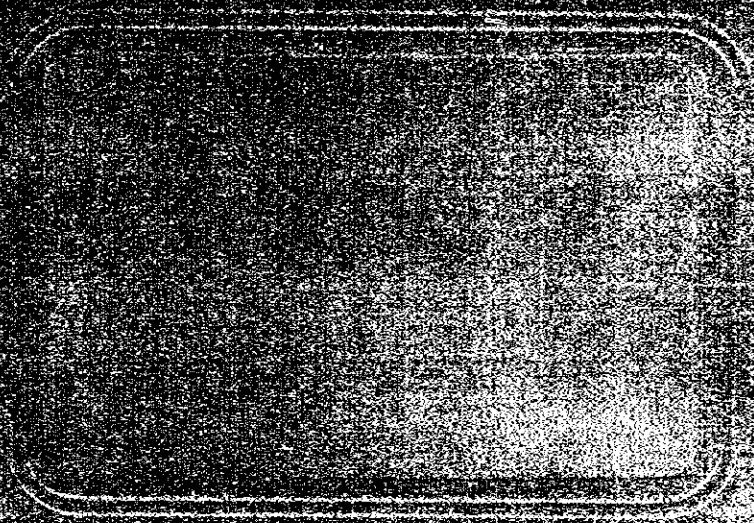


SAMBOR PROJECT REPORT

(EXTRACTED DRAFT)

JUNE 1969

OVERSEAS TECHNICAL COOPERATION AGENCY


1155306 (2)

PREFACE

The Government of Japan, at the request of the Committee for Coordination of Investigations of the Lower Mekong River Basin, expressed its intention to undertake a comprehensive investigation of the Sambor Project at the Seventeenth Session of the Committee, and in December 1962, entrusted this task to the Overseas Technical Cooperation Agency (OTCA) which is an executing agency of the Government of Japan.

The OTCA decided to organize a survey team to implement the investigations and studies both at the Project sites and in Japan with the cooperation of government organizations, consultants firms and research institutions concerned.

The general management of these works was assumed by Mr. Goro Inouye, Director of the OTCA. The first and second teams were headed by Mr. Motonaga Ohto, Executive Director of the OTCA, and the third, fourth and fifth teams by Dr. Koichi Aki, Advisor to the OTCA.

The field investigations were carried out during the four-year period from January 1963 to March 1967 mainly within the Project area, i.e., the Kratie Province of Cambodia. Some of the investigations related to navigation and power markets were carried out in areas extending outside the Project area as well as in the neighboring countries of Laos, Thailand and Vietnam.

Subsequently, the planning, design calculation, analysis and review with regard to the Project were performed in Japan, and compiled into the present Report which consists of the following eight volumes:

Volume I	General Report (1)	
Volume II	General Report (2): Sambor with Nam Ngum and Pa Mong	
Volume III	Supplementary material to Volume I:	Dam and Hydroelectric Power
Volume IV	" "	: Irrigation and Agriculture
Volume V	" "	: Navigation
Volume VI	" "	: Fishery
Volume VII	Appendix (1) to Volume III	: Basic Data
Volume VIII	Appendix (2) to Vol. III and Vol. V	: Drill Hole Logs

As is summarized at the outset of the Volume I, the Sambor Project is a multipurpose development project for hydroelectric power, agriculture and navigation. The Report concludes that the Project as such is feasible from technical, economic and financial points of view, and recommends its early execution for the economic development in the Lower Mekong River Basin.

Finally, on behalf of the OTCA, I take this opportunity to express my hearty gratitude to the U.N. Special Organizations the Mekong Committee, the Royal Governments of Cambodia, Laos, Thailand and the Government of Republic of Vietnam for their kind cooperation and assistance.

June, 1969

Shin-ichi Shibusawa
Director General
Overseas Technical Cooperation Agency
Tokyo, Japan

LETTER OF TRANSMITTAL

Dear Sir,

I have the great pleasure of submitting herewith to you the Feasibility Report on the Comprehensive Development Project at the Sambor site on the Mekong River in Cambodia.

The Sambor Project, one key factor in the comprehensive development of the Mekong, aims at fulfilling general electric demand and promotion of industries through effective use of hydro electric-power, extension and stabilization of agricultural production, improvement of navigation, downstream from the Sambor site, as well as preservation or increase in fishery resources in the area.

The development of the Mekong is a prerequisite for the future economic and social development of the riparian countries in the Lower Mekong River Basin. Surveys and planning for the Mekong development have therefore been promoted for a long time by the Division of Water Resources Development of ECAFE and the Committee for Coordination of Investigations of the Lower Mekong River Basin (Mekong Committee).

At the 14th Session of the Mekong Committee held in Bangkok in May 1961, the Government of Japan expressed its intention to conduct a survey of the Sambor Project which was accepted by the Mekong Committee.

Thereafter, the preliminary survey and comprehensive investigations in five phases have been conducted up to 1967. These investigations were carried out mainly by engineers of the Electric Power Development Co., Ltd. (EPDC) which was responsible for the power aspect; Sanyu Consultants International, Ltd. responsible for the agricultural aspect and Japan Port Consultants, Ltd. responsible for the navigation aspect, with the coordination of the Overseas Technical Cooperation Agency (OTCA).

In 1968 discussions were held between the OTCA and the Mekong Secretariat, Division of Water Resources Development (ECAFE) and the Royal Government of Cambodia with respect to the survey's findings, and it was agreed that the Sambor Project Report would consist of the General Reports and detailed reports dealing with the Dam and Power, Irrigation and Agriculture, Navigation and Fishery. These reports are hereby submitted.

The expenses required for the field survey and the preparation of the report, amounting to the equivalent of about $800,000 were borne by the Government of Japan. The total amount of money spent for the overall investigations including contributions from the Royal Government of Cambodia, Australia and other countries amounted to more than $1,100,000.

The Sambor Project, located in the lowermost reaches of the Mekong Mainstream, when completed will greatly benefit the economic and social development of the downstream areas. The project has a close interrelationship with the upstream projects of the Pa Mong, The Nam Ngum, the Stung Treng, etc. with regard to scale, timing and economy of development. Of these upstream projects, the scale of the Stung Treng Project has not been determined. The present report therefore deals with two cases, i.e., the case wherein the project is treated as an isolated project, and the case

wherein the effects of the upstream projects, the Pa Mong and the Nam Ngum are taken into account.

The Outline of the Sambor Project is as described below:

The Sambor Dam site, some 500 km upstream from the estuary of the Mekong, is located on the Mekong Mainstream about 15 km upstream of Kratie – one of major towns in central Cambodia. The proposed dam will be a combination type of rock-fill, earth-fill and concrete dam with a total crest length of about 30 km and a height of 54 m in the river section.

In regard to the power aspect, the total installed capacity will be 875 MW and the annual energy output will be 7,000 million kWh. When the upstream projects are completed, the total installed capacity will be increased to 2,100 MW and the annual energy output will be nearly doubled to 14,100 million kWh. Power thus generated will be supplied to Phnom Penh and Sihanouk Ville in Cambodia and to Saigon in Vietnam through extra high tension transmission lines of 345 kV.

In regard to the agricultural aspect, irrigation improvement utilizing water supplied from the regulated discharge through the Sambor Dam and other sources will increase the total arable land from the present 12,469 ha to 34,000 ha and the planting area from 16,980 ha to 60,739 ha, with the annual net income per ha of each farming household also rising to a level 3.82 times size of the present one.

The Sambor Project will become even more advantageous when large-scale irrigation in the Deltaic Area is made possible by the combination of the Sambor power and the increase in the dry season discharge downstream of the Sambor Dam which will be attained upon completion of the Pa Mong Project.

As for navigation, the construction of the inclined passage facility of three lines, the increase in the dry season discharge due to the dam operation and the dredging of shallow sections of the river will make it possible for vessels presently plying only downstream of Kratie to serve as far upstream as Stung Treng throughout the year.

For the purpose of preservation and increase of fishery resources, a design for fish ladders is included in the present report.

The construction cost of the Sambor Project excluding the fishery aspect amounts to an equivalent of approximately $358 million in the case of the isolated project and an equivalent of approximately $478 million when the upstream projects are taken into consideration.

In order to finance the construction of the project, financial aid from cooperating countries will have to be sought in addition to long-term low-interest loans from international financing organizations.

As detailed in the report, the Sambor Project promises immense direct and indirect benefits which technically and economically justify its construction, even as an isolated project, when funding and other conditions are satisfied.

The construction of the Sambor Project is not simply very desirable but rather it is absolutely essential as it is the key to great economic and social benefits for all the riparian countries.

On this occasion, I wish to express my sincere thanks to all who extended their valuable assistance in the preparation of the Present Report. My appreciation also goes to the Royal Government of Cambodia and other riparian countries, ECAFE, the Mekong Committee, and the Embassies of Japan which extended unlimited cooperation in the execution of the field surveys. I sincerely hope that the development of the four riparian countries can be quickly begun through the early completion of the Sambor Project.

Yours respectfully,

May 28, 1969

Goro Inouye

Goro Inouye
Director of OTCA
in Charge of Sambor Project

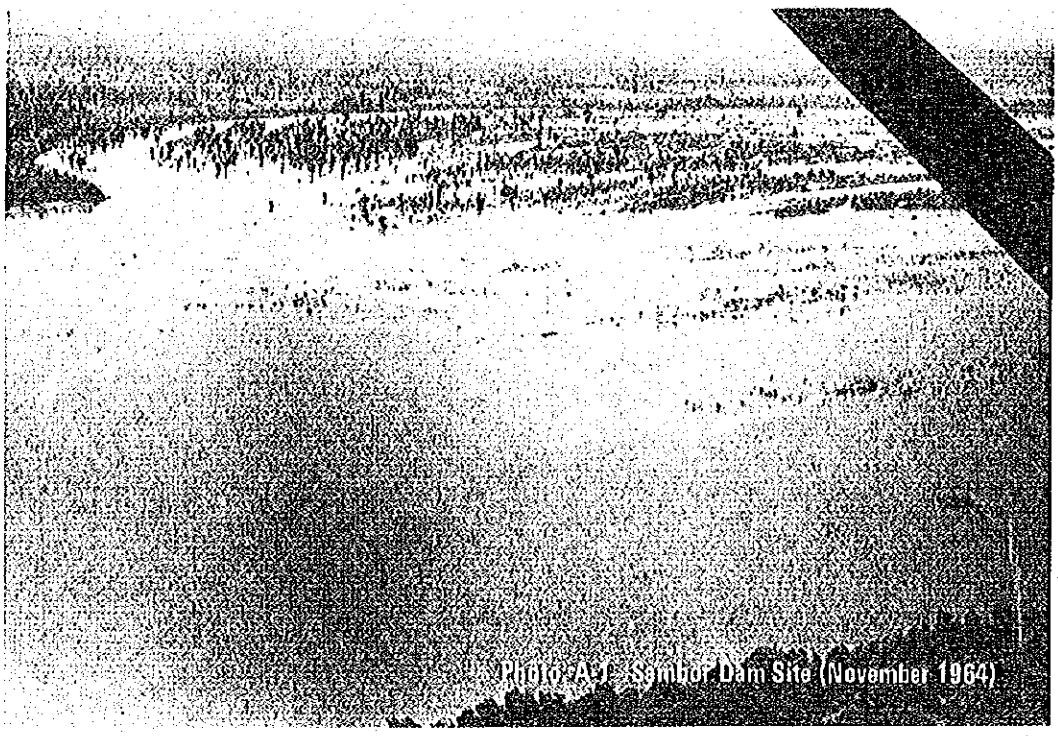


Photo. A-1 Samhor Dam Site (November 1964)

