SAMBOR PROJECT REPORT

Lower Mekong River Basin

Volume II

GENERAL REPORT (2)

Sambor with Nam Ngum and Pa Mong

OVERSEAS TECHNICAL COOPERATION AGENCY

GOVERNMENT OF JAPAN

JUNE 1969

SAMBOR PROJECT REPORT

The Sambor Project Report 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	Dam and Hydroelectric Power — Supplementary Material to Volume I
Volume IV	Irrigation and Agriculture — Supplementary Material to Volume I
Volume V	Navigation — Supplementary Material to Volume I
Volume VI	Fishery — Supplementary Material to Volume I
Volume VII	Basic Data — Appendix (1) to Volume III
Volume VIII	Drill Hole Logs — Appendix (2) to Volumes III and V

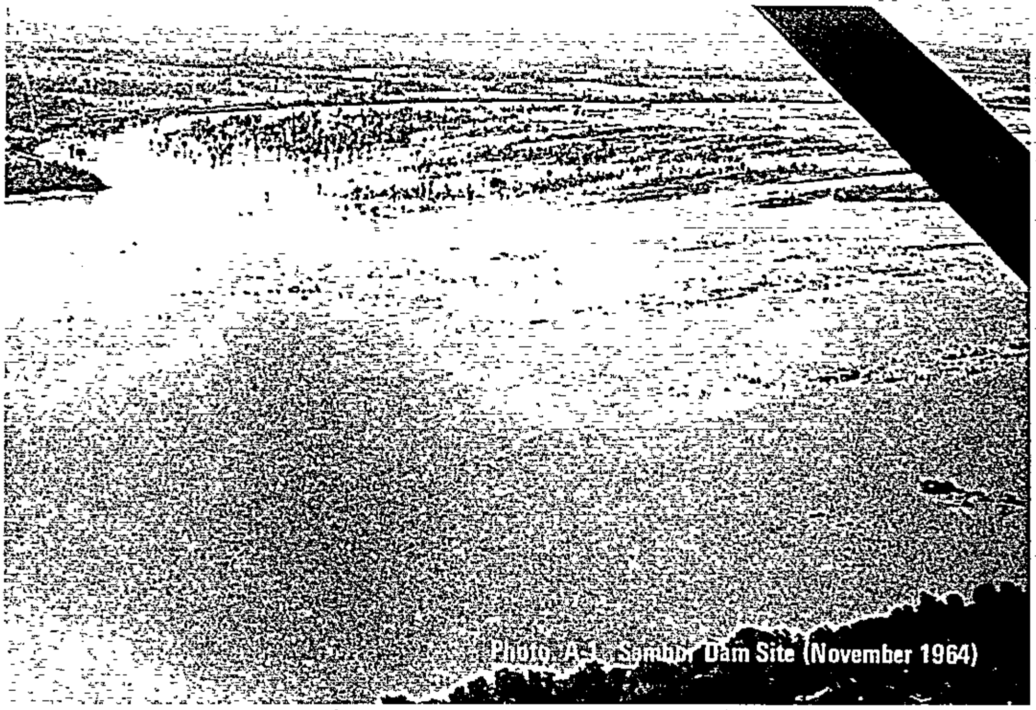


Photo. A-1 Sambor Dam Site (November 1964)

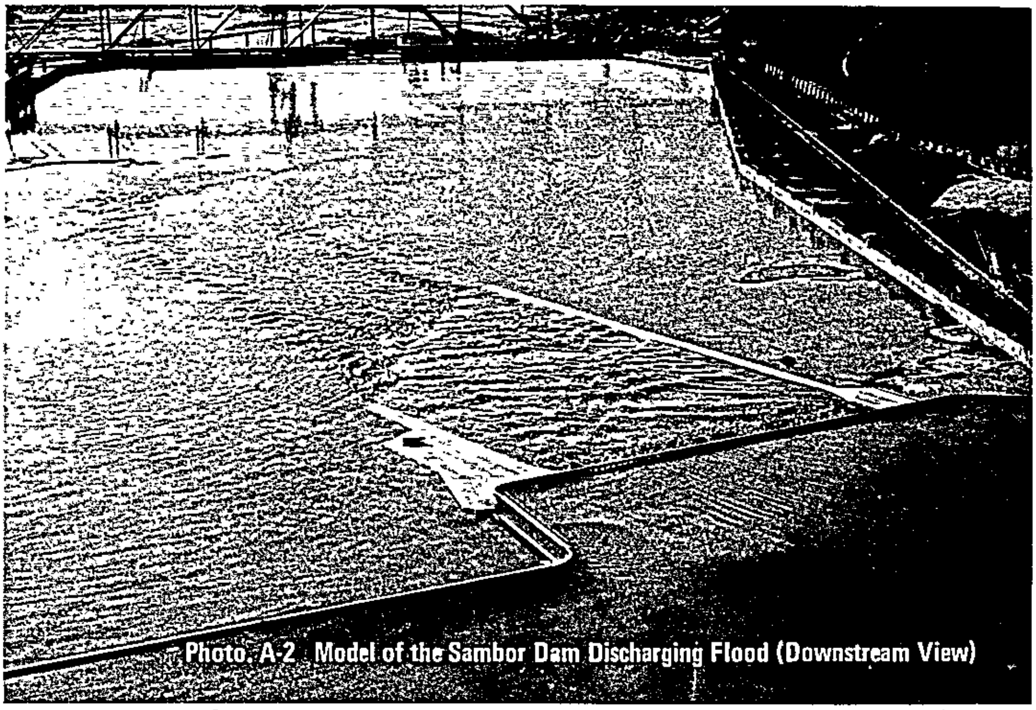
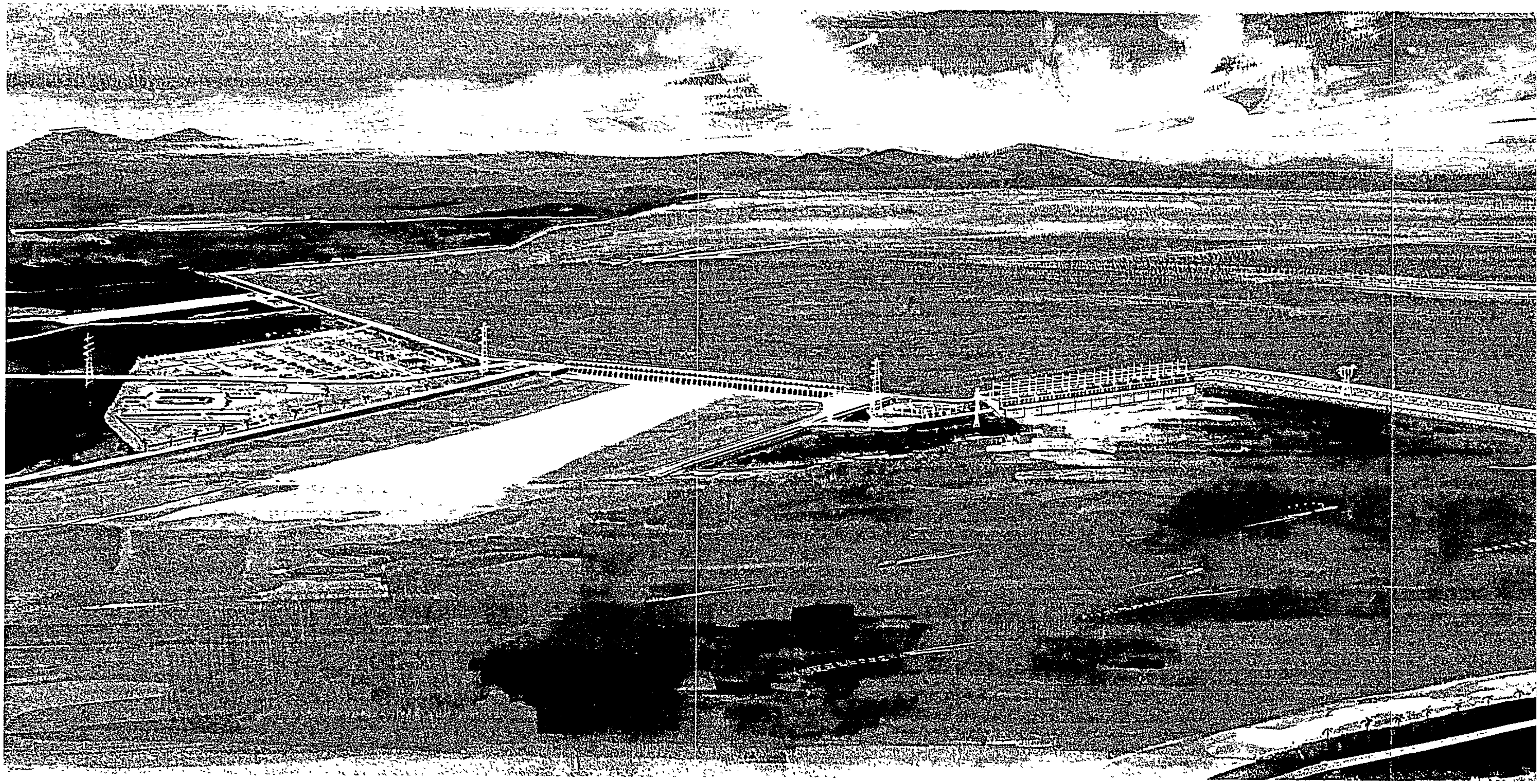
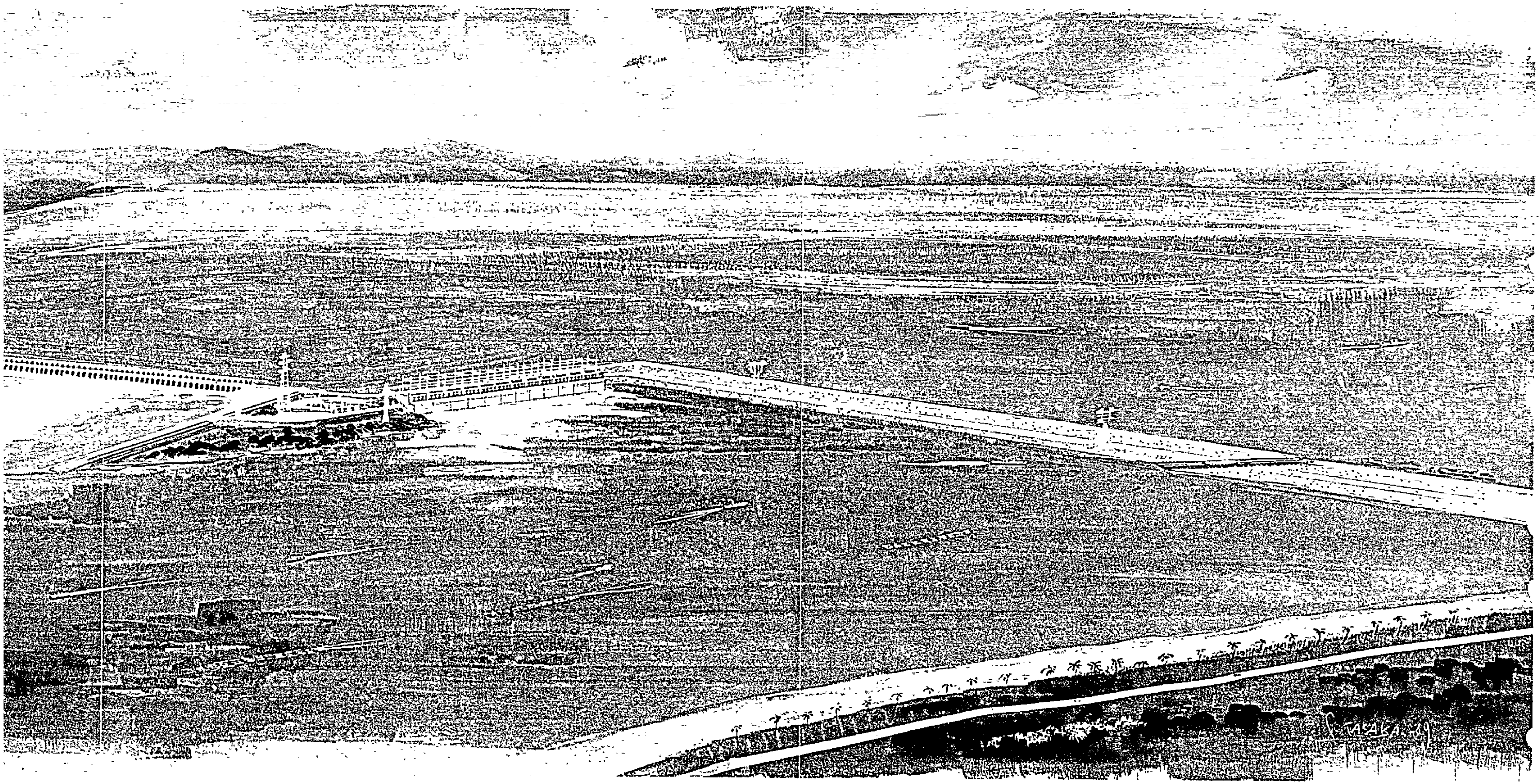


Photo. A-2 Model of the Sambor Dam Discharging Flood (Downstream View)



Aerial View of



Aerial View of the Projected Sambor Dam

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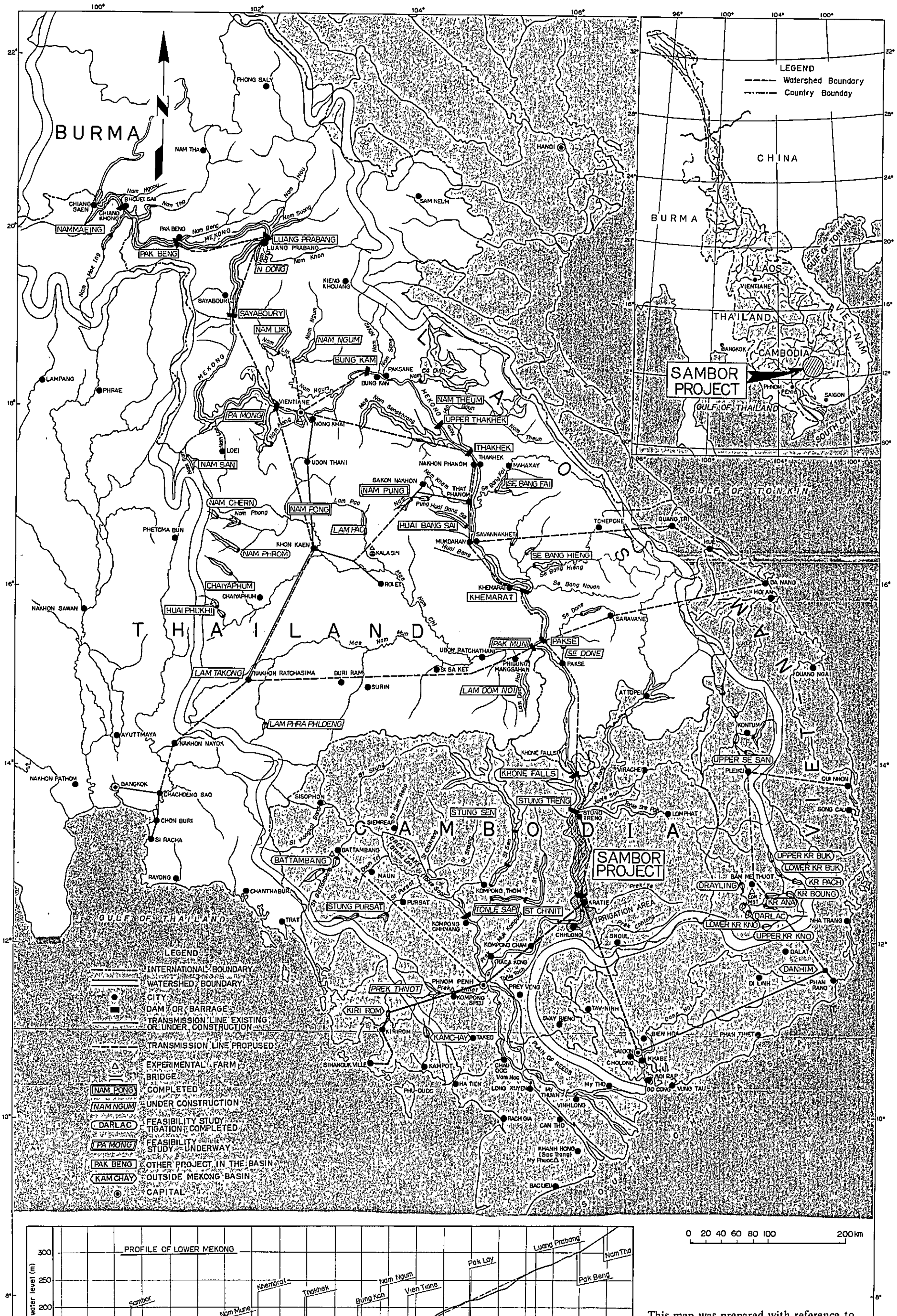
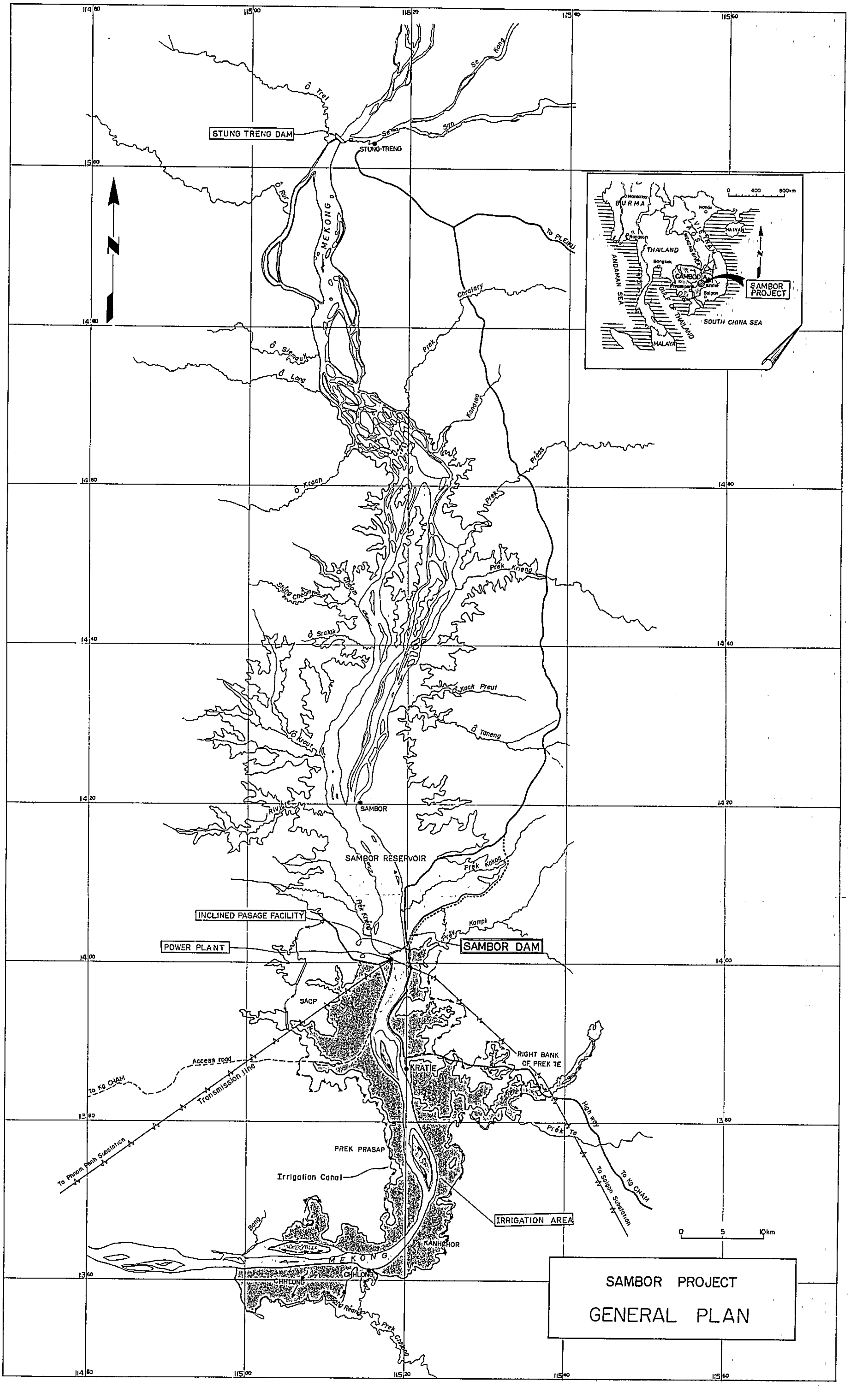


This map was prepared with reference to the basin map of the Mekong Committee's Annual Report 1967 and the boundaries shown hereon do not imply official endorsement or acceptance by the United Nations.

