SAMBOR PROJECT REPORT

LOWER MEKONG RIVER BASIN

SAMBOR PROJECT REPORT

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UNIT OF MEASURES

mm	:	Milimetre
cm	:	Centimetre
m	:	Metre
km	:	Kilometre
sq.mm	:	mm^2; Square milimetre
sq.cm	:	cm^2; Sqpare centimetre
sq.m	:	m^2; Square metre
sq.km	:	km^2; Square kilometre
ha	:	Hectare
cu.m	:	m^3; Cubic metre
gr	:	Gram
kg	:	Kilogram
ton	:	Metric ton
m/sec	:	Metre per second
cu.m/sec	:	m^3/s; Cubic metre per second
cu.m/sec-day	:	m^3/s-day, Cubic metre per second per day
kW	:	Kilowatt
MW	:	Megawatt
kV	:	Kilovolt
kVA	:	Kilovolt - ampere
kWh	:	Kilowatt - hour
mill	:	U. S. mill
c.	:	U. S. cent
$	:	U. S. dollar
p.p.m.	:	Parts per million
EL	:	The height above mean sea level
°C	:	Centigrade
D.W.T.	:	Dead weight tonnage
hr	:	Hour
ps	:	Horsepower (Germany)
R	:	Riel

C O N V E R S I O N   T A B L E

1 m	39.37 inches	3.2808 feet
1 km	0.6214 mile	3,2808 feet
1 sea mile	1,852 m	
1 sq.m	1.196 sq. yards	10.764 sq. feet
1 sq.km	100 ha	247.1 acres
1 ha	10,000 sq. m	2.471 acres
1 cu.m	1,000 liters	35.31 cu. feet
1 kg	2.2046 pounds	
1 ton	1,000 kg	2,204.6 pounds
1 cu.m/sec	35.31 cu.ft/sec	
^{o}C	$5/9\ (^{o}F - 32^{o})$	
1 $	¥360	35 R (Official), 60 R (Current)
1 ps	0.98635 HP	

CHAPTER 1. SUMMARY

1.1 INTRODUCTION

The international River Mekong starts from the Tibetan Plateau, which is called the roof of the Asian Continent, and runs through China and the Indo-China Peninsula until it meets the South China Sea. Its total length of waterway is about 4,200 kilometres and the catchment area is about 795,000 square kilometres.

The basin of the Mekong in the Indo-China Peninsula consists of the Hill Land and the Plateau in the north and of the vast plain including the Delta in the south. The tropical climate is clearly divided into two types, a dry season and a rainy season, by monsoon. Difficulties in transportation have long hindered this area from development, and though the Mekong Delta has been utilized for a world-wide rice fields the river has hardly been controlled.

The water level of the Mekong changes greatly between the dry and the rainy seasons, and also there are rapids and falls at places which makes it impossible for inland-going vessels to be navigated. At present, however, fast economic development in the developing countries is an urgent problem. There is a need for a multi-purpose project of the Mekong that can improve navigation, irrigate the plain, generate hydroelectric power, control flood, and so on. Based on this general idea, the Economic Commission for Asia and the Far East (ECAFE) is promoting the comprehensive development of the Mekong River as the first typical case.

The Sambor Project studied here is a component of the master plan for the development of the Mekong and involves the lowest site in the main stream. This project is supposed to solve the primary problem of the Sambor Rapids by constructing the Sambor Dam, which is 54 metres high and has the total storage capacity of $10,000 \times 10^6$ cubic metres, and furthermore, the Sambor Dam is expected to produce annual generating energy of $7,000 \times 10^6$ kilowatt-hour with an output of 875 megawatts and to contribute to the agricultural development of an arable land of 34,000 hectares.

1.2 PROBLEMS IN THE PROJECT AREA

The Sambor Project area is located at the lowest point of the main stream programme, and the project is a part of a master development plan for the Lower Mekong Basin.

a) Navigation

Presently in the main stream of the Mekong River, ocean-going vessels up to the 5,000-ton class can go as far as Pnom Penh from the estuary of the river, and vessels of 500 tons or less up to Kratié, during the rainy season. In the dry season it is impossible for the vessels of over 2,000 tons to go beyond Pnom Penh, and only river vessels of 200 tons or less can go up to Kratié. Up stream from Kratié, only small vessels of about 50 tons are able to be navigated to Stung Treng, even in the rainy season, because of the Sambor Rapids. The Khone Falls bar any river traffic beyond Stung Treng. This geographical situation provides an impetous to Laos to hope for rapid development of the Lower Mekong Basin.

b) Power

The following figures were the general costs of electric power per kilowatt-hour in this area in 1963: In Pnom Penh, 8.7 cent per kilowatt-hour for domestic use and 6.5 for industrial use; in the Saigon-Cholon district of Viet-Nam the overall fare is 5.6 and in the rural areas 10.5. It is quite expensive and it can be said this is mainly due to small-scale power generation dependent upon imported crude petroleum for fuel.

In this area the present demand is fulfilled mostly by independent electric power plants, which are not efficient enough to supply low-priced electric energy. However, a considerable amount of latent demand for electricity exists because of insufficient facilities and relatively high cost. If it is possible to supply adequate and economical power, the demand will increase because of the articulation of the presently latent demand. Should this occur the old independent generation plans can be removed. And if it is possible to supply low cost energy for industrial use, the constant rate of economic increase (12.7-15 per cent yearly) can expected to grow larger.

Economy in this area is developing. It is undergoing a metamorphosis from the older type of economy to a new one, and this transition requires large amounts of electric energy. It is evident that the change in economic structure will take place along with an increasing demand for and an increasing supply of electrical power resulting from development of the Mekong.

c) Irrigation

Climactic conditions along the Lower Mekong Basin includes both rainy season and dry season converted by monsoon. Most of the rainfall occurs during the rainy season from May to October in which the average rainfall is about 240 millimetres per month and very small quantity of rainfall about 30 millimetres during the dry season from November to April.

Approximately 90 per cent of the arable land along the Lower Mekong is utilized for irrigated rice farming. However, the shortage of water is quite noticeable during the dry season, because most of the rainfall in the main Mekong Basin is concentrated in the rainy season. Farming conditions are not satisfactory even during the rainy season if a southwest monsoon begins to blow late or stops in the midst of a season, or if a dry period comes early at the end of a season.

Sound agricultural management requires diversified crop cultivation. Along the Lower Mekong, especially in the Cambodia plain and Mekong Delta, the soil becomes too heavy and adhesive during the rainy season to be suitable for crops other than rice and jute, which makes diversified cropping in this area possible only in the dry season. Therefore it must be emphasized that it is necessary to irrigate the land during the dry season if diversified cultivation is to be achieved.

In order to increase produce, overcome the irregular climate and the peculiar seasonal wind, and lessen the damage of crops caused by droughts, the kinds of crops and fertilizers should be carefully selected and supplementary irrigation in the rainy season should be properly managed. Furthermore it is necessary to control irrigation for available land to grow the second crops during the dry and rainy seasons.

Demand for more irrigation is a general trend in the Lower Mekong Basin and Cambodia. Thus the development of the water resources of the Mekong has been increasingly urged.

1.3 POSSIBILITIES OF DEVELOPING THE LOWER MEKONG BASIN

According to the data about its water balance, the Mekong has ample potential to provide satisfactory resources for the related countries to promote inland water transportation, water-power generation, and irrigation.

According to the data 1/ compiled by the Mekong Committee for 33 years (1933-1965), the Mekong, with a drainage area of 795,000 square kilometres, has discharged an average of 445,700 million cubic metres per year at Kratié which has a drainage area of 648,000 square kilometres. This indicates an average minimum discharge of 1,790 cubic metres per second, an average maximum discharge of 52,400 cubic metres per second and an average discharge of 14,130 cubic metres per second. (Refer to Table 5-1, Chapter 5, Water Resources.) Hence, the ratio of the maximum water discharge to the minimum one in the Mekong, which indicates fluctuation in water discharge becomes 29.

1/ Lower Mekong Basin Discharge Data, (1933-1965), 1967, Mekong Committee

In the main stream of the Mekong, the major locations that can possibly be developed for water-power generation are the Sambor Rapids, Khone Falls, Khemarat Gorge, Pa Mong Gorge and the upper valleys. There are also many other possible areas along the tributaries. Although there are some differences among them, they are capable of being developed from the enforcement and power-consumption point of view. The basin plan in the Lower Mekong by the Mekong Committee is shown in Figure 1-1.

As mentioned in Chapter 2 various resources can be found in the Lower Mekong, and the demand for electricity is expected to increase along with development of industries in the area with availability of main materials and cheaper electric power.

Fig. 1-1 General Map of the Development Project in the Lower Mekong Basin
(Source: Annual Report of the Mekong Committee, 1967)

The Mekong has possibilities of becoming an excellent route for inland-bound vessels, as in other big rivers in the world.

Since the Mekong does not meander excessively and the waterway length rarely exceeds the present land route, transportation costs are expected to decrease appreciably. Still, there are hardly navigable some places in the lower reaches of the river where water resource development in the main stream aimed at generation of electricity, waterway improvements or irrigation and flood control dams will increase the low level of water discharge.

Rapids and falls are handled by water dammed up, and eventually the barely navigable places will be improved and it will be possible for vessels to navigate deep into the upper river areas throughout the year. Thus the development of inland water transportation and reduction of its cost can foster demands for the facilities and development of forestry and mining along the river, as is expected of the economy of this area.

The water discharge of the Mekong, coupled with reservoirs, can potentially be used to irrigate vast new areas of cultivable land. Only 3 per cent of the cultivated area along the Lower Mekong is irrigated artificially, but if an attempt to average the water discharge throughout the year is made by constructing a series of dams on the main stream, it will be possible to maintain the present low water discharge and, with surplus water, develop or improve an area of several million hectares.

The Mekong periodically floods several million hectares of the arable land in the Delta, and has made people learn to live with floods, developing the land without controlling the water. Therefore they have had stable rice harvests, but the productivity of land has remained in low level. It is said recently that harvest has decreased in the Mekong Delta area due to an increasing salt density. In an area like this, subject to distinct rainy and dry seasons, salt tends to accumulate and improvement in drainage becomes urgent. Therefore soil preparation is needed in the areas between the main stream and the estuary of the river, and measures must be taken to prevent flooding.

A series of reservoirs in the main stream would make it possible to increase productivity by irrigation, and can also be very successful in preventing harmful salt damage.

As stated above, the Mekong River can potentially be used for water-power generation, inland water transportation and irrigation, thus providing resources for further development of the Delta, industries and agricultures.

1.4 CONCLUSION

(1) The leading purpose of the Sambor Project is to expedite development of the Lower Mekong Basin as a whole, including the inland area.

(2) The Sambor Project is conceived as a multipurpose project,having purposes of power, navigation and irrigation.

(3) The power section is the mainstay of the project and is conceived as an independent power station or system, because enough data are not yet available to evaluate the sites in the upper stream.

(4) Construction of the Sambor Dam including a power station and a spillway is technically feasible, because the construction does not includes difficulties in such problems as transportation, materials, conditions of foundation and river flow treatment.

(5) Construction of the transmission lines is feasible in Viet-Nam as well as in Cambodia, according to the field survey limited within the Cambodian territory.

(6) The power sector seems to be payable as it is, but it is necessary to take measures in order to lower power cost as far as possible, so that the sector may invite power oriented industries, which is to make up shortage of demand.

(7) Cost allocation is not put into practise because the power sector is extremely large compared with the navigation sector and separate cost is indiscernible in the irrigation sector.

(8) Three types of power demand are examined, in order to make up the shortage, and the internal rates of return are in the sector as follow.

Type I	(domestic consumption, aluminum refining and electric furnaces)	4.4 per cent
Type II	(domestic consumption and electric furnaces)	5.3 per cent
Type III	(domestic consumption)	5.3 per cent

(9) On completion of both Pa Mong and Nam Ngum dams, the generation capacity of the Sambor station can be enlarged to 1,200 thousand kilowatts.

(10) Development of irrigable land of 34,000 hectares is feasible technically and economically down the dam along the river and rice and maize are to be cultivated as key crops.

(11) Farmland of 4 hectares per farm household is to be owned by farmers and farm management is to be payable with three family members and livestock employed. About 2,000 submerged farm households are to be resettled in the project area.

(12) The full benefit of the irrigation sector is to come to 95.7 U.S. dollars per hectare and the internal rates of return are from 2.9 to 7.6 per cent and 4.5 per cent on the average.

(13) There are no technical problem in constructing navigation facilities and dredging river bed in order to extend navigable waters to Stung Treng.

(14) The internal rate of return is estimated at 3.9 per cent in the navigation sector.

1.5 Recommendation

(1) It is necessary to reexamine and, if need be, improve the project

design of Sambor power station, after the project design is definitely planned.

(2) In studying the definite plan of Sambor Project, it is indispensable to investigate and study further geological conditions of foundation of structures, construction materials of the dam body and aggregate for mixing concrete.

(3) Considering that Cambodia and the Saigon district in Viet-Nam are supplied with the power generated at Sambor, it is requisite to make power rates properly corresponding to power demand, amount of energy consumed and load factors.

(4) Nothing that Sambor power station is of a run-off type, it is necessary to calculate the optimum cost and scale of cooperation of hydro and thermal power stations in the case of Type I in relation to power demand, so that firm power may be increased and secondary power may be diminished correspondingly.

(5) More accurate investigations and studies are essential to location of an aluminum refinery and electric furnaces and it is necessary also to reexamine how to distribute and supply the secondary power according to the result.

(6) It is necessary to investigate and study how to establish and organize an operational body including both the power and navigation sectors and to draft according to the result.

(7) Before establishment of the operational body, it is requisite to conclude among riparian countries a convention on utilization of the inland waters along the main stream on the lower Mekong and on bonded warehouses, factories or areas adjacent to the dam sites under the Mekong scheme.

(8) It is requisite to establish pilot and demonstration farms, taking demonstration effects into account, in order to expedite effects of develop-

ment, improve techniques of cultivation and technical training, and it is necessary to establish or expand in order to research breeding of varieties and techniques of cultivation and strengthen extention activities.

(9) More precise investigations are requisite to individual farm management and farm size, before the project is set out, lest the farm households inferior in management should not fall off from district projects.

(10) On the basis of correct comparison in capacity between the government and cooperatives, it is recommendable to decide and organize an operational body financing in irrigation facilities of the project in advance.

(11) Noting that the actual rates of interest is in a exceedingly high level in Cambodia, it is essential to establish a financial institution in order to raise a fund supplying low interest loans to farmers, who take part in the project.

(12) Considering that there is possibilities of cost inflation caused by spending of huge money relating to construction, it is requisite to investigate investment multiplier in Cambodia and device measures to protect the economy from the inflation.

(13) It is desirable to plan a navigation scheme of the main stream as a whole and, in accordance with it, investigate undeveloped resources accurately and to devise a master plan of development of the river basin.

CHAPTER 2. GENERAL DESCRIPTION OF THE PROJECT AREA

2.1 TOPOGRAPHY AND CLIMATE

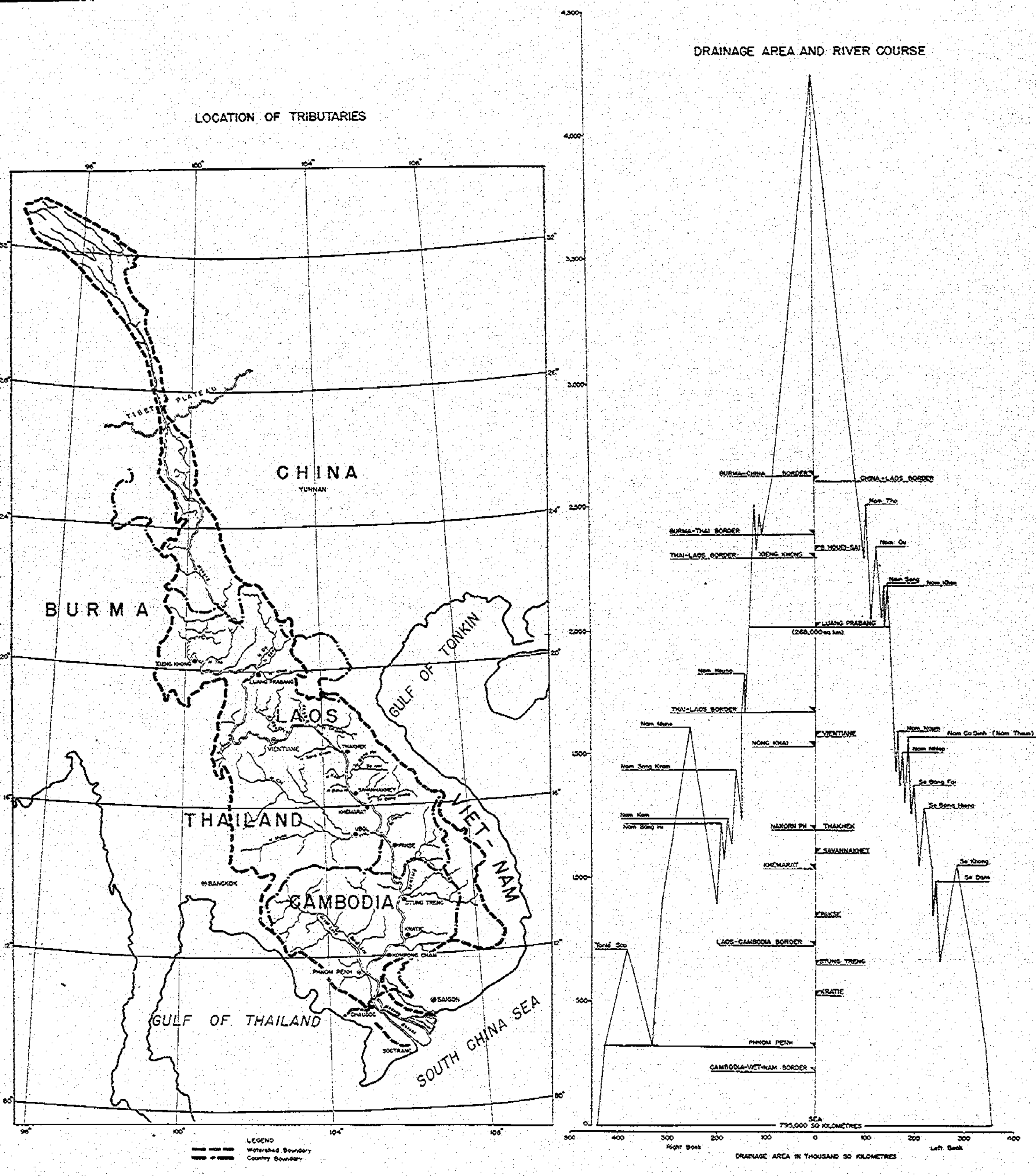
2.1.1 Topography in the Lower Mekong Basin

The Mekong River is an international river, with a length of about 4,200 kilometres, which rises from the Tibetan Plateau, runs through the six countries of China, Burma, Laos, Thailand, Cambodia and Viet-Nam, and flows into the South China Sea at the southernmost part of the Indo-China peninsula. The river runs narrow gorge in the upper reaches, but gradually widens drainage area to the extent that it finally occupies more than half of the width of the Indo-China peninsula.

The Lower Mekong Basin, the present project area is an area which is south of the border between Burma and Thailand and includes parts of Laos, Thailand, Cambodia and South Viet-Nam area of 609,000 square kilometres (about 77 per cent of the whole basin). Within this area the Mekong River runs through a total of 2,520 kilometres, as is seen in Fig. 2-1.

In the Lower Mekong Basin, from about 18 degrees of latitude the river turns abruptly to the left and flows eastward, where the hills are carved into valleys with steeps on both sides. In the down stream from Pa Mong, it runs through a vast plain between the northern Vientiane Plain and the southern Korat Plateau, and as it runs farther east, it meets the fringes of the Annam mountains, and then it again changes course, this time foward the south. From here down to Cambodia the Annam ridge runs parallel to the river on the left bank and continues to a ridge, about 2,500 metres above sea level, at a point about 150 kilometres from Namtheura. To the right of the river the hills that make up the eastern end of the Korat Plateau runs for about 200 to 300 kilometres and joins the ridge which divides central and eastern Thailand. Here, there are a few rapids and the famous Khone Falls, but generally the slope is easy. In Cambodian territory land spreads out, forming vast alluvial plains, with a great, natural retarding basin called

Fig. 2-1 **Relation between Drainage Area and River Course**



Source: Development of Water Resources in the Lower Mekong Basin, 1957, U. N.

The boundaries shown on this map do not imply official endorsement or acceptance by the United Nations

Grand Lac in the east, which is connected to the Mekong by the Tonlé Sap River.

In the rainy season, part of the flood water of the Mekong is controlled by the retarding action of the Grand Lac so that flooding in the lower delta area is somewhat moderate. The waterway down stream from the confluence of the Tonlé Sap and the Mekong turns southwards and flows into the South China Sea, forming the great delta south of Pnom Penh.

The Lower Mekong Basin can be divided into four areas from the view of geography and land utilization: the Hill area, the Plateau, the Mekong Plain and the Mekong Delta. (see Fig. 2-2)

The Hill Area

This region includes most of the land over 200 metres above sea level in the north, covering all of the area of northern Laos, north of Vientiane, and, to the south the area beside the Annam Range on the left bank of the Mekong and the area running along the Pong Phya Yen mountains and the Cardamomes Range on the right bank.

These two southern areas surround the Plateau and the Mekong Plain. The Hill area is mostly covered with forests, but a part of it consists of the patches of arable land that are cultivated for rice and grain crops.

