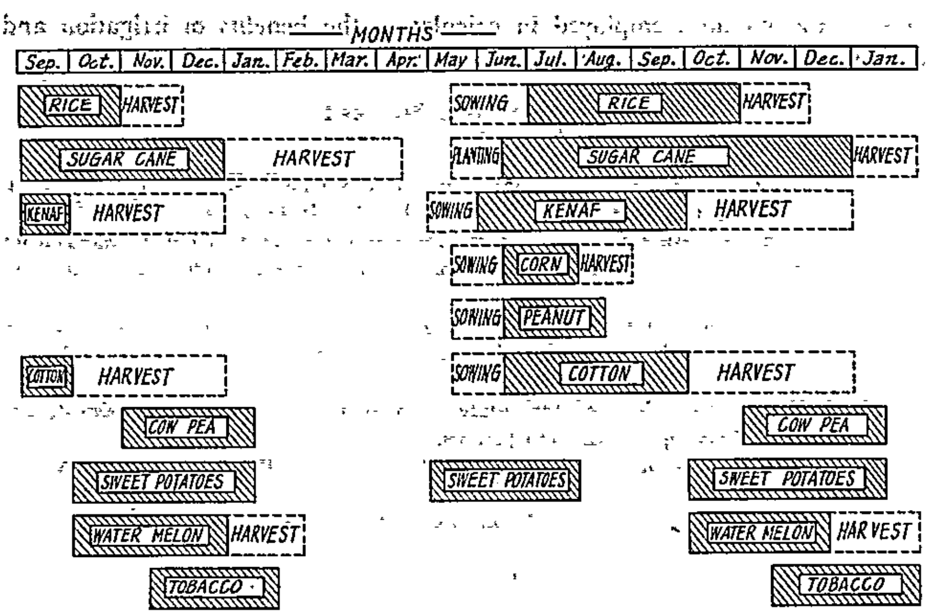

Fig. 1 Cropping schedule (Nam Kam Project)

crops, the growing period being limited (January to April), tobacco, maize, sesame and peanuts are to be grown. Vegetables for home consumption and to supply neighboring towns are also to be grown. Eventually, the total area for upland farm crops will be 10,100 ha. (See the "Nam Kam Project in Thailand", p. 193)

The Lam Pao Project has no detailed cropping plan like that of the Nam Kam Project. Only a glimpse of it can be had in Table XIII but at any rate there is a large scale year-round cropping plan made for this region and the cultivation of sweet potatoes and maize is of special note. Along with an overestimation in selling prices these large scale cropping plans have greatly raised the gross agricultural production. As has been explained before, property was specially assessed when calculating the gross agricultural income that was to be used to calculate the cost-benefits ratio of the Lam Pao Project. The value of land property was assessed very high which in turn raised the gross agricultural income to a very high level. On the other hand, farm management expenses were estimated at only about $0.56 per annum, so eventually the net agricultural income rose and consequently the cost-benefits ratio came to 5.30.

It is clear from what has been explained so far that even by taking these two projects as examples, the calculations of cost-benefits ratios vary largely. It hardly seems worth the trouble and it seems to have no meaning at all to calculate and compare the values of benefits of different projects. Every project has different assumptions on which the calculation of the cost-benefits ratio is based and if the bases of the assumptions crumble away the values obtained lose much of their importance. This problem is receiving much attention, discussion and study and we believe it very necessary to reexamine as soon as possible the methods employed in calculating the benefits of irrigation and drainage projects of these developing countries.