Key and
Location Map



SAMBOR PROJECT

GENERAL PLAN

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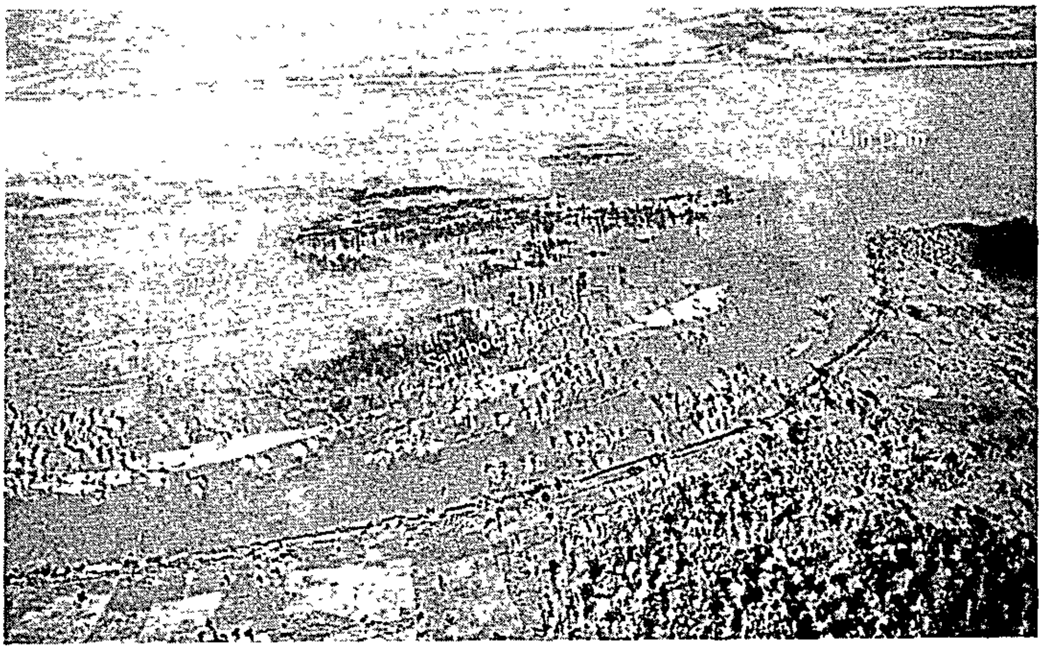

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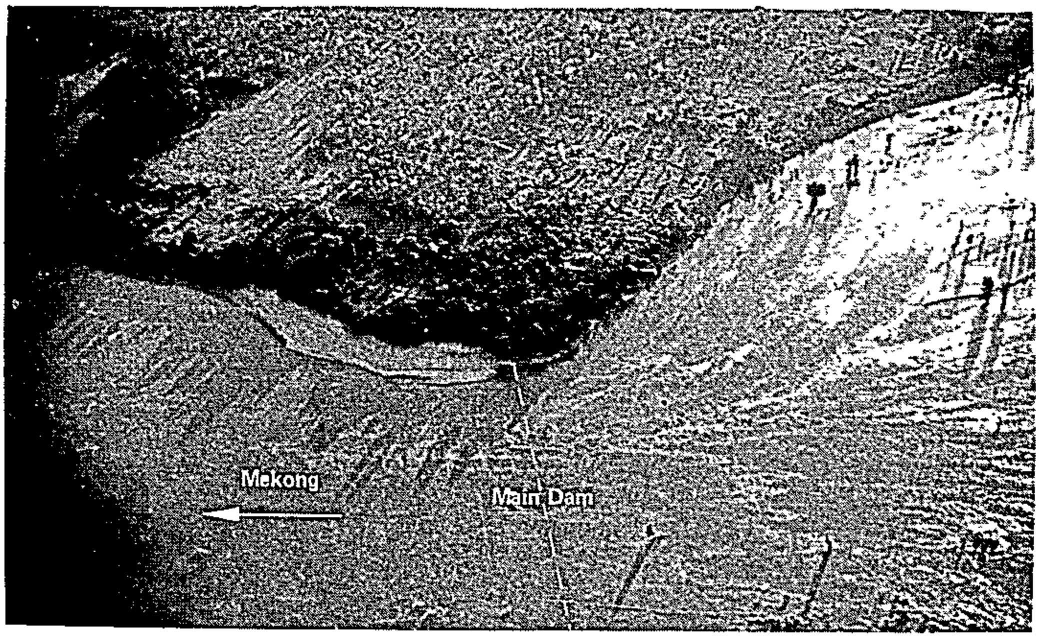

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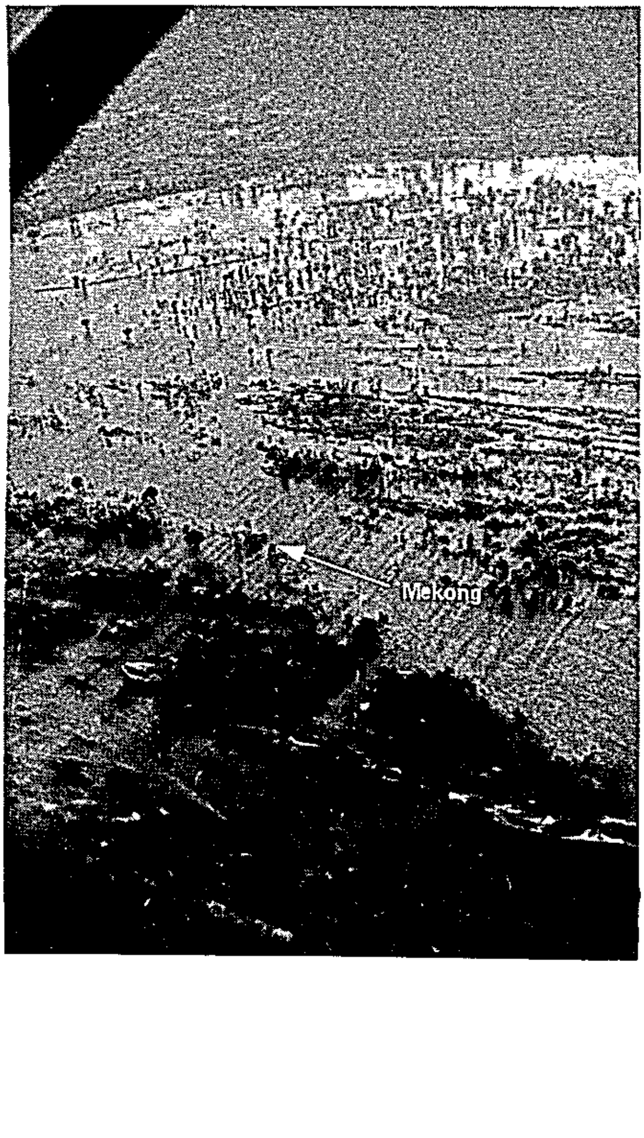

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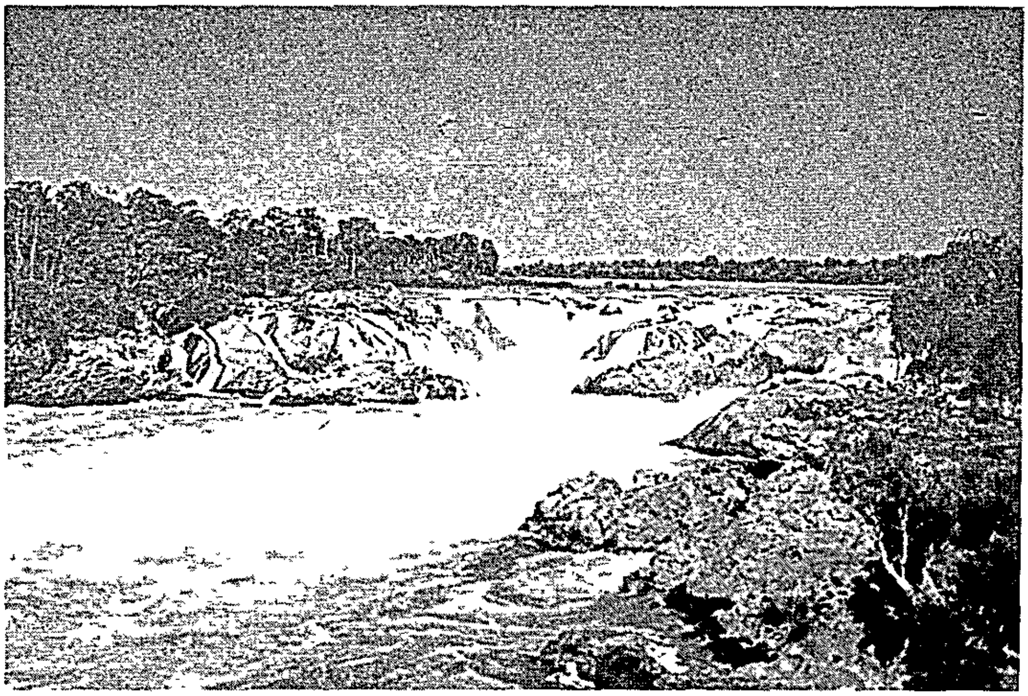

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MAIN FEATURES OF THE PROJECT

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 S318.1 million S437.6 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

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 the 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 River 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 Government of Japan to make a study of the Sambor Project with the flow regulation of the Nam Ngum and the 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 power aspect, that is, 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.

As for the navigation, the influence of the regulated flow is only studied in regard to the water level fluctuation downstream of the Sambor Dam, and the construction cost and dimensions of facility, etc. are estimated as the same as those of the Isolated Project. However, this report also explains about the future plan of navigation as a reference in Chapter K in the event that the canal and the lock system will be necessary to adopt.

As for the agricultural aspect, the influence of the regulated flow upon the project area (34,000 ha) is not studied here, but a preliminary study is being made on the development of agriculture in the Deltaic Area in the downstream of the Mekong with expectation of increased runoff in the dry season due to the regulated flow and low-cost power supply from the Sambor Power Plant.

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

For the fishery, no definite conclusion has been reached yet, but the construction of fish ladders is to be taken into consideration. However, this matter has been kept for a separate discussion in Vol. VI of the Isolated Project and is not included in the financial plan under this project.

Note. 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

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 not assumed to be interconnected with any other power plants under consideration for the upper Mekong, not to mention the Nam Ngum and the Pa Mong.

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

(4) The flow at the Sambor dam site, upon realization of the Nam Ngum and the 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.

Note: 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.

CHAPTER B. CONCLUSIONS AND RECOMMENDATIONS

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B-1 Conclusions

When both the Pa Mong and the 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. 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 are expected to be 693 MW and 3.60 billion kWh in 1980, and 1,818 MW and 9.6 billion kWh in 1990. 1/

(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. Thus, the flow at the site will be improved 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: 2 m, 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 Plant 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 generator 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 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 meet 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.

Note: 1/ *Statistical Bulletin*, Mekong Secretariat, Dec. 1967.

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/

(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 aluminum, 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 and the power plant of an installed capacity of 700 MW (175 MW x 4 units) with 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, the construction of a dam and the power plant of an installed capacity of 175 MW (1 unit) with 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 the 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.

Note: 1/ In Vols. I and III 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.

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:	$296.85 million
Foreign currency:	$219.12 million
Domestic currency:	$ 77.73 million

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 the following two cases, [that is: foreign currency is assumed to be provided by various international monetary institutions and financial institutions of various countries, while all local currency be furnished by the Royal 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'Equipement (Case II), and the terms of payment will be either 24 years (Case I), or 29 years (Case II) 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 in regard 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 II), 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 tolls. The Cash balance will start showing a favorable return from the sixth year after the start of operation in Case II and from the seventh year in Case II, 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%).

(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 Deltaic Area, in addition to 34,000 ha downstream of the dam, of which about 600,000 ha does not seem to involve any difficulty in the development.

Note: 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.

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 the Pa Mong Projects in the upstream are assumed to be 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 the Pa Mong and the 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 the 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 study and investigation 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 the Pa Mong and the 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.

CHAPTER C. DEMAND LOAD FORECAST AND POWER CONSUMPTION SCHEME

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C-1 General

Appropriate ultimate installed capacity of the Sambor Power Plant is considered to be 2,100 MW. This is about 6 times the total installed capacity of 330 MW in both Cambodia and Vietnam as of the end of 1965, and corresponds to about 2.5 times the estimated maximum demand of 830 MW in both countries in 1980. As means of power consumption for such a great power resource, the following two types may be considered.

(1) The type which encourages progressive power consumption by inviting industries in parallel with the development of power resources in addition to the consumption of power by ever increasing general demand following the growth of the economy (Type I′).

(2) The type which calls for gradual expansion of facilities in proportion to the increase in demand following the growth of the economy and which envisages power consumption only by the natural increase of general demand (Type III′).

The method under Type I′ requires procurement of a large amount of funds in a short period of time compared with that under Type III′, but enables fast realization of effectiveness of invested capital as a whole, and at the same time brings about greater secondary effects that stimulate the development of industry and economy. The method under Type III′, when compared with that under Type I′, requires a longer period for the completion of all facilities and delays the realization of effectiveness of capital invested in the common facilities such as the dam, etc., but on the other hand provides the merit of easier procurement of required funds.

Selection of either Type I′ or Type III′ as the power consumption scheme will be a matter to be decided according to the economic policy of each individual country, therefore power consumption in this Chapter has been studied with these two methods.

C-2 Load Forecast

C-2-1 Forecast on General Demand

General demand, as referred to in this section, is demand of households and general industries, and has been defined to give distinction between the above and the power-oriented industries to be induced in parallel with the development of the Sambor Project for the encouragement of active consumption of power energy generated at the Sambor Power Plant.

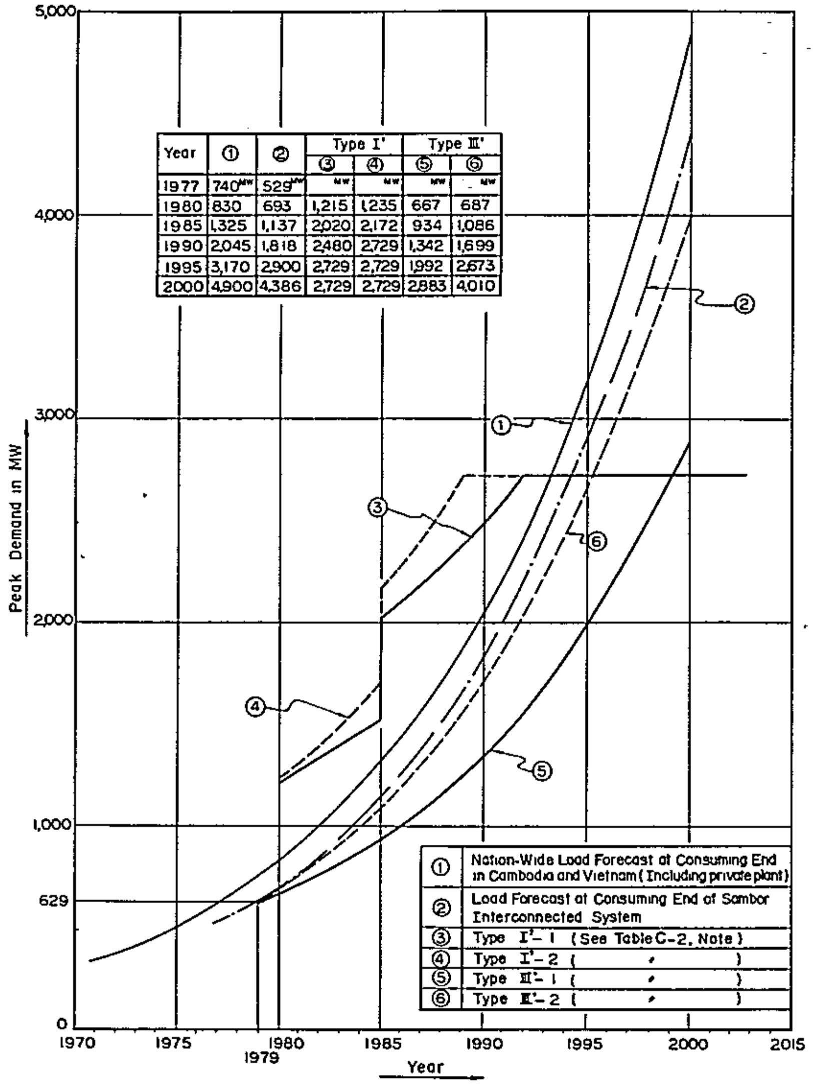
(1) Method of estimation of general demand: General demand which will be the object of the Sambor Power Plant system was estimated in the following way.