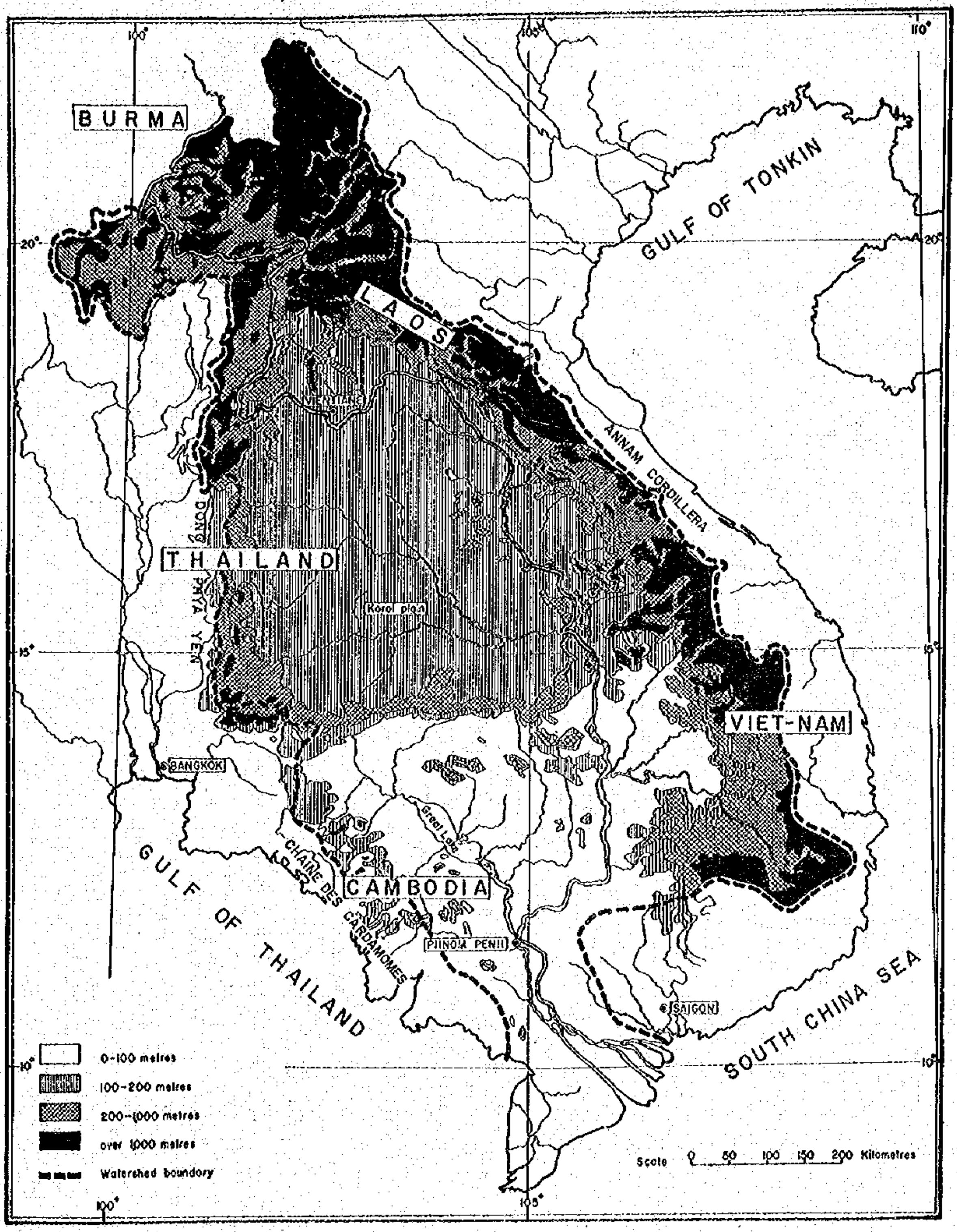
The Plateau

Most of the Plateau is a part of the Korat Plateau which has an elevation of between 100 and 200 metres and is a gently undulating plain with a slight slope to the southwest, where the river Nam Mune runs, toward the Mekong. Rice is grown in this area in the alluvial lands of the Nam Mune and east bank of the Mekong.

The Mekong Plain

A major portion of the area is a part of the Cambodian Plain, and of an

Fig. 2-2 Simplified Topographic Map of the Lower Mekong Basin



Source: Development of Water Resources in the Lower Mekong Basin, 1957, U. N.

altitude of less than 100 metres. The northern district reaches the border between Thailand and Laos, and the southern district, the vague line near Kompong Cham. The land on both sides of the Mekong is cultivated in plots of about 1-2 kilometres width, and rice as well as various other crops are cultivated. In the hinterlands, are the dense forests. The western district surrounds the Grand Lac Basin and rice is the most popular crop here.

The Mekong Delta

The Delta starts from the lower part of the Kompong Cham and consists of the vast alluvial land formed by the Mekong. The river swells every year between September and November, and flood water spreads over the lower basin, carrying mud in suspension that eventually settles there. This flooded delta area is like a swamp in the rainy season, and the major component of its soil is sticky mud. Most of the delta is cultivated for rice crops and is the chief granary area in Southeast Asia.

2.1.2 Climate and Hydrology in the Lower Mekong Basin

The Indo-China Peninsula is located in southeast part of the Asian Continent, bordered by the vast continent in the north and the ocean on the southeast coast. Its climate is strongly influenced by monsoons. This is particularly noticeable in the lower part of the Mekong basin where there is a distinct rainy season between May and October due to southwestern monsoons containing warm moisture from the Indian Ocean. This monsoon loses a part of its moisture when it blows across the mountains in Cambodia and then releases most of it when it goes over the Annam Range, causing heavy rainfall in this area. In the period between November and April the Lower Mekong Basin is dry season when a northeast monsoon blows, because is just behind this mountainous area.

Few of the typhoons that reach the Indo-China Peninsula at the end of the rainy season in September and in October bring rain to the Lower Mekong

Basin, however they sometimes cause great floods in the tributary basins in the Annam mountainous area.

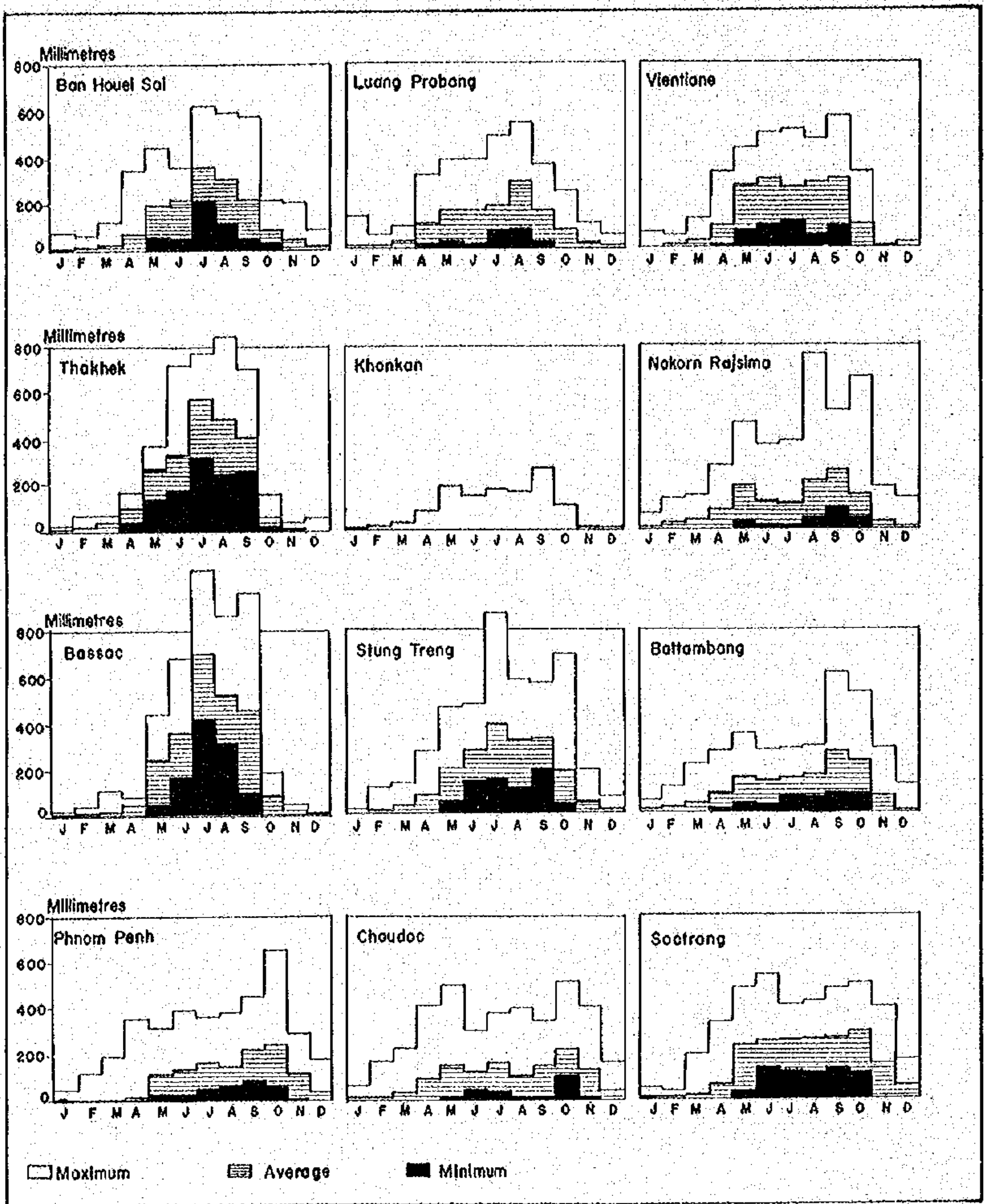
The amount of rainfall in the Lower Mekong Basin is thus affected by monsoon. The southwest part of the Chine Des Cardamomes Range have the highest annual rainfall (3,000-4,000 millimetres) and in the highlands the figure is almost 5,000 millimetres. The foot of the Annam Range and the northern part of Laos generally have more rainfall (1,500-3,000 millimetres) than the lower areas.

The Mekong Plain, including the Korat plateau and Grand Lac, is protected by mountains in the southwest and has annual rainfall of less than 1,000 millimetres. This is the driest area in the whole basin. Monthly and yearly rainfall at each station and its distribution is shown in Fig. 2-3 and 2-4.

Climate in the Lower Mekong Basin is tropical and thus warm and humid. The mean yearly temperature in the lower basin is high (between 25-28 degrees centigrade) and the average maximum monthly temperatures is 35-36°C. Temperature fluctuation during the year is generally small (4.5 degrees in the south, and 7-8 degrees in the northern mountains), whereas the temperature in a day may vary up to 10 degrees. Relative humidity is between 60 and 90 per cent throughout the year but expectedly reaches 100 percent in the Mekong Delta during the rainy season. Since the water discharge of the Mekong is strongly affected by monsoon, the water level changes in a twelve month cycle, repeating the same pattern every year.

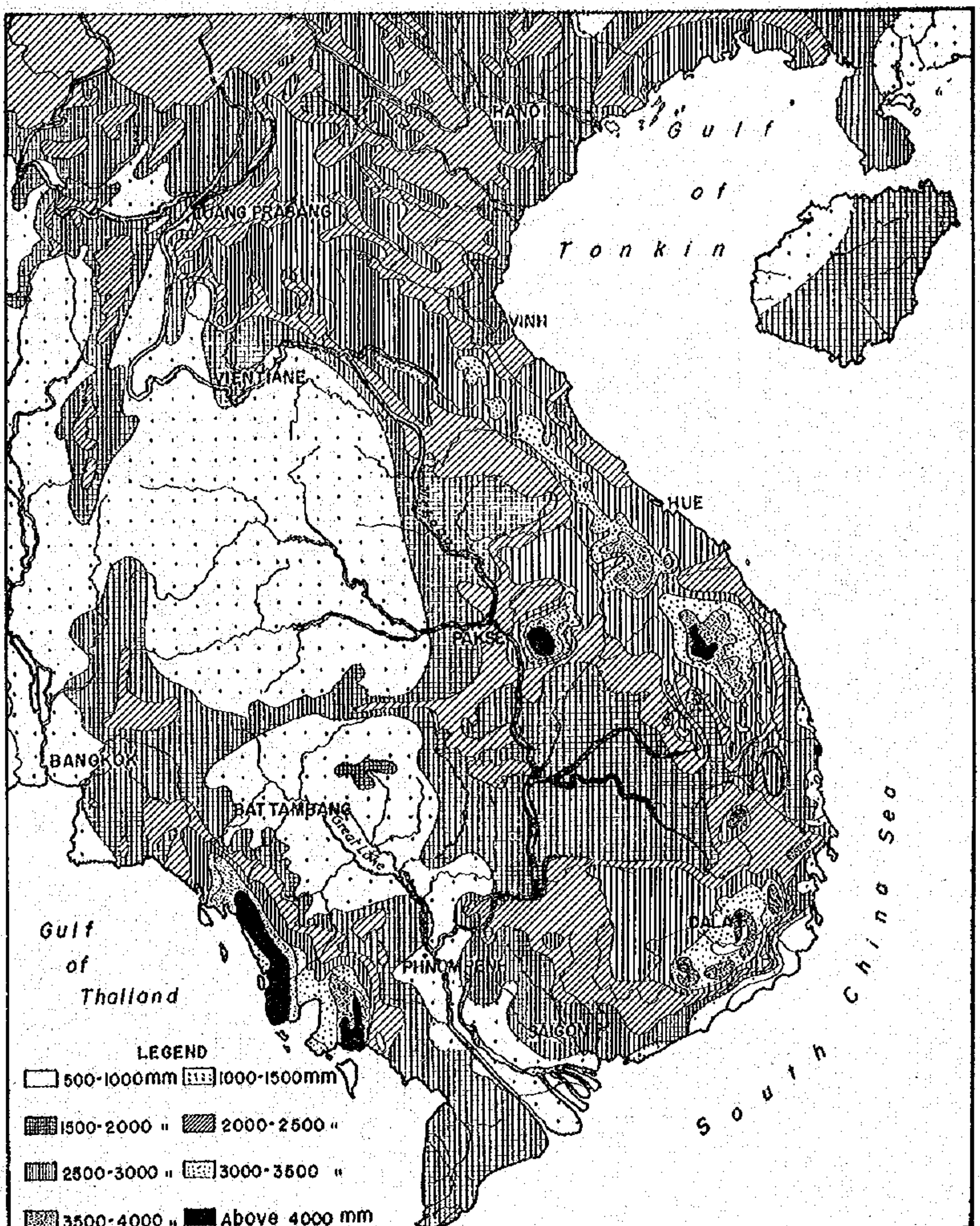
As southwest monsoons begin to blow in May, the Mekong gradually swells and after the peak of rainfall, between August and October in the latter half of a rainy season, a maximum level is reached. The water level begins to drop by December and gradually continues to go down until it reaches the minimum point just before monsoons begin to blow again. In some years several minor peaks of rainfall may appear independently, yet the flow

Fig. 2-3 Monthly Rainfall at Selected Stations



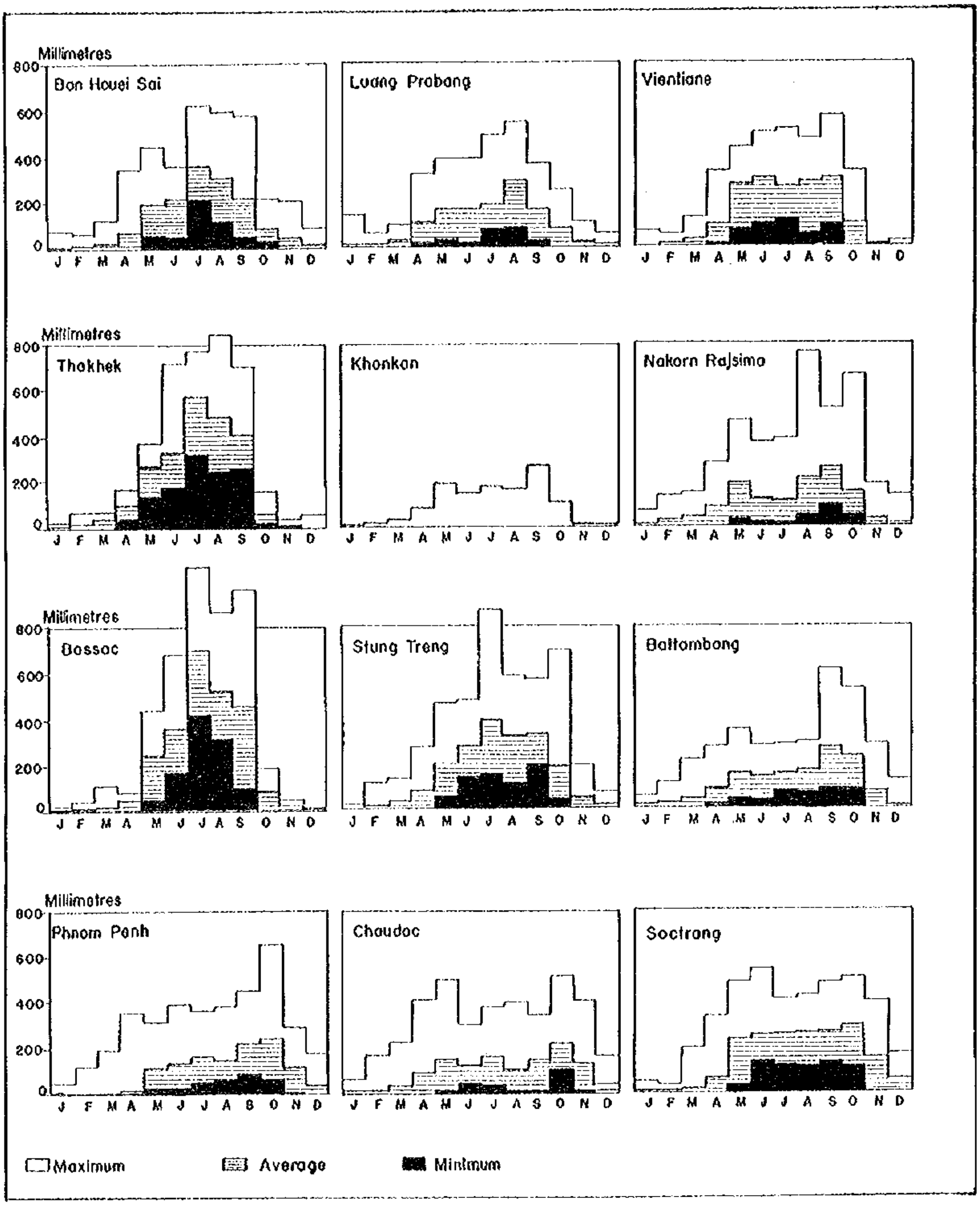
Source: Development of Water Resources in the Lower Mekong Basin, 1957, U. N.

Fig. 2-4 Isopluvial Map of the Lower Mekong Basin



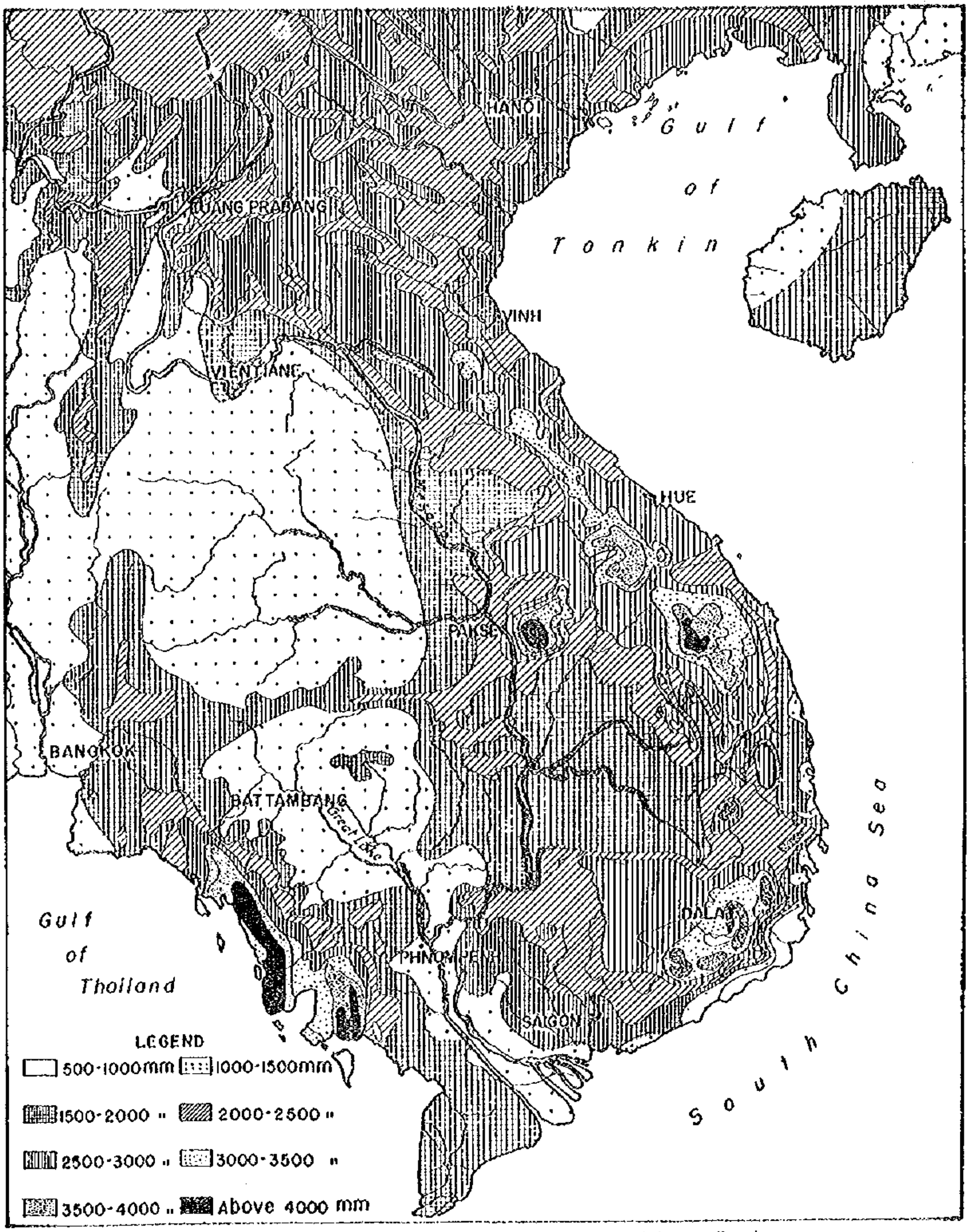
Source: Development of Water Resources in the Lower Mekong Basin, 1957, U. N.

Fig. 2-3 Monthly Rainfall at Selected Stations



Source: Development of Water Resources in the Lower Mekong Basin, 1957, U. N.