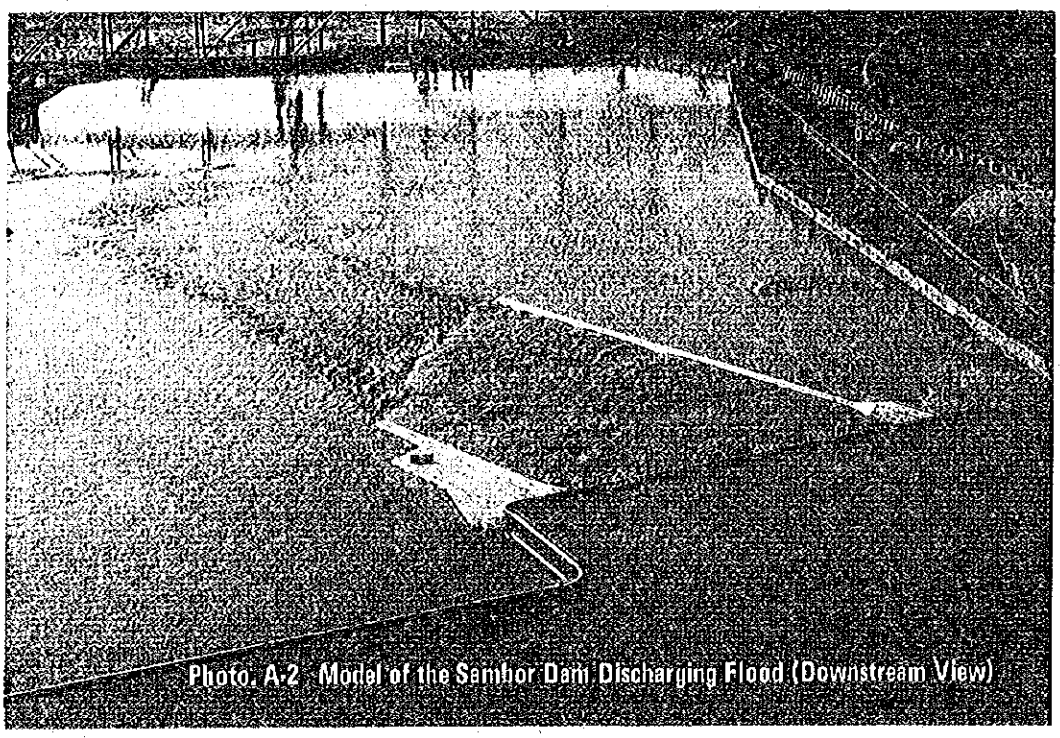
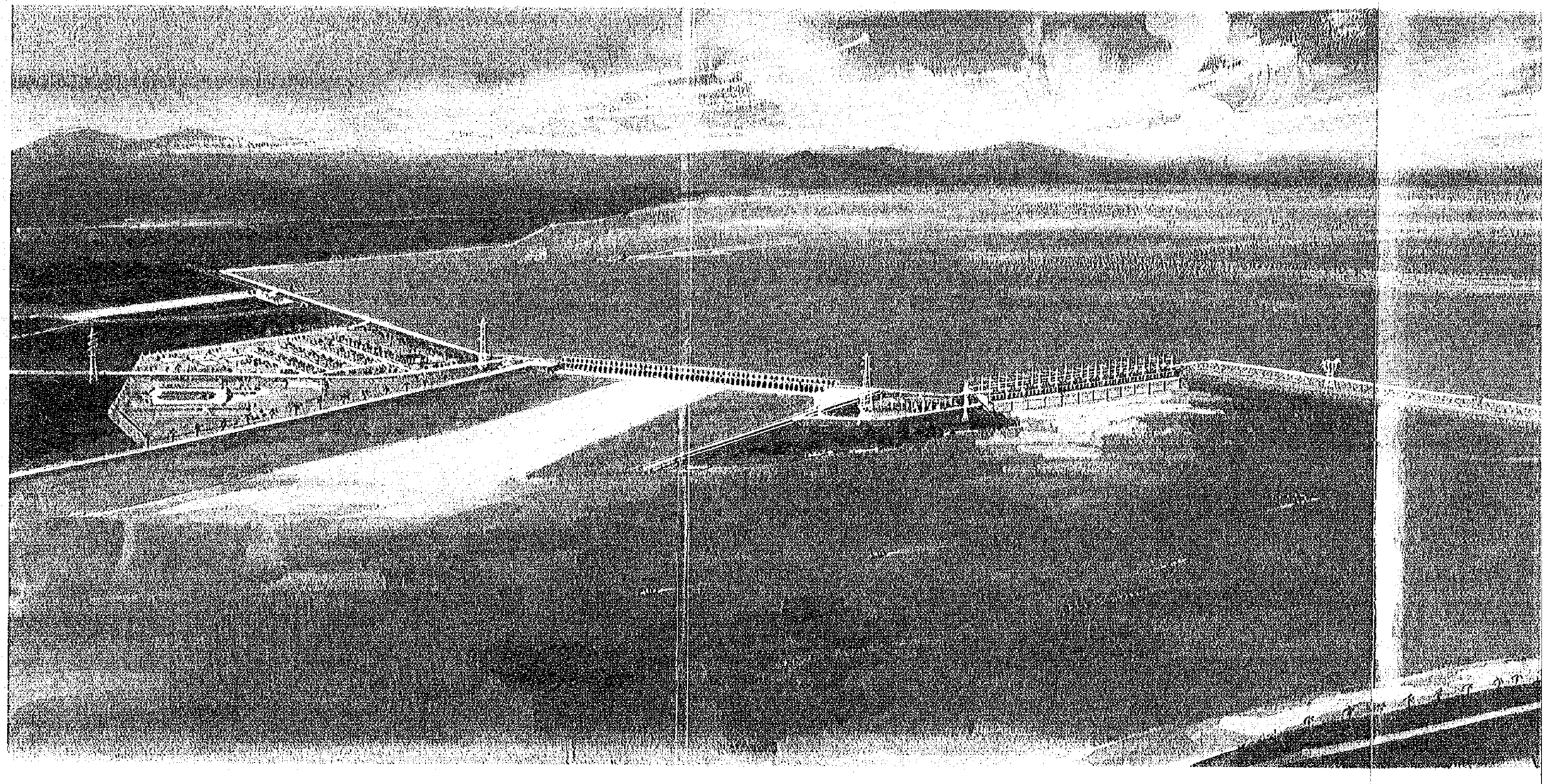
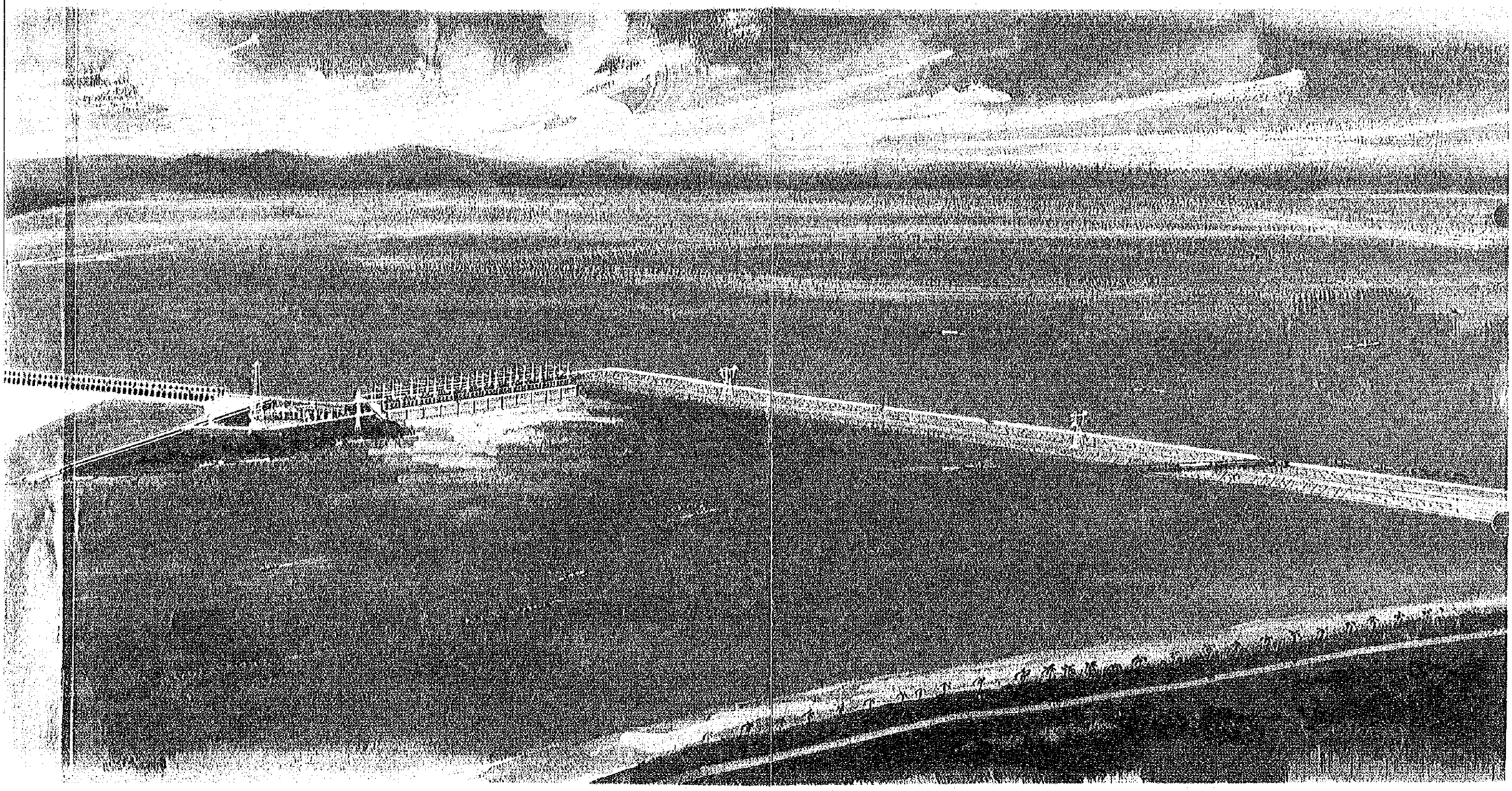