(a) As described in detail in Vol. III, estimates of the total demand in both Cambodia and Vietnam was first made by applying two different methods, that is an analytical method and an overall method, on the basis of available actual records, (see Fig. C-1, ①).

(b) The ratio of demand for the Sambor interconnected system to the total demand in both countries was then estimated by taking into account the existing transmission lines and transmission line expansion projects in both countries, from which general demand for the system to be supplied by the Sambor Power Plant was estimated (see Fig. C-1 ②).

(2) General demand of the Sambor Interconnected System: Fig. C-1, ⑤ ⑥ show general demand for the Sambor Interconnected System which was estimated by the above-mentioned method.

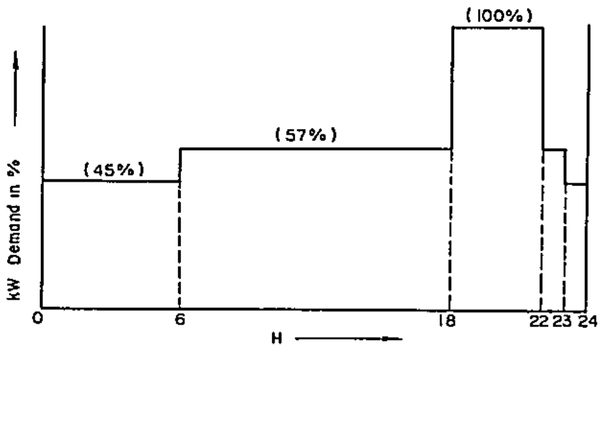
Fig. C-1 Load Forecast



Year	①	②	Type I'		Type III'	
			③	④	⑤	⑥
1977	740 MW	529 MW	MW	MW	MW	MW
1980	830	693	1,215	1,235	667	687
1985	1,325	1,137	2,020	2,172	934	1,086
1990	2,045	1,818	2,480	2,729	1,342	1,699
1995	3,170	2,900	2,729	2,729	1,992	2,673
2000	4,900	4,386	2,729	2,729	2,883	4,010

The pattern of the daily load curve was based on the actual record, which through simplification gives us the following chart.

Fig. C-2 Daily Load Curve of Sambor Power Station for General Demand



Actual records show that the pattern of the load curve has no distinct seasonal fluctuation.

For this reason, demand was assumed to be represented by the same load curve throughout the year for simplication.

C-2-2 Load Forecast for Power-oriented Industries

In considering the establishment of industries for the positive acceleration of power consumption in parallel with the development of power resources as a means of power consumption for a large-scale power resource and in anticipation of its effect on the industry as a whole, a study was made on the type of industries to be invited and the estimate was made on the demand for power by such industries.

(1) Possibilities of industrialization: A survey on the possibility of industrialization of the lower Mekong revealed that there seems to be some disadvantages in this region such as poor mineral resources deposits as described in Vol. III, Chapter C-1-2, (2). However, to make up for such disadvantages, the following favorable conditions exist in the area:

(a) Broadness of potential development area
(b) Geographical location
(c) Willingness of the people

The following conclusions are drawn. The various conditions which hamper industrialization in this area is considered to be basically a lack of capital and technology. Although the area is somewhat inferior in respect to natural resources, the broadness of the area and the geographical location are advantageous. The willingness of the people is not lacking, and it is possible to improve the established socio-economic systems. Therefore, it is thought that capital and technical cooperation with the developed nations will be effective in bringing about industrialization of both countries.

(2) Type of industries to be invited: Selection of industries to be invited was made on the following conditions:

(a) Power-oriented industries which are preferred in that power consumption can be accelerated.

(b) Industries whose products are expected to increase in value in the world market and which can make the best use of geographical advantages of this area in relation to the availability of raw materials and the accessibility of marketing areas for power-oriented industries.

(c) Industries which aim at domestic markets using abundant raw material such as lime stone and silica which are found in Cambodia.

(d) Of the industries which satisfy the above requirements, those that can be a part of an industrial complex in order to increase the efficiency of the investment.

Based on the above conditions, aluminum refining, caustic soda, vinyl chloride, carbide, ferro-silicon, and silicon carbide industries have been selected as the industries to be invited.

(3) Proposed site for the invitation of power-oriented industries: From the stand point of means of transportation in and out of the country such as harbors and roads, availability of industrial water and land for plant site, and labor force availability, Sihanouk Ville and Phnom Penh in Cambodia and Saigon in the Republic of Vietnam may be considered as possible sites for inviting power-oriented industries. Among these three locations Phnom Penh is a river port which makes the mooring of large-sized ships more difficult, and therefore has disadvantages compared with Sihanouk Ville and Saigon. Under this project, because of the fact that the power plant is to be constructed in Cambodia, Sihanouk Ville will be designated as the site for inviting power-oriented industries.

(4) Scale of power-oriented industries and power consumption requirements: In view of the necessity of helping accelerate positive power consumption, it was assumed that about one-half of the maximum output of 2,100 MW of the Sambor Power Plant would be consumed by power-oriented industries. It was planned that one-half of the plant facilities of industries will be put in operation in 1980 when the Sambor Power Plant will start operations and that the remaining one-half will be added in 1985.

Table C-1 Load Distribution for Power-oriented Industries

	Power Requirement, maximum, (1,000 kW)				Basic power unit kWh/ton
	1980-84		after 1985		
	Consuming end	Generating end	Consuming end	Generating end	
Aluminum	240	(250)	480	(500)	16,100
Caustic Soda	158	(60)	116	(120)	3,700
Vinyl chloride	15	(16)	30	(32)	1,000
Carbide	29	(103)	198	(206)	3,150
Ferro-silicon	27	(28)	54	(56)	10,150
Silicon carbide	27	(28)	54	(56)	10,000
Total	466	(485)	932	(970)	

Note: Maximum power energy at the generating end is the sum of maximum power energy at the consuming end and 4% transmission loss.

The power supply to industrial use should be made with firm power as much as possible. Sambor Power Plant, however, because of its characteristics, involves secondary power accounting for about 33% of the total power energy of 14,600 million kWh. In order to promote the consumption of this secondary energy, the following industries will be designated for the consumption of power with the consideration of the characteristics of each industry.

The order of industry to be effected by restrictions on the use of power was determined so as to give priority to the industries which use more firm power. For aluminum refining, firm power is supplied with a daily load factor of 100% and an average annual load factor of 96%. It was provided that the use of power would be restricted during the power shortage period for caustic soda manufacturing, carbide industry, ferro-silicon industry, silicon carbide industry and vinyl chloride industry.

C-2-3 Load for Pumping Irrigation and Drainage

With the completion of the Pa Mong dam, flood discharge will decrease and discharge in the dry season will increase. As a result, a plan has been worked out for the irrigation of approximately 590,000 ha in the neighborhood of Phnom Penh. (See Fig. J-1)

Load for pumping irrigation and drainage is estimated as follows:

Load in the final stage (after 1995): 240 MW

Trend of load increase: Continuous upward trend for 15 years from 1980 to 1995.

Conditions for power supply:

Period : Dry season (Nov.–Mar.)

Daily load: On power shortage days power supply will be suspended for four hours from 6 p.m. to 10 p.m.

C-2-4 Load Forecast

Summary of load forecast for general demand, power-oriented industries, and pumping irrigation and drainage are shown in Table C-2.

Table C-2 Load Forecast for Sambor Interconnected System

Type and Year		Cambodia and Vietnam Generating End Annual Energy million kWh	Peak Demand (MW)	Annual Average Load Factor	Consuming End Annual Energy million kWh	Peak Demand (MW)
	1980	4,519	586	0.89	4,338	563
	1985	9,384	1,391	0.81	9,009	1,335
Type I'-1	1990	11,642	1,851	0.72	11,177	1,777
	1995	12,297	2,100	0.67	11,806	1,998
	2000	12,559	2,100	0.68	12,097	2,016
	1980	4,609	606	0.87	4,425	582
	1985	10,035	1,543	0.78	9,634	1,481
Type I'-2	1990	12,253	2,028	0.69	11,763	1,947
	1995	12,298	2,100	0.67	11,806	1,998
	2000	12,559	2.100	0.68	12,057	2,016
	1980	202	38	0.61	194	37
	1985	1,621	305	0.61	1,556	293
Type III'-1	1990	3,789	713	0.61	3,637	685
	1995	7,244	1,363	0.61	6,954	1,309
	2000	11,160	2,100	0.61	10,713	2,016
	1980	308	58	0.61	296	56
	1985	2,429	457	0.61	2,332	439
Type III'-2	1990	5,686	1,070	0.61	10,459	1,027
	1995	9,757	2,044	0.61	10,428	1,962
	2000	11,160	2,100	0.61	10,713	2,016

Note: (1) Type I'-1 : Meetes 60% of increased load of general demand, load of all power-oriented industries, and load of irrigation and drainage.

(2) Type I'-2 : Meets 90% of increased load of general demand, load of all power-oriented industries, and load of irrigation and drainage.

(3) Type III'-1: Meets only 60% of increased load of general demand.

(4) Type III'-2: Meets only 90% of increased load of general demand.

(5) Each figure represents the increased portion with the end of 1979 as the basis.

C-3 Power Consumption Plan

C-3-1 Type of Power Consumption Plan

Since the type of consumption of power energy generated at the Sambor Power Plant is influenced not only by the scale and pattern of demand but also by the supply characteristics of existing and future power plants other than the Sambor Power Plant, the power consumption plan should be worked out first on the basis of the total demand and total supply capacity, from which the trend of power consumption for the Sambor Power Plant should be determined if an accurate estimate is to be obtained. However, because of unavailability of data necessary for projecting the power demand-supply plan, the following simplified method has been adopted. Nevertheless, a result obtained through this method seems to have sufficient reliability for a study of the economics of the Sambor Project because of the high ratio of the power supply capacity of the Sambor Project to the total demand.

Demand to be satisfied by the supply of the Sambor Power Plant in the case of both Type I' and Type III' will be as follows:

All demand in the power-oriented industries and the pumping irrigation and drainage will be satisfied by the Sambor Power Plant.

As for general demand, the capacity of hydroelectric power plants to be developed in the two countries during the 1980-87 period is expected to reach 40% to 60% of increased portion of the demand on the basis of installed capacity in 1977. And even though the project to be developed is not known yet for the years after 1986, it is considered that there may exist a considerable number of sites available for power development.

Since the development of these sites may be considered to be multipurpose in conjunction with water utilization in those areas independent of the Sambor Project, it is not advisable to consider that all of the general demand is to be satisfied by only the Sambor Power Plant.

Therefore, general demand to be satisfied by the Sambor Power Plant was estimated to be 60% of the increased demand using demand in 1979 as the basis by giving due consideration to the other projects in the two countries and also in view of a conservative evaluation of the economics of the Sambor Power Project.

However, since it may be expected that some delays in development of the other projects or unexpected rapid increase in demand would happen, a study was also made in the case that 90% of the increased demand previously stated is to be satisfied by the Sambor Power Plant in order to know the effect of these factors on the power consumption plan and the economics of the Sambor Project.

C-3-2 Timing of Capacity Addition of Sambor Power under Each Power Consumption Plan

Scale of the Sambor Power Plant at the beginning of operation in 1980 will be four units of 175 MW for Type I' plan, and one unit of 175 MW for Type III' plan. Additional installation is to be made corresponding to the increment of demand, and the ultimate installation (175 MW x 12 units) will be attained by 1991 for Type I'–1, 1989 for Type I'–2, 1995 for Type III'–1, and 1992 for Type III'–2. (See Table C-4)

The timing of generator capacity addition has been decided by taking the following into consideration:

(1) That maximum output will not be below the maximum demand.

(2) That dependable peak output will not be below the maximum of firm demand (general demand and aluminum refining).

(3) That firm output will not be below the average power output of firm demand.

The number of generators at the Sambor Power Plant which is to be determined by the conditions stated above will be as follows against each power consumption pattern. (See Fig. C-3)

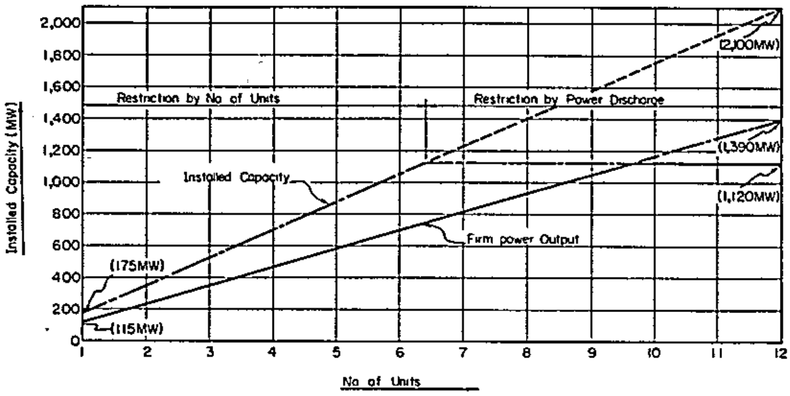
The Sambor Power Plant has the characteristics of firm power and dependable peak output as follows:

The minimum average monthly regulated inflow is 4,380 cu.ms of February in 1960 where the effective head and the discharge from a unit is 30.5 m and 674 cu.ms respectively. In this case the unit can generate 175 MW, and the capacity increases proportionate to the number of installed unit. However, when the number of units exceed six, that is, the inflow (4,380 cu.ms) is less than the total discharge capacity of installed units, the power plant can not generate more than 1,120 MW due to the shortage of discharge for generation.

On the other hand, the lowest effective head is 20 m of August in 1952 where the average monthly regulated inflow and the discharge from a unit is 40,700 cu.ms and 672 cu.ms respectively. In this case the unit can generate 115.5 MW and the capacity increases proportionate to the number of installed units.

The relationship between output and number of installed units is shown below on either case described above, from which the firm output and the dependable peak output are determined.

Firm Power Output and Number of Units



Relation of maximum output, firm output and dependable peak output to the number of generators are shown in the table below.

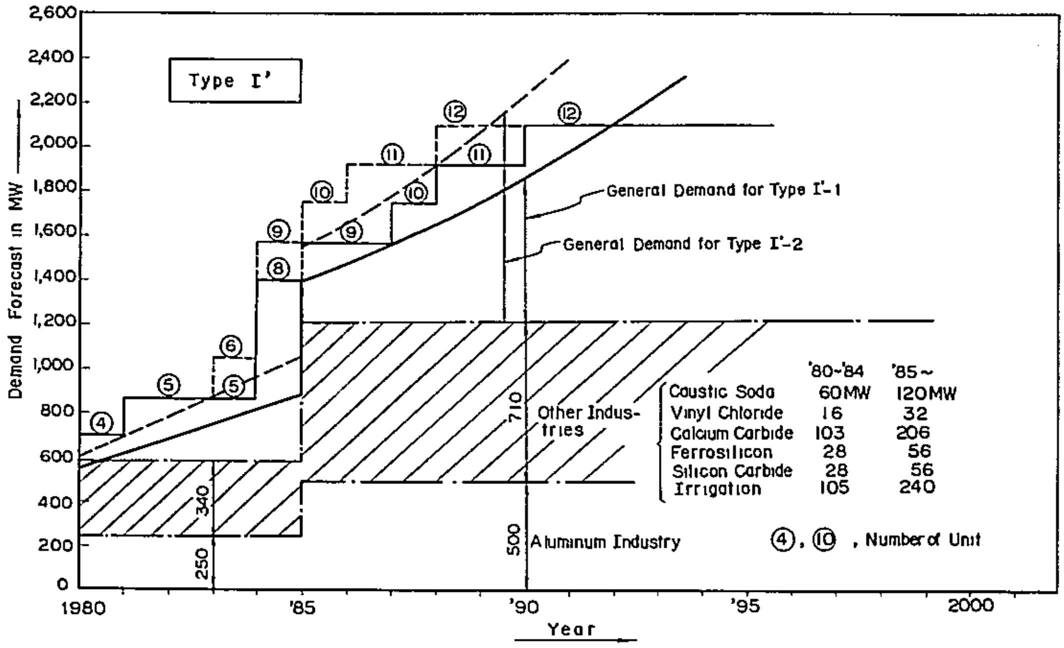
Table C-3 Relations between the Number of Generator and Output

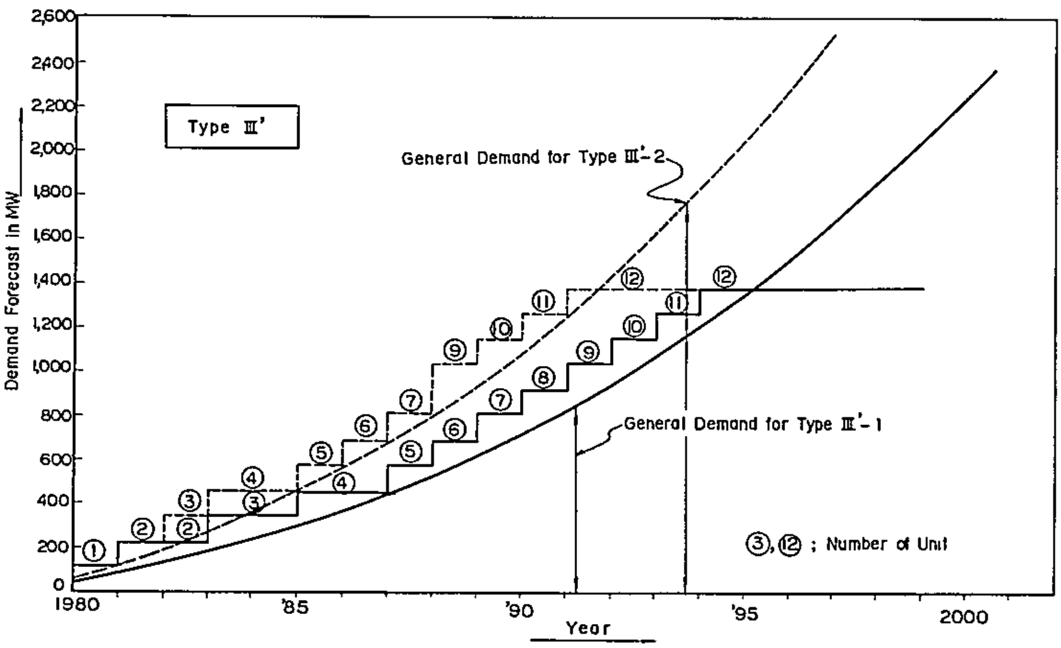
Number of generators	Max. output	Firm output	Dependable peak output
1–9	175 MW x No. of Units	115.5 MW x No. of Units	115.5 MW x No. of Units
10–20	175 MW x No. of Units	1,120 MW	115.5 MW x No. of Units

Table C-4 Power Consumption Pattern and Generator Expansion Program

Type I'				Type III'			
I'-1		I'-2		III'-1		III'-2	
1980–81	4 units	1980–81	4 units	1980–81	1 unit	1980	1 unit
1982–84	5 units	1982–83	5 units	1982–83	2 units	1981–82	2 units
1985	8 units	1984	6 units	1984–85	3 units	1983	3 units
1986–87	9 units	1985	9 units	1986–87	4 units	1984–85	4 units
1988	10 units	1986	10 units	1988	5 units	1986	5 units
1989–90	11 units	1987–88	11 units	1989	6 units	1987	6 units
1991	12 units	1989	12 units	1990	7 units	1988	7 units
				1991	8 units	1989	9 units
				1992	9 units	1990	10 units
				1993	10 units	1991	11 units
				1994	11 units	1992	12 units
				1995	12 units		

Fig. C-3 Demand Forecast at Generating End and Capacity Installation Schedule





C-3-3 Power Consumption Method

C-3-3-1 Type I'

Tables C-5 (1) and C-5 (2) show a supply-demand balance for the period from 1980, the year when the Sambor Power Station will start its initial operation, until the year of the final installation of units.