Fig. 2-4 **Isopluvial Map of the Lower Mekong Basin**



Source: Development of Water Resources in the Lower Mekong Basin, 1957, U. N.

pattern throughout the years is nearly the same. At a point upstream from Kratié (a drainage area of 648,000 square kilometres) the hydrograph of the main stream of the Mekong shows a fluctuating line which is closely related to the fluctuation of water discharge from the upper basin; however, at points downstream from Kompong Cham (a drainage area of 655,000 square kilometres), the hydrograph shows a gently fluctuating graph. At Pnom Penh (a drainage area of 668,000 square kilometres) the peak water discharge during floods is less than that at Stung Treng (a discharge area of 640,500 square kilometres) which is located upstream from Pnom Penh. It means that during flood periods water flows into both sides of the river and that effective water control is performed by Grand Lac. (Refer to Fig. 2-5 and 2-6.)

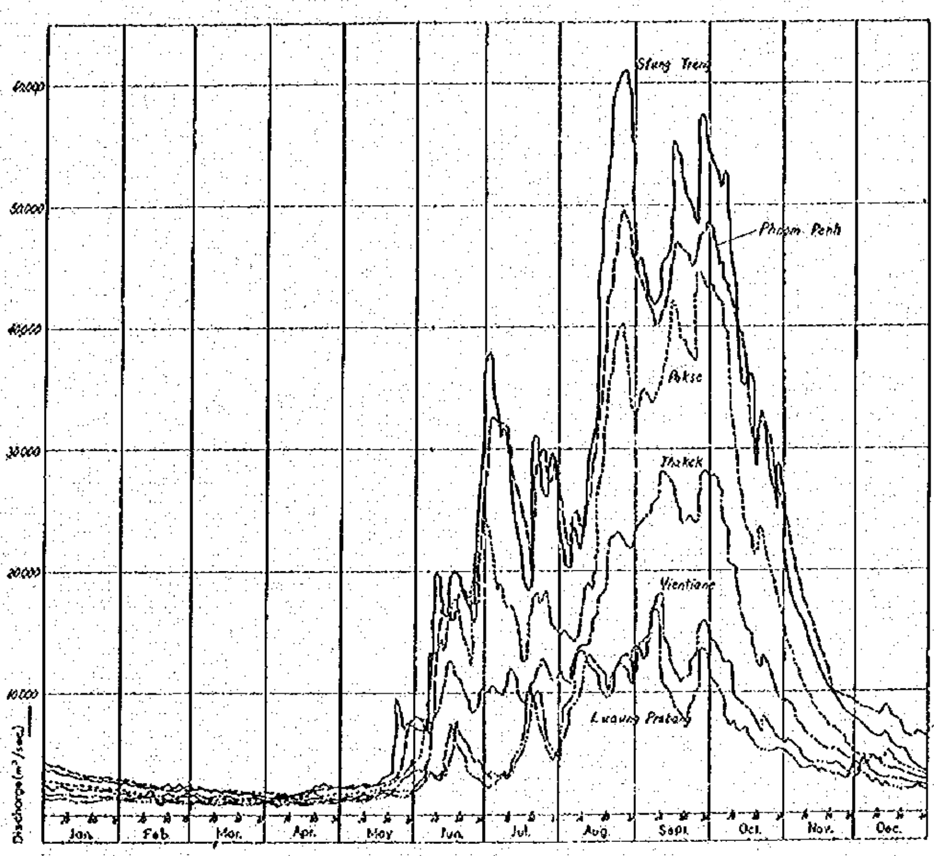
Water discharges of the tributaries show considerable differences from each other, with regard to rainfall distribution in their basins. That is, the tributaries on the right side of the Mekong have little water in the dry season, but on the left side and in the rivers in northern Laos there is abundant water.

2.2 NATURAL RESOURCES

An Outline of Geology

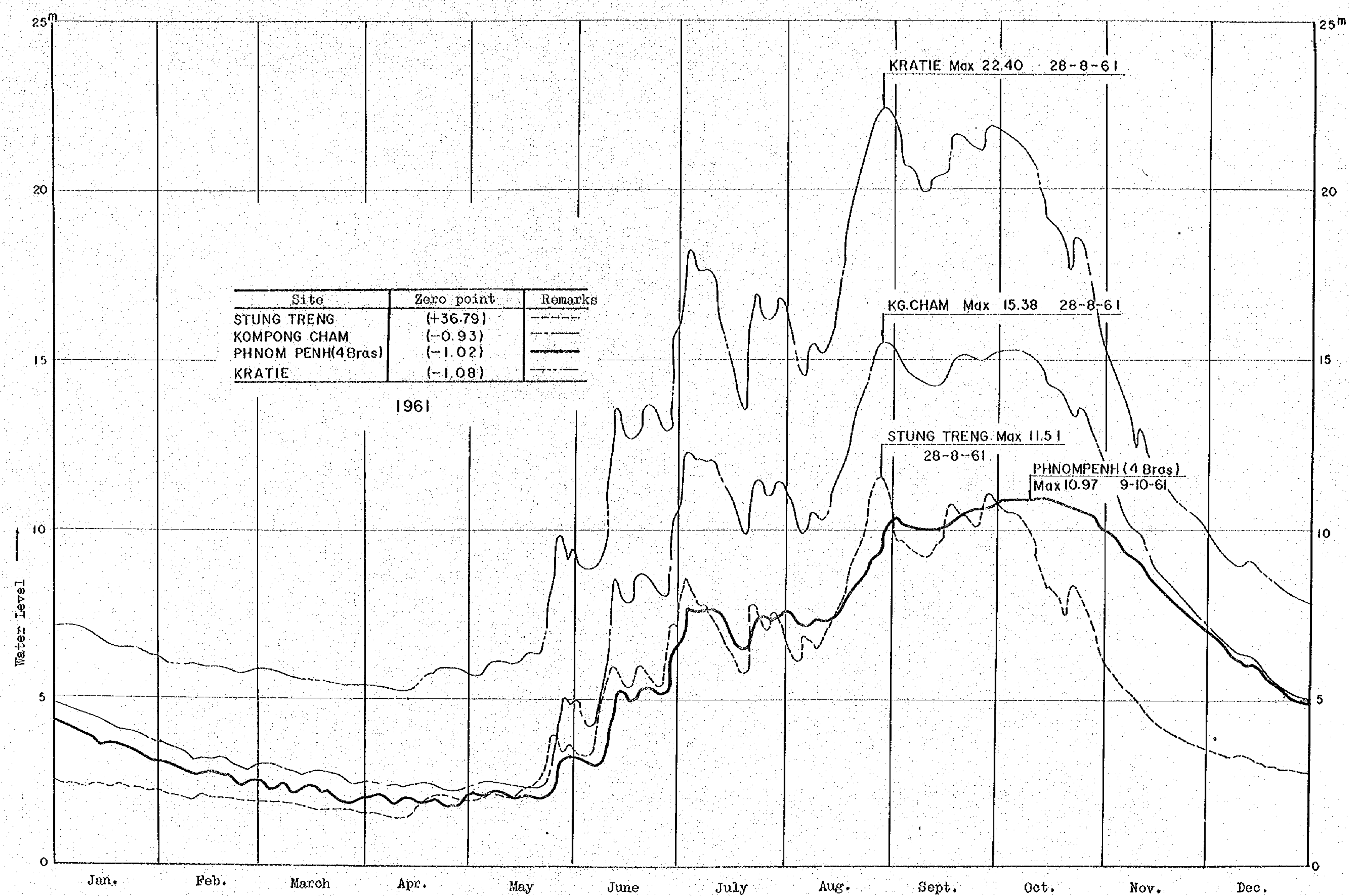
The northern mountain area of the Lower Mekong Basin mainly consists of crystalline schist series of the Archaezoic, Paleozoic and Mesozoic eras and its stratum zone has a general strike that runs from north-north-east to south-south-west. In the middle of the Lower basin, especially west of the Mekong, the vast area that mainly consists of gently rolling Mesozoic sand-stone regions spreads and forms the Korat Plateau. This Mesozoic formation has few mining resources, but has minor rock salt and gypsam deposits. In the Annam Range basalt and andesite are exposed in places, penetrating Mesozoic formation, and it is said that a part of

Fig. 2-5 Hydrograph of the Mekong Main Stream (1961)



Source: T. Takenouchi, A Hydrologic Study of the Mekong Basin, Symposium Series III, p. 58, 1966. The Center for Southeast Asian Studies, Kyoto University.

Fig. 2-6 Graphs of Flood of the Mekong River



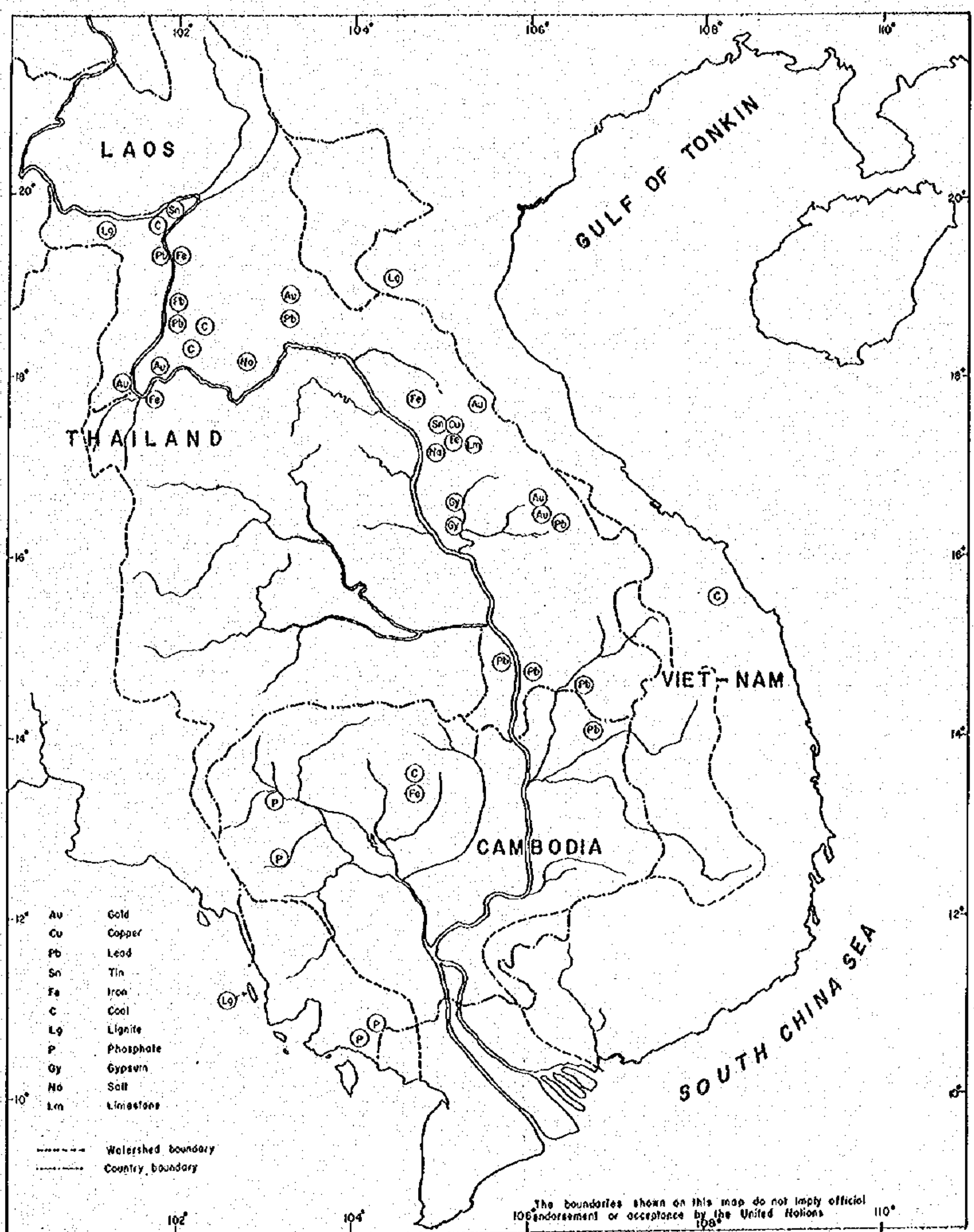
Source: From "The First Interim Report of Full-Scale Survey at Sambor of the Mekong" this area contains coal and nonferrous metal deposits. In the lowest part of the basin are vast areas of diluvium and alluvium formations, including Grand Lac and continuing to the Mekong Delta.

Mineral Resources

This basin has not been surveyed well for mineral resources, because of transportation difficulties, and so only an outline of mineral resources that relate to the development plan of the main stream of the Mekong in the lower basin can be referred to here. In northern Laos and in the Annam Range, gold, silver, copper, tin, lead, and zinc are known to be deposited, and in the northeastern area of Thailand near the Laotian border iron deposits, estimated to be of several ten-million tons were discovered. There are anthracite deposits in southern Laos. In the Korat Plateau sandstone layers hold between them salt-containing shale and it is known that sometimes this sandstone forms a salt-rock layer. In the eastern part of Savannakhet and in the Korat Plateau gypsam layers can be found. In Cambodia, magnetite and hematite deposits have been discovered around Grand Lac, but an attempt at development failed because of the difficulty in transportation. However there is a thin layer of coal near Phnom Ker which is worth extracting for use in iron manufacture.

In the Battambang and Kampat districts there is phosphate, which is a raw material for fertilizer. It is reported that there are lead, zinc and copper deposits in the Kompong Cham district, and that gold, lead, copper, and jewels such as sapphire and zircon can be found in the Stung Treng district. Also there is reportedly some sign of oil around Grand Lac and deposits of gypsam around the border between Cambodia and South Viet-Nam hopefully will be effective as raw materials for cement and carbide industries. (Refer to Fig. 2-7)

Fig. 2-7 **Map showing Mineral Deposits in the Lower Mekong Basin**



Source: Development of Water Resources in the Lower Mekong Basin, 1957, U. N.

Agricultural and Forestry Resources

The mountainous area in northern Laos has adequate rainfall, rich soil, and, as a whole, enormous agricultural and forestry resources. The widespread Mesozoic formation area from the Korat Plateau to the western slope of the Annam Range has poor soil and is not highly productive for either agriculture or forestry due to extreme climatic conditions that vary between rainy and dry seasons. Difficulties in transportation completely prevent these forests from large-scale development, and they are used only for timber and fuel such as charcoal.

The basaltic areas that are widely scattered in the Annam Range in southern Laos and in the eastern Cambodian Plain (Mekong Plain) are well weathered into rich Terre Rouge (Laterite) which is adequate for planting. However, parts of the mountainous area have sparse vegetation and poor soil shifting cultivation, but productivity can be slightly raised by rotation planting. The plain spreading from Grand Lac and the alluvium in the delta are rich formlands, fertilized naturally by floods, and they form the major rice crop area in Asia. On the other hand, around the estuary of the river in the delta, insufficient drainage accelerates accumulation of salinity at places, causing salt damage to crops. This kind of damage is expected to decrease remarkably by carrying out the drainage projects of the general development plan of the Mekong.

2.3 A SOCIO-ECONOMIC OUTLINE

For convenience in discussing development, the Mekong basin is devided into two parts, the upper basin and the lower basin. The ratio of the areas of these two basins is 1 to 3, the waterway length ratio is 1 to 1.3, and most of the people live in the lower basin.

The population of the Lower Mekong Basin is approximately 24,000,000 and the mean population density is less than 40 persons per square kilometre, but the closer the area is to the estuary of the river, the greater the density is. The population density in 1955 in riparian countries (taken from 'Statistical Yearbook 1966, the United Nations') is shown in Tab. 2-1.

Table 2-1 Population, Country, and Population Density In Riparian Countries

Name of Country	Estimated Population (thousand)	Area of Country (km^2)	Population Density (Persons per square Kilometre)
Laos	2,000	236,800	8
Cambodia	6,115	181,035	34
Rep.of Viet-Nam	16,124	170,806	94
Thailand	30,591	514,000	60

In terms of general economic conditions, various situations exist in the Lower Mekong Basin. In Laos the major export resources are forestry and tin. In Cambodia, rice, maize, fish, and rubber are the major products as well as important exports. The Mekong Delta in South Viet-Nam was once called the granary of Asia and produced and exported great quantities of rice, however at present, the political situation is so unstable which also causes come denundation in paddy fields, that production has decreased and food has to be imported. South Viet-Nam also produces large amounts of rubber, but its production is decreasing every year. As for manufacturing in Cambodia mainly tobacco, ice, alcohol and salt are produced and other products are negligible. In the Saigon-Cholon district of South Viet-Nam, textiles, matches, tobacco, salt, soft drinks, beer, ice, and a few more articles are produced. The major agricultural and industrial products of 1965 are shown in Tab. 2-2, based on the 'Statistical Yearbook 1966, United Nations.'

Table 2-2 Major Agricultural and Industrial Products In the Riparian Countries (1965)

Unit: 1,000 tons

Name of Country	Rice	Maize	Rubber	Tin Concentrates	Salt
Laos	740	19#		0.49	
Cambodia	2,376	210	48.9		
Rep.of Viet-Nam	4,822	44	61.0		123
Thailand	9,588	1,000	216.5	19.353	188

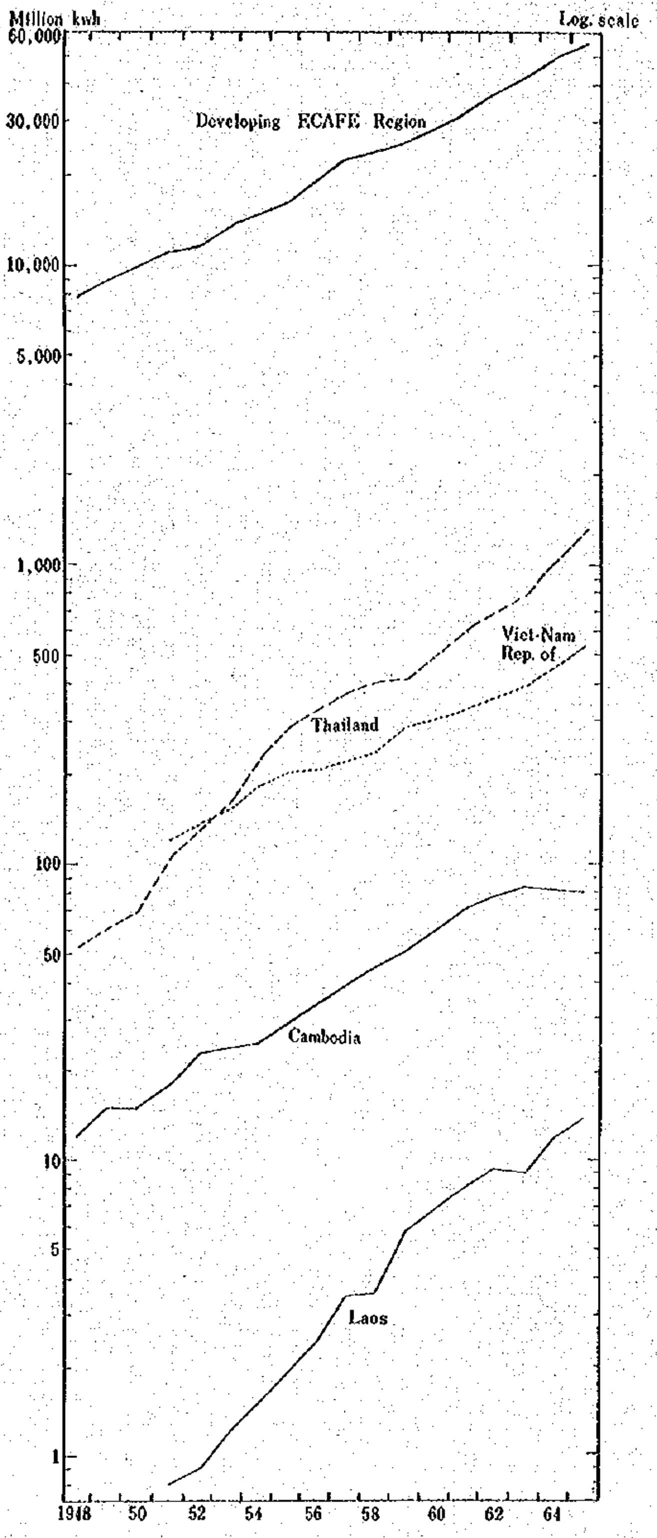
#Revised by 'Economic Survey and the Far East 1965' issued by the ECAFE.

Very little energy is generated in the four rigarian countries and the major part of it is used for domestic purposes. The installed capacity of power generation in Cambodia at the end of 1963 was 30,873 kilowatts and generated energy during this year was 86,764 megawatt-hours. Average rates of generation increase in the past 10 years are 10.9 per cent and 13.8 per cent, respectively. In South Viet-Nam at the end of 1963 the totals are 203,202 kilowatt and 408,877 megawatt-hours, and the average rates of increase in the past 7 years are 15.3 per cent and 9.9 per cent respectively. The ratio of domestic demand for electric power to general industrial demand is 75 to 25 in Cambodia, where the average rates of increase in the past 7 years were 15 per cent and 12.7 per cent, respectively; while in South Viet-Nam it is 60 to 40 and the average rates of increase in the last 6 years were 7.2 per cent and 12.6 per cent, respectively. According to the 'Statistical Yearbook 1966 of United Nations,' in 1965, it was 15,600 megawatt-hours in Laos, 81,000 megawatt-hours in Cambodia, 522,000 megawatt-hours in South Viet-Nam and 1,406,000 megawatt-hours in Thainland. And energy consumption per capita is 7.8 kilowatt-hours in Laos, 13.2 kilowatt-hours in South Viet-Nam, and 45.9 kilowatt-hours in Thailand. In the 10 year period from 1955 to 1965, it increased 6.3 times in Laos, 1.9 times in Cambodia, 2 times in South Viet-Nam, and 3.5 times in Thailand; meanwhile, the average rate of increase was 19.7 per cent in Laos, 6.9 per cent in Cambodia, 6.8 per cent in South Viet-Nam and 11.2 per cent in Thainland. Fig. 2-8 shows increase in generated energy in the four riparian countries in a recent period of 18 years.

Laos exports tin and forestry products, but imports of rice and other consumers' items make for an unfavorable balance of trade. Cambodia imports industrial products and consumer goods, and exports rice and maize as major exports, thus managing to maintain a favorable balance. South Viet-Nam used to export large quantities of surplus rice but political instability has gradually reduced production and the country is at present importing food. Thailand also has an unfavorable balance of trade and exports in spite of a large quantities of maize and others Japan or other countries and a little rice to Laos in the northeastern areas.