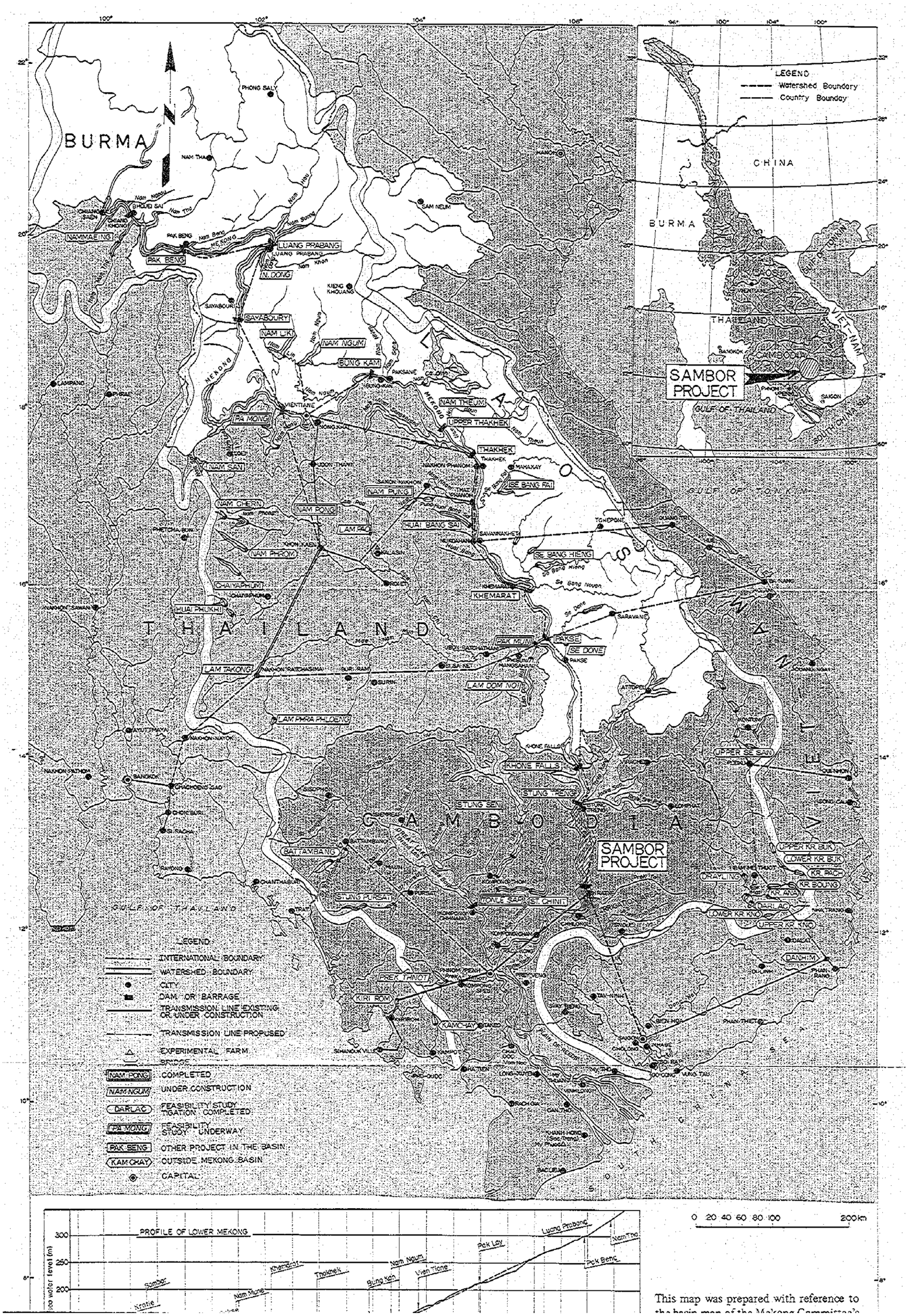
Photo. A-2 Model of the Samhor Dam Discharging Flood (Downstream View)