Table C-5 (1) relates to Consumption Plan Type I'-1, while Table C-5 (2) pertains to Type I.

As a result of accelerated consumption of the secondary power by major power-oriented industries, approximately 85% of the power energy generated at the Sambor Power Station is expected to be consumed from 1985 and afterwards, while consumption will remain around 75% during the 1980–84 period when power-oriented industries will still be small in size.

Type I' is a power consumption method in which secondary energy of maximum output and generated power energy as a result of change in discharge are absorbed by characteristic load of power-oriented industries with the exception of the aluminum refining industry

As the maximum demand will mark well over the maximum output of 2,100 MW in 1997 under Type I'-1 and in 1989 under Type I'-2, respectively, increase in the firm power supply by newly installed thermal plants might be required for both Type I'-1 and I'-2.

In this consumption plan, however, increase in power supply capacity by thermal generation is not considered. Instead, an assumption is made that the general demand to be supplied by Sambor is to be constant after 1992 under Type I'-1, and after 1989 under Type I'-2, and that all the remaining portion of general demand is to be satisfied by other supply sources.

Table C-5 (1) kW Balance for Type I'-1

Year	1980	1984	1985	1992
Number of Unit	4	8	9	12
Generating End				
(1) Max. Output (MW)	700	875	1,400	2,100
(2) Dependable Peak (MW)	462	577	924	1,390
(3) Available Energy (million kWh)	5,868	7,342	11,355	14,604
(4) Usable Energy (million kWh)	4,519	5,700	9,384	12,559
(5) Utility factor ((4)/(3) x 100%)	77	78	83	86
Consuming End				
(6) Energy for General Demand (million kWh)	194	1,245	1,556	4,541
(7) Max. Output for General Demand (MW)	37	234	293	854
(8) Energy for Aluminum Industry (million kWh)	2,016	2,016	4,032	4,032
(9) Energy for Caustic Soda (L2: million kWh)	486	486	908	908
(10) Energy for Vinyl Chloride (L3: million kWh)	129	129	241	241
(11) Energy for Calcium Carbide (L4: million kWh)	831	831	1,212	1,212
(12) Energy for Irrigation and Drainage (L5: million kWh)	255	388	402	465
(13) Energy for Ferro-silicon and Silicon Carbide (L6: million kWh)	427	377	658	658
(14) Total Energy for General Demand and Power-oriented Industries (million kWh)	4,388	5,472	9,009	12,057
(15) Max. Output for General Demand and Power-oriented Industries (MW)	563	801	1,335	2,016

Table C-5 (2) kW Balance for Type I'-2

Year	1980	1984	1985	1989
Number of Unit	4	6	9	12
Generating End				
(1) Max. Output (MW)	700	1,050	1,575	2,100
(2) Dependable Peak (MW)	462	693	1,040	1,390
(3) Available Energy (million kWh)	5,868	8,806	12,273	14,604
(4) Usable Energy (million kWh)	4,609	6,371	10,035	12,559
(5) Utility factor ((4) /(3) x 100%)	79	72	82	86
Consuming End				
(6) Energy for General Demand (million kWh)	296	1,868	2,332	4,541
(7) Max. Output for General Demand (MW)	56	351	439	854
(8) Energy for Aluminum Industry (L1: million kWh)	2,016	2,016	4,032	4,032
(9) Energy for Caustic Soda (L2: million kWh)	485	485	908	908
(10) Energy for Vinyl Chloride (L3: million kWh)	129	129	241	241
(11) Energy for Calcium Carbide (L4: million kWh)	831	831	1,212	1,212
(12) Energy for Irrigation and Drainage (L5: million kWh)	253	396	367	465
(13) Energy for Ferro-silicon and Silicon Carbide (L6: million kWh)	415	391	658	658
(14) Total Energy for General Demand and Power-oriented Industries (million kWh)	4,425	6,116	9,634	12,057
(15) Max. Output for General Demand and Power-oriented Industries (MW)	582	918	1,481	2,016

Since around 10% of the power energy which constitutes surplus power generated at Sambor is fully expected to be utilized completely combined with other supply sources, aforementioned estimates of power consumption may be said to be fairly conservative figures.

Figs. C-4 (1) and C-4 (2) show changes in power consumption after 1992 when the load exceeds installed capacity.

Fig. C-4 (1) relates to Type I'-1, while Fig. C-4 (2) relates to Type I'-2. Though the supply characteristics vary with hydraulic years, if this energy is to be supplied to power-oriented industries, 88% to 91% of the total energy to be generated at the Sambor Power Plant will be consumed. As a result, the annual load factor of power-oriented industries with the exception of the aluminum refining industry varies in the range of 80% to 90% for caustic soda manufacturing which has a relatively constant consumption rate and in the range of 50% to 85% for other industries.

Fig. C-4 (1) Utilization of Power (Type I'-1)

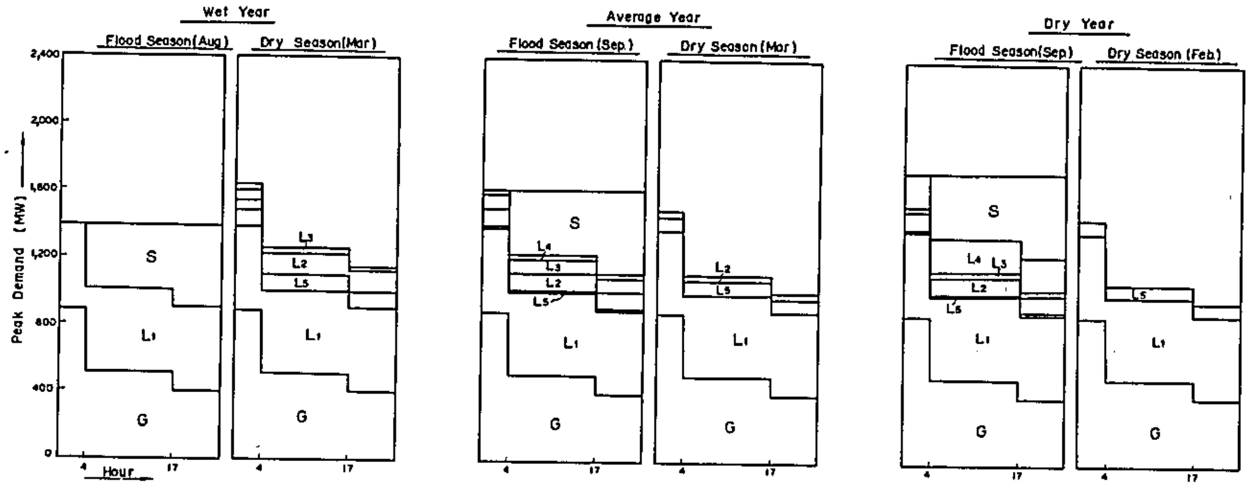
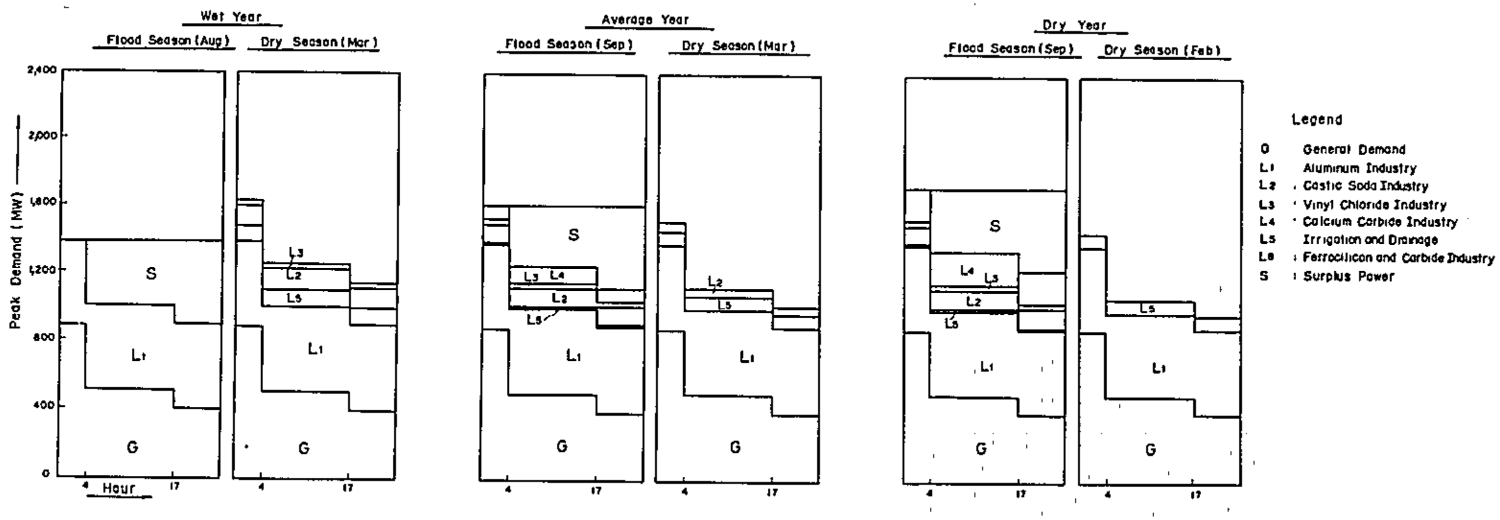


Fig. C-4 (2) Utilization of Power (Type I'-2)



C-3-3-2 Type III'

The Type III' power consumption plan envisages consumption of power by general demand alone. Due to lack of demand which can absorb secondary energy of maximum output and power energy as a result of change in the discharge, supplementary thermal generation will be needed at the peak time when general demand exceeds the 1,390 MW level of the maximum firm output at Sambor, and the need for thermal generation becomes constant when maximum demand exceeds the 2,100 MW level of the maximum output at Sambor.

A need for supplementary thermal generation will arise in 1986 under Type III'-1 and 1992 under Type III'-2. A constant need for thermal power at the peak time will arise after 2001 under Type III'-1, and after 1999 under Type III'-2.

Tables C-6 (1) and C-6 (2) show a supply-demand balance after 1980 on the mean value for 15 hydraulic years under the project. Table C-6 (1) relates to Type III'-1, whereas Table C-6 (2) relates to Type III'-2.

Table C-6 (1) kW Balance for Type III'-1

Year	1980	1984	1989	1995	1996	2000
Number of Unit	1	3	6	12	12	12
Generating End (Hydro)						
(1) Max. Output (MW)	175	525	1,050	2,100	2,100	2,100
(2) Dependable peak (MW)	115	347	693	1,390	1,390	1,390
(3) Available Energy (million kWh)	1,466	4,402	8,806	14,604	14,604	14,604
(4) Usable Energy (million kWh)	202	1,297	3,311	7,244	8,041	11,160
(5) Utility factor ((4)/ (3) x 100%)	14	30	38	50	55	76
Generating End (Thermal Power)						
Installed Capacity (MW)	–	–	–	–	250	750
Max. Output (MW)	–	–	–	–	48	492
Energy (million kWh)	–	–	–	–	3	282
Consuming End						
(6) Energy for General Demand (million kWh)	194	1,245	3,179	6,954	7,719	10,713
(7) Max. Output for General Demand (MW)	37	234	598	1,309	1,453	2,016
(8) Total Energy for General Demand (million kWh)	194	1,245	3,179	6,954	7,719	10,713
(9) Max. Output for General Demand (MW)	37	234	598	1,309	1,453	2,016

Table C-6 (2) kW Balance for Type III'-2

Year	1980	1984	1991	1992	1996
Number of Unit	1	4	11	12	12
Generating End (Hydro)					
(1) Max. Output (MW)	175	700	1,925	2,100	2,100
(2) Dependable peak (MW)	115	462	1,271	1,390	1,390
(3) Available Energy (million kWh)	1,466	5,868	13,886	14,604	14,604
(4) Usable Energy (million kWh)	308	1,945	6,574	7,600	11,160
(5) Utility factor ((4)/ (3) x 100%)	21	33	47	52	76
Generating End (Thermal power)					
Installed Capacity (MW)	–	–	–	250	750
Max. Output (MW)	–	–	–	4	492
Energy (million kWh)	–	–	–	1	282
Consuming End					
(6) Energy for General Demand (million kWh)	296	1,868	6,311	7,296	10,713
(7) Max. Output for General Demand (MW)	56	351	1,188	1,373	2,016
(8) Total Energy for General Demand (million kWh)	296	1,868	6,311	7,296	10,713
(9) Max. Output for General Demand (MW)	56	351	1,188	1,373	2,016

The consumption rate of Sambor Power will increase gradually from the initial 15%–20% in proportion to the increase in demand with a temporary decrease at the time of installation of each additional generator, and will be about 50% at the time of completion (1995 for Type III'-1 and 1991 for Type III'-2).

With constant consumption of secondary energy, thereafter, by supplementary thermal power, the consumption rate will be 76% by the time a constant thermal plant is required at the peak. (2001 for Type III'-1 and 1997 for Type III'-2).

In this consumption plan, supply to general demand by constant thermal power is not included in the power energy generated by the Sambor Power Plant. Therefore, for the same reason given in C-2-3-1, estimate on the consumption rate of Sambor Power energy is fairly conservative.

Since the operation of auxiliary thermal plant is extremely limited, its annual load factor is such an extremely low rate as to be around 6.5%.

Figs. C-5 (1) and C-5 (2) show the typical operational conditions of supplementary thermal power plant in the wet year, average year, and the dry year for the power consumption pattern Type III'-1 and Type III'2, respectively. As a result, the maximum supplementary thermal power required was 714 MW, which was produced in 1952 hydraulic year. This was recorded when the output of Sambor showed the 1,390 MW level firm output byan increase of high water level in tailrace at the flood time in August.

Supplementary thermal power reached its maximum in 1960 hydraulic year. This was ascribable to the shortage of water in the dry season from January to May, rather than to the decrease of output at Sambor during the wet season from August to October.

The working ratio of auxiliary thermal power facilities records the lowest in 1965 hydraulic year when the rate was as low as 1.9%, while the maximum was 10.4% recorded in 1960 hydraulic year, which are considered extremely low rates.

C-3-4 Production of Power-oriented Industries

Table C-7 shows estimated production of power-oriented industries in the case of Type I'-1.

Table C-7 Production of Power-oriented Industries

(Unit: ton/year)

	1980-84	Final Stage (1991)
Aluminum	125,000	250,000
Caustic soda	115,000 (120,000)	230,000 (240,000)
Vinyl chloride	120,000	240,000
Carbide	10,000 (190,000)	20,000 (380,000)
Ferro-silicon	17,000	33,000
Silicon carbide	17,000	33,000

Note: Figures in parentheses show the total amount of products. For example, 380,000 tons of carbide are produced as the total in which 20,000 tons are to be on market as carbide, while the remainder 360,000 tons are used again for production of 240,000 tons of vinyl chloride.