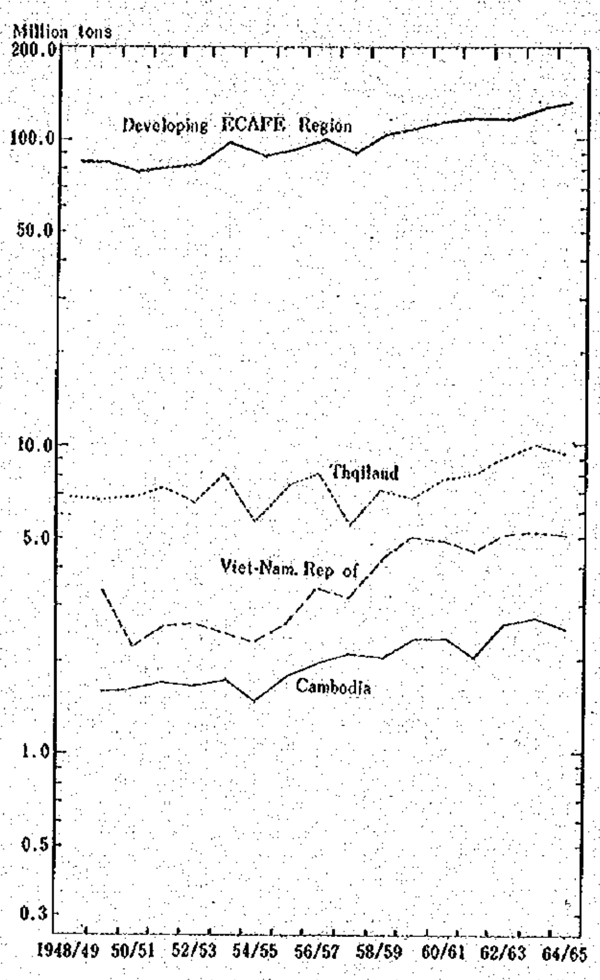
The rate of population growth in the Lower Mekong Basin is nearly 3 per cent in a year, however rice production in the riparian countries is decreasing. It couses a rice export decrease every year and countermeasures to increase rice production have to be established immediately for the riparian countries. Tab. 2-3 shows rice production in riparian countries from 1957 to 1965. (Statistical Yearbook of United Nations).

Fig. 2 − 8 Production of Electricity. 1948−1965



Source: Economic Survey of Asia and Far East 1965. United Nations

Fig. 2 − 9 Production of Rice (Paddy). 1948/49−1964/65



Source: Economic Survey of Asia and Far East 1965. United Nations

Table 2-3 Rice Production in Riparian Countries along the Mekong River

(Unhulled or cleaned rice)

Unit: 1,000 tons

	1948 -52	1957	1958	1959	1960	1961	1962	1963	1964	*1965
Cambodia	[1] 1,633	2,123	2,083	2,335	2,383	2,039	2,622	2,760	2,500	2,376
Laos	[1] 540	* 499	* 522	* 469	500	540	510	520	735	740
Thailand	6,846	5,570	7,053	6,770	7,834	8,177	9,279	10,168	9,640	9,588
Rep. of Viet-Nam	[2] 2,469	3,192	4,235	5,092	4,955	4,607	5,205	5,327	5,185	4,822

Note: 1 Mean value for 4 years

2 Mean value for 3 years

* tentative figure

The riparian countries trade mainly with France, the United States, Japan, and those countries of the ECAFE region which use the pound as a medium of exchange. Their balance of trade is unfavorable, with the single exception of Cambodia, and the situation is especially unfavorable for Laos and South Viet-Nam. According to the Statistical Yearbook of United Nations 1966, Table 2-4 shows the balance of trade for each country between 1957 and 1965.

Table 2-4 Balance of Trade in Riparian Countries

(Unit: Million dollars)

Nation / System / Import, Export	Cambodia Special Trade Import (c.i.f.)	Cambodia Special Trade Export (f.o.b.)	Laos Special Trade Import (c.i.f.)	Laos Special Trade Export (f.o.b.)	Thailand General Trade Import (c.i.f.)	Thailand General Trade Export (f.o.b.)	Rep.of Viet-Nam Special Trade Import (c.i.f.)	Rep.of Viet-Nam Special Trade Export (f.o.b.)
Year								
1957	58	52	42	1	407	365	289	81
1958	76	53	26	1	393	309	232	55
1959	70	60	13	1	426	359	225	75
1960	95	70	12	1	453	408	240	86
1961	97	63	17	1	485	477	255	71
1962	102	54	24	1	541	462	264	57
1963	107	89	29	1	610	466	286	77
1964	82	96	26	1	667	599	298	48
1965	103	105	23	1	726	627	357	36

For reference, national income and gross national product (GNP) in each country is shown in Table 2-5.

Table 2-5 National Income and Gross National Product (GNP) in Riparian Countries

(Unit: Million dollars)

	Cambodia National income	Cambodia GNP	Rep.of Viet-Nam National income	Rep.of Viet-Nam GNP	Thailand National income	Thailand GNP
1960		626	1,138	1,357	2,350	2,680
1961		629	1,154	1,402	2,510	2,870
1962		661	1,293	1,554	2,720	3,120
1963		730	1,385	1,671	2,830	3,310
1964			1,560	1,885	3,000	3,580

Source: from Economic Survey of Asia and the Far East 1965, ECAFE

Note: Gross national product is based on the market prices. Tables of each year's data are based on the selling rate at the end of 1965.

Recent fluctuation of the living-cost index(1958=100) in the four riparian countries and the rate of increase between 1964 and 1965 compared with 1963 is 8 per cent in Cambodia and 19 per cent in Rep. of Viet-Nam. However the figure is remarkably high for Laos, and is rather static for Thailand.

Table 2-6 Living-Cost Index (1958=100)

	59	60	61	62	63	64	65
Laos (Vientiane)	106	109	104	134	256	529	572
Cambodia (Pnom Penh)	104	112	120	123	130	133	140
Rep. of Viet-Nam (Saigon)	102	101	108	111	119	125	142
Thailand (Bangkok)		96	98	100	101	104	104

Source: Economic Survey of Asia and the Far East 1965, ECAFE

CHAPTER 3 HISTORY OF THE INVESTIGATION

3.1 BACKGROUND OF THE INVESTIGATION OF WATER RESOURCE DEVELOPMENT IN THE LOWER MEKONG BASIN

At the 7th plenary session in 1951 the ECAFE (Economic Commission for Asia and the Far East) decided to add investigation of technical problems about flood control of international rivers to the working plan of its Bureau of Flood Control. The Bureau proposed a plan which was approved to study the Lower Mekong Basin, and an investigation of the basin was undertaken by its officials. Their results were revealed through a report submitted to the commission entitled 'The Problems of Flood Control and Development of Water Resources in the International River Mekong.' Later the field survey had become inactive — disturbed by political affaris — until the Geneva Agreement was codified in July, 1954. In 1955, urged by the four reparian countries concerned, and the ICA (International Cooperation Administration) of the United States made a reconnaissance studies concerned and submitted a report entitled 'Reconnaissance Report, Lower Mekong Basin' to ECAFE. Further, in 1956, an advisory survey group of the ECAFE made a field survey, and 'Development of Water Resources in the Lower Mekong Basin,' and the five projects, PA MONG, KHEMARAT, KHONE FALLS, SAMBOR and TONLÉ SAP, were admitted as projects for the main stream.

Following the recommendation of the 13th session of the ECAFE in March, 1957, the governments of the four countries, Cambodia, Laos, Thailand and Viet-Nam, established a Committee for Cordination of Investigation of the Lower Mekong Basin (abbreviated as the Mekong Committee in this report) in October, 1957, and started to promote, adjust, supervise, and integrate planning and investigation of the water resource development project in the Lower Mekong Basin. And also in 1957, in response to a request made by the Mekong Committee, an investigation group headed by Lieutenant-General R.A. Wheeler and organized by the United Nations was sent, and a five year plan of investigation was recommended in a report entitled 'Programme of Studies and Investigations for Comprehensive Development of the Lower Mekong Basin, sometimes called the Wheeler Report.

The first five-year plan covering the period from 1959 to 1963 was adopted by the committee in January, 1958, on the basis of the Wheeler Report, and several investigations ensued. Between 1959 and 1960 comprehensive reconnaissance survey on the major tributaries of the Lower Mekong Basin was conducted by the Jananese government, as a result of which a new idea was suggested with regard to the development of tributaries. In 1961 another investigation of economic and social problems was completed by the group headed by Professor Gillert F. White of Chicago University and aided by Ford Foundation funds. This study led to a new stage of investigation of the development of water resources in the Lower Mekong Basin.

During the 20th plenary session (1963), the second five-year plan 'Provisional Work Programme and Financial Plan for 1964-68,' was adopted, following the first five-year plan. The new five-year plan recommends that a report on the master plan be finished with regard to the PA MONG SAMBOR and TONLÉ SAP projects of the five projects mentioned above, and that bases for calculation of construction funds be completed. Further, in the 29th plenary session in August, 1965, a ten-year programme for the general development of the Lower Mekong Basin in the decade from 1965 to 1975 was revealed by the Committee.

3.2 BACKGROUND OF THE INVESTIGATION AT SAMBOR

It was in the special session of the Mekong Committee held in Bangkok in December, 1958, that Japan, with the aid of countries such as the United States, France, and Australia indicated, in response to the Mekong Committee, intent to participate in the development project of the Lower Mekong Basin. Thus Japanese government undertook a survey of the major tributaries in the two years starting from 1959. As a result, the 'Comprehensive Report of Reconnaissance on the Major Tributaries of the Mekong' was sent to the Committee in September, 1961. This report has been a guide for the new development plan for the Lower Mekong Basin. The Mekong Committee has long considered a plan for the main stream, aiming at multi-purpose development, namely improvement of navigation up to Vientiane, the capital city of Laos, flood control in the Lower Mekong Basin, irrigation, and water-power generation. As for the Sambor Project, many tasks such as a geological survey by Australia, a survey using aerial photographs by Canada, and a hydrological survey by the United States have already been carried out, but at the 14th plenary session of ECAFE held in Bangkok in May, 1961, the Japanese government, in response to a request made by the Committee, expressed a willingness to make and received approval for a preparatory survey of the Sambor. At the outset, an economic and technical discussion took place with regard to the preparatory survey about water-power generation, irrigation, navigation, and industrial development. This led to decisions as to survey outlines, and a survey group was organized under the chairmanship of Mr. Goro Inoue of Chubudenryoku Co., Ltd. (an electric generation company in Japan). This group made three surveys in October and November, 1961; between January and March, 1962; and in September, 1962; and 'A Report on Preparatory Survey at Sambor' was submitted to the Mekong Committee by the Japanese government.

Based on this report, the Mekong Committee again asked the cooperation of the Japanese government, which decided to continue to make surveys in details from 1963 on. For this project Mr. Motonaga Ohto, a director of Overseas Technical Cooperation Agency (OTCA), was selected as the leader, and, assisted by private organizations, the Japanese government made two surveys pertaining to power generation (including dams and power transmission lines), navigation, agriculture and power markets.

The first detail survey was carried out from January to March, 1963, and the second one from October, 1963, to the following January. The results of these surveys were revealed in two interim reports, the first of which was submitted to the Mekong Committee in November, 1963, and the second in November, 1964. The third detail survey was conducted both in the rainy season from September to October, 1964, and in the dry season from November, 1964, to February, 1965, under the leadership of Dr. Koichi Aki, Advisor of the Overseas Technical Cooperation Agency. This third detail survey covered final field survey — excluding agriculture — and its results were submitted to the Mekong Committee in September, 1965, as an interim report. In the agricultural field, a survey during the rainy season was done from August to September in 1965. A fourth survey team conducted investigations between December, 1966, and March, 1967, completing the final field survey and keeping pace with the map work of the anticipated agricultural area by the Cambodian government. A complementary survey, concerning utilization of electricity, was made by sending experts to the area between February and March, 1967. In July of that year, each report in the respective fields was finalized after arranging, analyzing, and discussing the data collected by the field surveys of the preceding four years. Based on those reports and the data contained therein this report was integrated by the staff headed by Dr. Aki.

CHAPTER 4. PLAN OF DEVELOPMENT

4.1 NECESSITY FOR THE SAMBOR PROJECT AS AN INTRODUCTION

As one of the factors of general development of the Mekong, the Sambor Project has to be effectively carried out for the purpose of harmonized returns to every concerned countries in the Basin.

Sambor is located so close to the developed area that the Project could be easily started, and the basic purpose of development is to dam up water of the Sambor Rapids which are primary difficulties for navigation between the estuary of the river and the inland, and this is the common purpose of the people within the area. Moreover, using abundant water discharge, this Project is to supply cheap energy and dammed water of reservoirs has an advantage for irrigation on arable land in the lower basin. On the other hand, utilization of a part of generated energy for both irrigation and drainage could be the trigger of development of the Mekong Delta that has good possibility. In the future Sambor will be naturally affected by development of places in the upper basin like Pa Mong that have great reservoirs, and capacity of energy generation and irrigation at Sambor will be increased along with expected increase in a length of navigation route.

In a period when Sambor is being developed, the Project has a minor disadvantage of some preceding investment on generating facilities, preparing for the development of reservoirs in the upper basin, but in the future generating capacity is to be increased twice as big as the original installation so that it provides with sufficient and economical energy. Moreover, as for original generating installation, it can possibly generate rather cheap energy for power oriented industries and is expected to promote development in this area. It also means that it prompts a motive for industrialization in the underdeveloped hinterland like the Lower Mekong Basin and raises the standard of living, and that it is especially significant in contributing to the development of national economy.

4.2 THE SAMBOR PROJECT

4.2.1 The Outline and Function of the Project

Sambor Project is supposed to be constructed in eastern Cambodia, at the northern point which is 560 kilometres upper from the estuary of the Mekong. And the Project is scheduled to be the first part of the master plan of the main stream of the Mekong, and has been surveyed for development as well as the Pa Mong Project.

The purpose of Sambor Project, as one of the component parts of the master plan of the Mekong, in relation to each of the planned projects in the upper stream, aims at a part of strong effects such as improvements of inland navigation, promotion of electric generation enterprises, stabilization and expansion of agricultural production and conversion of crops, increase of fishery and forestry production, decrease of damage of flood, and so on. As for Sambor Project alone, major effect of its development is to match general demand for energy by its generating capacity and to promote new demand by large-scale industries, and further to improve navigation route up to Stung Treng and to stabilize and expand agricultural production by irrigation in the down stream area of Sambor dam. However function of reservoirs themselves to control the flood can not be expected.

Following the purpose stated above, backbone of Sambor Project is supposed to be the construction of Sambor Dam, whose reservoir has total storage capacity of $10,000 \times 10^6$ cubic metres. The reservoir is utilized for many purposes such as navigation and irrigation, besides electric generation. When its effective depth of water is 2 metres, storage capacity becomes 2,050x10^6 cubic metres. At present, as for power, navigation and irrigation that are purposes of Sambor Project, following results are possibly expected by using the Sambor Reservoir.

Power

Energy of 7,000x10^6 kilowatt-hours is generated with output capacity of 875 megawatts by 7 generators whose unit capacity is 125 megawatts, and it covers domestic power of the area. Moreover, developing power oriented industries, for example, aluminum and/or vinyl chloride industry, it makes possible to produce 125,000 tones of aluminum a year and/or 125,000 tons of vinyl chloride a year. Furthermore, in the future when scheduled construction of a series of reservoirs in the upper stream is completed, output capacity of Sambor generating site will possibly increase to 2,400 megawatts.

Navigation

Sambor Reservoir makes it possible to extend waterway for navigation by some 130 kilometres up to Stung Treng, the end of the back water. Also it is possible in an original plan to transfer 120,000 tons of goods and 200,000 people in a year to both directions of the dam by constructing 3 inclines at Sambor Dam. In the future in the case of completion of a series of reservoirs in the upper stream, it comes to have strong possibility to become a major route for inland navigation, connecting both sides of the dam by locks and canal and increasing capacity of transportation.

Irrigation

An area of 34,000 hectares that spreads over both sides of the Mekong, in the lower stream from Sambor Dam site including both developed and undeveloped lands, is selected as an object area for agricultural development, where irrigation, drainage, improvements on crops and introduction of agricultural techniques will increase the planting area, rate of planting and yield per unit area. Increase of yield per unit area is estimated to increase three times as for rice and maize, two times on the average as for other dry field crops.

As a result, annual rice yield is expected to increase from 5,700 tons to 86,200 tons, maize from 10,300 to 72,600 tons, and other dry field crops from 2,270 to 16,100 tons.

4.2.2 Cost of Construction

Total cost of construction for the first section of the plan of the Sambor Project is estimated 351,260,000 U.S. dollars. Details are shown in Table 4-1.

Table 4-1 Summery of Estimated Construction Cost

(Unit: 1,000 U.S. Dollars)

	Foreign Currency	Local Currency	Total
Power (Reservoir, Dam, Power Plant, Transmission line and Substation)	236,600	81,500	318,100
Irrigation (Reclamation, Canels, Drainage, Pumping Station, Pondage and Calmatage)	16,770	12,530	29,300
Navigation (Incline facilities and Dredging)	2,720	1,140	3,860
Total	256,090	95,170	351,260

The cost of construction does not include interest during a period of construction and is calculated based on commodity prices in January in 1967, considering natural conditions that may affect the construction, local public circumstances, the scale of construction, present standard of techniques, and so on. However it does not include following costs:

1) Wages with regard to overall project

2) Wages payed to the officials of the Cambodian government

3) Taxes and other public charges such as the tariff, the enterprise tax and the sales tax

4) Costs supplies by the Cambodian government and the local autonomies

Each cost of construction is primary calculated by yen and then converted to U.S. dollars under the rate that one U.S. dollar is 360 yen. As for local currency, actual rate is that one U.S. dollar is 60 riels.

4.3 PROGRAMME OF DEVELOPMENT

91 per cent of constructions for Sambor Project is occupied for power, and 8 per cent and one per cent for irrigation and navigation respectively. As for construction programme of power, in the first stage 5 turbine generator equipments are to be installed and later in the second stage the 2 more equipments are planned to be added. The first stage requires about 8 years and the second stage is divided into two parts, requiring 4 years altogether.

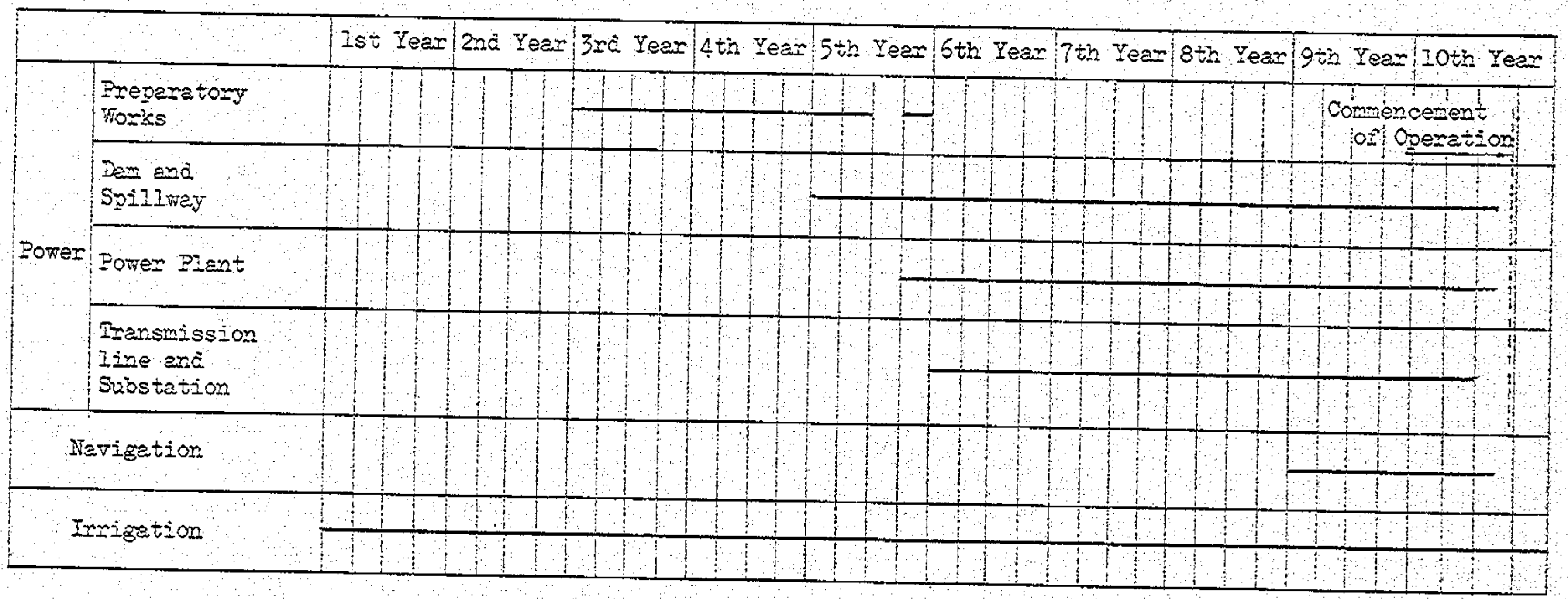
As for navigation, goods and passengers will continue to increase until they reach to the estimated amount 20 years after completion of the Sambor Dam. The inclines are to be constructed, catching up with the growing traffic, in the first period (the first and the second year), in the second period (the thirteenth year) and in the third period (the eighteenth year). One incline is supposed to be constructed in each period.

In the project of the development of agriculture, the benefited area is divided into 12 districts from the view of farm management and water use. The construction programme is to be carried out in 17 districts, considering the kind of work and the time to start it. The period of each construction is two years, and, taking the construction of the Sambor Dam into account, the total period is decided as 10 years. The Sambor area consists of 12 districts of them and before the completion of the project in the whole area, the effects of construction will gradually come out in each district where the period of construction is short. No benefit is expected during construction but it is to increase straight to the full benefit in 10 years after the completion, namely from the third year to the thirteenth year, and two pilot farms will accelerate the increasing effects of development.

The construction programme of the Sambor Project is mainly based on the construction of dams and other programmes are decided according to this programme. The navigation facilities are scheduled to be finished in the last stage, at the same time when dams are completed.

As for irrigation, since the water resources are not related to the dam site except the part near the Sambor Dam Reservoir, the construction works are started early so that it is finished before the whole construction is completed and that irrigation facilities can be used earlier. Moreover, as for the agricultural development, the workings could be started independently, preceding the construction of the Sambor Dam, if it is needed by the Cambodian government from the agricultural point of view. The construction programme of the Sambor Project is shown in Table 4-2.