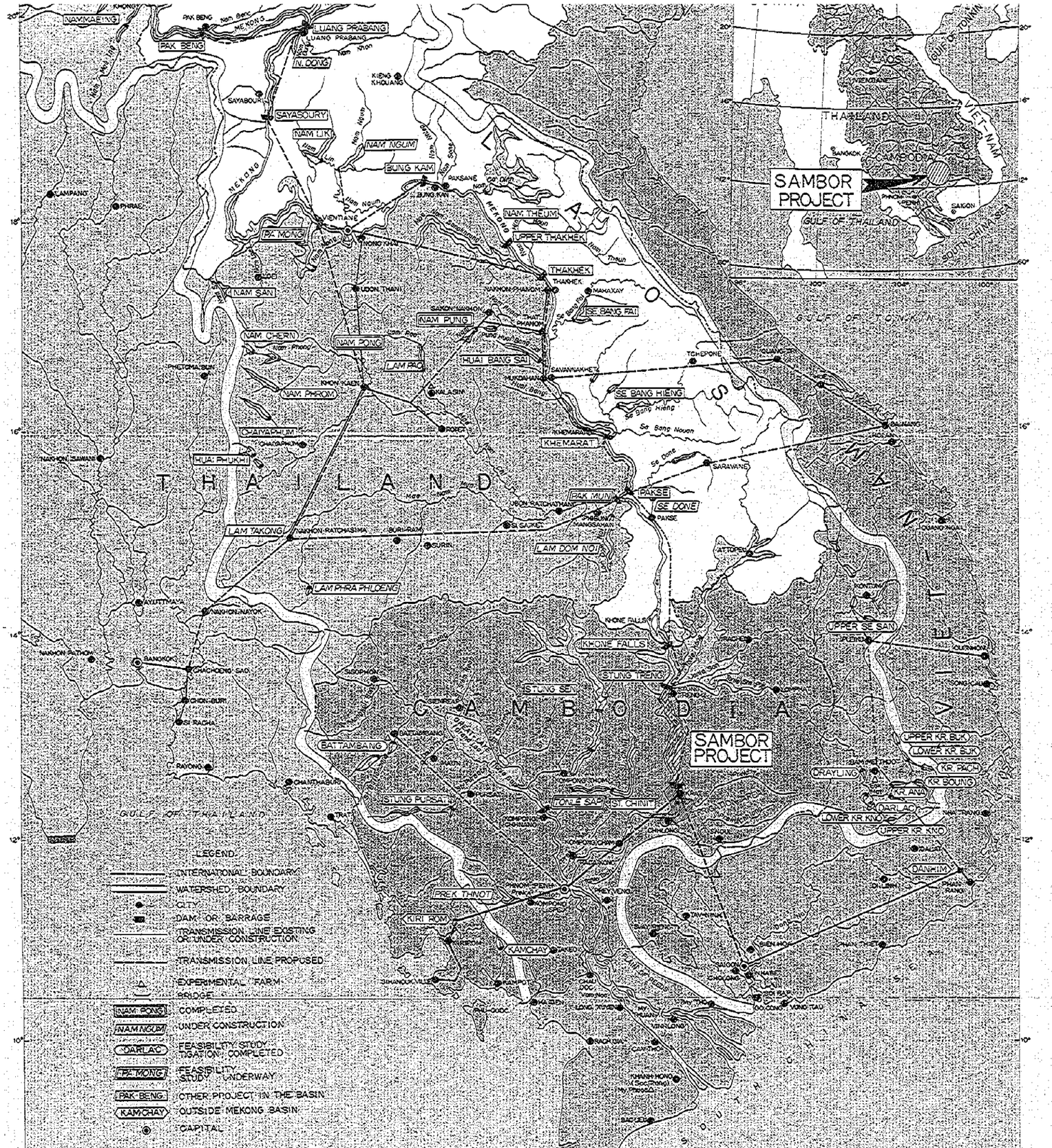
Aerial View of the



Aerial View of the Projected Sambor Dam

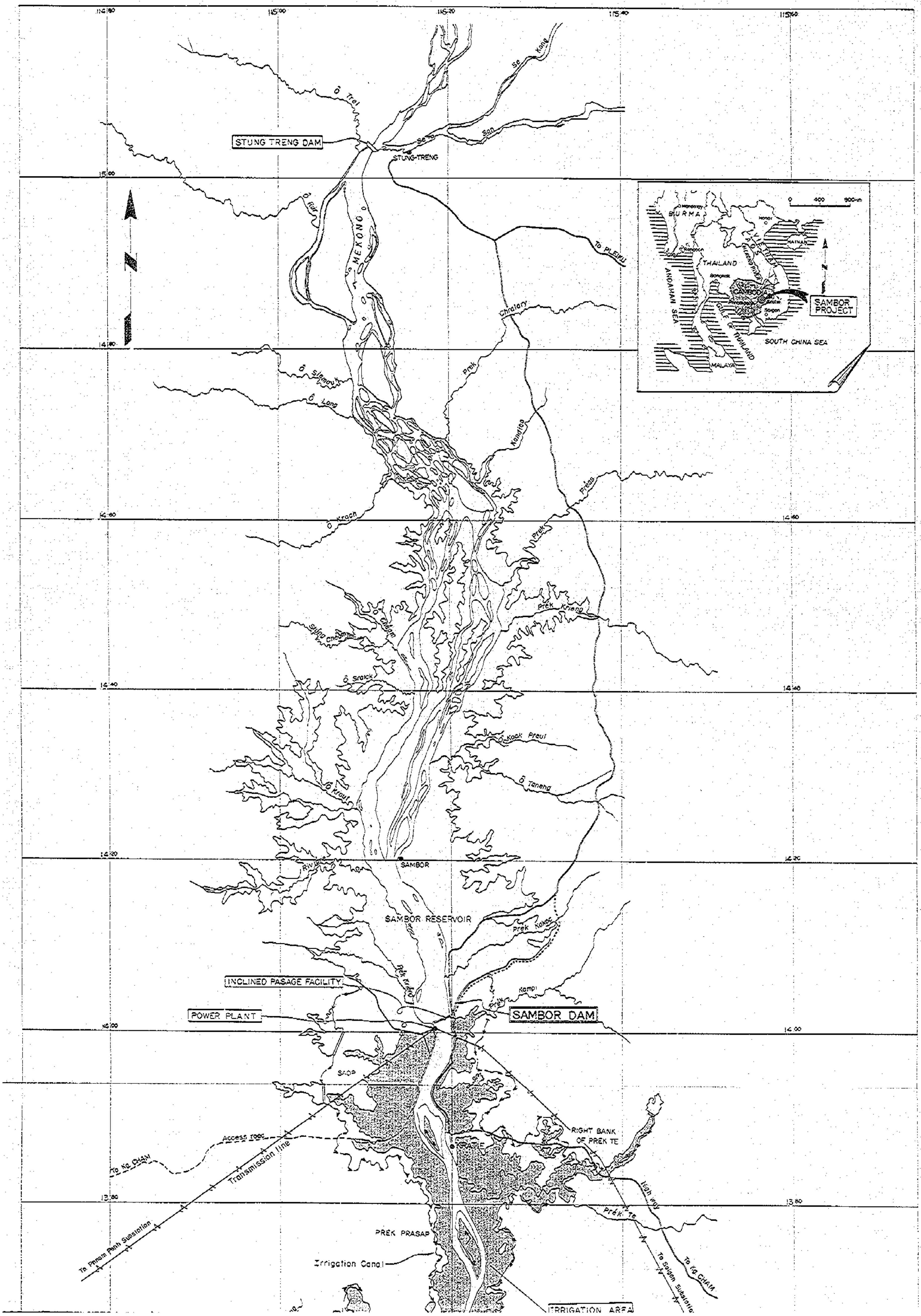


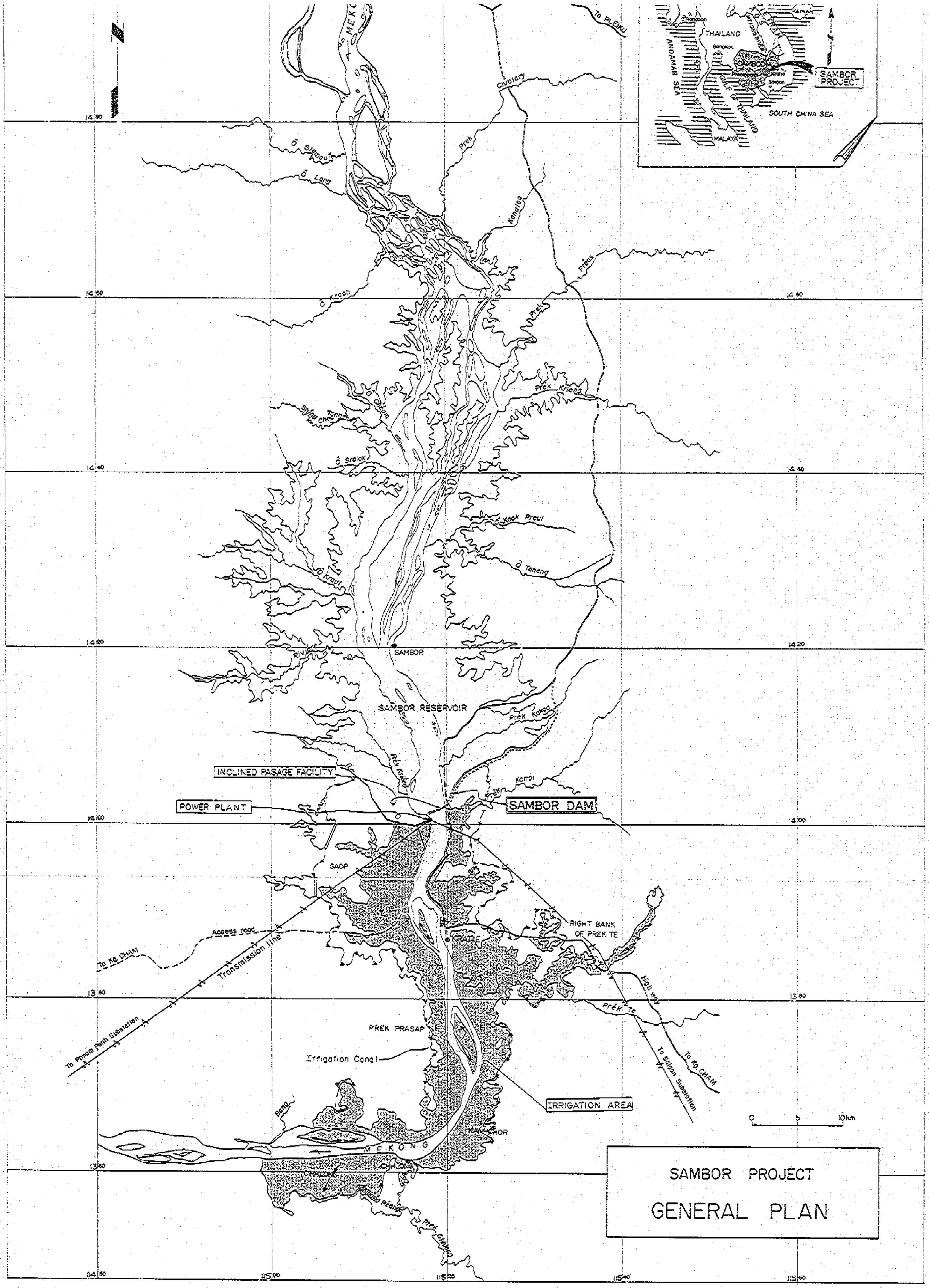
This map was prepared with reference to the basin map of the Mekong Committee's



This map was prepared with reference to the basin map of the Mekong Committee's Annual Report 1967 and the boundaries shown hereon do not imply official endorsement or acceptance by the United Nations.

Key and
Location Map


STUNG TRENG DAM
STUNG-TRENG
MEKONG
Se Kong
San
To PLEIKU
Chralory
Prek
SAMBOR PROJECT
BURMA
THAILAND
ANDAMAN SEA
GULF OF THAILAND
SOUTH CHINA SEA
MALAYA
Ô Trel
Ô Rur
Ô Siemau
Ô Long
Ô Krach
Kanetha
Prek Preas
Prek Krieng
Ô Sraick
Ô Kock Preul
Ô Taneng
Ô Kraut
SAMBOR
SAMBOR RESERVOIR
Prek Kokor
Prek Krabe
Kampi
INCLINED PASAGE FACILITY
POWER PLANT
SAMBOR DAM
SAOP
KRATIE
RIGHT BANK OF PREK TE
Access road
Transmission line
To Kg CHAM
To Phnom Penh Substation
High way
Prek Te
To Saigon Substation
PREK PRASAP
Irrigation Canal
IRRIGATION AREA


SAMBOR PROJECT
GENERAL PLAN
SAMBOR DAM
POWER PLANT
INCLINED PASAGE FACILITY
SAMBOR RESERVOIR
SAMBOR
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To PLEIKU
THAILAND
ANDAMAN SEA
GULF OF THAILAND
SOUTH CHINA SEA
MALAYA
SAMBOR PROJECT
0 5 10km

MAIN FEATURES OF THE PROJECT

TOTAL CONSTRUCTION COST of the PROJECT	$358.0 million
in which FOREIGN CURRENCY	$256.5 million
DOMESTIC CURRENCY	$101.5 million

A. Power and Dam Sector

1.	Location	15 km Upstream of Kratie, Cambodia
2.	Catchment Area	646,000 sq.km
3.	Annual Inflow	446,000 million cu.m (average 14,000 cu.ms)
4.	Design Flood	90,000 cu.ms
5.	Reservoir	
	Max. High Water Level	EL 42 m
	Normal High Water Level	EL 40 m
	Reservoir Surface Area	1,157 sq.km
	Reservoir Storage Capacity	10,000 million cu.m
	Effective Storage Capacity	2,050 million cu.m
	Available Draw-down	2 m
6.	Dam	
	Type	Combined Dam of Earth-fill, Rock-fill, and Concrete
	Elevation of Crest	EL 44 m
	Height of Dam	54 m
	Crest Length	Total 30.7 km:
		Earth-fill 26.1 km
		Rock-fill 2.4 km
		Others (Top of Spillway and Powerhouse) 2.2 km
	Slope of Upstream Face	1:2.0 - 2.5 (Rock-fill), 1:3.0 (Earth-fill)
	Slope of Downstream Face	1:1.5 - 1.3 (Rock-fill), 1:2.5 (Earth-fill)
	Volume Earth-fill	17.2 million cu.m
	Rock-fill	8.7 million cu.m

	Concrete	Refer Spillway and Power Plant

7. Spillway

Type	Overflow Type with Roller Gates
Energy Dissipator	Horizontal Apron
Capacity	90,000 cu.ms at Flood Water Level EL 42 m
Length	1,471 m (Net Length: 1,003 m Effective Length: 795 m)
Crest Road Width	6 m
Concrete Volume	900,000 cu.m
Gate	14 m (H) x 15 m (W) Roller Gates, 53 gates

8. Power Plant

Type	Outdoor
Final Dimension of House	485 m (L) x 30 m (W) x 31 m (H)
Concrete Volume	1.5 million cu.m

9. Power Generation and Consumption Pattern

Installed Capacity	875 MW
Firm Output	473 MW
Dependable Firm Peak Output	637 MW
Annual Energy Output	7 billion kWh
Firm Energy	4.1 billion kWh
Secondary Energy	2.9 billion kWh

Power Consumption Pattern (in which Type I is the most recommended)

Type I	1)	General Demand
	2)	Power-oriented Industries including Aluminum Refining
Type II	1)	General Demand
	2)	Power-oriented Industries excluding Aluminum Refining and its Related Industries
Type III		General Demand

10. Power Generation Facilities

Unit Capacity	125,000 kW
Number of Units Installed	7
Room Provided for Additional Installation of Unit	5 Turbine Rooms and Draft Tubes
Turbine	
Type	Vertical Shaft Kaplan Type
Rated Head	19.7 m
Max. Discharge	775 cu.ms
Rated Output	128,000 kW
Number of Units Installed	7
Generator	
Type	Three-phase Synchronous Generator, Vertical Shaft Rotating Field Enclosed Type
Capacity	140,000 kVA
Voltage	15,400 V
Frequency	50 c/s
Power Factor	89%
Number of Units Installed	7

11. Transformer

Type	Three-phase, Outdoor, Forced Oil, Forced Air-cooled Type
Capacity	140,000 kVA
Voltage	15,400 V/345,000 V
Frequency	50 c/s
Number of Units	7

12. Transmission Line

Location	Sambor-Phnom Penh	P. Penh-Sihanouk Ville	Sambor-Saigon
Distance	190 km	160 km	230 km
Number of Circuits	2 cct	2 cct	1 cct
Voltage	345 kV	345 kV	345 kV
Conductor	410 sq.mm ACSR x 2	ditto	ditto

13. Substation

Location	Phnom Penh	Sihanouk Ville	Saigon
Secondary Voltage	115 kV	115 kV	220 kV
Capacity	100 MVA (100 x 1)	600 MVA (120 x 5)	360 MVA (120 x 3)

14. Telecommunication Equipment

Powerline Carrier Telephone and VHF Radio Telephone

15. Construction Cost (excluding interest during construction)

Reservoir and Dam	$104.3 million
Power Station	$165.4 million
Transmission Line and Substation	$48.4 million
Total	$318.1 million

in which

Foreign Currency	$236.6 million
Domestic Currency	$81.5 million

16. Construction Period in Development of Type I Power Consumption Pattern:

First Stage:	1970 - 1977	Completion of Dam, Installation of 625 MW and Beginning of Operation
Second Stage:	1979 - 1980	Additional Installation of 125 MW
	1983	Additional Installation of 125 MW

17. Economic Evaluation and Financial Analysis

Type I Power Consumption Pattern	4.4%
Type II Power Consumption Pattern	5.3%
Type III Power Consumption Pattern	5.3%

Financial analysis are made by changing the rate of interest corresponding to the objects, where the interest during construction is also included in the cost.

MAIN FEATURES OF THE PROJECT

TOTAL CONSTRUCTION COST of the PROJECT	$358.0 million
in which FOREIGN CURRENCY	$256.5 million
DOMESTIC CURRENCY	$101.5 million

B. Agricultural Sector

1. Scale of Development

Irrigation Area	34,000 ha (Paddy Field – 58%, Upland Field – 42%)
Drainage Improvement Area	2,845 ha
Total Planting Area	60,739 ha (including 1,957 ha for Cultivation of Feed)
Number of Farming Households	8,500 (including 2,000 Households expected to settle from Farmland to be submerged under the reservoir)

2. Water Requirement and Facilities

Water Requirement	468 million cu.m
	Sambor Reservoir – 238 million cu.m Other Sources – 230 million cu.m
Division of Area	12 Districts
Length of Irrigation Canal	557 km
Length of Drainage Canal	31 km
Pumping Station	27 Stations
Irrigation Pumping Stations	23 (6,900 kW)
Drainage Pumping Stations	4 (1,900 kW)
Total Power Required	8,800 kW
Reservoir	3 Reservoirs
Effective Storage Capacity	35 million cu.m
Dam Embankment Volume	783 million cu.m
Lakes and Ponds with Gates	8 provided with 10 Gates
Colmatage Method	To be practised at 8 Places
	Canal length – 8.6 km

	Experimental Farm	To be established at 2 Places
3.	Construction Cost	
	Foreign Currency	$17.04 million
	Domestic Currency	$17.86 million
	Total	$34.90 million
4.	Construction Period	1970 - 1979
5.	Economic Evaluation and Financial Analysis	
	Averaged Internal Rate of Return	7.9%

Financial analysis are made by changing the rate of interest corresponding to the objects, where the interest during construction is also included in the cost.