Fig. C-5 (1) Utilization of Power (Type III'-1)

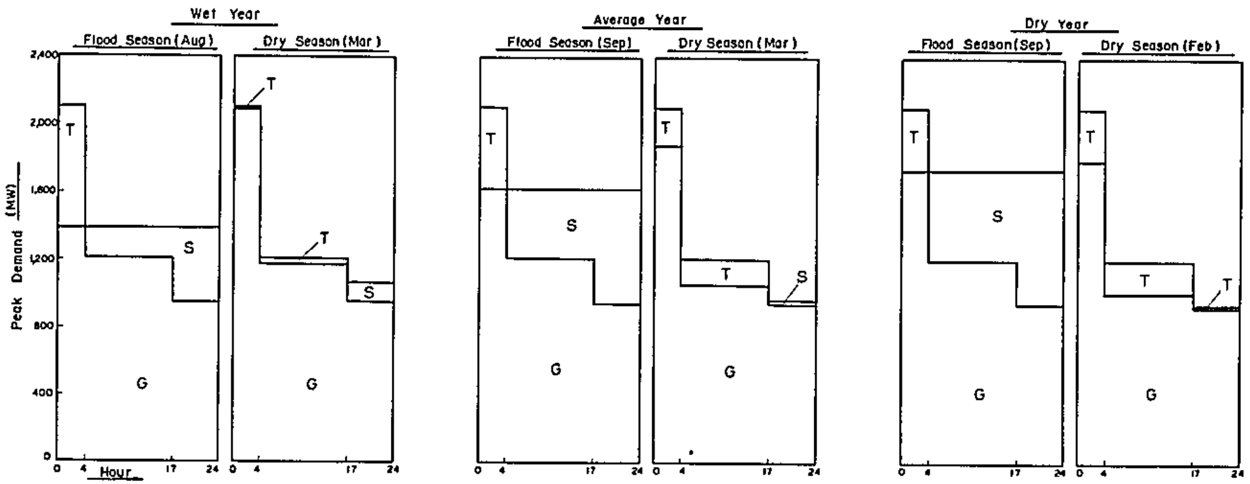


Fig. C-5 (2) Utilization of Power (Type III'-2)

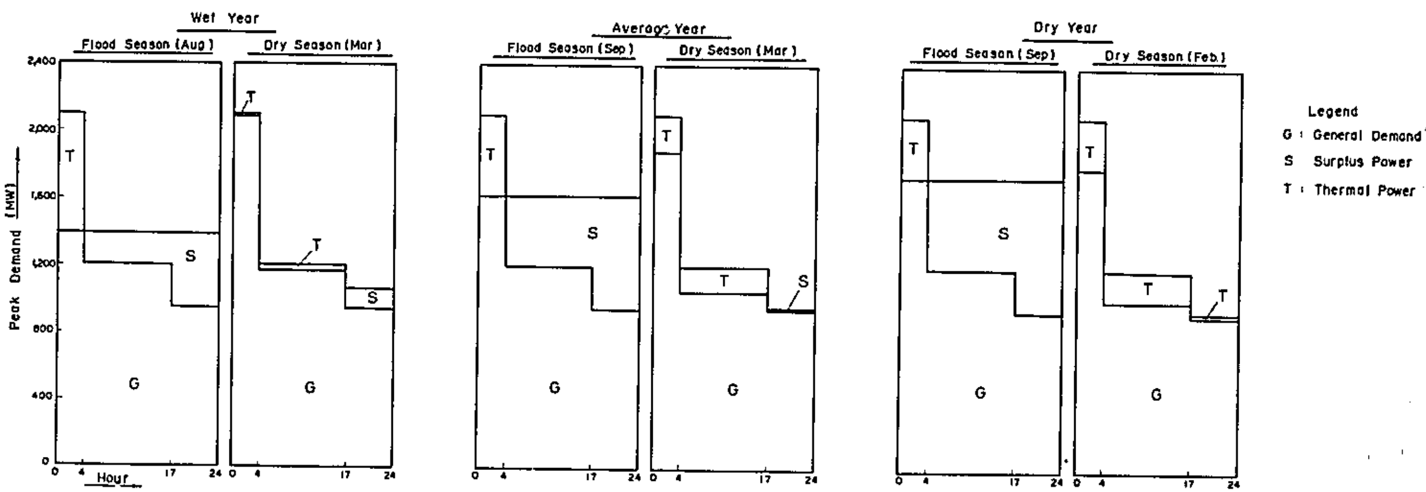
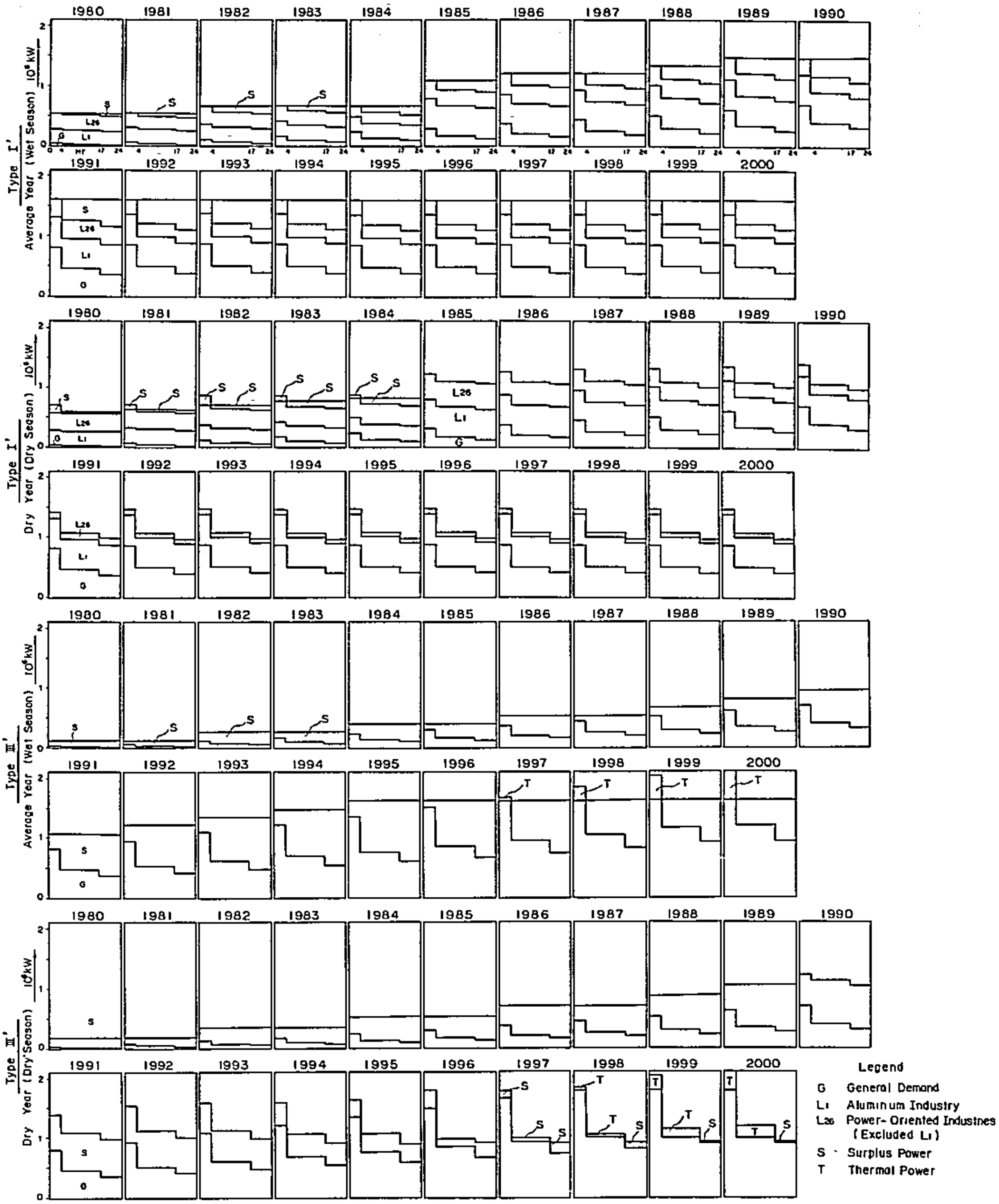


Fig. C-6 Trend of Daily Duration Curve of Demand



As seen in Table C-7, the production of caustic soda is as the same as that of vinyl chloride. If caustic soda and vinyl chloride are assumed to be consumed in the region (Cambodia and Vietnam), the amount of consumption per capita in 1982 and 1990 will be approximately 1.3 kg and 2.5 kg, respectively, for either production. These figures are nearly half and one-third of per capita consumption of Japan as of 1965, and are not necessarily considered to be excessive for the Lower Mekong River Basin region which is expected to make a rapid growth in consumption.

Table C-8 shows changes in the production of power-oriented industries depending on flow conditions as of 1997 except for the aluminum refining industry. Fig. C-6 shows an assumed trend of daily duration curve of demand from 1991 to 2000 for Type I' and Type III' power consumption pattern, respectively.

Table C-8 Changes in Production of Power-oriented Industries depending on Flow Conditions except for Aluminum Refining

	Maximum (ton/year)	Minimum (ton/year)
Caustic soda	255	220
Vinyl chloride	191	138
Carbide	490	275
Ferro-silicon and Silicon carbide	87	48

CHAPTER D. RESERVOIR AND POWER GENERATION PROJECT

CHAPTER D. RESERVOIR AND POWER GENERATION PROJECT

D-1 Reservoir

D-1-1 Change of Low Conditions due to the Nam Ngum and the Pa Mong Projects

Possible discharge change in the downstream areas when the Nam Ngum and the Pa Mong Projects are assumed to be completed has been studied by the secretariat of the Mekong Committee. 1/

As shown in Tables D-1 (1), (2) and (3), the result of the study indicates a monthly increase of 150 cu.ms–380 cu.ms for the Nam Ngum Project and an increase of 1,000 cu.ms–3,300 cu.ms for the Pa Mong Project for the dry season (December–May) during the period from November 1950 to December 1965.

Table D-1 (1) Regulated Inflow at Sambor Site after Completion of the Nam Ngum and the Pa Mong Projects. (Nov. 1950 –Dec. 1965)

	Monthly Average Natural Flow (cu.ms)	Monthly Average Inflow (cu.ms)
Jan.	3,371	5,487
Feb.	2,452	4,954
Mar.	1,958	5,047
Apr.	1,876	5,302
May	3,268	6,397
Jun.	11,117	12,433
Jul.	20,456	17,917
Aug.	32,983	27,991
Sep.	38,166	29,946
Oct.	24,750	23,697
Nov.	12,046	12,255
Dec.	5,803	7,401

The Nam Ngum and the Pa Mong Projects, which show the prerequisites of this study, are outlined below.

(1) The Nam Ngum Project.

The project aims at the development of the Nam Ngum River which runs through the Vientiane Plain in Central Laos to supply electric power to Laos and Northeast Thailand. Construction work was commenced in 1958. Beginning of power operation is expected in 1971 and the total capacity of 135 MW is scheduled to be installed by 1985.

The dimension of the reservoir is as follows:

Catchment area:	8,460 sq. km
Total capacity:	7.05 billion cu.m.
Effective capacity:	4.70 billion cu.m.
High water level:	EL 212 m.
Draw-down depth:	16 m (LWL : EL 196 m)

Capacity and area curves are shown in Fig. D-1.

1/ Reservoir Operation and Power Output of the Sambor Project with the Flow Regulation of Nam Ngum and Pa Mong Reservoirs. Mekong Secretariat, Sept. 18, 1968.

Note: In their report 1/, two different figures that is 107 billion cu.m and 105,650 million cu.m, are found as the total reservoir capacity of the Pa Mong Project Firm output is also represented by two different figures; 2,195 MW and 2,190 MW. However, in this report the former is adopted in either case.

Table D-1 (2) Regulated Inflow at Sambor Site after Completion of Nam Ngum and Pa Mong Projects

Year & Month	Sambor Natural Flow 1/ (1)	Nam Ngum Natural Flow 1/ (2)	Nam Ngum Regulated Flow 1/ (3)	Nam Ngum Increased Flow (4)=(3)-(2)	Pa Mong Natural Flow 1/ (5)	Pa Mong Regulated Flow 1/ (6)	Pa Mong Increased Flow (7)=(6)-(5)	Sambor Inflow (8) =(1)+(4)+(7)
1950								
Nov.	17,940	206	256	50	3,013	3,085	72	18,062
Dec.	7,800	112	261	149	2,058	3,351	1,293	9,242
1951								
Jan.	4,043	75	264	189	1,495	3,175	1,680	5,912
Feb.	3,099	52	271	219	1,234	3,507	2,273	5,591
Mar.	2,082	42	285	243	892	3,879	2,987	5,312
Apr.	2,026	40	310	270	940	4,219	3,279	5,575
May	3,700	74	447	373	1,415	4,301	2,886	6,959
June	14,477	371	371	0	5,795	7,072	1,277	15,754
July	22 813	789	416	(-) 373	7,763	4,388	(-) 3,375	19,065
Aug	36,403	1,502	819	(-) 683	14,684	11,361	(-) 3,323	32,397
Sept.	34,443	914	495	(-) 419	11,304	3,122	(-) 8,182	25,842
Oct.	23,716	355	355	0	8,038	7,276	(-) 762	22,954
Nov.	12 459	206	256	50	3,218	3,218	0	12,509
Dec.	6,208	112	261	149	2,315	3,679	1,364	7,721
1952								
Jan	3,070	75	265	190	1,564	3,244	1,680	4,940
Feb.	1,961	52	271	219	1,084	3,357	2,273	4,453
Mar.	1,762	42	285	243	1,016	4,003	2,987	4,992
Apr.	1,718	40	310	270	985	4,264	3,279	5,267
May	3,203	56	429	373	1,539	4,425	2,886	6,462
June	7,211	428	346	(-) 77	2,619	3,896	1,277	8,411
July	18,810	995	737	(-) 258	6,967	3,592	(-) 3,375	15,177
Aug.	44,445	1,574	1,182	(-) 392	14,261	10,938	(-) 3,323	40,730
Sept.	46,697	1,326	562	(-) 764	15,723	6,753	(-) 8,970	36,963
Oct.	30,813	372	372	0	7,904	7,904	0	30,813
Nov.	13,620	206	256	50	3,219	3,219	0	13,670
Dec.	5,030	112	261	149	1,504	3,089	1,585	6,764
1953								
Jan	2,770	75	265	190	889	3,102	2,213	5,173
Feb	2,206	52	271	219	962	3,123	2,161	4,586
Mar	1,828	42	285	243	700	3,175	2,475	4,546
Apr.	1,833	40	310	270	835	3,970	3,135	5,238
May	4,577	70	443	373	1,632	4,518	2,886	7,836
June	14,630	471	394	(-) 77	3,014	4,291	1,277	15,830
July	20,345	604	309	(-) 295	6,552	3,448	(-) 3,104	16,946
Aug.	33,100	1,357	636	(-) 721	10,264	6,670	(-) 3,594	28,785
Sept.	33,687	785	399	(-) 386	10,949	3,127	(-) 7,822	25,479
Oct.	20,771	291	291	0	4,555	3,445	(-) 1,110	19,661
Nov.	10,492	206	256	50	3,133	3,133	0	10,542
Dec.	5,098	112	261	149	2,042	3,405	1,363	6,610
1954								
Jan.	3,159	75	265	190	1,215	3,100	1,885	5,234
Feb.	2,110	52	271	219	804	3,115	2,311	4,640
Mar.	1,689	42	273	231	643	3,391	2,748	4,668
Apr.	1,967	40	281	241	775	4,054	3,279	5,487
May	3,853	84	305	221	1,378	4,264	2,886	6,960
June	10,398	279	322	43	2,871	4,148	1,277	11,718
July	13,219	369	324	(-) 45	4,976	3,500	(-) 1,476	11,698
Aug	25,416	1,111	282	(-) 829	11,328	6,106	(-) 5,222	19,365
Sept	41,887	661	270	(-) 391	13,244	4,274	(-) 8,970	32,526
Oct.	26,758	257	257	0	5,737	5,737	0	26,758
Nov.	10,970	206	256	50	3,113	3,113	0	11,020
Dec.	5,019	112	261	149	2,115	3,478	1,363	6,531
1955								
Jan.	3,124	75	263	188	1,329	3,099	1,770	5,082
Feb.	2,237	52	271	219	985	3,158	2,173	4,629
Mar.	1,869	42	285	243	793	3,780	2,987	5,099
Apr.	2,038	40	310	270	953	4,232	3,279	5,587
May	2,589	52	332	280	1,324	4,210	2,886	5,755
June	8,182	503	340	(-) 35	2,684	3,961	1,277	9,464
July	20,285	697	314	(-) 383	8,561	5,186	(-) 3,375	16,527
Aug.2	25,378	1,274	510	(-) 764	15,663	12,340	(-) 3,323	21,291
Sept.	30,233	1,057	728	(-) 329	14,054	5,084	(-) 8,970	20,934
Oct.	17,091	252	258	6	3,865	3,865	0	17,097
Nov.	11,432	206	256	50	3,882	3,882	0	11,482
Dec.	7,688	112	261	149	2,173	3,536	1,363	9,200
1956								
Jan.	4,035	75	273	198	1,361	3,099	1,718	5,971
Feb.	2,506	52	288	236	871	3,114	2,243	4,985
Mar	1 934	42	273	231	690	3,646	2,956	5,121
Apr.	1,991	40	302	262	642	3,921	3,279	5,532
May	5,551	86	416	330	1,149	4,035	2,886	8,767
June	11,980	468	503	35	3,073	4,350	1,277	13,292
July	20,992	898	489	(-) 409	5,000	3,498	(-) 1,502	19,081
Aug	39,341	1,102	404	(-) 698	14,550	9,354	(-) 5,196	33,447
Sept	41,350	815	447	(-) 368	11,056	3,125	(-) 7,931	33,051
Oct.	18,431	199	256	57	4,162	3,156	(-) 1,006	17,482
Nov.	9,032	206	258	52	1,895	3,087	1,192	10,276
Dec	4,578	112	262	150	1,327	3,099	1,772	6,500
1957								
Jan.	3,420	75	271	196	971	3,112	2,141	5,757
Feb.	2,600	52	272	220	899	3,153	2,254	5,074
Mar.	2,093	42	275	233	816	3,213	2,397	4,723
Apr	2,103	40	291	251	791	3,300	2,509	4,863
May	3,056	42	315	273	1,179	3,396	2,217	5,546
June	10,013	304	332	28	2,232	3,507	1,275	11,316
July	22,684	642	305	(-) 337	5,406	3,484	(-) 1,922	20,425
Aug.	24,733	678	277	(-) 401	5 255	3,371	(-) 1,884	22,448
Sept.	34,844	623	270	(-) 353	6,129	3,279	(-) 2,850	31,641
Oct.	27,683	260	266	6	5,851	3,190	(-) 2,661	25,028
Nov.	10,221	208	267	59	1,842	3,170	1,328	11,608
Dec.	5,085	112	269	157	1,155	3,218	2,063	7,305
1958								
Jan	3,345	75	271	196	691	3,301	2,610	6,151
Feb.	2 510	52	273	221	633	3,418	2,785	5,516
Mar.	1,919	42	290	248	558	3,599	3,041	5,208
Apr.	1,733	40	312	272	684	3,834	3,150	5,155
May	2,163	49	363	314	1,106	4,106	3,000	5,477
June	9,386	338	380	42	2,347	4,472	2,125	11,553
July	20,809	879	347	(-) 532	6,773	4,451	(-) 2,322	17,955
Aug	25,077	885	282	(-) 603	10,555	3,915	(-) 6,640	17,834
Sept.	42,717	847	270	(-) 577	8,771	3,474	(-) 5,297	36,843
Oct.	19,780	214	259	45	4,037	3,322	(-) 715	19,110
Nov	8,729	206	261	55	2,717	3,321	604	9,388
Dec.	4,431	112	265	153	1,606	3,368	1,762	6,346
1959								
Jan.	2,383	75	270	195	993	3,496	2,503	5,081
Feb	1,945	52	271	219	1,030	3,659	2,629	4,793
Mar	1,730	42	279	237	1,021	3,869	2,848	4,815
Apr	1,648	40	296	256	1,041	4,139	3,098	5,002
May	2,205	66	330	264	1,563	4,601	3,038	5,507
June	6,360	176	365	189	4,025	4,977	952	7,501
July	11,915	984	480	(-) 504	5,952	5,013	(-) 939	10,472
Aug.	26,128	1,251	411	(-) 840	11,665	4,258	(-) 7,407	17,881
Sept.	37,304	1,163	859	(-) 304	12,859	3,533	(-) 9,326	27,674
Oct.	24,029	270	270	0	7,489	3,217	(-) 4,272	19,757
Nov.	10,042	206	255	49	3,952	3,151	(-) 801	9,290
Dec.	4,161	112	259	147	2,127	3,153	1,026	5,334
1960								
Jan	2,878	72	269	197	1,351	3,191	1,840	4,915
Feb.	2,296	38	270	232	1,229	3,247	2,018	4,546
Mar	1,827	30	276	256	858	3,329	2,471	4,544
Apr.	1,357	24	289	265	729	3,461	2,732	4,354
May	1,799	45	315	270	1,164	3,634	2,470	4,539
June	6,318	133	345	212	2,553	3,769	1,216	7,746
July	13,545	434	356	(-) 78	6,030	3,722	(-) 2,308	11,159
Aug	39,539	1,078	339	(-) 739	13,711	5,664	(-) 8,047	30,753
Sept.	36,117	1,155	369	(-) 786	12,830	3,861	(-) 8,969	26,362
Oct.	28,394	375	375	0	6,409	6,409	0	28,394
Nov.	11,381	159	256	97	3,326	3,326	0	11,478
Dec.	5,827	99	264	165	2,328	3,691	1,363	7,355
1961								
Jan.	3,284	68	269	201	1,279	3,099	1,820	5,305
Feb.	2,388	52	271	219	1,083	3,201	2,118	4,725
Mar	2,004	43	286	243	880	3,867	2,987	5,234
Apr.	1,972	39	309	270	1,193	4,472	3,279	5,521
May	3,935	75	355	280	1,722	4,608	2,886	7,101
June	16,183	499	422	(-) 77	4,538	5,815	1,277	17,383
July	28,200	693	430	(-) 263	6,043	3,464	(-) 2,579	25,358
Aug	40,039	808	397	(-) 411	11,320	7,207	(-) 4,113	35,515
Sept.	49,790	1,428	837	(-) 591	14,917	5,947	(-) 8,970	40,229
Oct	39,371	796	674	(-) 122	9,593	9,593	0	39,249
Nov	13,273	204	262	58	4,257	4,257	0	13,331
Dec.	6,445	114	263	149	2,759	4,122	1,363	7,957
1962								
Jan	4 165	78	270	192	1,649	3,329	1,680	6,037
Feb	3,137	55	274	219	1,253	3,526	2,273	5,629
Mar	2,503	41	284	243	1,027	4,014	2,987	5,733
Apr.	2,166	45	315	270	1,060	4,339	3,279	5,715
May	3,692	83	363	280	1,789	4,675	2,886	6,858
June	14,612	357	342	(-) 15	4,782	6,059	1,277	15,874
July	25,232	655	319	(-) 336	6,745	3,440	(-) 3,305	21,591
Aug	37,658	1,053	306	(-) 747	12,050	8,657	(-) 3,393	33,518
Sept.	36 408	693	402	(-) 291	9,830	3,139	(-) 6,691	29,426
Oct	24,662	317	317	0	6,208	4,003	(-) 2,205	22 457
Nov	11,309	143	261	118	3,231	3,231	0	11,427
Dec	5,241	91	265	174	1,926	3,289	1,363	6,778
1963								
Jan	3,181	66	271	205	1,181	3,100	1,919	5,305
Feb.	2,372	48	273	225	971	3,116	2,145	4,742
Mar.	1,929	42	285	243	879	3,743	2,864	5,036
Apr.	1 757	37	307	270	837	4,116	3,279	5,306
May	1,848	60	340	280	1,176	4,062	2,886	5,014
June	9,763	296	358	62	2,696	3,973	1,277	11,102
July	21,985	920	487	(-) 433	8,183	4,808	(-) 3,375	18,177
Aug	41,603	1,475	627	(-) 848	14,455	11,132	(-) 3,323	37,432
Sept.	36,657	1,158	890	(-) 268	10,819	3,127	(-) 7,692	28,697
Oct	21,745	397	397	0	6,517	5,281	(-) 1,236	20,509
Nov.	13,655	285	335	50	7,316	7,316	0	13,705
Dec.	6,775	131	280	149	2,982	4,345	1,363	8,287
1964								
Jan	3,689	86	269	183	1,663	3,343	1,680	5,552
Feb.	2,520	60	279	219	1,246	3,519	2,273	5,012
Mar.	1,965	50	293	243	1,103	4,090	2,987	5,195
Apr.	1,854	53	323	270	1,210	4,489	3,279	5,403
May	4,225	111	391	280	2,187	5,073	2,886	7,391
June	9,375	528	416	(-) 112	3,481	4,758	1,277	10,540
July	19,329	799	382	(-) 417	10,074	6,699	(-) 3,375	15,537
Aug	27,358	795	399	(-) 396	11,916	8,593	(-) 3,323	23,639
Sept.	37,897	1,043	586	(-) 457	13,087	4,117	(-) 8,970	28,470
Oct.	31 845	426	426	0	8,577	8,577	0	31,845
Nov.	15 690	186	259	73	4,313	4,313	0	15,763
Dec.	7,414	108	263	155	2,833	4,196	1,363	8,932
1965								
Jan	4,015	79	271	192	1,728	3,408	1,680	5,887
Feb.	2,890	60	279	219	1,362	3,635	2,273	5,382
Mar.	2,243	46	289	243	1,079	4,066	2,987	5,473
Apr	1,980	43	313	270	1,032	4,311	3,279	5,529
May	2,623	78	358	280	1,377	4,263	2,886	5,789
June	17,890	753	599	(-) 154	4,569	5,846	1,277	19,013
July	26,674	1,036	569	(-) 467	8,389	11,764	3,375	29,582
Aug	28,629	876	407	(-) 469	10,387	7,064	(-) 3,323	24,837
Sept	32 463	679	353	(-) 326	10,220	3,134	(-) 7,086	25,051
Oct	16,158	283	283	0	6,718	4,895	(-) 1,823	14,335
Nov	12,483	242	292	50	7,482	7,482	0	12,533
Dec	6,040	103	252	149	3,539	4,902	1,363	7,552