Table 4-2 Construction Programme of the Sambor Project



CHAPTER 5. WATER RESOURCES

5.1 CLIMATE

The lower basin of the Mekong River is located in tropical humid zone where the climate is divided clearly into a wet and a dry season. The former continues from May to October, when the south-west monsoon blows, and the latter lasts from November to April, when the north-east monsoon blows. Rainfall is abundant on south-western slopes of Annam Cordillera against which the south-western monsoon blows, but fairly less in rain shadows of the Cordillera.

Rainfalls in the Lower Mekong Basin are heavily concentrated in small area and in short hours only a few thunder-storms occur. Both of which are caused by the terrain and the intertropical convergence zone, because air mass which bring rainfall is very hot and highly humid, and unstable in physical character. The flood peak which occurs from August to September every year in the lower Mekong is considered to be caused by the rainfalls stated above.

Precipitation There are many squall-like rainfalls in the region which are different from each other quantitatively in time and locality. According to precipitation records, mean annual rainfalls at Kratié and Stung Treng are 1,200 and 1,600 milimetres respectively and are concentrated in the period from May to November. (see Fig. 5-1)

Rainfall is the main resource for irrigation water in the Lower Mekong Basin. Therefore, the south-western monsoon have the most important influence on agriculture in the riparian countries. The term and rainfall of the wet season, however, vary considerably from each year.

Temperature and humidity Temperature in Cambodia is generally the highest in April and the lowest in the months from November to January, but its range is from 4 to 6°C on an average. The mean temperature shows about

27°C at Kratié. Pnom Penh recorded the highest temperature of 40.5°C in April of 1926 and the lowest 13.3°C in January of 1955. (see Fig. 5-2)

Relative humidity which changes from 60 to 90 per cent, is considerably high around the year.

Evaporation Evaporation is the lowest toward April just prior to a wet season and the highest toward August. There is no remarkable difference of monthly mean relative evaporation between the wet and the dry seasons as well as in locality. The yearly average value is below 6 milimetres per day. Evaporation from the surface of the reservoir will be stated below.

Wind While the south-western monsoon carries humid air from the south sea, the north-eastern monsoon brings dry air from the continent. Wind velocity is approximately 1.5 to 2.5 metres per second, which is almost constant throughout the year except the time between January and April, when it is somewhat stiffer. When a typhoon rages or a thunder-storm breaks, the maximum wind velocity is as high as 25 to 40 metres per second. Fig. 5-3 shows daily wind movement at Stung Treng from 1961 to 1965, which is higher in a dry season and diminishes gradually in a wet season.

Thunder-storm According to observations of meteorological agencies, thunder-storms occur 90 times every year on the average at Saigon and from 140 to 180 times at Pnom Penh.

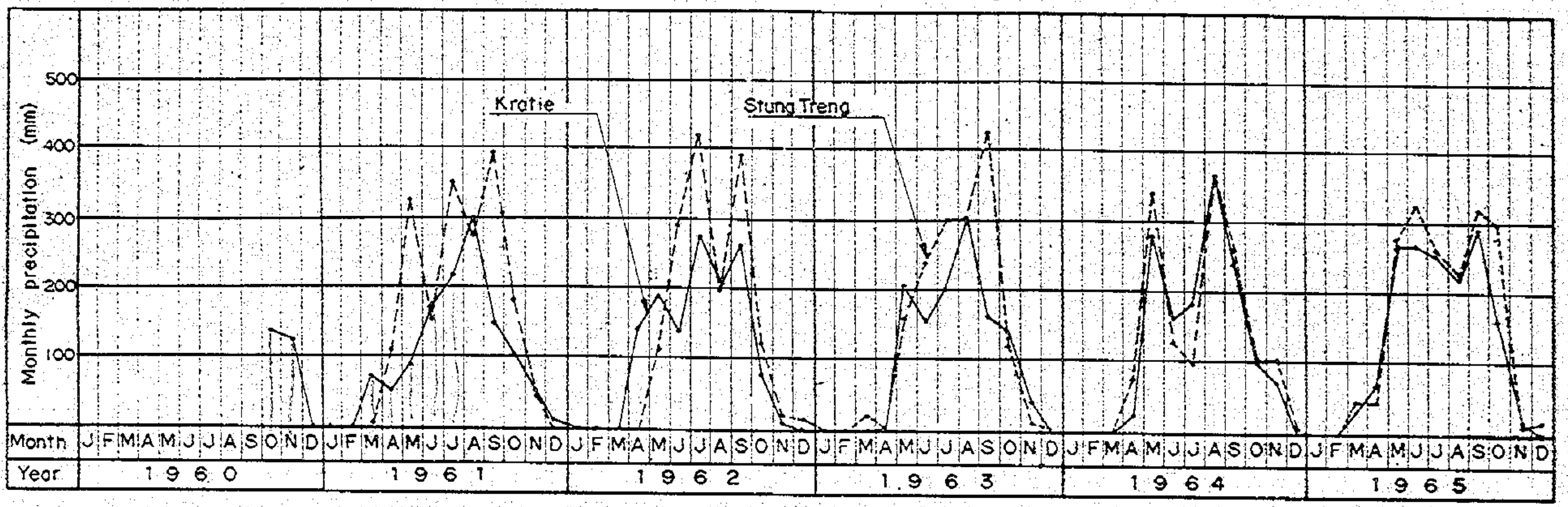
Sunlight Sunshine hours on the average are about 9 hours a day during dry seasons and about 5 hours during wet seasons in Cambodia.

5.2 SURFACE WATER

5.2.1 Surface Water

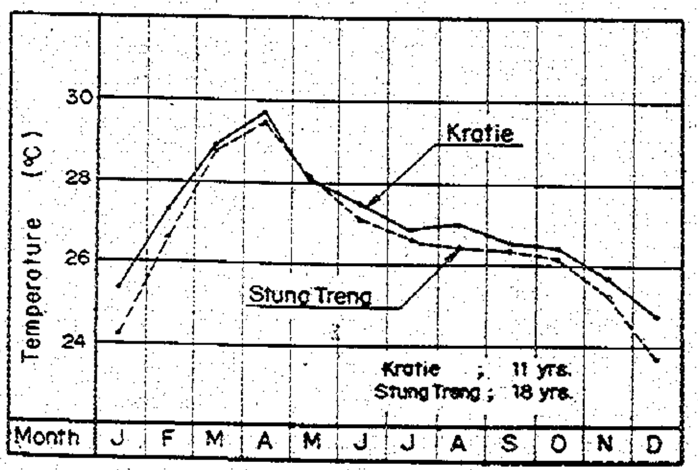
The total catchment area of the Mekong River, up the Guaging station at Kratié, which lies 15 kilometres below the Sambor dam site, is 646,000 square kilometres. It occupies 81 per cent of the whole drainage area of the river in Cambodia. At Stung Treng 130 kilometres from Kratié, which is

Fig. 5-1. MONTHLY PRECIPITATION



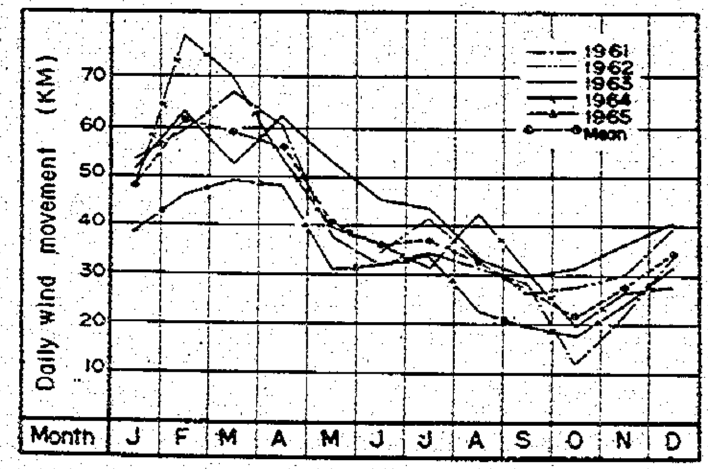
Source: Investigation data from Harza Engineering Co. (1960-1961), Mekong Committee (1962-1965)

Fig. 5-2. MONTHLY MEAN TEMPERATURE



Source: Data from Cambodian Government

Fig. 5-3. DAILY WIND MOVEMENT AT STUNG TRENG



Source: 1961, Hydrologic data Mekong River Basin Cambodia, Harza Engineering Co.
Lower Mekong Hydrologic Yearbook, 1962-1965.

up the river from Se Kong, Se San and Sre Pok, join the mainstream of the Mekong on the left bank. In close vicinity of Pnom Penh, the Capital of Cambodia, Tonle Sap joints the Mekong and just down of Pnom Penh, Tonle Bassac branches from it, both on the right bank.

Run-off of the Mekong River is dominated by rainfall in the rainy zone which is spread over from the eastern part of the Tibetan Plateau to the Indochina Peninsula. The Mekong begins to increase its run-off at the beginning of June and attains its peak from August to September. In October, the run-off begins to decrease. The minimum flow is toward April. The running water contains much of very small, floating mud in the wet season, because mountainous soil and surface soils are eroded by torrential downpours.

"Lower Mekong Basin Data (1933-1965)," edited by the Committee for Co-ordination of Investigation of the Lower Mekong Basin was employed as basic data on discharge record. The data published in April 1967 as a new edition supplemented two works issued by Harza Engineering Co. and the Mekong Committee, because of a lack in some observations. These were completed up, resting on the basis of correlation between specific run-offs at Kratié and Pakse. Table 5-1 shows monthly mean discharges, annual run-off and annual minimum and maximum discharges.

As the Mekong has its minimum run-off in April or in May, the minimum discharge year and an average discharge year can be chosen by looking at the aggregate run-off in a dry season from January to April as follows;

the primary dry year:	1933
the secondary dry year:	1953
an average year:	1956

As water level is observed every day and run-off is measured periodically at the babble gauge station at Kratié correlation between them can be measured. Meanwhile, water level at Sambor dam site is observed twice a month, with the observation hours coinciding with those at Kratié. A water

Table 5-1. DISCHARGE DATA AT KRATIE (1933 – 1965)

(Unit : cu.m/sec)

Year \ Month	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL RUN-OFF (10^6 cu.m)	ANNUAL MAX. DIS	ANNUAL MIN. DIS
1933	2,600	1,800	1,300	1,290	1,620	5,630	19,430	34,290	30,430	20,320	12,190	4,910	358,958	53,900	1,160
34	2,930	2,210	1,790	1,470	2,620	5,000	22,430	39,950	44,550	30,210	12,070	5,950	452,451	52,900	1,410
35	3,460	2,300	1,810	1,590	2,990	10,490	26,320	32,780	33,910	30,740	21,150	7,880	463,478	44,200	1,490
36	3,860	2,740	2,210	2,080	2,970	9,470	25,750	34,830	38,880	15,190	6,040	3,800	390,554	55,200	1,900
37	2,800	2,030	1,780	1,540	4,060	12,590	31,580	49,500	55,660	24,620	11,090	6,460	538,081	64,300	1,380
38	4,440	3,420	2,770	3,160	4,230	16,850	29,080	33,420	35,460	35,990	13,990	8,440	505,341	54,100	2,650
39	4,580	3,110	2,560	2,610	4,540	15,950	26,620	45,730	47,430	33,270	12,680	6,860	543,932	66,700	2,200
1940	4,020	2,980	2,350	2,180	3,150	12,520	34,750	49,930	60,260	20,830	8,230	5,120	544,895	73,600	1,950
41	3,710	2,990	2,470	2,240	3,540	13,990	27,120	44,600	39,250	31,070	17,220	7,620	517,454	60,300	2,040
42	4,180	3,050	2,270	2,280	4,090	11,670	29,180	42,170	39,820	22,020	13,400	5,860	475,455	53,100	2,100
43	3,810	2,670	2,400	2,790	3,360	14,850	24,580	35,510	44,550	26,190	12,460	5,280	470,804	54,000	2,300
44	3,820	3,020	2,320	2,070	3,460	8,150	21,520	39,150	29,070	25,070	14,150	7,300	420,989	47,600	1,990
45	4,200	3,030	2,470	2,200	4,760	17,270	28,070	30,770	43,850	19,330	10,450	6,100	454,857	48,500	2,200
46	4,010	2,680	2,090	1,890	4,550	15,390	23,400	35,990	46,530	25,900	12,290	6,160	477,190	52,400	1,620
47	3,900	3,000	2,130	2,260	6,420	11,620	32,860	37,910	45,860	23,090	10,500	5,420	488,528	48,900	1,850
48	3,670	2,700	2,090	2,180	4,520	12,820	24,490	36,870	49,620	27,220	13,110	6,810	491,248	57,100	1,820
49	4,020	2,990	2,300	2,080	3,770	4,690	13,670	34,420	43,100	30,640	16,710	8,380	440,163	48,100	1,910
1950	4,700	3,040	2,190	1,920	2,890	11,360	25,250	36,000	38,350	32,200	17,940	7,800	485,066	52,900	1,820
51	4,040	3,100	2,080	2,030	3,700	14,480	22,810	36,400	34,440	23,720	12,460	6,210	436,912	51,000	1,730
52	3,070	1,960	1,760	1,720	3,200	7,210	18,810	44,450	46,700	30,810	12,260	4,260	465,596	53,000	1,680
53	2,080	1,920	1,630	1,620	5,110	14,630	20,350	33,100	33,690	20,770	10,490	5,070	395,666	48,900	1,470
54	2,850	1,890	1,510	1,700	3,170	9,080	11,300	22,580	37,160	23,560	10,570	4,770	343,016	45,460	1,330
55	3,120	2,240	1,870	2,060	2,560	7,960	20,290	25,380	30,230	17,090	11,430	7,690	348,325	33,980	1,670
56	3,960	2,510	1,930	1,990	5,550	11,980	20,990	39,340	41,350	18,430	8,940	3,740	424,483	49,170	1,750
57	3,430	2,540	1,970	2,000	2,650	10,000	22,680	24,730	34,840	27,680	10,220	5,090	390,388	46,370	1,970
58	3,350	2,510	1,920	1,730	2,160	9,390	20,810	25,080	42,720	19,780	8,730	3,750	374,078	58,620	1,660
59	2,180	1,950	1,730	1,650	2,210	C,360	11,920	26,130	37,300	24,030	10,040	4,160	342,843	42,340	1,580
1960	2,880	2,300	1,830	1,360	1,800	6,320	13,550	39,540	36,120	28,390	11,380	5,830	400,017	53,200	1,250
61	3,280	2,390	2,000	1,970	3,940	16,180	28,200	40,040	49,790	39,370	13,270	6,450	546,481	62,400	1,680
62	4,170	3,140	2,500	2,170	3,690	14,610	25,230	37,660	36,410	24,660	11,310	5,240	451,043	50,100	2,030
63	3,180	2,370	2,030	1,760	1,850	9,760	21,990	41,600	36,660	21,750	13,660	6,720	431,472	50,840	1,600
64	3,690	2,520	1,970	1,850	4,230	9,380	19,330	27,360	37,900	31,850	15,690	7,410	430,982	56,000	1,660
65	4,000	2,890	2,240	1,980	2,620	17,900	26,700	28,600	32,500	16,200	12,500	6,040	407,000	39,800	1,920
Average Discharge	3,580	2,610	2,070	1,980	3,520	11,380	23,370	35,930	40,450	25,250	12,380	6,020	445,720		

Source:

level and discharge rating curve, therefore, is drawn from the presumed run-off at Sambor from the rating curve at Kratié. (see Fig. 5-4)

5.2.2 Ground Water

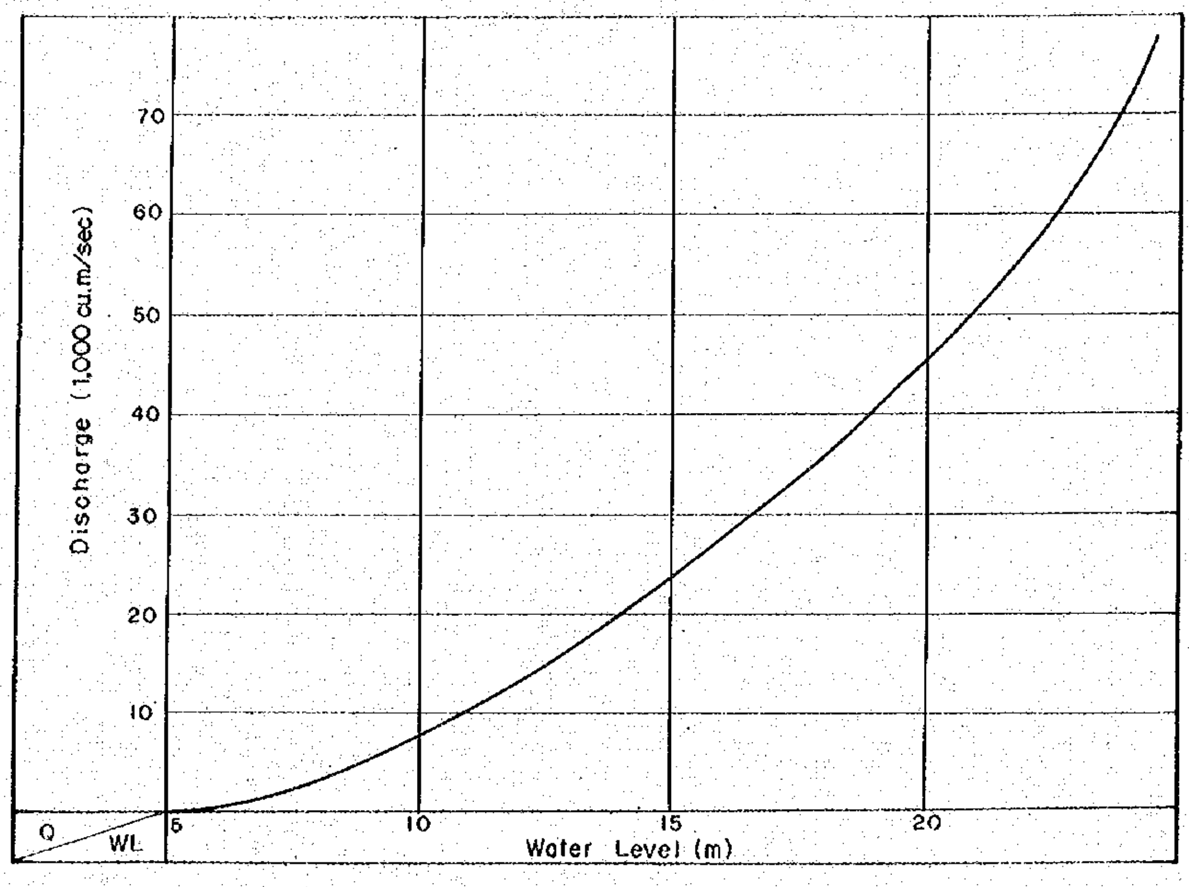
In the area along the Mekong and its tributaries many wells are dug mainly for domestic use. The surface of the water is 1.5 to 4 metres below ground in the vicinity of Kratié between December and January. The water level begins to rise toward May, and attains the maximum value between July and September. It becomes the minimum in March or April, and some wells even dry up. The farther down the river, the lower surface of the water becomes. At some wells it is 10 to 11 metres underground. It is evident that groundwater in this area is supplied by rainfall and water of the Mekong.

Yearly shifting of the groundwater table is fairly behind the water level of the Mekong in its phase of cycle and smaller in its range. At present groundwater is used only in drinking and is in general less economical as a source of irrigation than surface water of the main stream and its tributaries. But, some promising cases of such irrigation in smaller scale may be found.

5.2.3 Flood Studies

As Sambor dam will be of a combined type of earthfill and rockfill, its design flood is to be based on the probable maximum flood at Sambor site on the Mekong. In order to investigate the maximum flood, all the annual maximum discharges at Kratié were taken from the data on discharges in a 34 year period from 1933 to 1966, (see Table 5-2). Each flood discharge required was culculated corresponding to return periods by means of a statistical method called extreme value distribution of Gumbel type. The results are shown in Table 5-3.