MAIN FEATURES OF THE PROJECT

TOTAL CONSTRUCTION COST of the PROJECT	$358.0 million
in which FOREIGN CURRENCY	$256.5 million
DOMESTIC CURRENCY	$101.5 million

C. Navigation Sector

1. Inclined Passage Facilities

Location	Component Part of Rock-fill Dam near the Left Bank
Specifications	1 Line for Rafts
	2 Lines for medium-sized Vessels (30 to 50 tons)
	Length - 855 m
	Gradient – 1/11
	Volume of Embankment – 820,000 cu.m

2. Dredging

Location	Shoals 3 km on the Downstream of the Inclined Passage Facilities
Designed Channel Width and River Bed Elevation	45 m, EL + 3.5 m
Rock Excavation	95,000 cu.m
Location	Shoals existing at a Point 25 km, and Those between 7 and 14 km Downstream of Stung Treng
Designed Channel Width and River Bed Elevation	60 m, EL +34.4 m
Dredging	570,000 cu.m

3. Construction Cost (excluding interest during construction)

Foreign Currency	$2.95 million
Domestic Currency	$2.08 million
Total	$5.03 million

4. Construction Period

1976 - 1977	1 Line for Rafts
1988	1 Line for Medium-sized Vessels
1993	1 Line for Medium-sized Vessels

5. Economic Evaluation and Financial Analysis

Internal Rate of Return	5.2%

Financial analysis are made by changing the rate of interest corresponding to the objects, where the interest during construction is also included in the cost.

CHAPTER B. CONCLUSIONS AND RECOMMENDATIONS

B-1 Conclusions

The Sambor Project is a multipurpose development scheme for power, navigational and agricultural development in the Lower Mekong River Basin. The percentages of the construction cost of each aspect to the total cost are 89% for power including the dam, 1% for navigation and 10% for agriculture. Thus, power constitutes the major part of the project. The principal conclusions resulting from the field surveys as well as studies and analyses made in Japan are summarized below.

(1) The Sambor Project is feasible from the economic and technical point of view, and is recommended that the project be implemented as early as practicable when the required conditions can be satisfied.

(2) The Sambor Project will create large direct benefits and also immeasurable indirect benefits such as providing more employment opportunities, promotion or improvement of related industries, education and culture, etc.

(3) The accumulation of internal reserve will amount to approximately $380 million to $440 million in the power and navigation sectors over a 50-year period after the completion of project, and a net income of about $138 million to $140 million will be realized from the agricultural sector, if the required conditions and financial program can be satisfactory fulfilled.

(4) Getting implementation financing for the Sambor Project seems to be relatively easy compared with other mainstream projects such as the Pa Mong and the Stung Treng, because the net construction cost is estimated as $358 million which is about one-third that of the other projects.

(5) The Sambor Power Plant will be able to supply electric power at a relatively low cost with a maximum capacity of 875 MW and an average annual energy of seven billion kWh.

The general demand of Cambodia and Vietnam will be met sufficiently by approximately one-third of the energy at the firm power at a cost of 9 mills/kWh for a long period of time.

About one-third of the energy is to be delivered to the aluminum industry as firm power at a cost of 2.5 mills/kWh at the receiving end of the primary substation, and the remaining energy (approx. one-third of the energy) as secondary energy to the other power-oriented industries at a cost of 2 mills/kWh, when the Type I power consumption pattern is adopted as a development scheme.

Therefore, firm power can be supplied approximately at an average cost of 5.7 mills/kWh when the required conditions can be satisfied.

The results of studies on the technical, economical and financial aspects of the project will be discussed below.

B-1-1 Growth of General Demand and Necessity for Early Development of the Sambor Project

(1) At present, Cambodia has an installed capacity of approximately 45 MW and Vietnam an installed capacity of about 285 MW. There is a shortage of power supply capacity to meet demand for power in both countries. The charge for electric service currently in force in Phnom Penh and Saigon, where electricity is supplied at the lowest rate, is as high as 60 to 70 mills/kWh. The annual growth of general demand in these countries during the past 10 years average 10% and 11% respectively. Therefore, if abundant and inexpensive power becomes available, it would not only satisfy potential demand but also create new demands causing a fast growth in the demand for power.

(2) If the transmission lines from the Sambor Power Plant are connected with the existing systems linking to Phnom Penh, Sihanouk Ville, Saigon, and Chholon, and if independent systems (privately operated power plants) are to be intereconnected with such power systems, 73% to 78% of power demand of the two countries will be concentrated in the said power systems. The total power demand in the two countries is expected to reach 576 MW (Cambodia--121 MW, Vietnam--455 MW) in 1978 when the power plant is to be commissioned, and 1,520 MW in 1988 (Cambodia--346 MW, Vietnam--1,174 MW).

(3) Cambodia plans to develop 197 MW from nine projects and Vietnam 454 MW from six projects. Thus, development of a 240 MW is planned for completion by 1977. The commissioning of the Sambor Project, even if construction progresses smoothly, will be in 1978. If all these projects are developed as scheduled, it is likely that the demand and supply balance will be maintained until 1976, but in 1977 there will arise a deficiency in supply of 170 MW against a maximum demand of 590 MW in Vietnam, necessitating the construction of a thermal plant to cover the shortage. Six of these projects (three each in the two countries) are scheduled after 1978 to generate 73 MW in Cambodia and 262 MW in Vietnam. In the two countries, a deficiency of 56 MW is expected against the demand increment of 164 MW in 1980. In 1988, the deficiency will increase to 656 MW against the demand increment of 991 MW. Therefore, completion of all projects, including the above-mentioned six, will not provide sufficient power to satisfy the deficiency which will range from 30% to 70% of the total demand increment.

(4) The deficiency of supply will gradually increase after 1980 requiring a large-scale power development. The Sambor Project has the benefit over other mainstream projects because (a) its development will be facilitated as its site is located at about the center of Cambodia, (b) its reservoir area will be confined within Cambodian territory, (c) its submerged area including farm land will be smaller than that of other mainstream projects, (d) its estimated cost is about one third of that of the Pa Mong and Stung Treng Projects, and (e) it will provide power for general demand at a low rate of about 9 mills/kWh, delivered at the primary substation.

B-1-2 Necessity and Feasibility of Inducing Power-Oriented Industries

(1) Power generation of the Sambor Project has been designed to satisfy 60% of the increment of general demand until the maximum output of 875 MW is attained. Therefore, if the power is consumed solely by the general demand, it will take about 13 years before the Sambor Project enters the stage of full load operation provided that it is commissioned in 1978. This calls for the inducement of power-oriented industries which would serve the purpose of effective utilization of power for the purpose of early economic development of the Lower Mekong River Basin.

(2) Power-oriented industries suitable for inducement into the Lower Mekong River Basin include aluminum refining industry, caustic soda industry, calcium carbide industry, ferro-silicon industry, silicon carbide industry and vinyl chloride industry. For the aluminum refining industry, the Sambor Project can supply firm energy at the prevailing international rate of 2.5 mills/kWh. For the other power-oriented industries, the Sambor Project can provide secondary energy at approximately 2 mills/kWh. It may be added that Sihanouk Ville, Saigon and Phnom Penh are all port cities with suitable conditions for the establishment of these power-oriented industries.

B-1-3 Power Generation Program

(1) Comparative studies were made on geological and topographical conditions of the four alternative sites located between the Samboc Rapids and a point about 6 km downstream, which led to the selection of the dam site proposed in this report.

(2) A fill-type dam has been adopted in consideration of various factors including the diversion and care of the river, geology, topography, availability and transportation of embankment materials. Structures such as the powerhouse and the spillway will be built on highland on the right bank. The dam will be a rock-fill structure in the river section and earth-fill structures on both wings adjoining it. The normal high water surface level of the reservoir has been designed to be 40 m in consideration of the tailrace water level of the proposed Stung Treng Project to be constructed upstream of the Sambor Project. The total storage capacity will be 10 billion cu.m, but this will not provide any flood control capacity since the storage capacity is only 2.2% of the average annual discharge of 446 billion cu.m at the dam site (average for period 1933 to 1965). The dam will be 54 m high and have a crest length (including the intake) of 30.7 km. The draw-down of the reservoir has been designed to be 2 m in consideration of the influence to navigation and irrigation. The effective storage capacity, therefore, will be 2,050 million cu.m. Construction of the dam including powerhouse and spillway is technically feasible, and there are no problems in the transportation of machines and equipment, availability of construction materials, foundation treatment, and diversion and care of the river.

(3) In determining the scale of power development, studies were made on the combined hydro and thermal operation which is designed to firm up secondary hydro energy and on the hydro generation only to supply firm energy. This led to the conclusion that an output of about 900 MW would be most optimum for either case. The unit capacity of the generator has been selected to be 125 MW at a rated head of 19.7 m and maximum discharge of 775 cu.ms. The total installed capacity is assumed to be 875 MW (125 MW x 7 units).

If Type I is employed as a pattern of consuming electric power, five units of turbines and generators are to be installed in the first stage, while two units installed in the second stage. When the upstream projects are completed, fluctuations fo the flow will be mild. In anticipation of this situation, five additional bays will be constructed in the first stage. The five bays for the future extension and the two bays for the second stage will be utilized as diversion channels during construction. In the design of the units, consideration has been made to increase the capacity of a unit to be installed in the first and second stages up to 200 MW by adjusting the vanes.

(4) It is anticipated that before completion of the Sambor Project a 110 kV line connecting Phnom Penh and Sihanouk Ville, and a 220 kV line between Saigon, Da Nhim and Don Nhoi will be constructed creating 220 kV and 66 kV systems. It is therefore planned to build primary substations in the suburbs of Phnom Penh, Sihanouk Ville and Saigon to receive power from the Sambor Project. Two circuit of 345 kV lines are to be constructed between Sambor and Phnom Penh (190 km) and Sihanouk Ville (160 km), on the assumption to supply power to power-oriented industries, and a single-circuit 345 kV line Sambor and Saigon (230 km).

(5) Among the mainstream projects, the Sambor Project is located in the lowermost reaches. Due consideration was therefore given to create no excessive variation of the river water level that may be caused by the powerhouse operation. The fluctuation of water level at Kratie will be held within 1 m, which is expected to cause no adverse effect on the water level at Phnom Penh.

B-1-4 Navigation Program

(1) Navigation on the Mekong is quite active in the section downstream of Kratie. Upstream of Kratie, however, navigation is obstructed at many places including the Samboc Rapids. When these obstacles are submerged by the dam and appropriate navigation facilities are provided, the navigable distance will extend to 680 km from the estuary of the Mekong up to Stung Treng. This will largely contribute not only to the future economic development of the lower basin but also to the development of upstream areas.

(2) Comparative study was made on a number of navigation programs with attention directed to the rate of population growth in the four riparian countries, estimated transport demand, cost, etc. As a result, the conclusion reached was that the construction of inclined passage facility would be the best to attain the desired thoroughfare for vessels that navigate upstream beyond the dam and vice versa. The inclined passage facility will consist of one line for passing raft and two for medium-size boats of 30 tons to 150 tons. The one line for passing raft should be constructed, and completed simultaneously with the dam, and the two for medium-size boats are to be constructed corresponding to the increase in the volume of traffic.