Note: 1/ : The figures are provided by the Mekong Secretariat in September, 1968

The return flow (20%) from Pa Mong Irrigation Area is not included in the Inflow at Sambor site.

Table D-1 (3) Discharge Data at Kratie (1924 - 65)

Year \ Month	Jan	Feb.	Mar.	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov.	Dec	Annual Runoff (10^6cu m)	Annual Average
1924	-	-	-	1,969	2,824	11,166	27,402	54,466	35,621	19,938	12,951	6,087	456,489	19,158
25	3,395	2,446	2,074	1,939	3,075	10,004	27,206	32,280	44,628	17,520	8,102	4,822	415,602	13,124
26	3,243	2,692	2,158	2,015	1,953	6,733	19,649	39,151	33,398	26,209	12,599	7,077	414,752	13,073
27	4,223	2,707	2,426	2,449	3,658	14,165	20,218	42,601	27,881	29,858	11,897	6,043	460,805	14,511
28	3,574	2,500	2,245	2,953	4,471	17,480	29,495	34,027	33,826	19,593	8,457	4,742	431,701	13,614
29	3,076	2,293	1,987	2,067	2,843	11,189	29,685	47,071	46,041	27,082	9,715	5,537	498,552	15,716
30	3,486	2,502	2,158	2,117	4,142	11,434	28,017	39,082	56,229	24,393	10,010	5,589	499,101	15,763
1931	3,509	2,404	2,054	2,122	2,925	6,040	12,832	31,373	32,631	24,097	7,728	4,326	348,843	11,003
32	2,745	2,128	1,770	1,861	2,341	6,593	23,433	26,566	33,839	26,168	11,853	6,079	381,651	12,115
33	3,381	2,505	1,777	1,603	2,099	6,244	19,441	34,287	30,430	20,316	12,185	4,910	367,765	11,598
34	2,932	2,206	1,787	1,473	2,619	5,000	22,433	39,948	44,550	30,206	12,067	5,954	452,452	14,265
35	3,464	2,296	1,813	1,592	2,994	10,486	26,324	32,784	33,913	30,742	21,147	7,876	463,479	14,619
36	3,864	2,742	2,207	2,075	2,965	9,474	25,745	34,826	38,883	15,194	6,040	3,800	390,555	12,318
37	2,798	2,025	1,780	1,543	4,058	12,589	31,584	49,500	55,660	24,616	11,089	6,460	538,082	16,975
38	4,440	3,418	2,767	3,164	4,231	16,849	29,077	33,416	35,463	35,994	13,990	8,436	505,343	15,937
39	4,578	3,106	2,564	2,612	4,537	15,946	26,619	44,819	47,580	32,400	12,677	6,887	539,649	17,027
40	4,015	2,983	2,345	2,182	3,148	12,518	34,752	47,600	55,173	20,832	8,230	5,122	525,470	16,575
1941	3,706	2,994	2,466	2,243	3,543	13,992	27,119	44,603	39,250	31,071	17,223	7,621	517,456	16,319
42	4,180	3,050	2,268	2,278	4,087	11,666	29,181	42,168	39,823	22,019	13,395	5,861	475,454	14,998
43	3,805	2,674	2,401	2,789	3,355	14,852	24,577	35,513	44,553	26,187	12,455	5,284	470,804	14,870
44	3,823	3,023	2,317	2,066	3,463	8,145	21,523	39,145	29,070	25,071	14,150	7,302	420,989	13,258
45	4,198	3,027	2,464	2,264	4,763	17,274	28,065	30,774	43,850	19,332	10,445	6,096	455,000	14,379
46	4,007	2,684	2,086	1,888	4,551	15,386	23,397	35,987	46,533	25,903	12,294	6,161	477,190	15,073
47	3,899	2,995	2,132	2,262	6,421	11,618	32,852	37,910	45,857	23,090	10,497	5,418	488,528	15,413
48	3,671	2,698	2,091	2,179	4,515	12,817	24,494	36,871	49,623	27,216	13,110	6,808	491,249	15,508
49	4,022	2,993	2,295	2,270	4,204	6,719	13,948	34,416	43,103	30,642	16,710	8,383	447,818	14,142
50	4,704	3,043	2,189	1,921	2,890	11,357	25,252	36,000	38,350	32,197	17,940	7,800	485,070	15,304
1951	4,043	3,099	2,082	2,026	3,700	14,477	22,813	36,403	34,443	23,716	12,439	6,208	436,911	13,789
52	3,070	1,961	1,762	1,718	3,203	7,211	18,810	44,445	46,697	30,813	13,620	5,030	471,347	14,862
53	2,770	2,206	1,828	1,833	4,577	14,630	20,345	33,100	33,687	20,771	10,492	5,098	399,530	12,611
54	3,159	2,110	1,689	1,967	3,853	10,398	13,219	25,416	41,887	26,758	10,970	5,019	386,056	12,204
55	3,124	2,237	1,869	2,038	2,589	8,152	20,285	25,378	30,233	17,091	11,432	7,688	423,795	11,010
56	4,035	2,506	1,934	1,991	5,551	11,980	20,992	39,341	41,350	18,431	9,032	4,578	427,160	16,852
57	3,420	2,600	2,093	2,103	3,056	10,013	22,684	24,733	34,844	27,683	10,221	5,085	383,152	12,378
58	3,345	2,510	1,919	1,733	2,163	9,386	20,809	25,077	42,717	19,780	8,729	4,431	375,881	11,883
59	2,383	1,945	1,730	1,648	2,205	6,360	11,915	26,128	37,304	24,029	10,042	4,161	342,504	10,821
60	2,878	2,296	1,827	1,357	1,799	6,318	13,545	39,539	36,117	28,394	11,381	5,827	400,019	12,607
1961	3,284	2,388	2,004	1,972	3,935	16,183	28,200	40,039	49,790	39,371	13,273	6,445	546,482	17,240
62	4,165	3,137	2,503	2,166	3,692	14,612	25,232	37,658	36,408	24,662	11,309	5,241	451,045	14,232
63	3,181	2,372	1,929	1,757	1,848	9,763	21,985	41,603	36,657	21,745	13,655	6,775	431,345	13,593
64	3,689	2,520	1,965	1,854	4,225	9,375	19,329	27,358	37,897	31,845	15,690	7,414	431,055	13,597
65	4,015	2,890	2,243	1,980	2,623	17,890	26,674	28,629	32,463	16,158	12,483	6,040	406,360	12,841
Average	3,593	2,608	2,098	2,049	3,469	11,297	23,742	36,429	39,958	24,813	11,994	5,881	446,012	14,105

1/ Provided by Mekong Secretariat in Sept 1968

The reservoir is operated through a rule curve as shown in Fig. D-2, allowing 5 cu.ms of leakage from the dam and gates.

Fig. D-1 Area Capacity Curves of the Nam Ngum Reservoir

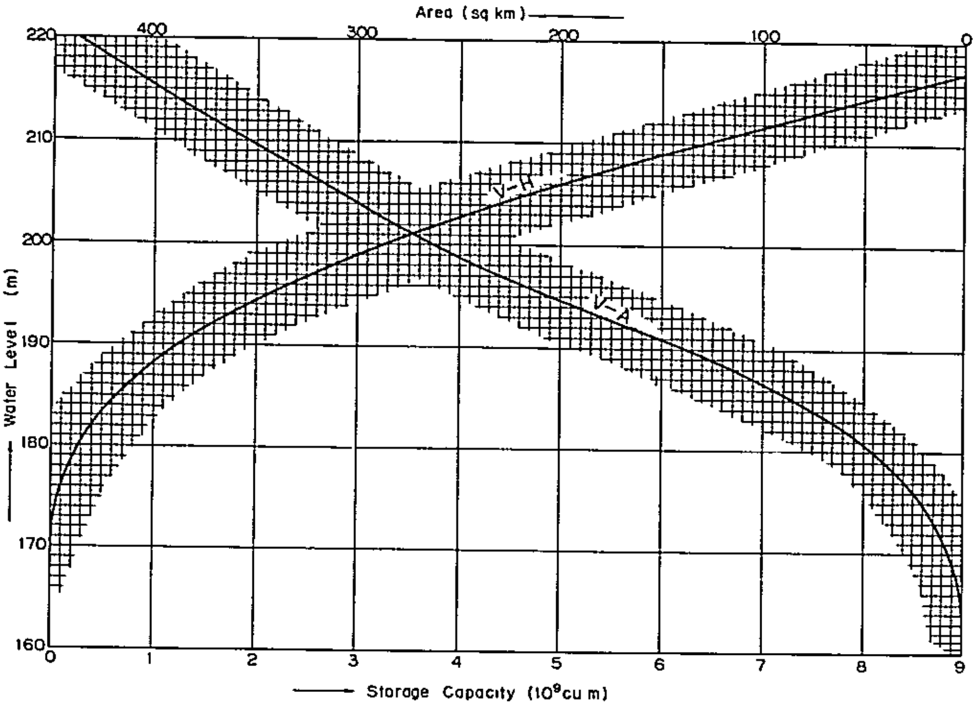
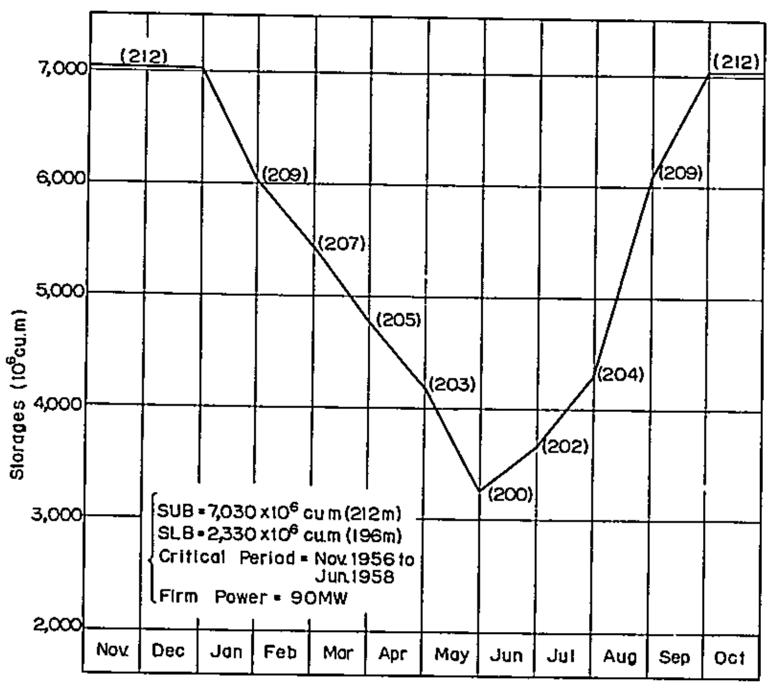


Fig. D-2 Operating Rule Curve of the Nam Ngum Reservoir



NOTE : ( ) = Reservoir Elevation in Meters

The power plant has the following capacity.

Installed capacity:	135 MW
Firm output:	81 MW

(2) The Pa Mong Project

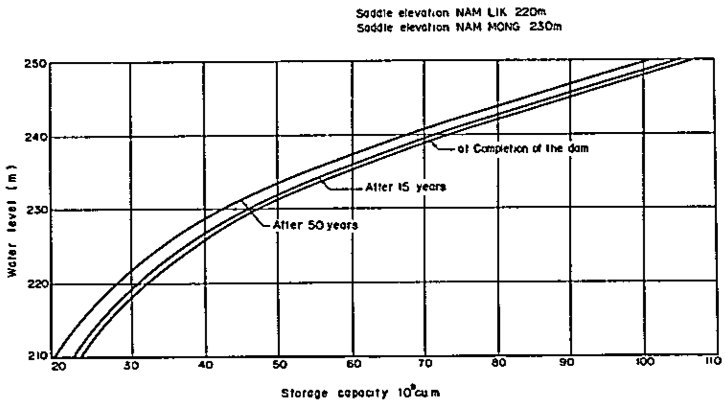
The dam is said to be constructed at a site about 30 km upstream of Vientiane on the Mekong River with a reservoir capacity of 107 billion cu.m, for contribution to the development of 1,000,000 ha of available land and for the installation of a 6,000 MW capacity power plant in the final stage.