Fig. 5-4. WATER LEVEL AND DISCHARGE RATING CURVE
AT SAMBOR SITE



Source:

Table 5-2. ANNUAL MAXIMUM DISCHARGE

(Unit: cu.m/sec)

Statistical Order	Date of Occurrence	Annual Max. Discharge	Statistical Order	Date of Occurrence	Annual Max. Discharge
1	66. 9. 12	75,600	18	50. 9. 14	52,900
2	40. 9. 2	73,600	19	46. 9. 16	52,400
3	39. 9. 3	66,700	20	51. 9. 11	51,000
4	37. 9. 12	64,300	21	63. 8. 14	50,800
5	61. 8. 27	62,400	22	62. 8. 9	50,100
6	41. 8. 18	60,300	23	56. 9. 12	49,200
7	58. 9. 13	58,600	24	47. 9. 5	48,900
8	48. 9. 7	57,100	25	53. 8. 24	48,900
9	64. 9. 27	56,000	26	45. 9. 21	48,500
10	36. 9. 8	55,200	27	49. 9. 25	48,100
11	38. 10. 2	54,100	28	44. 8. 20	47,600
12	43. 9. 25	54,000	29	57. 9. 7	46,400
13	33. 8. 7	53,900	30	54. 9. 3	45,500
14	60. 8. 27	53,200	31	35. 8. 3	44,200
15	42. 8. 6	53,100	32	59. 9. 2	42,300
16	52. 9. 8	53,000	33	65. 9. 12	39,800
17	34. 9. 22	52,900	34	55. 9. 19	34,000

Source:

Fig. 5-5. PROBABLE MAXIMUM FLOOD BY GUMBEL METHOD

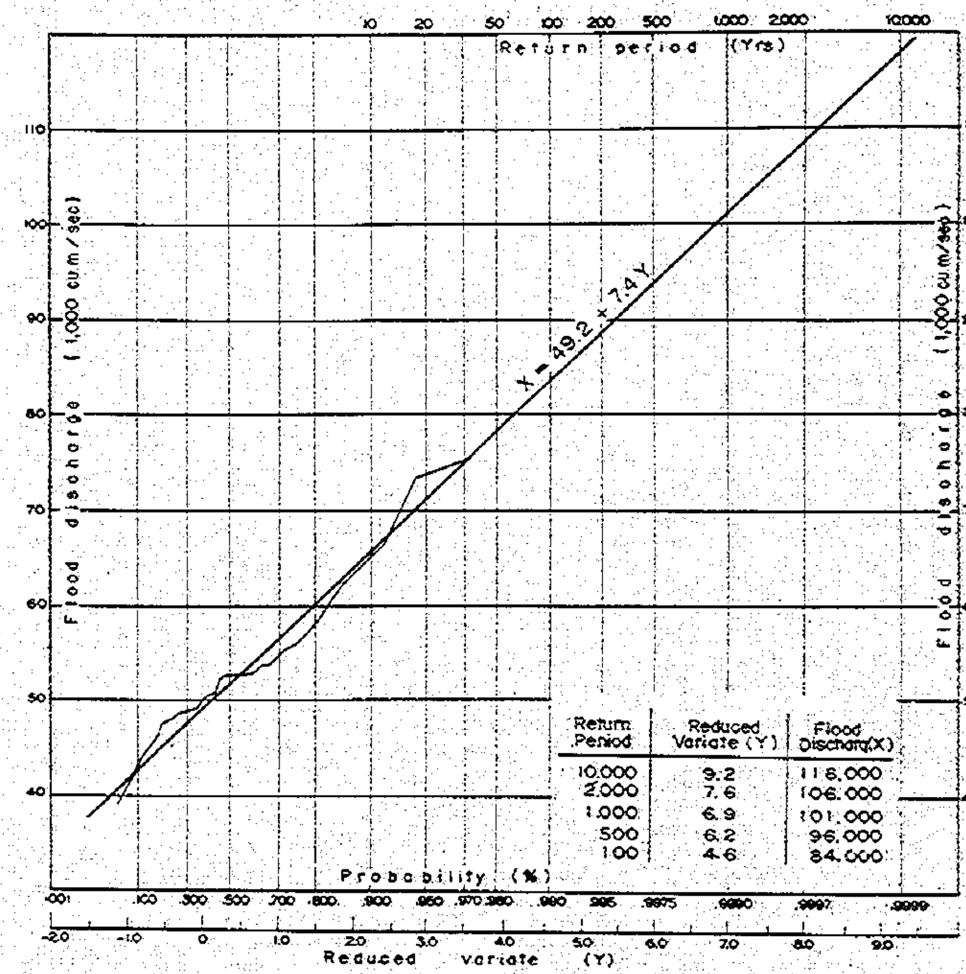


Table 5-3 Peak Flood Frequency By Gumbel Mepkod

Return Period (year)	Peak Flood
100	84,000
300	91,000
500	95,000
800	99,000
1,000	101,000
10,000	118,000

According to the calculations above mentioned, the design flood of Sambor dam is estimated to be 101,000 cubic metres per second. This is a flood discharge corresponding to a return period of 1,000 years. Spillway capacity is determined, having taken flood control capacity equivalent to 12,000 cubic metres per second into consideration, on the assumption that a flood equivalent to 101,000 cubic metres per second in its peak occur in an enlarged and similar type to the maximum flood in the past 33 years records which rose in 1966. The maximum discharge in this case is assumed to be 89,000 cubic metres per second and the maximum water level 42.0 metres above the sea level.

5.2.4 Sedimentation

Suspended load on the Mekong was surveyed by Harza Engineer Co. Ltd. in 1960 and 1961, and is been continued by the four riparian countries. The Mekong Committee will carry out a comprehensive sediment survey starting from 1967.

According to the survey of suspended load, suspension concentration depends on the run-off of the river and general observations at every station range in general between zero and several hundred particles per million cubic metres by weight. Because the number of observations are small, the suspended load at Kratié is deduced from relations of suspension concentration and discharge at Stung Treng and Pnom Penh.

The result is,

$C = 0.012\ Q,$

C is suspension concentration in particles per million cubic metres by weight and Q is run-off in cubic metres per second, each at Kratié.

With this equation employed, earth and sand which flows into Sambor dam site yearly is calculated at 163 million tons or 125 million cubic metres, reckoning bed load at 15 per cent of suspended load. If the accumulation factor is assumed as 75 per cent, 95 million cubic metres of earth and sand is heaped up in a year.

5.2.5 Evaporation from the surface of the reservoir

Evaporation has been observed and recorded at Stung Treng from 1960 by Harza Engineering Co. and the four riparian countries, and at Kratié by the Sambor Investigation Team of the Japanese Government.

In order to estimate evaporation from the surface of the reservoir, it is necessary to take into account that evaporation from the surface is substituted for evapotranspiration after the reservoir is constructed. The evaporation from the surface is calculated from monthly average evaporation at Stung Treng and an area factor, which is the quotient of surface evaporation divided by pan evaporation.

On the other hand, consumptive use of native vegetation is calculated after the Blaney-Criddle formula using the data on precipitation and temperature at Kratié. From comparison between the consumptive use of native vegetation and the evaporation calculated above, net correction factors are estimated monthly. The results are shown in Table 5-4.

5.2.6 Temperature and Quality of water

There are observation records on water temperature on the Mekong at Stung Treng in 1960 and 1961 by Harza Engineering Co. Water temperature is roughly from 25 to 30 degrees, C. throughout a year and varies in proportion

Table 5-4. Net Evaporation - Precipitation Correction Factors

Month	(1) Precipitation (mm)	(2) Temperature (°C)	(3) Consumptive Use of Native Vegetation (mm)	(4) Precipitation Consumed (mm)	Evaporation (mm)	Correction Factors (mm)
Jan.	0	25.3	103	0	134	(-) 134
Feb.	0	27.3	99	0	149	(-) 149
Mar.	22	28.9	117	22	161	(-) 139
Apr.	59	29.7	119	59	162	(-) 103
May	207	28.1	121	121	138	(-) 17
June	159	27.5	117	117	108	(+) 9
July	226	26.8	119	119	95	(+) 24
Aug.	279	27.0	117	117	81	(+) 36
Sept.	232	26.5	109	109	81	(+) 28
Oct.	120	26.4	109	90	102	(-) 12
Nov.	52	25.7	101	52	102	(-) 50
Dec.	3	24.7	101	3	114	(-) 111
Total	1,359	-	1,332	809	1,427	(-) 618

Note: (1) Monthly Average Precipitation at Kratié (1960 - 1965).

(2) Monthly Average Temperature at Kratié.

(3) Calculated by Blaney - Criddle Formula.

(4) Consumed Precipitation not to exceed 75 percent of Rainy Season Precipitation.

to temperature in general.

Water in the surveyed area is generally good in quality for irrigation and much sediment is included in turbid water during the wet season. In inundated areas, it is expected that mud carried in turbid water supplies nutrious substances, fresh earth and nitrogen accompanied by prolific algae and bacteria, which fertilize the soil. Colmatage, a technique which lets in turbid water and settles mud in a field is practised in places, and therefore, is considered suitable for conditions of the region.

Groundwater is yet unknown in quality but scarcely turbid.

5.3 WATER REQUIREMENT

5.3.1 Hidroelectric power

The Sambor dam is located at the lowest site among the projects of the basin plan in the lower Mekong along the main stream. The dam attached to the planned power station is so small in regulation capacity that the power station is similar to one of run-off river type. There will be neither power station nor irrigation which is hindered by the constructed dam and the utilized depth of reservoir water is designed so as not to interfere with irrigation and navigation of to-day.

Utilized water at the power station varies from 5,425 to 1360 cubic metres per second in proportion to the run-off of the river and hourly demand of power. The power station will be able to consume more water in the future in connection with the development of various upstream projects particularly the Pa Mong project. The operation will be in close liaison with those stations.

5.3.2 Irrigation

(a) Water for paddy field

The gross duty of water for paddy field is estimated from the data on soil percolation by soil texture obtained from the surveyed area and on evapotranspiration calculated after the Blaney-Criddle formula, estimating transmission and operation losses at 25 per cent. Its monthly figures are shown per 100 hectares of paddy field, shown in Table 5-5.

(b) Water for dry fields

To replenish the evapotranspiration suffice of crops irrigated in the field evapotranspiration is calculated from the Blaney-Criddle formula. The cropping coefficient is estimated at 0.75 for maize and feed crop, 0.65 for pulse, tobacco and sesame, and 0.55 for vegetables. Gross duty of field water is estimated by assuming transmission loss at 20 %, irrigation efficiency at 0.5 for sand, 0.7 for loam and 0.8 for clay. The monthly figures per 100 hectares of field is shown in Table 5-6.

Table 5-5. Roughly Planning Quantity of Water for Paddy Field

(m^3/sec/100 ha)

Month \ Soil Texture	Sandy Soil	Loamy Soil	Clayey Soil
Jan.	0.169	0.138	0.123
Feb.	0.179	0.148	0.133
Mar.	0.179	0.148	0.133
Apr.	0.175	0.144	0.129
May	0.158	0.127	0.111
June	0.163	0.132	0.117
July	0.148	0.117	0.101
Aug.	0.145	0.114	0.098
Sept.	0.143	0.112	0.096
Oct.	0.156	0.126	0.110
Nov.	0.165	0.134	0.118
Dec.	0.166	0.135	0.119
Mean	0.162	0.131	0.116

Table 5-6. Roughly Planning Quantity of Water for Dry Field

(m^2/sec/100 ha)

Soil Texture / Month	Sandy Soil			Loamy Soil			Clayey Soil		
	K=0.55	0.65	0.75	0.55	0.65	0.75	0.55	0.65	0.75
Jan.	0.098	0.116	0.133	0.070	0.083	0.095	0.061	0.072	0.083
Feb.	0.107	0.127	0.148	0.077	0.091	0.105	0.067	0.080	0.092
Mar.	0.107	0.127	0.148	0.077	0.091	0.105	0.067	0.080	0.092
Apr.	0.104	0.124	0.142	0.074	0.089	0.101	0.065	0.078	0.089
May	0.087	0.101	0.119	0.062	0.072	0.085	0.054	0.063	0.074
June	0.093	0.107	0.124	0.066	0.077	0.089	0.058	0.070	0.078
July	0.075	0.090	0.104	0.054	0.064	0.074	0.047	0.056	0.065
Aug.	0.072	0.087	0.098	0.052	0.062	0.070	0.045	0.054	0.062
Sept.	0.072	0.084	0.096	0.052	0.060	0.068	0.045	0.052	0.060
Oct.	0.084	0.010	0.116	0.060	0.072	0.083	0.052	0.063	0.072
Nov.	0.093	0.110	0.127	0.066	0.079	0.091	0.052	0.069	0.080
Dec.	0.096	0.113	0.130	0.068	0.081	0.093	0.060	0.071	0.081

(c) Miscellaneous use

Miscellaneous use of water is estimated at 0.1 millimetre per day and the gross duty of water is calculated at 0.002 cubic metres per 100 hectares. The assumed loss of water is calculated at 25 per cent.

(d) Seasonal and total water needs

Total duty of water is estimated at 685 million cubic metres per year, of which effective rainfall supplies 214 million cubic metres or 31 per cent. Supplemental water is 471 million cubic metres.

The cropping area of the project stands at its largest in February when the maximum duty of water occurs. The quantity of the water is estimated at 43.9 cubic metres per second. (see Table 5-7)

Table 5-7. Cropping Area and Required Max. Water Quantity

	Cropping Area (ha)	Required Max. Water Quantity cu.m/sec
paddy field	19,820	29.83
dry field	14,180	14.07
total	34,000	43.90

5.3.3 Navigation

The Mekong River is an important traffic route to and from inland areas. Although at places, sections are difficult or impossible to navigate. In a dry season, vessels of 2,000 tons sail up from the mouth of the river to Pnom Penh, while only boats of 200 tons can manage to cruise upstream from Pnom Penh to Kratié. From Kratié to Stung Treng only boats of 50 tons can go up against the stream in a wet season because of the Sambor rapids. Above Stung Treng, Khone falls obstructs even a skiff stubbornly.

The basin plan of the lower Mekong derived because of channel navigation problems below Vientiane. In order to solve those problems, which the Mekong Committee has been tackling, measures are prepared to build a series of reservoirs which submerge obstacles against navigation, the construction of several multipurpose dams for electric power, irrigation, flood control and navigation. Sambor dam is farthest downstream among them. It facilitates navigation from Kratié to Strung Treng, with lock gates or inclines installed.

The smallest of annual minimum discharges was 1,160 cubic metres per second in 1933 and the second was 1,250 cubic metres per second in 1,960. After completion of the Sambor dam, however, the controlled minimum discharge will be 1,360 cubic metres per second. This will help alleviate navigation problems below the dam.

5.3.4 Domestic, Municipal and Industrial Uses

Many wells are dug mainly for domestic use in the area along the Mekong and its tributaries. Presently it is difficult to investigate water for domestic, municipal and industrial uses, because of limited data on demands of water both at present and in the future, in relation to its quantity and location.

5.3.5 Fish and Wildlife

The mainstream of the Mekong within Cambodia is considered to be of poor feasibility in fish on account of muddy water caused by sand and mud from the upper stream and by erosion of the river banks. Many tributaries which pour into it play an important role in breeding water in the wet season, especially such large tributaries as Se San, Se Kong and Srepok which join north of Stung Treng, and inundated forests and swamps accompanying.

Fish are a main source of protein supply for inhabitants as well as fishermen in the region. Larger fishes are taken in a seine, a drift net, while smaller fishes are caught with a fish trap or weir near to the outlets of the tributaries. Statistics from the office of fishery insepctors at Kompong Cham and Kratié of hauls on the main stream of the Mekong are shown in Table 5-8.

Table 5-8 Hauls on the Mekong Mainstream

	Kg. Cham	Kratié
1960	4,953 ton	308 ton
1961	5,713	435
1962	5,985	545
1963	4,290	748
1964	3,164	625

It is characteristic of the area that fisheries in the form of semi-culture have been developed remarkably with a technique which keeps large catch living for a time and even feeds it until a season when a catch is poor in quantity. When the Sambor dam is constructed, it will prevent fishes from going upstream. However the reservoir is considered to be able to conserve and breed fish resources.

Wildlife is not considered to be an object of investigation, because its values in the project area are thought to be minor eventhough the Sambor reservoir will offer new resting areas to migratory birds.

5.3.6 <u>Recreation</u>

While there is no place suitable for recreation in the area at present, the reservoir to be built will create utility value for recreation. As is often the case with developed countries, rivers and reservoirs are valuable as playgrounds and their recreational purpose has at times priority to other purposes in those countries. The more the living standard of people in the area is raised, the more recreational value of the reservoir will be increased.

5.4 WATER RIGHTS

Both national and international laws are concerned to the development of the Mekong, which is an international river.

5.4.1 The National Law

Water rights and customs in Cambodia that have something to do with the Sambor study are mentioned below.

a) Hydroelectric Power

The Cambodian electric enterprises are controlled and supervised by the Minister des Travaux Publics, and directly belong to the Service du Controle des Eaux et de l'Electricite.

b) Irrigation

Conventional irrigation depends on the natural water resources. There is no written law of water rights in the Mekong Basin and its tributaries, but social order has been maintained actually by community leaders following customs.

c) Navigation

Water traffic on the Mekong is controlled by the Department of Harbors, and Arrondissement de l'Hydraulique et de la Navigation of Ministre des Travaux Publics.

d) Fishery

Fishery in the Mekong is supervised by the Department of River Fishery conducted by the Minister of Economy, and a fishery law—issued on April

23rd in 1956, the 87th N.S. law——that regulates pure-water fishery in Cambodia has been adopted. There are some people in the basin who live on fishery, and the farmers purchase fish from these fishermen, or, catch fish in the boeng, for their protein resources. Since waterway and drainage facilities of the dam have not been improved often, it is considered that agriculture and fishery rarely compete with each other for the utilization of water.

5.4.2 The International Laws

In terms of inland water transportation of the Mekong, 'The Treaty of Navigation in the Mekong and in the Rivers near the Saigon Harbor' which is concluded by Cambodia, Laos and Viet Nam has come into effect on the new year's day of 1955. So far there is no international law or treaty of water resources of the Mekong, however, a few basic resolutions were made about 'The Development of Water Resources in the Lower Mekong Basin' by the Mekong Committee held in 1957 and 1964.

5.5 WATER UTILIZATION

5.5.1 Present

In the vicinity of the Sambor dam site, there is neither a hydroelectric power plant, nor irrigation works which lets in water from rivers. Colmatage, however, takes place in parts below the dam site and admits mud water to make earth brought from another place. Vessels sail mainly below Kratié and few of them pass the dam site which lies above Kratié up the Mekong. Also there are a lot of wells are dug for domestic use in the areas along the river and its tributaries.

5.5.2 Potential

The reservoir filled with water to the brim after construction of the Sambor dam has vast potential energy which can generate 875,000 kilowatts in the maximum power output and produce 7,000 million kilowatt-hours in an annual average under system operation with thermal power station. It makes enough water available to irrigate arable land below the dam along the Mekong. Moreover, the reservoir above the dam is to open water transportation and to offer various sites for recreation.

If the Pa Mong project and other upstream schemes are taken into account, potential benefits are immense not only in navigation but also in power generation and irrigation. Influence of the Pa Mong project on the Sambor project is stated below in Chapter 11.

5.5.3 Reservoir Operation Studies

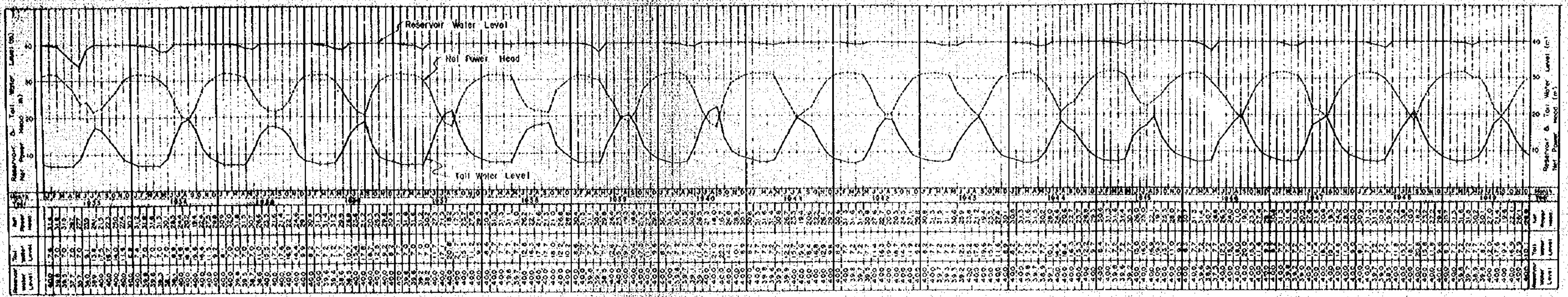
The gross volume of water kept in store within the Sambor reservoir is nearly equal to $10{,}000 \times 10^6$ cubic metres, which is to be operated in concert for navigation and irrigation as well as for power generation. The utilized depth of water is figured at 2 metres, lest sections to be mended within fairways should be too many and lower intake should decrease benefited area by irrigation. The effective storage of water, $2{,}050 \times 10^6$ cubic metres, which is about 0.5 per cent of the mean annual run-off, regulates discharge only during several months in a dry season. Thus the Sambor power station has nearly the same character as that of a power station of run-off river type.

Land irrigated by the Sambor reservoir is roughly 18,700 hectares in area on both banks of the Mekong near to the dam site. This is equal to 35 per cent of the developed area. The quantity of water irrigated from the reservoir, total to 238 million cubic metres.

As for the operation of the reservoir, at first three models are to be made by the quantity of water consumed for generation, substracting both the netevaporation-precipitation factor and the quantity of water irrigated from the inflows into the reservoir. This will represent cases of large, medium and small run-off within a dry season from January to May. After that which model of the reservoir shall be operated from the data of inflow observed in January and February of a year. The minimum quantity of water for generation will be decided in the dry season of the year, and so output and power which shall be generated are predicted within the year in advance.

The graphic representation of reservoir operation studies on Sambor reservoir during 1933 to 1965 is shown in Fig 5-6(1) and Fig 5-6(2) and the monthly average of power generation and output based on the above assumption are shown in Table 7-13, Chapter 7.