(3) For smooth and uninterrupted navigation, it will be necessary to dredge some sections of the river channel. Dredging should be carried out over a 3 km distance in the downstream direction from the downstream end of inclined passage facility to maintain a minimum effective channel width of 45 m with a water depth of 2 m at a minimum flow of 1,350 cu.ms after completion of the dam. Dredging should also be carried out in shoals existing near the extreme end of the reservoir backwater, i.e., in sections about 7 km to 14 km and 25 km downstream of Stung Treng, so that an effective channel width of 60 m may be maintained. These dredging works will greatly improve the dry season navigation between Kratie and Stung Treng and will also make it possible for vessels presently plying between Kratie and the estuary to serve as far upstream as Stung Treng.

(4) The dredging work mentioned above entails no technical problems and can be executed without difficulty. A navigation lock and canal will be required at Sambor in the future when the construction of upstream dams is completed. Considering the volume of traffic estimated for the project period, construction of a canal whicha requires large capital investment is not economic. In this report, therefore, no consideration has been given to the canal construction. (See Vol. II Chapter K)

B-1-5 Agricultural Program

(1) Agriculture in Cambodia occupies an important position as the country's basic industry. It has been proven in many developing countries that economic development can be put on the right track only when priority is given to the development of agriculture over other industries. Cambodia is no exception in this respect and agriculture constitutes an important part of the Sambor Project, too.

(2) In order to delineate the agricultural development area, investigations were conducted in the 69,000 ha of land which extends downstream of the dam site to the boundary of Kratie Province at an elevation lower than the reservoir low water level of 38 m. Investigations revealed that 34,000 ha would be technically and economically suitable for agricultural development.

(3) Crops presently cultivated in the proposed agricultural development area include rice, maize, green pea, peanut, sesame, tobacco and others. Crops recommended for cultivation in the area are mainly rice and maize.

(4) The total water requirement upon completion of the program is 468 million cu.m of which 238 million cu.m will be supplied from the Sambor Reservoir and 230 million cu.m from the Mekong Mainstream and tributaries as well as lakes and swamps. Due to limitations imposed by topography and cost, only 45% of the development area will be covered by the network of pump irrigation system. It is considered suitable to divide the area into 12 districts by the difference in irrigation and drainage systems and farm management, and to promote the development in a manner that best suits each district.

(5) Completion of this program will increase the total arable land from the present 12,469 ha to 34,000 ha (2.73 times) and the planting area from 16,980 ha to 60,739 ha (3.58 times). Number of farming households in the area is about 6,500 at present. When 2,000 households now in the area to be submerged under the reservoir will have settled in the development area, the total number of farming households will be 8,500. Upon completion of the program, each farming household is expected to enjoy an increase of arable and planting areas from the present 1.93 ha to 4 ha (2.1 times) and from 2.62 ha to 7.15 ha (2.73 times) respectively. The annual net income per ha of each farming household will also rise from $47.5 to $181.4 (3.82 times). It is therefore believed that farm management in the area will become economically attractive.

(6) Flood protection and drainage are factors that can not be neglected with in the agricultural development. At the present stage, however, an attempt to provide the entire development area with flood protection and drainage systems cannot be justified, and should await the completion of the flood control scheme of the Mekong Mainstream to be realized by the construction of upstream reservoirs. In the program under consideration, therefore, the drainage improvement is planned to be effected only in 2,845 ha whose topography will allow simple facilities including drainage pumps and dikes to produce sufficient effect. The *colmatage* method, which has been practised on a limited scale, will be introduced on a large scale.

B-1-6 Work Schedule

(1) Assuming that all prerequisite conditions and arrangements including the approval of the Mekong Committee, pledges of international financing organizations to finance the cost, preparation of detailed designs and bid documents, award of contracts to civil contractors and equipment suppliers could be obtained and completed within a couple of years from the present and that preparatory construction work including transport roads, access roads, construction camp and other structures could commence in or around 1970, the project could be completed in or around 1978 with the construction period taken into account. With respect to the powerhouse, spillway, transmission lines and dam, construction of the former three structures is assumed to commence in 1973 and that of the dam in 1974. Five turbines and generators will be installed in the first stage and the two additional units will be installed in stages corresponding to the growth of demand with target completion time in 1983.

(2) As regards the inclined passage facility for navigation, preparations for constructing one line for timber raft will be started three years prior to the completion of the dam, to be followed by the actual construction work which will commence one and half years before completion of the dam. The remaining two lines will be constructed to meet the estimated increase in transport load, i.e., one in 1988 and the second in 1993. One year will be required to construct each line.

(3) The agricultural development program has been prepared by dividing the entire development area into 12 districts. Actual work, however, will be carried out after dividing the area into 17 work districts so that the annual cost will become approximately equal. The period required for the development of each work district will be about two years, and a total of 10 years from 1970 to 1979 has been scheduled as the develop-period.

B-1-7 Estimated Cost

(1) The total estimated cost of the Sambor Project including power, navigation and irrigation amounts to $358 million, of which $256.5 million is foreign currency, and the remaining $101.5 million is local currency. The cost required for the first stage development assumed to be completed in 1978 is $322.5 million, of which $231.3 million is required in foreign currency and the remaining $91.2 million in local currency.

Breakdown of the costs is tabulated below.

(Unit: Million dollars)

(Item)	(Total Cost)			(Total Cost for First Stage)		
	Total	Foreign currency	Local currency	Total	Foreign currency	Local currency
Power	318.1	236.6	81.5	292.5	216.2	76.3
Navigation	5.0	2.9	2.1	3.8	2.2	1.6
Subtotal	323.1	239.5	83.6	296.3	218.4	77.9
Agriculture	34.9	17.0	17.9	26.2	12.9	13.3
Grand Total	358.0	256.5	101.5	322.5	231.3	91.2

[As for fishery see B-2, (5)]

(2) The above table covers, all costs for preparatory constructions, civil engineering works, machines and equipment, construction materials, transportation, engineering, and contingencies, but exclude interest during the construciton and the administrative costs of the executing agency of the project. (As for interest during construction, see Chapter K, K-4, of Vol. III)

B-1-8 Economic Soundness

(1) In planning the power supply program, the following three types of load combinations were studied, which revealed that the internal rate of return for power is 4.4% in case of Type I and 5.3% in both cases of Types II and III.

Type I : General demand and power-oriented industries with the aluminum refining industry as the major component (aluminum refining, calcium carbide, caustic soda, vinyl chloride, ferro-silicon and silicon carbide)

Type II : General demand and industries (calcium carbide, caustic soda, and vinyl chloride)

Type III: General demand only

Types II and III would take a longer time before the full load operation is attained, and would also invite dump power rate of 30% and 34% respectively as against 15% for Type I. Type I is therefore recommended for the early economic development and effective utilization of power.

(2) The internal rate of return method has been employed at the request of the Mekong Committee. It should be noted, however, that this method is effective only if there are competitive and optional projects. In the case of the Sambor Project, no such projects can be considered to exist since its implementation is easier than any of the upstream projects with respect to cost and other aspects. The method therefore is considered to serve only as a supplementary means to justify the economic soundness of the project.

(3) The calculated internal rate of return of 4.4% is not very high. It should be noted, however, that large-scale power development schemes in developing countries generally produce a low internal rate of return because of the long period required for load to build up to full load operation.

(4) Upon completion of the Pa Mong Project which is under study and the Nam Ngum Project which is under construction, the regulated discharge from these projects will enable the addition of capacity of the Sambor Project to a ultimate installed capacity of 2,100 MW. This increase will naturally be accompanied by a rise of internal rate of return to 6% to 7%. Therefore, the project feasibility can be readily established when studied solely from the standpoint of internal rate of return.

(5) The feasibility of the project has been studied on the basis of comprehensive judgement of the technical and economic soundness given above as well as the financial soundness that is described in Chapter B-1-9, which led to the conclusion that the Sambor Project is feasible in every aspect though its internal rate of return would not exceed 4.4% at the outset.

(6) The internal rate of return of the navigation aspect is about 5.2%. Since the absolute cost required for navigation improvement which is less than 2% of the total project cost, it is assumed to be absorbed into the internal rate of return of power as a part of the cost of the dam. Evaluation of navigation improvement must be also made in the light of the secondary benefits it will create for forestry development in areas upstream of Kratie as well as the development of forestry and mineral resources in Laotian territory in the future.

(7) The internal rate of return of agriculture is 7.9%, and this is on the international level. However, the benefits created by the agricultural development program cannot be directly appropriated to debt financing. Therefore, in negotiating possible loans from international financing organizations, efforts should be directed to securing loans at an interest rate far lower than the expected internal rate of return.

B-1-9 Financial Soundness

(1) Separate financial programs for power and navigation and for agriculture have been prepared for the following reasons.

a) Time of benefits from power and navigation do not coincide with that from agricultural development.

b) Benefits from agricultural development cannot always be appropriated to debt financing.

c) Agricultural development has more opportunity to be financed by soft loans than industrial development.

For the financing of the project, it was assumed that all foreign currency would be raised in the form of loans outside of Cambodia, but for domestic currency the following two cases were assumed : (Case 1) total amount is to be borne by the national treasury of the Government of Cambodia, and (Case 2) half of the amount is to be borne by the national treasury and the remaining half is to be raised from domestic financing institutions.

As for interest rate and term of repayment, an anticipated amount of loans from each of various international financing institutions and other foreign financing institutions for the power and navigation aspects were first assumed, then the weighted mean of the current interest rate charged by these financial institutions were calculated, and the overall interest charge and term of repayment for the first and second stages of construction were obtained.

The results are as follows:

Case 1:	Interest charge	–	First stage	4%
			Second stage	6.2%
	Repayment period	–	First stage	25 years after start of its operation
			Second stage	18 years after start of its operation

Case 2:	Interest charge	—	First stage	4%
			Second stage	5.9%
	Repayment period	—	First stage	28 years after start of its operation
			Second stage	18 years after start of its operation

For agriculture the interest charge is 3.5%, and repayment period is 20 years.

(2) Results of calculation based on the above condition for power and navigation indicates that the cash balance takes a favorable turn from the eighth year after start-up for Case 1 and also for Case 2. After all borrowings, including both foreign and domestic, are completely redeemed, and if governmental contribution is set aside, the accrued reserve which is net income and depreciation reserve will amount in 50 years after start-up to $550 million for Case 1 and $490 million for Case 2. After deducting costs for replacement, the accrued reserve will amount to $440 million for Case 1 and $380 million for Case 2.

(3) For agriculture, the principal and interest of both foreign and domestic borrowings will amount to $44.06 million for Case 1 and $48.73 million for Case 2. On the other hand, the net income of the farmers in the 50 years after the creation of the initial benefit is estimated to amount to $186.9 million. In the case of agriculture source of funds for repayment may not necessarily be collected from farmers, but judging from the above earnings the net income in terms of national economy in 50 years will be $143 million for Case 1 and $138 million for Case 2.

(4) The burden on the treasury of the Government of Cambodia in the 10 years after start of construction of the Sambor Project will be $10,490,000 per year on the average and $16,400,000 in the peak years for Case 1, and $6,012,000 per year on the average and $8,200,000 in the peak years for Case 2. Under the Second Five Year Program of the Government of Cambodia, the GNP in 1972, the last year of the Five Year Program, is estimated at 39.1 billion Riel ($1,120 million), and if it is assumed that the GNP will continue to increase at an annual rate of 5% thereafter, the ratio of the burden to the treasury of the Government of Cambodia will be around 0.7% to 0.8% of the GNP for Case 1, and 0.4% to 0.5% for Case 2, which is considered to be an amount that seems to be shouldered by the state treasury. As a result of the above study, it is concluded that the Sambor Project is financially feasible if the required conditions can be satisfied.