The dimension of proposed reservoir is as follows:

Catchment area:	299,000 sq. km
Total capacity:	107 billion cu.m
Effective capacity:	74,997 million cu.m
High water level:	EL 250 m
Draw-down depth:	30 m (LWL ; EL 220 m)

The area capacity curve is shown in Fig. D-3.

Fig. D-3 Area Capacity Curves of the Pa Mong Reservoir (including the Nam LiK and the Nam Mong Reservoirs)



The reservoir is to be operated as follows:

Irrigation water requirement for 250,000 ha (Phase 1) of arable land is shown in Table D-2. 10 cu.ms of leakage from reservoir and gates is allowed for operation rule, which is given in Fig. D-4.

The power plant has the following capacity:

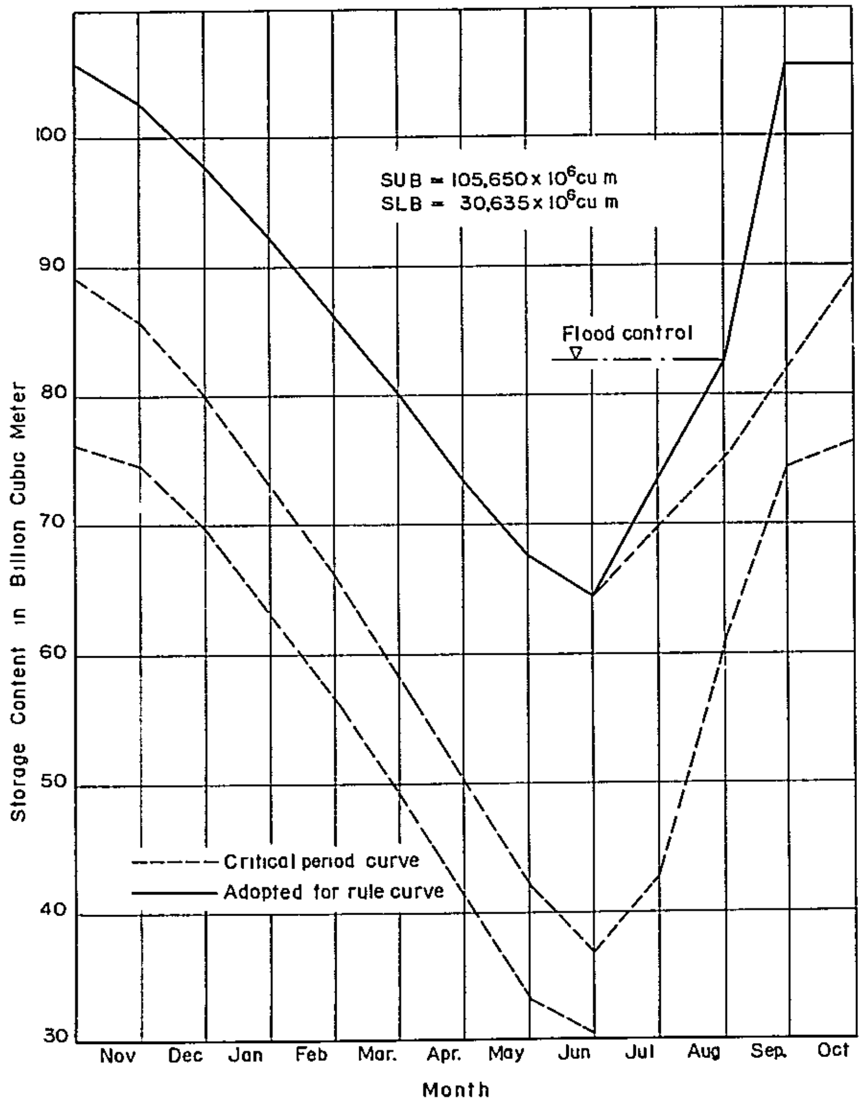
Installed capacity :	6,000 MW (Rated head 67.5 m)
Firm output :	2,195 MW

Table D-2 Irrigation Diversion of the Pa Mong Project (Intermediate Stage)

(Estimated Irrigation Area: 250,000 ha)

Month	cu. ms	Month	cu. ms
Jan.	183	Jul.	56
Feb.	143	Aug.	46
Mar.	118	Sep.	21
Apr.	100	Oct.	45
May	0	Nov.	19
Jun.	1	Dec.	10

Fig. D-4 Operating Rule Curve of the Pa Mong Reservoir (250 m)



D-1-2 Operation of the Sambor Reservoir

(1) Prerequisites

The followings are prerequisites in setting up the operating rules for the Sambor Reservoir.

(a) The Sambor Reservoir is to be of the same dimensions as planned under the isolated development project with the capacity and area curve as shown in Fig. D-5, with 40 m HWL and 38 m LWL. Effective capacity is to be 2,050 million cu.m.

(b) Flow records at Kratie from 1924 to 1965 presented by the Mekong Secretariat in Sept. 1968 are to be used as flow at Sambor. (Table D-1 (3))

The data differs partly from those which were used in the isolated case (presented by Mekong Secretariat in April 1967, see Vol. III, Chapter D.)

According to the records, the severest dry year so far was 1959, followed by 1960 and 1932.

(c) Correction for evaporation and precipitation will be based on the same criterion as for the isolated case. (Table D-3)

Table D-3 Net Evaporation – Precipitation Correction Factors

Month	(1) Precipitation (mm)	(2) Temperature (°C)	(3) Consumption Use of Native Vegetation (mm)	(4) Precipitation Consumed (mm)	(5) Evaporation (mm)	(6) = (4)–(5) Net 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
Jun.	159	27.5	117	117	108	(+) 9
Jul.	226	26.8	119	119	95	(+) 24
Aug.	279	27.0	117	117	81	(+) 36
Sep.	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:

Column: (1) Monthly Average Precipitation at Kratie (1960–65)

(2) Monthly Average Temperature at Kratie

(3) Calculated by Blaney-Criddle Method

(6) (+) indicates the amount of holding and (-) indicates the amount of loss

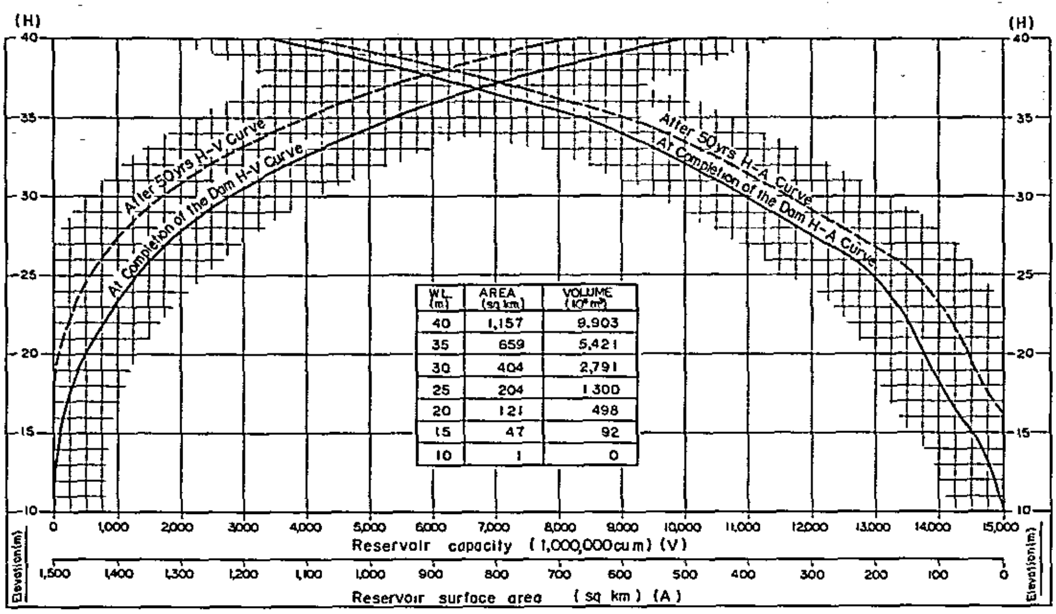
(d) Irrigation water requirement will be the same as the isolated case (see Fig. D-6) with an annual requirement being 4.68 million cu.m. The maximum will be 44 cu.ms in February and the minimum will be 0 cu.ms in May.

(e) 40 cu.ms are allowed as the loss from the leakage at the inclined passage facility and gates.

(f) 20% of irrigation water taken from the Pa Mong Reservoir is to be returned to the Mekong River. 1/

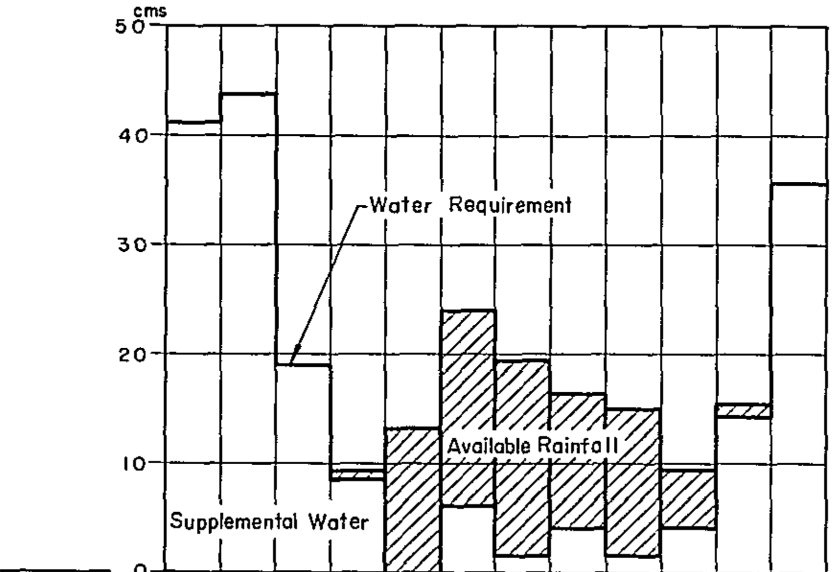
Note: 1/ *Reservoir Operation and Power Output of Sambor Project with the Flow-Regulation of Nam Ngum and Pa Mong Reservoirs,* Sept 18, 1968 Mekong Secretariat.

Fig. D-5 Area Capacity Curve of Sambor Reservoir



W.L. (m)	AREA (sq km)	VOLUME (10^6m^3)
40	1,157	9,903
35	659	5,421
30	404	2,791
25	204	1 300
20	121	498
15	47	92
10	1	0

Fig. D-6 Irrigation Water Requirement



Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Water Requirement	41 1	43.8	19 0	9 3	13 4	23 9	19 4	16 4	15 0	9 3	15 4	35 8
Available Rainfall	0	0	0	0.8	13.4	17 7	17.9	12 3	13 5	5 2	1 1	0
Supplemental Water	41.1	43.8	19.0	8.5	0	6 2	1 5	4 1	1.5	4 1	14 3	35.8

(2) Operating Rule

The operating rule of the Sambor Reservoir has been established in the following manner:

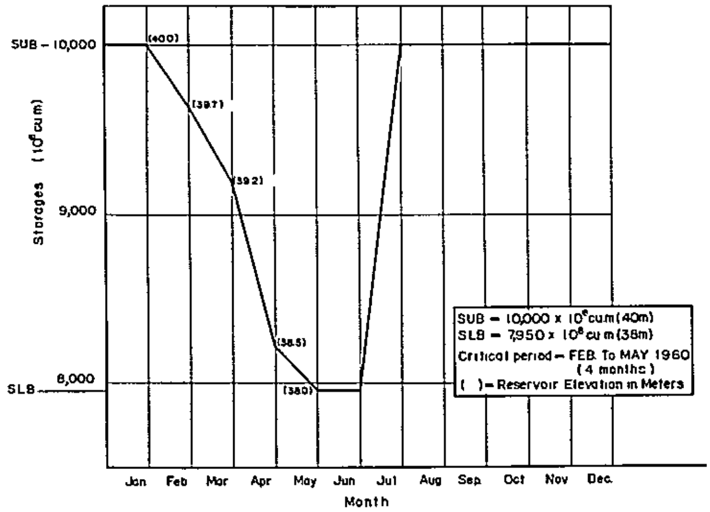
The amount of water increased or decreased, in the immediate downstream of the Nam Ngum and the Pa Mong Reservoirs by the operation of these reservoirs as stated in section D-1-1, is assumed to be increased or decreased at the Sambor site.

Based on the above assumption, the flow at Sambor for the period from November 1950 to December 1965 was estimated. As a result, it was found that the flow during the February – May period in 1960 was minimum.

The operating rule for the reservoir was determined after giving due consideration to the year's flow conditions and the aforementioned prerequisites by making various changes in the discharge for power generation during the four months of the dry season (February – May) so that the corresponding output would be maximum.

As a result, the rule has been obtained as shown in Fig. D-7, by which a firm output of 1,120 MW was found.

Fig. D-7 Operating Rule Curve of Sambor Reservoir



(3) Amount of discharge for power generation

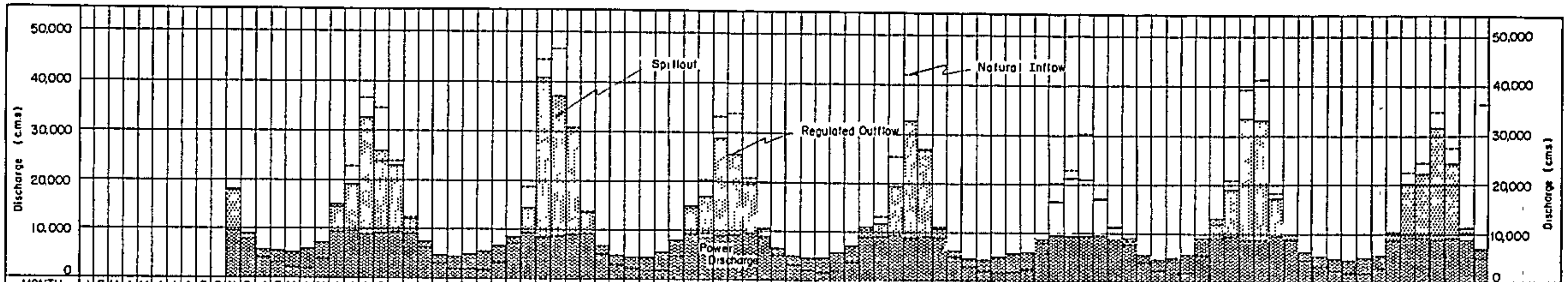
The regulated flow at the Sambor Dam site during the period from November 1950 to December 1965 is shown in Fig. D-8.

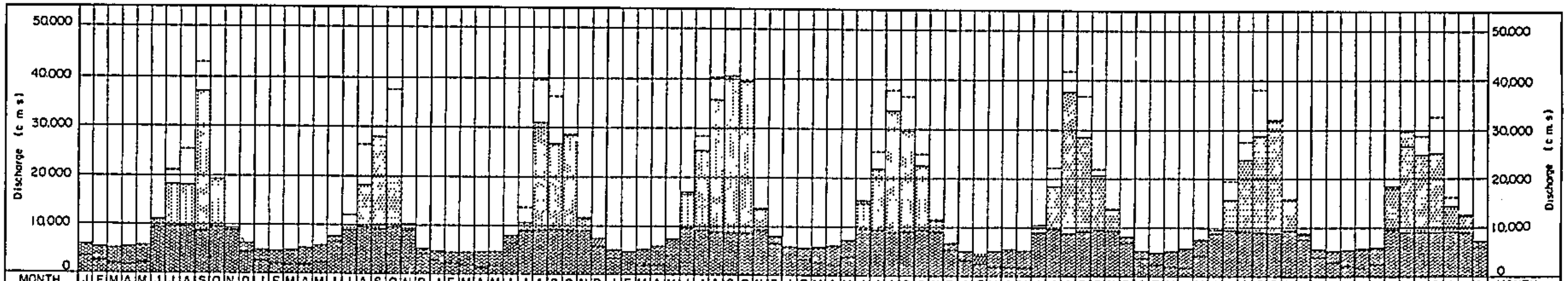
(4) The estimated amount of water available for irrigation in the Lower Mekong Delta

Since it is not permissible to lower the water level in the Mekong in the dry season below the past and present levels, it is considered appropriate to limit the discharge available for irrigation to within 2,000 cu.ms – 2,200 cu.ms, which is the increased amount during the dry season influenced by the flow regulation of the Nam Ngum and the Pa Mong.

The minimum mean value of the discharge into the downstream by the operation of the Sambor Reservoir in the dry season (Dec. to May of the following year) during a 15-year period after 1951 was about 4,600 cu.ms recorded in 1960, whereas the minimum mean value of the average monthly discharge was about 4,400 cu.ms recorded in February of the same year. These figures, when compared with about 2,200 cu.ms of the dry season mean discharge and 1,360 cu.ms (April) of the minimum monthly mean discharge, represent an increase of about 2,200 cu.ms and 3,040 cu.ms respectively (see Fig. D-8). From the above discussion it is presumed that if irrigation water is to be limited to 2,200 cu.ms, the residual discharge in the immediate downstream of the Sambor (actual intake will be done at Phnom Penh) will not decrease to below the 2,000 cu.ms level (see Table D-1 (3)).