Fig. 5-6(I) RESERVOIR OPERATION



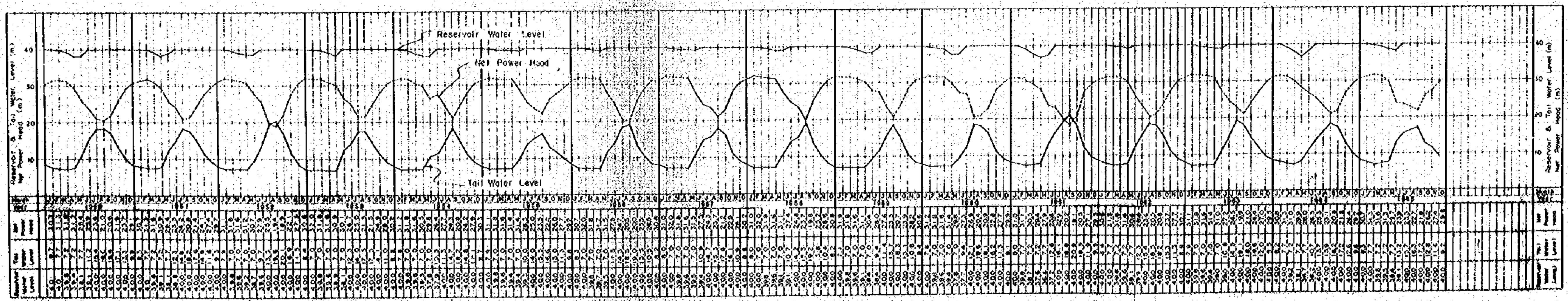
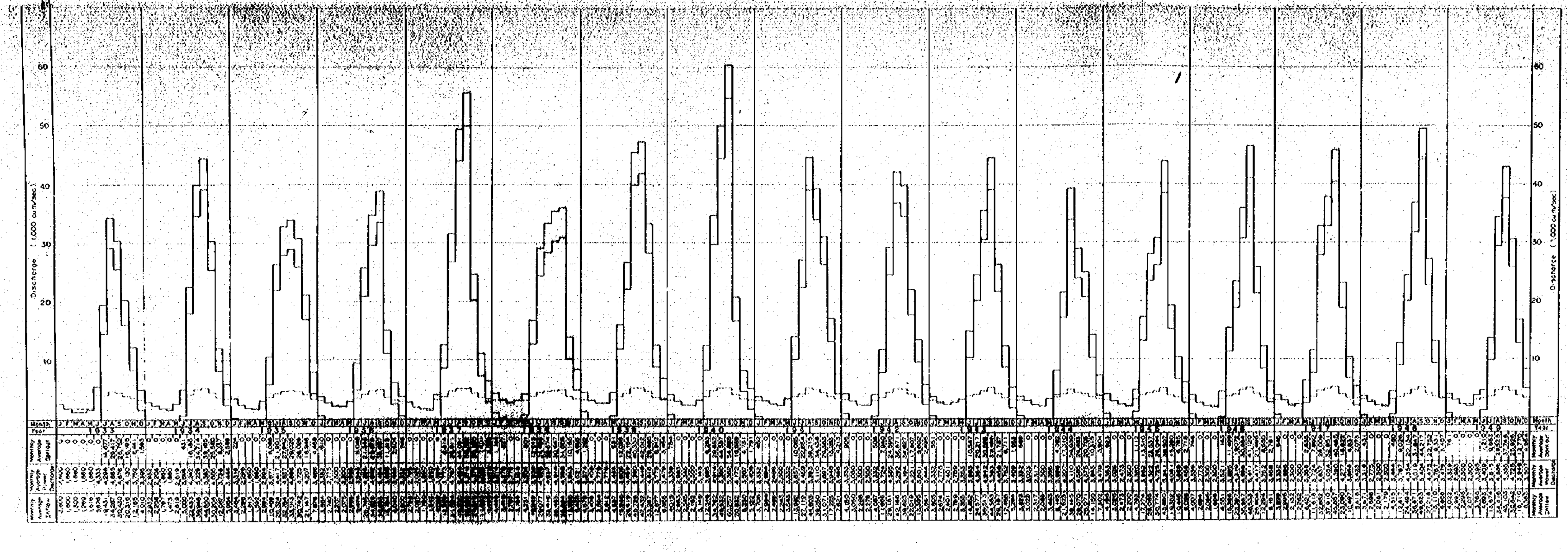
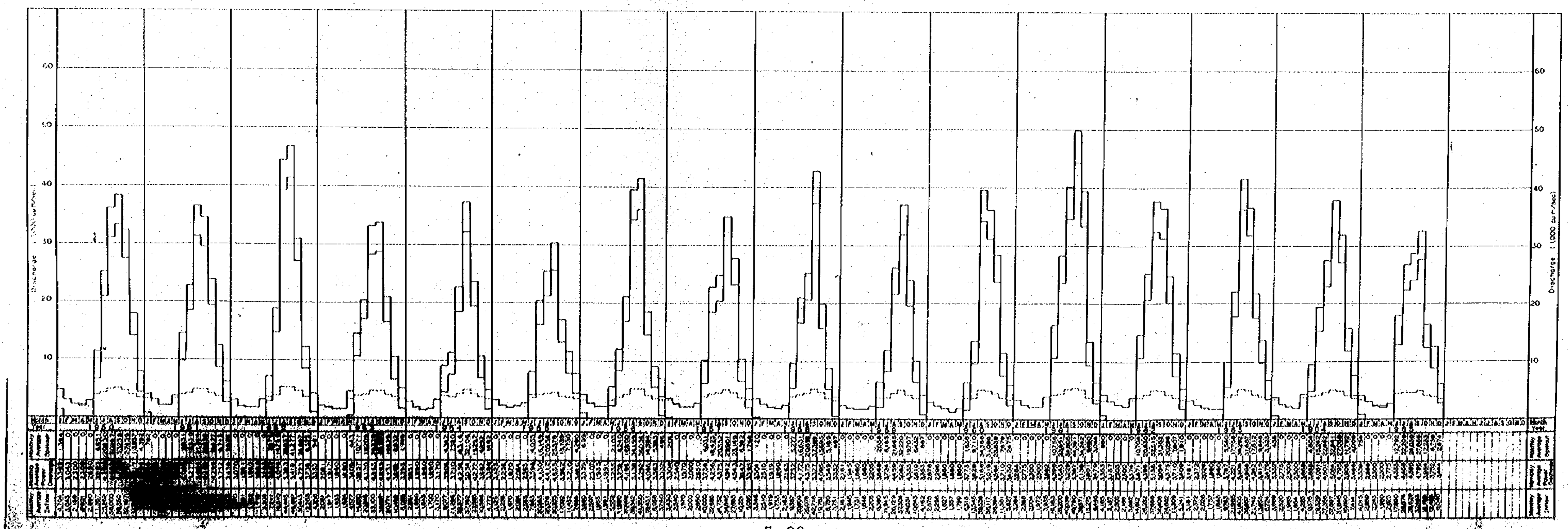


FIG. 5-6(2) RESERVOIR OPERATION





CHAPTER 6. LAND RESOURCES

6.1 INTRODUCTION

The project area for agricultural development related to the Sambor dam covers roughly 60 kilometres on both banks of the Mekong River downstream from the dam site and all belongs to the Province of Kratié. It lies within an area of 45 square kilometres (202,500 ha), contained by two meridians of 105°50' and 106°15' east and by two parallels of 12°12' and 12°37' north, of which nearly 69,000 hectares below 40 metres above sea level were studied. As a result, 38,410 hectares have been found arable and picked up as the projected area, of which 34,000 hectares are irrigable, as shown in Fig. (Location Map.)

The present investigation is started with a view to get data on farming, soil, land use and irrigation, necessary for land characterization survey, in order to measure development potential of irrigation in the project area. Those studies include such field survey as soil, geomorphology, geology, hydrography, topography, meteorology, water requirement and drainage. Laboratory works support those surveys on soils and qualities of water at the selected locations.

The method of land classification follows the lines of resolutions in 1962 of the Agriculture, Forestry and Fishery Research Council, Ministry of Agriculture and Forestry, Japanese Government. The Council organizes cooperative systems and promote researches on urgent problems in response to new trends in agriculture of Japan. And also this land classification were explained by Japanese experts at the joint meeting of Bangkok with the U.S. Pa Mong Project team held May, 1966.

6.2 DESCRIPTION OF LAND

6.2.1 Topography

The project area lies in an intermediate zone where the Mekong shifts from a mountainous zone to a plain, and consists of an undulating plain and a flood plain, which was dissected by the main stream of the Mekong and formed by its tributaries.

Mekong alluvial plain The flood plain extends with a range between five and ten kilometres on both banks along the Mekong. Natural levees make steeply sloping banks, which are swollen by nearly 14 metres above the low water level. The farther they are from the banks, the lower they become in the level. This develops into back marshes in which swamps filled with water even in a dry season are found at places roughly 100 metres from the banks.

The marsh lies in the lowest level and the farther becomes a patch of land apart from the marsh, the higher is a level of land, and it attains hillside at about 30 metres above the sea level. The low area in back is covered by shrubs, patched with swamps, fields and paddy fields. Tall weeds grow around 20 metres above sea level, which corresponds to flood elevation. Above 20 metres in elevation, short weeds spring, while sparse groves begin to grow at about 30 metres above sea level.

Undulating plain The undulating plain lies from 30 to 40 metres above sea level and grows only sparse groves, because the weathering of both sand stone and shale is thin and also eroded considerably. Valley bottom plains and concave slopes, which were made everywhere by small rivers and brooks running only during rainy season, are utilized mostly as paddy fields and grow bamboo in part.

Buried river course On the right bank of the dam site, there is a buried river course of 3 kilometres in breadth and 11 kilometres in length, of which the depth is observed at 11 metres. The buried river course lies over 30 metres above sea level and is slightly higher than the surroundings and grow dense forests.

The tributaries of the Mekong that made natural levels with their deposits decrease running waters considarably during dry season but they flood in rainy season and inundate the back marsh of the main stream.

6.2.2 Soils

The greater part of the surveyed area consists of alluvial soil, which covers 47,700 hectares with low humic gley soil. This puts together, roughly 70 per cent of the area. Much of the alluvial soil is fine textured, while medium and coarse textured alluvial soils are distributed on natural levees or places where those materials are carried directly from the main stream of the Mekong through the inundation of the river flow.

Getting nearer to back marsh, soil texture becomes finer, so that the land drains worse and has at places swamps filled with water even in a dry season. The alluvial soils are mostly undeveloped or weakly developed in soil profile features.

On hilly land slope adjacent to the alluvial plain red-yellow podzolic soil is distributed. It is coarse in texture and contains poorly organic matters and bases. In the bottom valleys of the hilly land, low humic gley soil caused by cultivation of paddy fields is found. Hilly land consists partly of soils intergrading into regur, which were developed from basalt as parent material.

6.2.3 Drainage

Drainage in the project area is extremely different in its phase between wet and dry seasons. In wet season, the Mekong raises its water level, with flood water flowing backward in its tributaries and inundates, coupled with run-off from the tributaries, 19,000 hectares or 56 per cent of the area. The inundated area continues to submerge for several months. Toward dry season, the water level of the river sinks slowly and flood water is drained through the tributaries so that some of them dry up toward March or April.

Water holding capacity, which is represented by soil texture, porosity, and groundwater level are all important factors dominating drainage class. Back slopes in natural levees of the Mekong are good in drainage. But, low areas in the back and valley bottom plains in hilly land consist of clayey soil and are poor in drainage. It is presumed from water level of many wells of domestic use, that groundwater level is influenced by rainfall and water level of the Mekong.

Drainage of low area of the rear dike is to depend on pumping out. There is no drainage at present in rain-fed paddy fields of valley bottom plains or in the paddy fields which are inundated shallowly for a short span of time where water is drained to lower places following the configuration of the ground.

When the area is irrigated in dry season, groundwater level may be raised within the range of several metres, with subsoil being saturated. The water, however, is to be drained naturally as the area is not plain over a large area, but inclined everywhere.

6.2.4 Geology

The project area is situated in the southern part of the North-Eastern Cambodia Plain and is about 40 metres high in elevation of very gentle slope. There is a small protruding hilltop, Phnom Samboc, 97 metres high above sea level.

Base-rocks in the area are comprised in Indonesian formation which is the main body of Indonesian (massif). Strata in the area consist of shale, sand stone, fine mud stone and their layers, and are generally calcareous in nature. They are accompained by thin layers of limestone and conglomerate uncommonly. Those base-rocks are covered with alluvial or residual soils.

Fine sand is mainly piled up in the fluvial region and silty soil of medium plasticity and clayey soil of high plasticity occupying lowlands on both banks along the Mekong, where paddy fields are cultivated in wet season. The hillside regions on both banks of the river are covered thinly with weathered residual soil exposed to weak laterization. Sparse groves and dense forests also grow here.

6.2.5 Land Use

The alluvial soil formed by the Mekong River is the most fertile of soils in the area of which silty loam is utilized as fields while clayey soil is cultivated as paddy fields. Low humic gley soil is used as paddy fields at bottom valley plains in hilly land. Hilly lands on which sparse groves grow and soils on which forests become dense, are red-yellow podzolic soil, which is poor in productivity. In other words, paddy fields are distributed in alluvia and bottom valleys, and dry fields lie on natural levees and back land on the Mekong and its tributaries. Colmatage, which is practised everywhere along the river, is effective measure to fertilize fields with mud piling up.

Paddy fields grow mostly in rainy season paddy and at the back of dry fields, those for dry season paddy are scattered. The former, which relies on flood and rainfall, has neither irrigation reservoir and canal nor an agricultural road. Boeng, a marshy natural pond is the source of irrigation water, which is supplied through ditches. There are only a few irrigated fields, which are supplied with water by pumps or human power. In upland fields mostly maize, tobacco, mung bean, sesame and peanut are cultivated and some fields grow cucumber, water-melon and sugar cane.

Capital other than reclamation cost is scarcely invested in farmland. Every forest and waste land is state-owned and permission must be requested from the governor of the province in order to reclaim land. Cattle and buffaloes are bred for farming use, while pig and poultry are bred for meat use. All of the animals are left free and graze on grass sprung in wasteland and forests, without feedstaff cultivated. In general, cultivation is practised mostly with farm implements by cattle or human power, and fertilizer and insecticide are generally not used excluding the case of field irrigation.

6.3 SURVEY

6.3.1 General Discussion

It can be said gravity irrigation is possible physically in a very large area lying below about 40 metres above sea level down the Mekong from the dam site. The level land below about 40 metres in elevation, however, is a long narrow area below the two large tributaries, Prek Te and Prek Saop, which occupy large areas on both banks of the river. As a result the area to be surveyed is limited to 69,000 hectares of land below 40 metres in elevation within the province of Kratié, lest development of the area should not be uneconomical by means of gravity irrigation.

And further, 38,410 hectares are selected as the project area, considering possible soil productivity indices based on the soil survey and social characteristics. As for irrigation sources of the projected area, measures suitable for the terrains of land are to be used, such as local tributaries, ponds and water pumped up from the Mekong, excluding in the vicinity of the dam site.

Field surveys which are divided into four categories of farming, land use, soils and water supply, were carried out from 1963 to 1967, as follows.

Farming Reserch on the actual condition by hearing as well as collection of data from the agencies concerned were carried out in order to seize actual farming.

Land Use Actual land use was surveyed by means of statistics and reconnaissance in reference to fertility, terrain and, in particular, inundation of the area.

Soil Terrains in the area were classified by means of topographical maps and aerial photos, soil samples of model sites were collected in relation to every physical feature, and laboratory analysis was carried out in physical and chemical nature of the soils necessary to soil and land classification.

And further, soil microbe activity and flora were investigated in the profile of each exemplary soil.

Water Supply Meteorological and hydrological data observed by the Cambodian Government were collected and analysed. Measurement and analysis were carried out, of meteorological, hydrological and irrigation water by means of the gauges which the survey team set up at Sambor. Actual customs of water supply were surveyed by hearing and field investigation in the area and colmatage. The water supply peculiar to Cambodia, and inundation in a dry season were investigated in particular.

Provisional bench marks were set up in the whole surveyed area, geographical features in the area were measured tentatively and measurement of water level on the Mekong was carried out in order to plan a construction programme.

The Cambodian Government and the United States Army supplied the survey team with various maps. The maps which were employed mostly were ones on the scale of one-to-fifty thousand published by the United States Army and ones on the scale of one-to-twenty thousand specially made for the survey by the Cambodian Government.

6.3.2 Topographical Classification Categories

The topographical classification map which was made from aerial photos by means of topographical analysis, are shown in Fig.

According to the map physical features in the area are divided into eight categories as follows:

Hilly land slope of tertiary rocks lies at the highest level and consists mostly of sparse groves growing at shallow foundations and partly of dense forests.

Valley bottom plains inside hilly land are plains formed palmately by tributaries, large and small, of the Mekong and grows mostly rainy season paddies.

Gentle slope in mountain foot is a region which shifts from hilly lands to low areas including marsh and comprises of calluvial soil in mountain feet being mostly tales.

Ridge in natural levee is the higher part of the natural levee made by the Mekong, which runs along the river drawing gentle curves, and makes main passing roads.

Back slope in the natural levee is back slopes of levees formed by sedimentation of the Mekong from ridges in the natural levee toward protected low-lands, the greater part of which inundates in rainy season, and is utilized as dry fields, which are the most festile in the area.

Sedimented areas by the small rivers in marshy lands are natural levees and deltaic areas made by small tributaries and are mostly inundated.

Low areas in back of the river are the lowest areas within the areas lying between 14 and 20 metres in elevation and are completely inundated in rainy season, being scarcely utilized.

Lakes, ponds or shallow concave areas in back marshes of the river are areas including an old river bed, an old meandering route, residual ponds and the like. They are surely inundated in rainy season, while most of them are filled with water throughout a year.

6.3.3 Soil Survey

(a) Soil Classification

On the reconnaissance soil survey in 1964, soil in the survey area is classified into five soil groups as follows:

Alluvial plain	Silty alluvial soils
	Clayey alluvial soils
Undulating plain	Podzolic residual soils
	Clayey fan soils
	Podzolic Sandy soils

As the result of the basic soil survey in 1965, the soil is divided into fifteen soil series as shown in Table 6-1, "Comparison soil Series and Great

Table 6-1. Criteria for Soil Series Classification and Comparison with Great Soil Groups

Great Soil Groups	Soil Series	Parent Material	Texture	Drainage Class	Profile Development	Area
						hrs
Red-Yellow Podzolic Soils (Red member)	1. Krâkôr	Old Alluvium	LS	Good	Medium	5,200
Red-Yellow Podzolic Soils (Yellow member)	2. Kêng	"	"	"	"	1,500
"	3. Tuol	Old Alluvium/Tertiary	"	Moderately good	Medium to strong	7,200
Low-Humic Gley Soils	4. Kâmpi	Alluvium/Tertiary	CL	"	Medium	2,300
"	5. Sembok	Alluvium	C	"	"	21,400
"	6. Russei Char	"	"	Poor	"	7,200
"	7. Stung Preah	"	SL	Good	Strong	300
"	8. Roha	"	SiC	Poor	Medium	5,600
Alluvial Soils	9. Chông Kaoh	"	S	Good	None to weak	400
"	10.Pôngrô	"	SiL	"	"	2,500
"	11.Bos Léav	"	SiCL	"	Weak	4,800
"	12.Môreum	"	"	Very Poor	"	3,200
Vertisols	13.Prek Chamlack	Basaltic	C	Moderately good	"	1,200
"	14. Srê Prâng	Basaltic/Tertiary	"	"	"	2,500
Lithosols	15.Poû	Basaltic		Good	None	700

Soil Groups."

The greater part of soils in the survey area are alluvial soils, which occupy 47,700 hectares, 70 per cent of the whole area. The soil profile features undeveloped or weakly developed alluvial soils which are grouped into nine series on the ground of soil texture and drainage.

Over undulating plains red-yellow podzolic soil is distributed, of which red member occupies higher plains and yellow member lies on lower plains and in regions adjacent to alluvial plains. Yellow member is divided further into two series on the ground of existence of tertiary bed rocks.

In bottom valleys of undulating plains, there are low humic gley soils caused by paddy cultivation, which are grouped into two series on the ground of soil texture. In Bos Léav and Kanhchor, soil intergrading to Regur occurs, partly, which developed from basalt as parent material.

Soil classification into fifteen series is based on soil colour, presence of mottles and concretion and gravel content, which are shown in columnar sections. Fig. 6-1 shows exemplar columnar sections of various soil series.

(b) Land Classification

Land classification rests on the basis of a classification method, which was resolved in 1962 by the Agriculture, Forestry and Fishery Conncil, Japan, and shows grading of both dry and paddy fields in relation to productive capability. The results are described in Table 6-2 (a) and Table 6-2 (b).

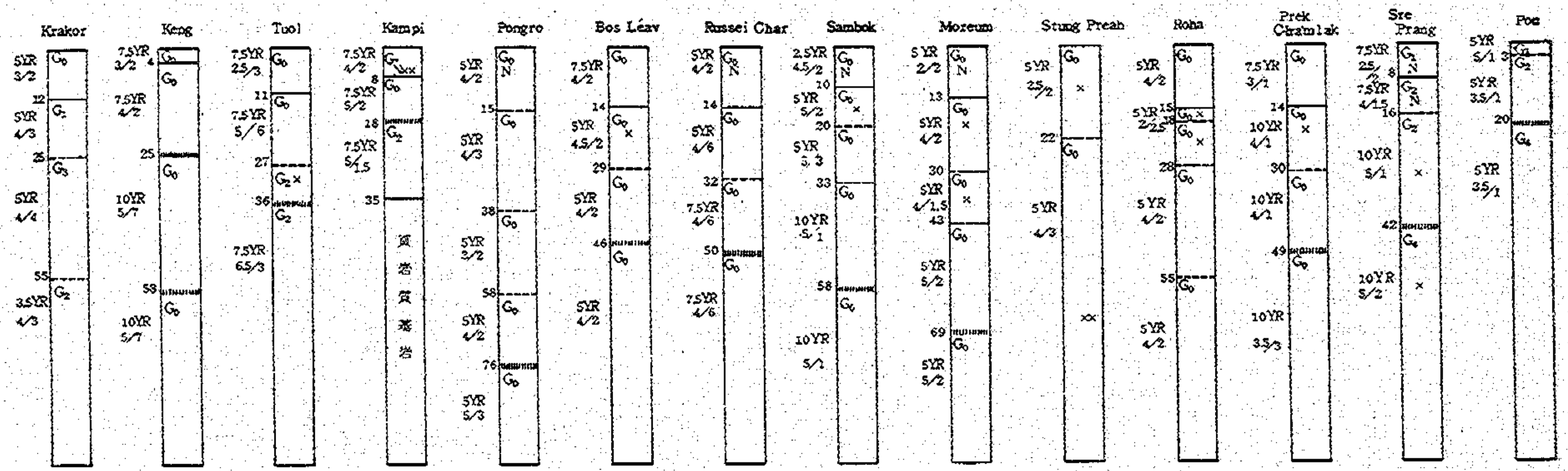
The standards of land classification are based on grades of limitation, hazards and risks of soil damage against normal yields or right soil control as follows:

First class; land presumed good for cultivation in which there are scarcely not only limitations or hazards but also risks of soil damage;

Second Class; land in which there are a few limitations or hazards, or somewhat risks of soil damage;

Third Class; land in which considerable limitations or hazards exist, or

Fig. 6-1. Exemplar Columnar Section of Various Soil Series in the Sambor Area



Abrupt boundary —— NN humus 20 - 10%
Clear ········ NN " 10 - 5%
Gredual ━━━ N " 5 - 2%

G_4 Gravel soil 50% or more
G_3 Gravel quantity 50 - 20%
G_2 " 20 - 10%
G_1 " 10 - 5%
G_0 " 5% or less

xx Mottles & concretions 20% or more
x " 20 - 2%

Table 6-2 (a) Land Classification based on Soil Production Capability (dry field)