B-2 Recommendations

Based on the conclusions given above, the following recommendations are made.

(1) The Sambor Project is technically, economically and financially feasible, even if developed as an isolated project. The project is of a suitable scale from the standpoint of the economy of Cambodia and Vietnam since its construction cost is about one third of that of the Pa Mong Project and the Stung Treng Project. It is therefore recommended that every effort be made for its early development so that the basis for economic and industrial development may be established in the two countries.

Upon completion of the upstream Pa Mong Project and the Nam Ngum Project, the regulated discharge from those project will enable the Sambor Project to increase its ultimate installed capacity to more than 2,000 MW which will result in an immense increase in energy output. It is therefore recommended that social and economic development be initiated at an early stage to create environments in which power from the Sambor Project can be utilized to the fullest extent.

(2) Since the introduction of aluminum refining industry and other power-oriented industries is one of the important controlling factors to the successful development of the project, concerted efforts should be made to attract power-oriented industries into the area. Studies on the possibility of establishment of power-oriented industries should be made also as early as possible.

(3) In order that the benefits of agricultural development may be realized at an early stage, it is recommended that experimental and demonstration farms be established to provide technical training and guidance in improvement of irrigation and drainage technique, and to disseminate information in farming technique and plant breeding.

(4) In order to enhance to the fullest extent the benefits of navigation improvement, it is desirable to prepare an industrial development plan of the Stung Treng District and to conduct investigations of unexploited natural resources of the Mekong River Basin.

(5) The tributaries of the Mekong, those which join the mainstream near Stung Treng, particularly the Se San, Se Kong, and the Sre Pok, and the adjoining inundated forests and swamps seems to be excellent breeding grounds for fish in the wet season. The Sambor Reservoir is expected to play an important role in the preservation and production of fish resources, but it is unknown yet whether the catches in downstream waters will be affected by the construction of a dam. Taking into account fish migration, the present study includes fish ladders which are estimated to cost approximately $5 million. It is recommended that fishery studies be carried oiut to establish appropriate measures for the preservation and production of fishes.

(6) Before construction of the project may begin, the following supplementary investigations will be necessary in order to prepare the detailed designs.

a. Study of the probable maximum flood by meteorological data, and the method and influence of flood control operation.

b. Detailed study on the construction of the rock-fill dam in the river channel section.

c. Geological investigation of the former river bed.

d. Geological survey of foundations of supporting structures for the transmission line to be built on soft ground along the proposed route.

e. Sounding of shallow water and geological investigation in the neighborhood of Stung Treng.

f. Detailed land classification study in the proposed irrigation development area, and study on construction, maintenance and management of hydraulic structures.

g. Study of socio-economic influence of the Sambor Project upon the projected area or Cambodia and Vietnam.

MAIN FEATURES OF THE PROJECT

TOTAL CONSTRUCTION COST	$477.5 million
FOREIGN CURRENCY	$362.7 million
DOMESTIC CURRENCY	$114.8 million

If the scale of development in the agriculture and navigation aspects is assumed to be the same as that of the isolated project, the total construction cost of the Project in this case will be increased from $358.0 million of the Isolated Project to $477.5 due to the increment of total cost of electrical equipments.

A. Power and Dam Sector

1. Reservoir (Same as the Isolated Project)

Catchment area	646,000 sq. km
Total storage capacity	10.0 billion cu.m
Normal high water level	40 m
Draw-down depth	2 m
Effective storage capacity	2,050 million cu.m
Dam type	Combined Dam of Earth-fill, Rock-fill, and concrete
Total length	30.7 km
Height	54 m
Volume	Fill-type 25.9 million cu.m
	Concrete 1.43 million cu.m
Design flood	90,000 cu.ms
Total length of spillway	1,003 m (Effective length: 795m)
Spillway gate	14 m high x 15 m wide : 53 gates

2. Power Plant:

	Isolated Case	Case with Nam Ngum and Pa Mong
Installed capacity	875 MW 125 MW x 7 units	2,100 MW (ultimate) 175 MW x 12 units
Room for additional installation of unit	5 (Turbine rooms and draft tubes)	None
Available water, max.	5,425 cu.ms	9,600 cu. ms
normal	1,860 cu.ms	4,380 cu. ms
Effective head	16.7m–32m 1/	20.0m–30.5m 2/
Rated head	19.7 m	26 m
Firm power	473 MW	1,120 MW
Dependable Peak Output	637 MW	1,390 MW
Available annual energy	7,000 million kWh	14,600 million kWh
Firm energy	4,100 million kWh	9,780 million kWh
Secondary energy	2,900 million kWh	4,920 million kWh

3. Power Load Distribution (Generating end)

	Isolated Case			Case with Nam Ngum and Pa Mong	
Type of Power Consumption Pattern	I	II	III	I'	III'
Load	MW	MW	MW	MW	MW
General demand	390	760	875	890	2,100
Aluminum industry	250	-	-	500	-
Caustic soda ind.	60	60	-	120	-
Vinyl chloride ind.	16	16	-	32	-
Carbide calcium ind.	103	39	-	206	-
Agricultural pumping	-	-	-	240	-
Ferro-silicon Silicon carbide	56	-	-	112	-
Total	875	875	875	2,100	2,100

Notes: 1/ Average monthly runoff during the 33-year period since 1933.
2/ Average monthly runoff during the 15-year period since 1950.

4. Power Transmission Facilities

	Isolated Case	Case with Nam Ngum and Pa Mong
Voltage	345 kv	345 kv
Total length and the number of circuits:		
Sambor – Phnom Penh	190 km x 2	190 km x 3 (1)
Phnom Penh – Sihanouk Ville	160 km x 2	160 km x 2 (–)
Sambor – Saigon	230 km x 1	230 km x 2 (3)
Capacity of primary substations:		
Phnom Penh	100 MVA x 1	160 MVA x 3 (3)
Sihanouk Ville	120 MVA x 5	270 MVA x 4 (–)
Saigon	120 MVA x 3	250 MVA x 3 (6)

Note: Parenthesized figures indicate the number of circuits to be used for general demand only (Type III').

5. Starting Year of Plant Operation 1978 1980

6. Construction Period:

Stage I	1970–77	1972–79
Stage II	1979, 1980, 1983	1981–90 (1994)

Note: Parenthesized figures indicate the time for general demand only (Type III').

7. Construction Cost $318.1 million $437.6 million

8. Economics (Internal rate of return)

	Isolated Case	Case with Nam Ngum and Pa Mong			
		(1)	(2)	(3)	(4)
Power consumption, type I (I)	4.4 %	7.2 %	6.2 %	7.6 %	6.4 %
Power consumption, type II	5.3 %	-	-	-	-
Power consumption, type III (III')	5.3 %	7.8 %	6.3 %	8.6 %	7.0 %

Notes:
1. (1) and (2) indicates the results of supplying 60% of the increased portion of general demand.
2. (3) and (4) indicates the results of supplying 90% of the increased portion of general demand.
3. Fare per kWh is 9 mills for general demand, 2.5 mills for aluminium, 2.0 mills for other uses in the case of (1) and (3).
4. In the case of (2) and (4) the fare is 7 mills for general demand and that of other uses are the same as with (1) and (3).

B. Irrigation and Agriculture

		Isolated Case	Case with Nam Ngum and Pa Mong (Figures excluding those of the project area of the isolated case)
1.	Project area	34,000 ha (In which 2,845 ha is for improvement of drainage system)	587,000 ha (Downstream of the project area of the isolated case)
2.	Gross irrigation water requirement	468 million cu.m (In which 238 million cu.m is for Sambor Reservoir)	152 cu. ms--774 cu.ms
3.	Water resources and pamping station:		
	Sambor reservoir	(as previously mentioned)	
	Reservoirs on tributaries	3 sites	
		Effective storage capacity 35 million cu.m. Volume of Embankment 783,000 cu.m	
	Pumping station	23 sites: 6,859 kW	212,000 kW
		(From mainstream, tributaries, lakes and swamps)	
	Total length of irrigation canal	557 km	870 km
4.	Drainage		
	Total length of drainage canal	31 km	
	Pumping station	4 sites; 1,937 kW	
5.	Land reclamation	14,800 ha	251,000 ha
6.	*Colmatage* canal	8 routes, 8.6 km	
7.	Experimental station	2 sites	
8.	Construction period	1970-80	(1976-90)
9.	Construction cost	$34.9 million	$525 million
10.	Economics (Internal rate of return)	7.9 %	10.1 %

C. Navigation (Same as the Isolated Project)

1.	Inclined Passage Facility:		
	Number of routes		3
	Total length		855 m
	Volume of embankment		820,000 cu.m
2.	Dredging		665,000 cu.m
3.	Construction Period:	Stage I	1975–77
		Stage II	1988, 1993
4.	Construction Cost		$5.03 million
5.	Economics (Internal rate of return)		5.2 %

CHAPTER A. Introduction

This report describes the feasibility of the Sambor Project with consideration of influence of flow regulation by the two projects upstream of Sambor: the Nam Ngum which is under construction and the Pa Mong Project which is now in the planning stage. Beside these three projects, plans for many other projects are being worked out for the lower reaches of the Mekong.

Construction work on the Nam Ngum Project was commenced in 1968, under the supervision of Nippon Koei of Japan, and surveys and studies for the Pa Mong Project are being carried on by the United States Bureau of Reclamation (USBR) since 1961.

The scale of the Pa Mong Project is one of the largest in the Lower Mekong Basin, and the flow in the lower reaches is expected to be improved very greatly with the operation of the reservoir.

Therefore, if details of these projects especially the Pa Mong are clearly outlined and there is a fair prospect of realization of the projects, it will be necessary to take into consideration these upstream projects in working out a definite development plan for the Sambor Project which is located the furthest downstream. The initial Sambor Project, as described in Volume I, was worked out as an isolated project without considering any upstream projects because of the ambiguity of these projects at the initial stage of planning. With the progress of studies on these projects the details have come to be known to some extent. The Mekong Secretariat at the end of 1967 requested the Japanese Government to make a study of the Sambor Project with the flow regulation of Nam Ngum and Pa Mong reservoirs. 1/

The study was made following the completion of a report on the Isolated Sambor Development Project, and the report on the study was compiled as an annex (Vol. II) to the General Report (Vol. I).

For this reason, items which remained unchanged in the Isolated Project -- hydrometeorology, geology, reservoir scale, hydraulic structure, inclined passage facility, and the irrigation project covering an area of 34,000 ha on the immediate downstream of the Sambor -- have not been touched or have only been briefly described in this report. Emphasis has been placed on the study of the scale of power generation, the power consumption plan and the economic aspects of the project, although some parts of the description in Vol. I are reiterated in order to help understand.

The items covering power aspect are discussed in Chapters C to I.

For the navigation project, the report touches lightly upon the future plan (Chapter K, Canal and Lock System) in the event that the upstream project such as Stung Treng comes to realization besides the two upstream projects which are being taken up only in regard to water level fluctuation of the Sambor Reservoir.

For the irrigation project, a preliminary study is being made on the development of agriculture in the delta area of Cambodia with the expectation of increased runoff in the dry season in the downstream of the Mekong and low-cost power supply from the Sambor Power Plant.

The items covering navigation (inclined passage facility) and irrigation aspects are discussed in Chapter J.

For the fishery, no definite conclusion has been reached yet, but the construction of fish ladders is under consideration. However, this matter has been kept for separate discussion in the isolated project (Vol. VI) and therefore is not included in the financial plan under this project.