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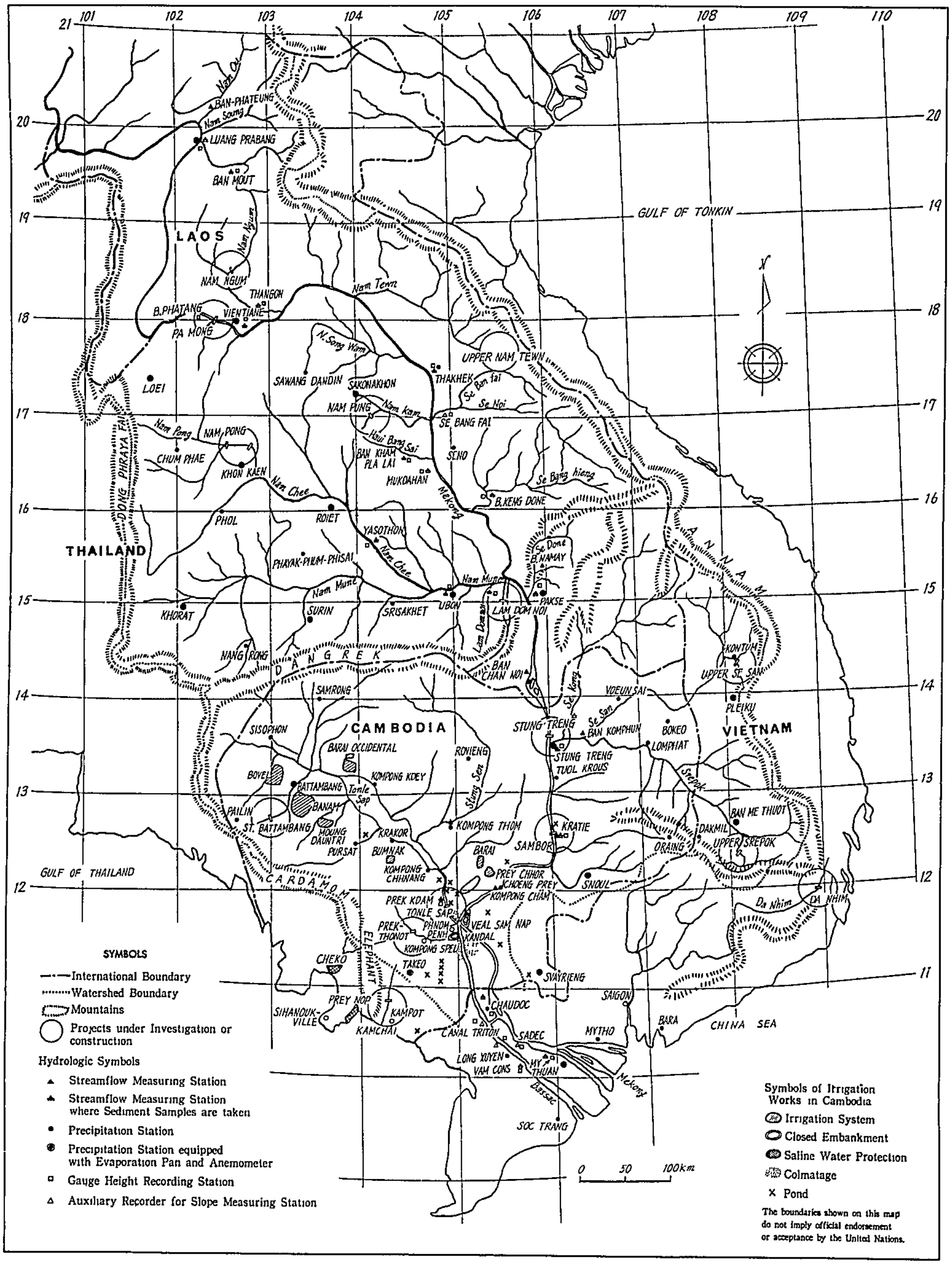
Table Appendix I General table of Southeast Asian countries

Country	Population (×1000)	Total* land area (km²)	Agricultural land				Former governing nation***	Independence year ***	currency***	
			Area** cultivated (km²)	Percentage of cultivated area	Area per person (ha)	Percentage of irrigated area**				
Brunei	90	5,765	—	—	—	—	England	1959		
Burma	23,183	678,033	147,580	21.8	0.64	4	England	1948	Kyat	$ 0.21
Cambodia	5,740	181,035	29,380	16.2	0.51	2	France	1949	Riel	$ 0.029
Indonesia	98,515	1,904,345	176,810	9.3	0.18	31	Holland	1949	Rupiah	$ 0.022
Laos	1,882	236,800	10,000	4.2	0.53	—	France	1949	Kip	$ 0.0125
Malaysia	8,631	332,634	56,150	16.9	0.54	4	England	1963	Malayan dollar	$ 0.326
Singapore	1,733	581					England	1965	Malayan dollar	$ 0.326
Pakistan	96,558	946,719	255,000	26.9	0.26	—	England	1947	Rupee	$ 0.21
Philippines	29,257	299,681	112,100	37.4	0.38	8	U.S.A.	1946	Peso	$ 0.50
Thailand	27,995	514,000	100,880	19.6	0.36	17	—	—	Baht	$ 0.048
Timor	528	14,925	—	—	—	—	Portugal (present)			
North Vietnam	17,200	158,750	—	—	—	—	France	1945	Don	$ 0.28
South Vietnam	14,929	170,806	31,300	18.3	0.21	20	France	1955	Piastre	$ 0.0137

Sourse; * United Nation's statistical year book (1963)
** FAO statistical year book of agricultural production
*** Iwenami Gendai series, Today of the world currency; Culculated upon tee U.S. dollar

Appendix II The Lower Mekong Basin Area



Appendix III Chao Phraya River, the Mekong Tributaries Basin Area