Name of Soil Types	Land Classification based on Soil Productive Capability	Thickness of Top Soil (t)	Effective Depth of Soil (d)	Gravel Content in Top Soil (g)	Facility of Plowing (p)	(Texture of Top Soil)	(Stickness of Top Soil)	(Hardness of Air Dried Top Soil)	Wetness of Land (w)	(Water Permeability)	(Water Holding Capacity)	(Wetness in Soil Profile)	Inherent Fertility (f)	(Nutrient Holding Capacity)	(Nutrient Fixation Capacity)	(Base Status in Soil Profile)	Richness of Nutrients (n)	(Exchangeable Calcium)	(Exchangeable Magnesium)	(Available Phosphor)	(Micro Nutrient Elements)	(Acidity)	Inhibition (i)	(Chemical Inhibition)	(Physical Inhibition)	Slope (s)	(Natural Slope)	(Direction of Slope)	(Artificial Slope)	Erosion (e)	Degree of Erosion	Water Erodibility	Wind Erodibility
Krakor - 1	III	III	II	I	I	1	1	1	(IV)	1	3	(2)	III	3	1	1	III	3	3	3	2	2	III	1	3	I	1	-	-	I	1	2	1
Krakor - 2	IV	IV	IV	II	I	2	1	1	(IV)	1	3	(2)	III	3	1	1	III	3	3	3	2	2	III	1	3	II	2	-	-	III	3	2	1
Kong	III	II	I	I	I	1	1	1	(III)	1	3	(2)	III	3	1	1	III	3	3	3	2	2	I	1	1	I	1	-	-	I	1	2	1
Tuol	IV	III	III	I	II	1	1	2	(IV)	1	3	(2)	III	3	1	2	III	3	2	3	2	2	III	1	3	II	2	-	-	II	2	2	1
Kampi - 1	III	III	III	I	III	2	2	3	(IV)	1	3	(2)	III	3	1	1	III	3	3	2	2	2	III	1	3	I	1	-	-	I	1	2	1
Kampi - 2	IV	IV	IV	I	III	2	2	3	(IV)	1	3	(2)	III	3	1	1	III	3	3	2	2	2	III	1	3	II	1	-	-	III	3	2	1
Pongro	II	II	I	I	I	1	1	1	(II)	1	3	2	I	2	1	1	I	1	2	1	1	1	I	1	1	I	1	-	-	I	1	2	1
Bos Léav	II	III	I	I	III	3	2	3	(II)	1	2	2	I	2	1	1	I	1	2	2	1	1	I	1	1	I	1	-	-	I	1	2	1
Sambok	III	III	I	I	IV	3	3	3	(II)	3	1	1	I	1	2	2	II	2	2	2	1	2	III	1	3	I	1	-	-	I	1	2	1
Prek Chamlack	II	III	I	I	IV	3	3	3	(II)	3	1	(2)	I	1	2	1	I	1	1	2	1	2	III	1	3	I	1	-	-	I	1	2	1
Sre Prang	IV	III	IV	II	IV	3	3	3	(IV)	1	3	(2)	II	1	2	2	I	2	1	1	1	2	III	1	3	I	1	-	-	I	1	2	1
Pou		III	IV	II	IV	2	1	2	(IV)	2	2	(2)	I	1	2	1	I	1	1	1	1	1	III	1	3	I	1	-	-	I	1	2	1

Table 6-2 (b) Land Classification based on Soil Productive Capability (Paddy Field)

Name of Soil Types	Land Classification based on Soil Productive Capability	Thickness of Top Soil (t)	Effective Depth of Soil (d)	Gravel Content in Top Soil (g)	Requirement of Irrigation Water (i)	(Soil Texture at 50cm Depth Below Top Soil)	(Maximum Soil Hardness at 50cm Depth Below Top Soil)	Degree of Oxidation and Reduction (r)	(Content of Easily Decomposable Organic Matter)	(Degree of Gleyzation)	Wetness of Land (w)	(Water Permeability)	(Water Holding Capacity)	(Wetness in Soil Profile)	(Inherent Fertility) (f)	(Nutrient Holding Capacity)	(Nutrient Fixation Capacity)	(Base Status in Soil Profile)	Richness of Nutrients (n)	(Effective Nitrogen)	(Available Magnesium)	(Exchangeable Potasium)	(Exchangeable Magnesia)	(Available Silica)	(Micro Nutrient Elements)	(Acidity)	Hazardous Articles (h)	Sulpher Compounds	Mineral Salts Quantity	Heavy Metal Quantity	Irrigation Water	Calamity (a)	(Dangerous for Flood)	(Dangerous for Land Slid
Russei Char	II	I	I	I	I	1	1	I	1	1	IV	3	1	2	I	1	2	2	III	3	2	3	2		1	2	I	1	1	1	1	III	3	1
Sambok	II	I	I	I	I	1	1	I	1	1	IV	3	1	2	I	1	2	2	III	3	2	3	2		1	2	I	1	1	1	1	III	3	1
Moreum	II	I	I	I	I	1	2	I	1	1	IV	3	1	2	I	1	2	2	II	3	1	3	1		1	2	I	1	1	1	1	III	3	1
Stung Preah	III	I	I	I	II	3	2	I	1	1	IV	1	3	2	III	3	1	3	III	3	3	3	3		1	2	I	1	1	1	1	III	3	1
Roha	III	I	I	I	I	1	1	I	1	1	IV	3	1	2	I	2	1	1	III	3	3	3	3		1	2	I	1	1	1	1	III	3	1

fairly grave risks of soil damage are seen ahead;

Forth Class; land extremely difficult to cultivate in which very large limitation or hazards, or grave risks of soil damage are seen ahead.

Of all soil series in the area surveyed, those to which the project area belong are as follows:

Kêng series: well drained coarse textured soil having moderately developed profile. It belongs to the yellow member of red-yellow podzolic soils and lies on hills at Soap in a long, narrow strip land which stretches southward from Chrouy Bânteay. The land is covered with dense forests dotted with weeds and scarcely either inundated in a rainy season or eroded.

Pôngrô series: medium textured alluvial soil having weakly developed profiles. The profiles consist of many buried layers caused by inundation. It is distributed mainly on ridges of natural levees and on gentle slopes following natural levees at Jamau and Chhlong districts and is inundated in places in rainy season while it has scarcely risks of erosion with almost even physical features. Turf is mentioned besides shrubs as vegetation in the area but most land are utilized as farmland, in which banana, tomato, maize and dry land rice are cultivated.

Bos Léav series: Five textured alluvial soil having weakly developed profile. It has weak, blocky and often granular structure made by activities of earthworms and the like and has manganese mottles, but it is not suffered by gleyzation through the whole profile. It is distributed on natural levees made by tributaries in back marsh and is inundated mostly in rainy season but is nearly protected from erosion because the physical features are almost even. In rainy season peanuts, maize, tobacco and cucurbitaceous plants are cultivated, while bamboo groves, kapok and banana grow naturally.

Russei Char series: poorly drained very fine textured low-humic gley soil. It has weak blocky structure in a horizon and mottles within 50 centimetres. Horizon differentiation of this soil is weak. It lies mainly around back marsh and is scarcely utilized because it is mostly inundated for a long term in rainy season, from June to November. Grass is mostly grown naturally, and shrubs in places and dry season paddy are cultivated only quite partly.

Sambok series; the finest of the low-humic gley soils distributed on alluvial plains in the area, which is very fine textured and drains moderately well. With its distribution the largest in the area, the soil occupies 21,400 hectares, lies on alluvial plains sandwiched between natural levees and back marsh, and is inundated for one or two months in rainy season. It is influenced rather scarcely by groundwater and has some mottles within 20 centimetres from the surface but never below that level. Shrubs, bamboo groves and turf grow naturally in the area, while the land is utilized partly as dry or paddy fields in a dry season.

Roha series: Very fine textured low-humic gley soil distributed at bottom valleys within hilly land at Jamau, Chhlong and Prek Prasap. Its profile is moderately developed and iron and manganese deposits are separated in subsurface horizon caused by paddy cultivation. The greater part of the soil are cultivated as rain-fed paddy fields which grow rainy season rice.

(c) Land classification and land utilization

The present land use in the projected area is checked up with land classification and productive possibility grades of land as in Table 6-3.

According to the table, it is recongnized that second class and partly the third class of land in productive possibility are cleverly utilized as farmland. The greater part of paddy fields is rain-fed in rainy season which belongs to Roha series of the third class, although those for dry season of Sambok series which land category belongs to the second class, are rather superior in productive possibility. Actual yield of rice, however, does not necessarily coincide with the productive possibility because of varieties planted and irrigation facilities.

Table 6-3. Relations Between Land Category at Present and Soil Texture

Terms / Land Category	Area 1,000 ha	Soil Texture	Soil Series & Productive Capability Class	Flood
Paddy field	5.1	C, SiC, SL	Russei Char (II), Sambok (II), Stung Preah (III), Roha (III)	Covered flood water for all of (II) and partly of (III).
Dry field	7.7	Sil, SiCL, C	Pongro (II), Bos Léav (II0, Sambok (III)	50% or more covered flood water.
Swamp	26.8	C - S	Russei Char (II), Sambok (II), Moreum (II), Chong Kaoh (III), Pongro (II), Bos Léav (II)	Covered flood of all land.
Sparse grove	22.6	LS, CL, C	Krakor (III-IV), Toul (IV), Kempi (III-IV), Prek Chamlack (II), Sre Prang (IV), Pou (IV)	Almost nothing
Dense forest	4.8	LS	Keng (III), Krakor (III-IV)	Nothing
Total	69.0			

Land used for sparse groves and dense forests belong to the third and fourth classes in productive possibility and are too difficult to utilize for farming. The swamps which are inundated in a rainy season every year, are graded mostly to the second class in productive possibility, and are divided roughly into two: land suitable for dry fields which consists of silt loam or silty clay loam in soil texture, namely Pôngrô and Bos Léav series; and land suitable for paddy fields which comprises of clay in soil texture, namely Russei Char, Sambok and Môreum series.

(d) Soil microflora and their activity

Microbial activity At both paddy and dry fields, chemical synthesis of ammonium is the most active in alluvial soils which is flooded every year, while at uncultivated land, the sythesis is the most active in lithosol and the least active in vertisol.

At paddy fields, urease is activated more in alluvial soils than in low-humic gley soils, while at dry fields more in alluvial soils which suffered less flood. As for uncultivated land, urease is more active in lithosol and vertisol but less in red-yellow podzolic soil.

Oxygen uptake, which is an index denoting potential activity of a microbe, is not so large in any of soils in the area, with red-yellow podzolic soil the smallest, and shows necessity for supplying organic matters. Because both dry and paddy field increase degree of concretion in dry season, it is necessary to supply organic matters in order to improve tilth of soil.

Microflora Any soil in paddy fields continues to have characteristics of microflora of the soil under water-logged condition, which is rich in bacteria and unaerobatic bacteria and poor in fungi. And as there are sulfur reducing bacteria in no small number in the soil, it is essential, in cultivating paddy field rice, to be careful with water control so as not to cause abnormal reduction.

Furthermore it is necessary to be careful with nitrogen loss caused by activity of nitrobacter and denitrobacter, as it is assumed that any type of soils in paddy fields includes a large number of nitrobacter and denitrobacter and thus diminishes fertilizing effects of nitrogenous manures. And it is also assumed that richness in blue-green algae on the surface of alluvial soil at well drained paddy fields is helpful to improve soil nitrogen, because blue-green algae multiplies in water and take N_2 gas into its microcells.

It is characteristic of soil in dry fields that it has more actinomyces than soil in paddy fields. Either of both soils has a good many number of nitrobacter and denitrobacter and it is required to be careful in handling nitrogenous manures in rainy season. It is to be paid attention to that waste land, too, is abundant in actinomyces, activity of nitrobacter and denitrobacter are vigorous, and the soil is apt to lack for nitrogen.

6.3.4 Hydrology

(a) Infiltration and water holding capacity

Infiltration of water into surface soil and layers nearby varies mainly according to soil texture and ploughing conditions and is recognized as less than 120 millimetres at clayey soil and less than 500 to 1,000 millimetres at loam and sandy soil in dry fields.

In paddy fields filled with water, percolation is 48 millimetres per day at loamy soil in rainy season paddies and 18 millimetres per day at clayey soil in dry season paddies on the average.

In the greater part of soils in the area, maximum water holding capacity is 50 to 60 per cent, field capacity which moisture remained after extracting gravitational water, is a little under 30 per cent and the wilting point is 6 to 7 per cent. Thus, available moisture which is able to keep plants alive, is presumed roughly from 20 to 25 per cent.

Although almost all the soils hold water more than field capacity near to a saturation point in rainy season. Many soils have only several per cent of water, at least, near the surface of the earth toward the end of dry season.

(b) Porosity

Porosity of soil in the area is as much as 50 to 60 per cent equivalent to maximum water holding capacity. Effective porosity is presumed to be several per cent over twenty which is also equal to the available moisture.

Field capacity, which is nearly equal to water holding capacity after 24 hours of soil saturation, stands in inverse proportion to apparent-specific gravity of soil, as is shown in Fig. 6-2, with the former denoted by Fc and the latter by Sa. The figure indicates also the relations between Fc and Sa by land use and therefore characteristics of porosity by land use, too, can be assumed from it.

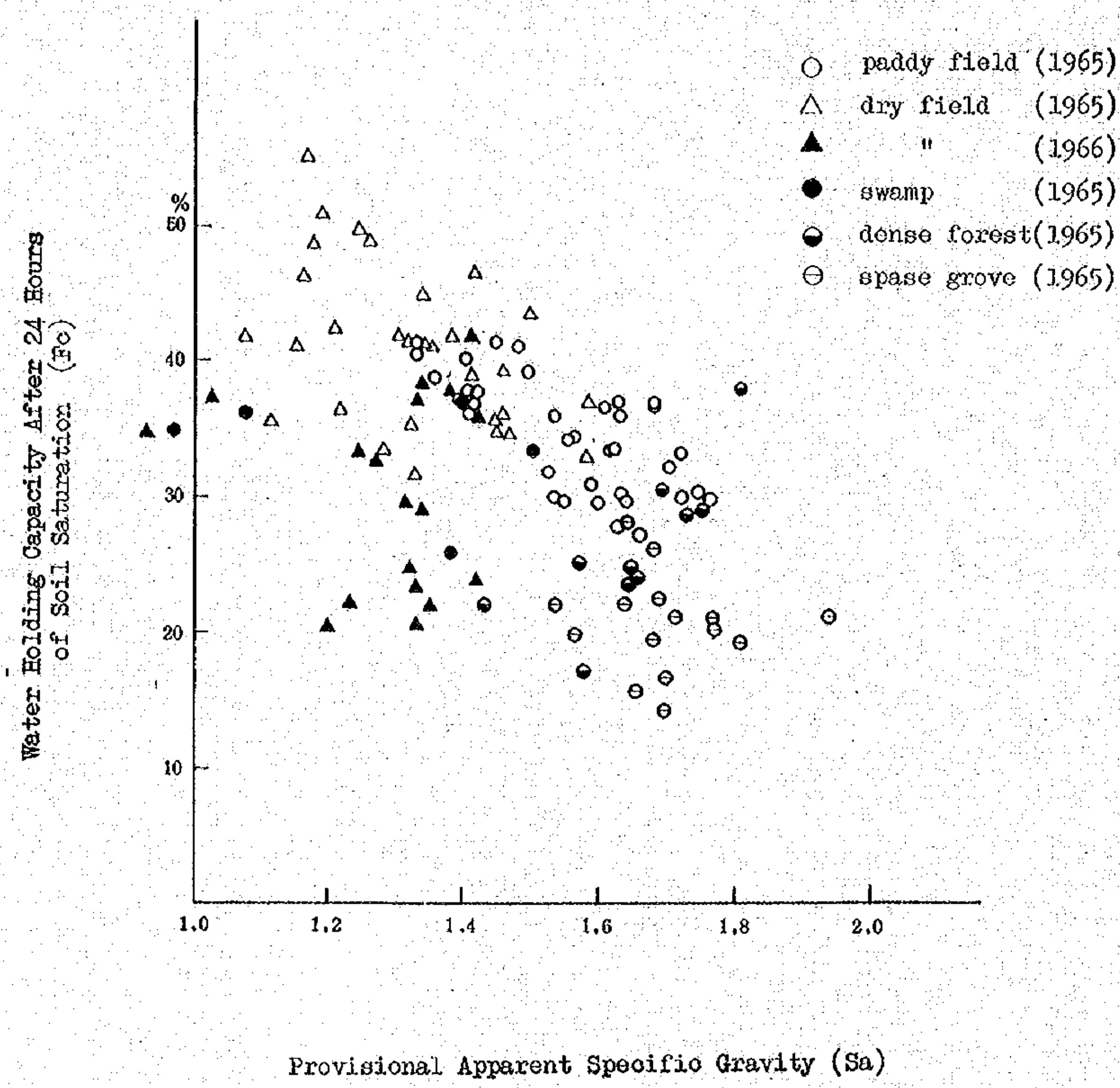
Dry fields in the area consist in alluvial soil of silty clay, which is derived from micaceous silt and developed strongly in granular structure. They have low values in Sa but the highest in Fc. Sparse goves grow on sedimentary soil of hilly land containing gravel or on residual soil derived from weathered sandstone and shale, and either of those soils has slow permeability and also has high values in Sa but the lowest in Fc.

Paddy fields lie on silty or clayey alluvial soil as well as on sedimentary soil and distributed widely between dry field and sparse grove groups in Fig. 6-2. Dense forests are presumed to be on alluvial soil on a buried river course. The soil has moderately rapid permeability with its Fc lying midway between paddy fields and sparse forests. Grassland that are swamps usually inundated, are almost all alluvial in soil and its values of Fc are nearly equal to those of paddy fields. Thus it is presumed that silty soil of the grassland is changed to dry fields and clayey soil to paddy fields without much trouble.

(c) Groundwater

Groundwater is stated under the preceding chapter, Water Resources.

Fig. 6-2. Relation Between Water Holding Capacity and Apparent Specific Gravity, Land Category



(d) Inundation

Water level of the Mekong is raised in rainy season so that flood inundation is caused in a considerably large area on both banks of the river through the tributaries. There are differences of periods under inundation and the depth of water in different localities, which are important factors in planning terms of crop cultivation, crop rotation and colmatage. According to the mean values of yearly inundation periods at various sites, 60 days at Prek Saop is the smallest, 105 days at Bang Mokoy the largest and 90 days is on the average. An example is observed in "Prek chick" where colmatage is best developed, and its period under inundation is roughly 100 days. Prek chick stands for " a river dug artificially " in Cambodian.

(e) Study on colmatage

In the surveyed area, colmatage has been practised for a long time as a means to bring sediment from the Mekong and warp farmland at such "prek chicks" as Khum Kanhchor and Khum Saop. The most fertile land in the area are dry fields in back land in natural levees, which is the alluvial soil brought for a long time directly by the Mekong or by inundation into back land through its tributaries.

In the project area, it is recommendable to make a new plan by means of colmatage in an inundated zone where natural levees are relatively narrow in back land of the Mekong and to let in sediment, reclaim dry fields and grow dry field crops.

Turbidity of the Mekong is caused by the fineness of soils composing river beds and there is no remarkable diffence in composition of soils from the upper reaches to the down reaches of river. It is presumed that sediment occurs nearly uniformly over the whole river. If the river is dammed, sediment should occur just below the dam site and it is assumed that sediment concentration is not far different from the present situation. Thus it is expected that proper designed feed canals allow effective warping.

(f) Losses due to evapotranspiration

Values of evapotranspiration essential for planning which are calculated after Blaney-Criddle formula, are 6.6 millimetres per day in dry season and 4.8 millimetres per day in rainy season with cropping factor set at 1.0.

6.3.5 Land Use

Farmland rate in the Province of Kratié is only one third of the ratio in the whole of Cambodia. The farmland in the province comprises dry field of 27 per cent and paddy field of 73 per cent and rate of dry field is about twice the rate on the average over all the provinces. Farmland of 55 per cent is distributed in Srok Kratié and Srok Chhlong and the rate is low on the right bank of the Mekong.

In general, houses and fields planted with perenial crops lie on ridges along natural levees of the Mekong. Dry fields are distributed on back slopes in natural levees with a range of one to three kilometres and streches into inundated areas on the river and its tributary. Paddy fields are situated in low land of the inundated areas and in low places along the other small tributaries.

Periods of inundation last from the beginning of July to the middle of October and are numbered 60 to 100 days. Under the conditions, various rice cultivation takes place as follows.

Hâtif (Early rice)	Sowed in May	reaped in October
Mi-saison (Semi-Season rice)	May or June	December
Saison (Season rice)	May or June	January
Tardif (Late rice)	May or June	January
Flottant (Floating rice)	May	December or January
Saison Seché (Dry-Season rice)	November	April or May

Dry field crops are cultivated in fields in back slopes of natural levees, what is called "chamcar" in Cambodian, which is a general term of all the fields except paddy fields. Most "chamcar" lies in rising parts of alluvial soil of the Mekong, outside which land is low and is cultivated with mung bean, tobacco and the like and, when water recedes, is planted with rice.

In the Province of Kratié, dry fields are mostly cultivated with red and white maize, mung bean, tobacco, sesame and peanuts and the present average cropping rate to 7,590 hectares of chamcar in the province is as shown in Table 6-4.

Crop rotation practised in Cambodia is "Mung bean-maize" and "vegetable-maize" are also seen in a relatively fertile zone along the Mekong.

Table 6-4 Present Average Cropping Rate in Kratió Province

	Red Maze	White Maize	Mung Bean	Sugar Cane	Peanut	Sesame	Cotton	Tabacco	Total	
Rainy Season	76 %	11	-	0.5	1	4	-	-	92.5	%
Dry Season	47	4	13.5	-	2.5	4	1.5	2.0	92.5	185

6.3.6 Conclusion

In order to plan a land use programme in the future, it is recommendable to consider such policies as follows:

(1) As a guiding principle, farmland already tilled should remain such paddy and dry fields as it is with its favourable conditions and should be furnished with irrigation facilities to stabilize in water supply. It is possible to save dressing for some time in inundated areas, in particular, where colmatage is practised. In case of perenial cultivation, however, it is essential to introduce effective manure to some extent in order to improve fertility and promote productivity.

(2) Half the project area would be occupied by reclaimable wastes, which are evidently marsh in soil. While they have a large limitation of inundation during the period of cultivation, to reclaim marshes is easier than to reclaim sparse groves or dense forest and more than offsets the limitation.

(3) If soil in reclaimable wastes remains as it is, the reclaimed land is mostly suitable for paddy fields in land use, and as inundation is too difficult to be controlled in most parts of the areas, dry season rice is to be planted. In case silt is let in from the Mekong newly through colmatage, however, it is possible to reclaim dry field at a good many places.

(4) Irrigation and dressing are essential, in case sparse groves and dense forests are reclaimed. The soil in the area, which is abundant in nutritive substance and is able to be carried by water, is to be made by earth, brought in fields from another places.

(5) Natural drainage through open ditch drains is suffice in order to drain both farmland already tilled and land to be reclaimed and pumping drainage with polder dikes and pumping up is to be considered in order to drain inundated areas.