The main items that are prerequisites to study are numerated below.

(1) Power energy generated at the Sambor Power Plant is assumed to be supplied only to Cambodia and Vietnam.

(2) The Sambor Power System is assumed not to be interconnected with any other power plants under consideration for the upper Mekong, not to mention Nam Ngum and Pa Mong.

(3) Operation of the Sambor Power Plant is assumed to start in 1980, the same as for the Pa Mong Project. 1/

1/ Informal discussions on the Sambor Project
Draft Report, Bangkok and Phnom Penh July 1968.

A letter from C. Hart Schaaf, Executive Agent to Mr. Wada, Minister and Representative of Japan to ECAFE, October 1968.

(4) The flow at the Sambor dam site, upon realization of the Nam Ngum and Pa Mong Projects, is assumed to be just the same as the results given in a study made by the Mekong Secretariat (Average runoff by month for the 1950-65 period, received Sept. 1968).

(5) The scale of the reservoir is assumed to be the same as in the isolated project having a normal high water level of 40 m with a draw-down depth of 2 m and an effective storage capacity of 2,050 million cu.m.

CHAPTER B. Conclusions and Recommendations

B-1 Conclusions

When both the Pa Mong and Nam Ngum Projects, above all the Pa Mong, are assumed to be in operation, the scale of the Sambor Power Plant will be increased to the ultimate capacity of 2,100 MW instead of the maximum capacity 875 MW of the isolated project.

The generated power is to be met not only by general demand of Cambodia and Vietnam but also by demand of power-oriented industries invited in the region.

The internal rate of return of this project becomes 6% to 8% which is pretty higher than that of the isolated project.

In addition to the large benefit in the power sector, the Sambor Project with the Nam Ngum and the Pa Mong will improve the navigation in the Mekong River considerably, and make it possible to develop approximately 600,000 ha of Deltaic Area downstream.

With the consideration of additional benefits in navigation and agricultural aspects, and also the intangible effects on social and economical development of the projected area, this project may be said to be a very attractive one.

Result of the study is summarized as follows:

(1) Installed capacity of power generating facilities in Cambodia and Vietnam as of 1965 was 45 MW and 285 MW respectively. 1/ Annual consumption of power energy in the two countries was 63 million kWh and 430 million kWh respectively. 1/The annual growth rate of power consumption in the past 10 years was about 10%.

The centers of demand for power in the two countries are to be Phnom Penh and Saigon accounting for 80% of the total demand in both countries. Annual growth rate of demand in these central areas is expected to reach around 10% to 17%. Maximum power and annual energy 1/ are expected to be 693 MW and 3.60 billion kWh in 1980, and 1818 MW and 9.6 billion kWh in 1990.

(2) When the two upstream projects are realized, the average runoff at the Sambor site in dry months will increase from 2,000 cu.ms in the case of the Isolated Project to 5,000 cu.ms and that in flood months will decrease from 40,000 cu.ms in the case of the Isolated Project to 30,000 cu.ms and the flow at the site will be dimproved considerably. Assuming that the scale of the Sambor reservoir is set at the same level as under the Isolated Project (HWL: 40m, draw-down depth: 2m, effective storage capacity: 2,050 million cu.m), the minimum quantity of discharge for power generation will increase from 1,860 cu.ms in the case of the Isolated Project to 4,380 cu.ms and the firm power will increase from 473 MW to 1,120 MW.

(3) When the Sambor Power Plant is assumed to be operated in combination with thermal power plants, the cost per kWh will become minimum when the capacity of the Sambor Power Plasnt is around 2,100 MW.

For this reason, the optimum scale of the Sambor Power Plant at the ultimate stage will be 12 units of 175 MW turbine and generators with a total output of 2,100 MW. With the above scale, annual available power energy will be 9,780 million kWh for firm energy and 4,820 million kWh for secondary energy totaling 14,600 million kWh. (under the isolated project, installed capacity will be

1/ Statistical Bulletin, Dec. 1967

875 MW, annual available energy will be 4,100 million kWh for firm energy and 2,900 million kWh for secondary energy, totaling 7,000 million kWh.

(4) It is desirable that the power energy produced by the Sambor Power Plant will not only be used to cater to the general demand mentioned above, but it will be supplied to power-oriented industries and pumping irrigation and drainage in the lower reaches of the Mekong.

In this report, two types of power consumption pattern are considered as follows:

One plan calls for the supply of power to general demand (890 MW), power-oriented industries (970 MW), and irrigation and drainage power source (240 MW) (hereinafter referred to as Type I' consumption pattern. 1/

Another plan calls for the supply of power to general demand only (referred to as type III' power consumption pattern in this report). 1/

1/ In Vol. I of this report, the power consumption pattern for general demand and power-oriented industries including aluminum refining is referred to as Type I and that for general demand only as Type III.

(5) The industrial complex for the power-oriented industries is assumed to be established in Cambodia, and the districts around Sihanouk Ville will be the most appropriate sites for this purpose. The appropriate production scale of the complex at the ultimate stage will be approximately 250,000 tons of aluminium, 240,000 tons of vinyl chloride, 230,000 tons of caustic soda and 86,000 tons of calcium carbide, ferro-silicon and silicon carbide.

(6) It is desirable that the development of the Sambor Project be progressed on the following step-by-step basis in correlation with the change in demand for power depending on power consumption type.

Type I': If the object of the project is to supply power to general demand, power-oriented industries and pumping irrigation, the construction of dam, the power plant with an installed capacity of 700 MW (175 MW x 4 units) and the necessary transmission facilities will have to be completed by 1979. The remaining installed capacity will be added in proportion to the increase in demand by around 1990.

Type III': If the object of the project is to supply the general demand only, construction of a dam, a power plant with an installed capacity of 175 MW (1 unit), and the required transmission facilities will be completed by 1979. The remaining portion will be added gradually by around 1994.

(7) Construction of the Sambor dam, the power plant and transmission and substation facilities are feasible from a technical point of view, and required construction cost is estimated as follows:

When the object of the project is to supply the general demand, power-oriented industries, and pumping irrigation (Type I'):

Total construction cost:	$437.6 million
	($318.1 million in case of the Isolated Project)
Foreign currency:	$342.7 million
Equivalent local currency:	$94.9 million

When the object of the project is to supply the general demand only (Type III'):

Total construction cost:	$419.5 million
Foreign currency:	$326.9 million
Equivalent local currency:	$92.6 million

(8) As for the economics of the Power Sector, the internal rate of return comes to 7.2% in the case of Type I' power consumption pattern with the unit cost of benefit being 9 mills per kWh for general demand, 2.5 mills per kWh for aluminum industry and 2.0 mills per kWh for others. The internal rate of return will decrease to 6.2% when the unit cost of benefit for general demand is assumed to be 7 mills per kWh.

When the object of the project is to supply the general demand only (Type III power consumption pattern), the internal rate of return will be 7.8% when the unit cost of benefit is 9 mills per kWh, and will be 6.3% at the unit cost of benefit of 7 mills per kWh.

Judging from the above analysis, the economics of this project may be said to be fairly high compared with the isolated project. 1/

(9) There is not so much difference in figures of the internal rate of return between Type I and Type III'. Therefore, development method of Type I seems to be more desirable that will be able to consume the generated power earlier and provide a greater impact upon the socio-economic aspect of the projected area.

Therefore, descriptions in the following chapters (Chapter F, Main Structures and Construction Plan, and Chapter I, Financial Analysis), are only related to the case of Type I' power consumption plan.

(10) In the case of Type I power consumption plan, the first stage of construction work of the power sector including navigation (inclined passage facility) is as follows:

Total:
in which,
foreign currency:
Domestic currency:

(10) If the funds required is assumed to be procured on the same basis as the isolated case, the average interest for the first construction stage will be around 4% in either case, [that is: foreign currency is assumed to be provided by various international monetary institutions and financial institutions of various countries, and all local currency be furnished by the Government of Cambodia (case I), or the half of the funds are assumed to be invested by the government and the remainder to be borrowed from Fonds National de l Equipment (Case 2), and the terms of payment will be either 24 years (case I) or 29 years (case 2) after beginning of operation.] In either case it will be necessary to provide a grace period of about 4 years after the beginning of operation inregard to the expected operating revenue. Funds required for the construction stage II can be procured on a commercial basis, and the interest rate will be 6.4% (case I) and 6.2% (case 2), and the terms of payment will be 18 years at the longest. The financial plan is prepared on the assumption that the funds are procured on the conditions stated above and payment is made with the proceeds from the sales of power (7 mills/kWh for general demand, 2.5 mills/kWh for aluminum industry and 2 mills/kWh for others) and the revenue from the inclined passage toll. The cash balance will start showing a favorable return from the sixth year after the start of operation in case 1 and from the seventh year in case 2, followed by smooth repayment of borrowings thereafter. The Sambor Project therefore is considered to be sufficiently feasible also from the financial point of view.

(11) As for navigation (inclined passage facility), the water level in the downstream of the Sambor dam in the dry season (February-April) will rise by 1.6m-3.0m compared with the isolated project. As a result, the same benefits gained in the isolated project will be obtained without undertaking dredging work downstream. If dredging is done as envisaged in the isolated project, navigation of 120 ton class vessels will become possible throughout the year. If no dredging is done downstream of the dam, the construction cost of $5.03 million under the isolated project may be cut by $1.0 million (20%).

Notes: 1/ With the Isolated Project the internal rate of return is 4.4% (see Vols. I and III, when the power consumption pattern is for general demand and power-oriented industries including aluminum refining (Type I), assuming the unit cost of benefit as follows.

General demand	9 mills/kWh
Aluminum refinery	2.5 mills/kWh
Others	2.0 mills/kWh

The internal rate of return is 5.3% when the power consumption pattern is for general demand and power-oriented industries excluding aluminum refining (Type II) and when the pattern is only for general demand (Type III), too.

(12) As for irrigation, the increase in the runoff in the Mekong during the dry season and the low-cost power supplied by the Sambor Power Plant will make a great contribution to the development of millions ha in the delta area, in addition to 34,000 ha downstream of the dam, of which about 600,000 ha seems not to involve any difficulty in development.

B-2 Recommendations

(1) It is recommended that, in view of the following, preparations be initiated at once for the procurement of required funds so that the construction work may be started as early as possible if the required conditions can be satisfied.

In the isolated case the economic feasibility might seem to be a little low. However, when the Nam Ngum and Pa Mong Projects in the upstream are assumed realized, the economic feasibility of the Sambor project becomes considerably better.

The Sambor Project is not too large in scale compared with other mainstream projects such as Pa Mong and Stung Treng, and so the procurement of the required funds may be considered to be relatively easy.

The Sambor Power Plant is also closely located to the Republic of Vietnam, and the power generated at the Sambor Power Plant could be used as a driving force in the rehabilitation of the economy of Vietnam.

The Sambor dam is located at the extreme downstream area of the Mekong compared to all other projects, and it should be given top priority as far as navigation is concerned.

(2) Inviting power-oriented industries centering on the aluminum refining industry is one of the important factors to the Sambor Project, therefore detailed studies and investigations of these matters need to be initiated as soon as possible.

(3) The Sambor Project is so much influenced by the flow regulation or flood control of the upstream projects, especially the big projects such as Pa Mong and Stung Treng, that every effort should be made to check the items shown in Chapter B of Vol. I, when those projects are to become more definite.