Fig. D-8 Regulated Outflow at Sambor Site (Available discharge for generation at the completion of Nam Ngum and Pa Mong Projects)





Year	Month	Natural Inflow	Regulated Outflow	Power Discharge	Spillout
1950	J				
	F				
	M				
	A				
	M				
	J				
	J				
	A				
	S				
	O				
	N	17,940	17,900	9,500	8,400
	D	7,800	9,000	8,700	300
1951	J	4,043	5,600	5,600	0
	F	3,099	5,400	5,400	0
	M	2,082	5,200	5,200	0
	A	2,026	5,800	5,800	0
	M	3,700	7,100	7,100	0
	J	14,477	15,000	9,300	5,700
	J	22,813	19,100	9,500	9,600
	A	36,403	32,400	8,800	23,600
	S	34,443	25,900	9,100	16,800
	O	23,716	22,900	9,300	13,600
	N	12,459	12,300	9,000	3,300
	D	6,208	7,500	7,500	0
1952	J	3,070	4,600	4,600	0
	F	1,961	4,400	4,400	0
	M	1,762	4,800	4,800	0
	A	1,718	5,500	5,500	0
	M	3,203	6,600	6,600	0
	J	7,211	8,400	8,400	0
	J	18,810	14,400	9,300	5,100
	A	44,445	40,700	8,400	32,300
	S	46,697	37,000	8,600	28,400
	O	30,813	30,700	8,900	21,800
	N	13,620	13,500	9,200	4,300
	D	5,030	6,600	6,600	0
1953	J	2,770	4,800	4,800	0
	F	2,206	4,400	4,400	0
	M	1,828	4,400	4,400	0
	A	1,833	5,400	5,400	0
	M	4,577	7,900	7,900	0
	J	14,630	15,100	9,300	5,800
	J	20,345	16,900	9,600	7,300
	A	33,100	28,800	8,900	19,900
	S	33,687	25,500	9,100	16,400
	O	20,771	19,600	9,400	10,200
	N	10,492	10,400	8,800	1,600
	D	5,098	6,400	6,400	0
1954	J	3,159	4,900	4,900	0
	F	2,110	4,500	4,500	0
	M	1,689	4,600	4,600	0
	A	1,967	5,700	5,700	0
	M	3,853	7,100	7,100	0
	J	10,398	11,000	8,900	2,100
	J	13,219	11,700	9,000	2,700
	A	25,416	19,400	9,400	10,000
	S	41,887	32,600	8,800	23,800
	O	26,758	26,700	9,100	17,600
	N	10,970	10,800	8,900	1,900
	D	5,019	6,300	6,300	0
1955	J	3,124	4,700	4,700	0
	F	2,234	4,500	4,500	0
	M	1,869	5,000	5,000	0
	A	2,038	5,800	5,800	0
	M	2,589	5,900	5,900	0
	J	8,152	8,700	8,600	100
	J	20,285	16,500	9,600	6,900
	A	25,378	21,300	9,400	11,900
	S	30,233	21,000	9,400	11,600
	O	17,091	17,000	9,600	7,400
	N	11,432	11,300	8,900	2,400
	D	7,688	9,000	8,600	400
1956	J	4,035	5,600	5,600	0
	F	2,506	4,800	4,800	0
	M	1,934	5,000	5,000	0
	A	1,991	5,700	5,700	0
	M	5,551	9,200	8,500	700
	J	11,980	13,200	9,200	4,000
	J	20,992	19,100	9,500	9,600
	A	39,341	33,500	8,800	24,700
	S	41,350	33,100	8,800	24,300
	O	18,431	17,400	9,600	7,800
	N	9,032	10,100	8,800	1,300
	D	4,578	6,300	6,300	0
1957	J	3,420	5,400	5,400	0
	F	2,600	4,900	4,900	0
	M	2,093	4,600	4,600	0
	A	2,103	5,100	5,100	0
	M	3,056	5,600	5,600	0
	J	10,013	10,500	8,800	1,700
	J	22,684	20,400	9,400	11,000
	A	24,733	22,500	9,300	13,200
	S	34,844	31,700	8,800	22,900
	O	27,683	24,500	9,200	15,300
	N	10,221	11,400	8,900	2,500
	D	5,085	7,100	7,100	0
1958	J	3,345	5,800	5,800	0
	F	2,510	5,300	5,300	0
	M	1,910	5,100	5,100	0
	A	1,733	5,300	5,300	0
	M	2,163	5,600	5,600	0
	J	9,386	10,800	8,900	1,900
	J	20,809	17,400	9,500	8,400
	A	25,077	17,800	9,500	8,300
	S	42,717	36,900	8,600	28,300
	O	19,780	19,000	9,500	9,500
	N	8,729	9,200	8,700	500
	D	4,431	6,100	6,100	0
1959	J	2,383	4,700	4,700	0
	F	1,945	4,600	4,600	0
	M	1,730	4,700	4,700	0
	A	1,648	5,200	5,200	0
	M	2,205	5,600	5,600	0
	J	6,360	7,500	7,500	0
	J	11,915	9,700	8,700	1,000
	A	26,128	17,900	9,500	8,400
	S	37,304	27,700	9,000	18,700
	O	24,029	19,700	9,400	10,300
	N	10,042	9,100	8,700	400
	D	4,161	5,100	5,100	0
1960	J	2,878	4,600	4,600	0
	F	2,296	4,400	4,400	0
	M	1,827	4,400	4,400	0
	A	1,357	4,500	4,500	0
	M	1,799	4,600	4,600	0
	J	6,318	7,800	7,800	0
	J	13,545	10,400	8,800	1,600
	A	39,539	30,800	8,900	21,900
	S	36,117	26,400	9,100	17,300
	O	28,394	28,300	9,000	19,300
	N	11,381	11,300	8,900	2,400
	D	5,827	7,200	7,200	0
1961	J	3,284	5,000	5,000	0
	F	2,388	4,600	4,600	0
	M	2,004	5,100	5,100	0
	A	1,972	5,700	5,700	0
	M	3,935	7,200	7,200	0
	J	16,183	16,600	9,600	7,000
	J	28,200	25,300	9,100	16,200
	A	40,039	35,500	8,700	26,800
	S	49,790	40,300	8,500	31,800
	O	39,371	39,300	8,500	30,800
	N	13,273	13,200	9,200	4,000
	D	6,445	7,800	7,800	0
1962	J	4,165	5,700	5,700	0
	F	3,137	5,500	5,500	0
	M	2,503	5,600	5,600	0
	A	2,166	5,900	5,900	0
	M	3,692	7,000	7,000	0
	J	14,612	15,100	9,400	5,700
	J	25,232	21,600	9,300	12,300
	A	37,658	33,500	8,800	24,700
	S	36,408	29,500	8,900	16,600
	O	24,662	22,300	9,300	13,000
	N	11,309	11,300	8,900	2,400
	D	5,241	6,600	6,600	0
1963	J	3,181	5,000	5,000	0
	F	2,372	4,600	4,600	0
	M	1,929	5,000	5,000	0
	A	1,757	5,500	5,500	0
	M	1,848	5,100	5,100	0
	J	9,763	10,300	8,800	1,500
	J	21,985	18,200	9,500	8,700
	A	41,603	37,400	8,600	28,800
	S	36,657	28,400	9,000	19,400
	O	21,745	20,400	9,400	11,000
	N	13,655	13,500	9,200	4,300
	D	6,775	8,100	8,100	0
1964	J	3,689	5,200	5,200	0
	F	2,520	4,800	4,800	0
	M	1,965	5,100	5,100	0
	A	1,854	5,600	5,600	0
	M	4,225	7,500	7,500	0
	J	9,375	9,800	8,700	1,100
	J	19,329	15,500	9,400	6,100
	A	27,358	23,600	9,200	14,400
	S	37,897	28,500	9,000	19,500
	O	31,845	31,800	8,800	23,000
	N	15,690	15,600	9,300	6,300
	D	7,414	8,700	8,600	100
1965	J	4,015	5,500	5,500	0
	F	2,890	5,200	5,200	0
	M	2,243	5,400	5,400	0
	A	1,980	5,700	5,700	0
	M	2,623	5,900	5,900	0
	J	17,890	18,300	9,500	8,800
	J	26,674	29,600	8,900	20,700
	A	28,629	24,800	9,200	15,600
	S	32,463	25,100	9,200	15,900
	O	16,159	14,300	9,300	5,000
	N	12,483	12,400	9,000	3,400
	D	6,040	7,300	7,300	0

As described in section J-2, the duty of water for the development of 587,000 ha in the Mekong Delta is about 800 cu.ms at the maximum in the dry season, which can be fully satisfied by the increased amount of water. In the event a need arises for the expansion of the development area as the result of land utilization survey, expansion up to about 1.5 million ha may be possible as long as no change is made on the operation of reservoirs (the Sambor Reservoirs with the Pa Mong and the Nam Ngum Reservoirs) or no other water sources are developed.

D-2 Power Generation Capacity

D-2-1 Method used for determining Power Generation Capacity

Electric power is usually supplied in a combination of various electric power sources in developed countries. In determining power supply type for the Sambor Power Plant, however, such a general power supply system was not considered because of the small percentage of other electric sources in the system, and only a combination of Sambor hydroelectric power and the other thermal power was taken up for consideration.

The scale of the Sambor Power Plant at a certain point when the supply cost per 1 kWh firm demand would be the lowest was considered as the optimum scale.

If the above method is to be followed, the optimum scale of the hydroelectric power plant is influenced not only by natural conditions such as topography and flow conditions at a particular site, but by the size of fixed cost, variable cost and load curve of demand of thermal power plant which is to be combined with the hydroelectric power plant. For this reason, these factors are handled in the following manner.

(1) Sambor Power Plant

Flow: Monthly mean flow for the period 1951–65

Effective head: The value after subtraction of hydraulic loss 1 m from the difference between the reservoir water level and discharge level.

Restrictions on power generation by the fluctuation of water level downstream:

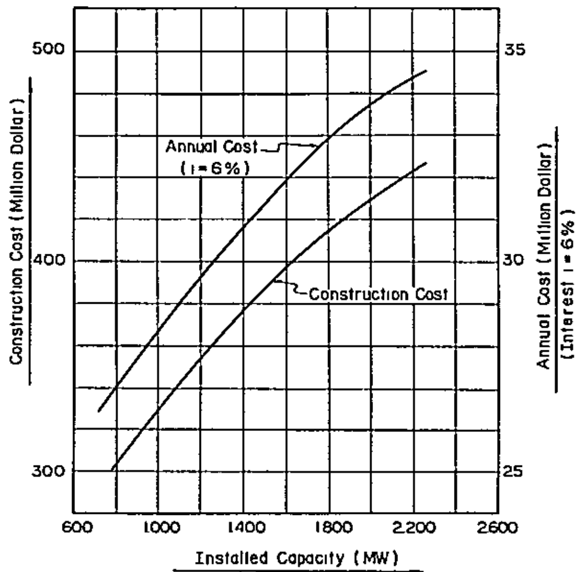
a) Minimum discharge: 1,350 cu.ms

b) Maximum discharge against minimum discharge:

When the minimum is $(1,350 + \alpha)$ cu.ms,
the maximum is $(2,250 + 2\alpha)$ cu.ms.

Construction cost and annual cost corresponding to the installed capacity are shown in Fig. D-9.

Fig. D-9 Curves for Construction Cost and Annual Cost



(2) As for the cost of thermal power plant to be combined with hydroelectric plant, calculation were made in the following two cases.

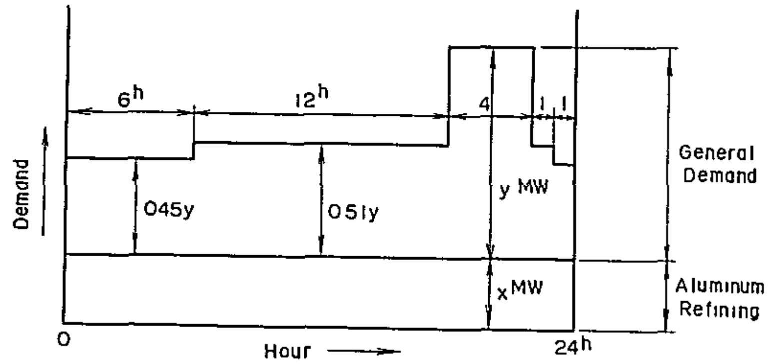
a) Fixed cost $11.0/kW, Variable Cost 5.36 mills/kWh
b) Fixed cost $9.4/kW, Variable Cost 3.70 mills/kWh

(3) Load curve and amount of demand.

Load curve: Demand of aluminum refining with 100% load factor and general demand are combined to make a load curve (see Fig. D-10).

Amount of demand: Demand in aluminum refining sector was assumed of 250 MW.

Fig. D-10 Composite Load Curve



Assuming that the combined thermal power is increased with the increase of demand, the secondary power used as a firm energy also increases. For the determination of its effect, the difference between the maximum firm supply capacity and the demand in aluminum refining was assumed to be the maximum general demand.

D-2-2 Determination of Optimum Capacity

Based on the result of the study discussed in section D-2-1, the capacity of the Sambor Power Plant was determined to be 2,100 MW. The calculation results are given in Figs. D-11 (1) and (2). Fig. D-11 (1) shows the unit cost per kWh versus the capacity of thermal power to be combined, with the scale of the Sambor Power Plant as parameter. Fig. D-11 (2) shows relations between the minimum power unit cost per kWh of each curve above and installed capacity of the Sambor Power Plant. In either case, the approximate value of 2,100 MW is considered to be the optimum scale, and the cost and other factors of combined thermal power have no significant bearing on the problem.

D-2-3 Capacity and Number of Unit

Unit capacity and the number of turbines and generators of the Sambor Power Plant were determined as follows:

Turbine: Unit capacity (rated head: 26 m, maximum discharge: 800 cu.ms)
Number of units 12 (units)
Generator: Unit capacity 200 MVA (power factor 90%)
Number of units 12 (units)

In determining proper unit capacity of turbines and generators for the optimum capacity of power generation, due consideration was given not only to the difference in the construction cost as a result of changes in the number of units and technical limitations on the fabrication of equipment but also the significant effect of shutdown of the power plant for maintenance purpose or due to failure of equipment of the entire system in view of a large share of the Sambor Power Plant in the interconnecting system at an initial stage of the operation.

After a comprehensive study was made on these various factors, the unit capacity and the number of units to be installed were determined as mentioned above.

D-3 Potential Power Capacity and Annual Potential Power Energy

If the power plant is to be operated under operating rules described in section D-1-2, with an installed capacity of 2,100 MW, effective head will fluctuate in the range of 20 m to 30.5 m 1/ and potential power capacity and annual potential power energy will be 1,120 MW – 2,100 MW and 823 – 1,512 million kWh. (average 14,604 million kWh) respectively. (See Figs. D-12, 13)

Firm power is 1,120 MW (dry season in 1960) as described in section D-1-2 (2) and firm annual potential power energy will be 9,780 million kWh, while secondary power energy will be 4,820 million kWh. Dependable maximum capacity in this case will be 1,390 MW. This is due to the fact that the discharge in August 1952 was 40,734 cu.ms with a resultant effective head of 20 m.

D-4 Additional Installation of Generators

Power plant capacity in the final stage is to be 2,100 MW (175 MW x 12 units) as explained in section D-1, but the capacity of the power plant at the start of operations in 1980 will be as follows (depending on power consumption type):

In the case of Type I' :	175 MW x 4 units
In the case of Type III':	175 MW x 1 unit

Number of generators will be increased gradually in proportion to the increase of load. The program of additional installation available power and energy in each stage of the development work is shown in Table D-4.

In the calculation of the available power energy at the generating end, the minimum discharge was set up at 1,350 cu.ms the same as in the isolated case, and in order to minimize the fluctuation of water level downstream at the time of the peak and off-peak, the discharge at the peak time was limited to $2,250 + 2\alpha$ cu.ms when the discharge at the off-peak time was $1,350 + \alpha$ cu.ms. To meet the load under Type I', the operation will be possible within the above limit of discharge, but in the case of Type III' the supply capacity will be restricted and an additional thermal power supply will be required at the peak time.

Notes: 1/ Those figures are based on the monthly average discharge for 15 years after 1950, while in the isolated case the effective head fluctuates within the range of 16.7m–32m which are based on monthly average discharges for 33 years after 1933. The effective head of 20 m corresponds to that of 18.9 m in the isolated case, using the 15 years data.

Fig. D-11 (1) Optimum Scale of the Sambor Power Plant
(Hydro and Thermal Power Combined System)

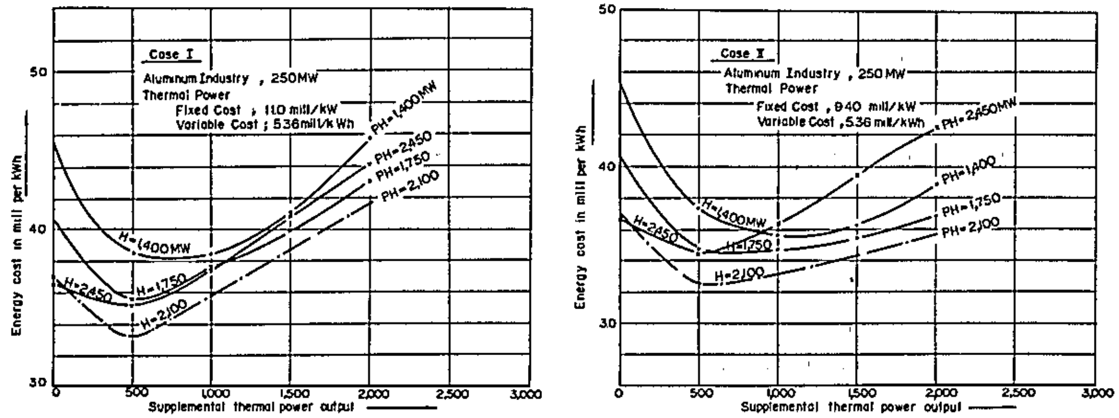
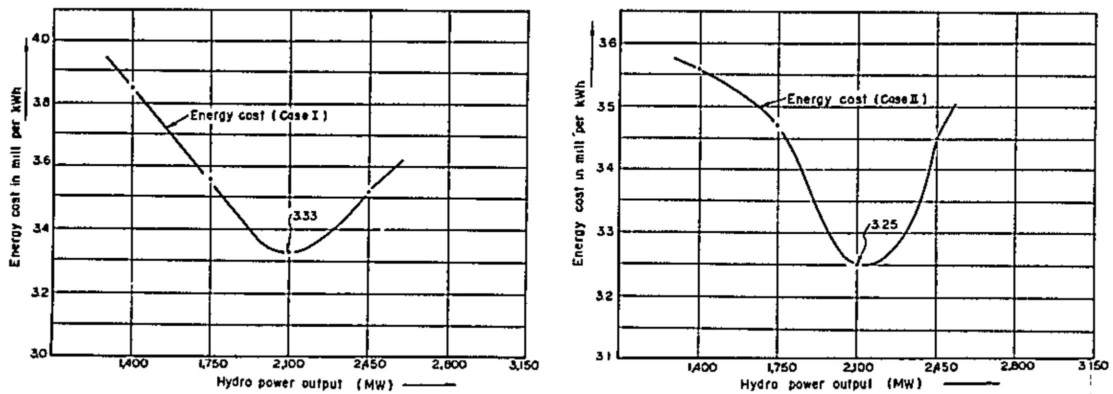


Fig. D-11 (2) Optimum Scale of the Sambor Power Plant
(Hydro Power System)



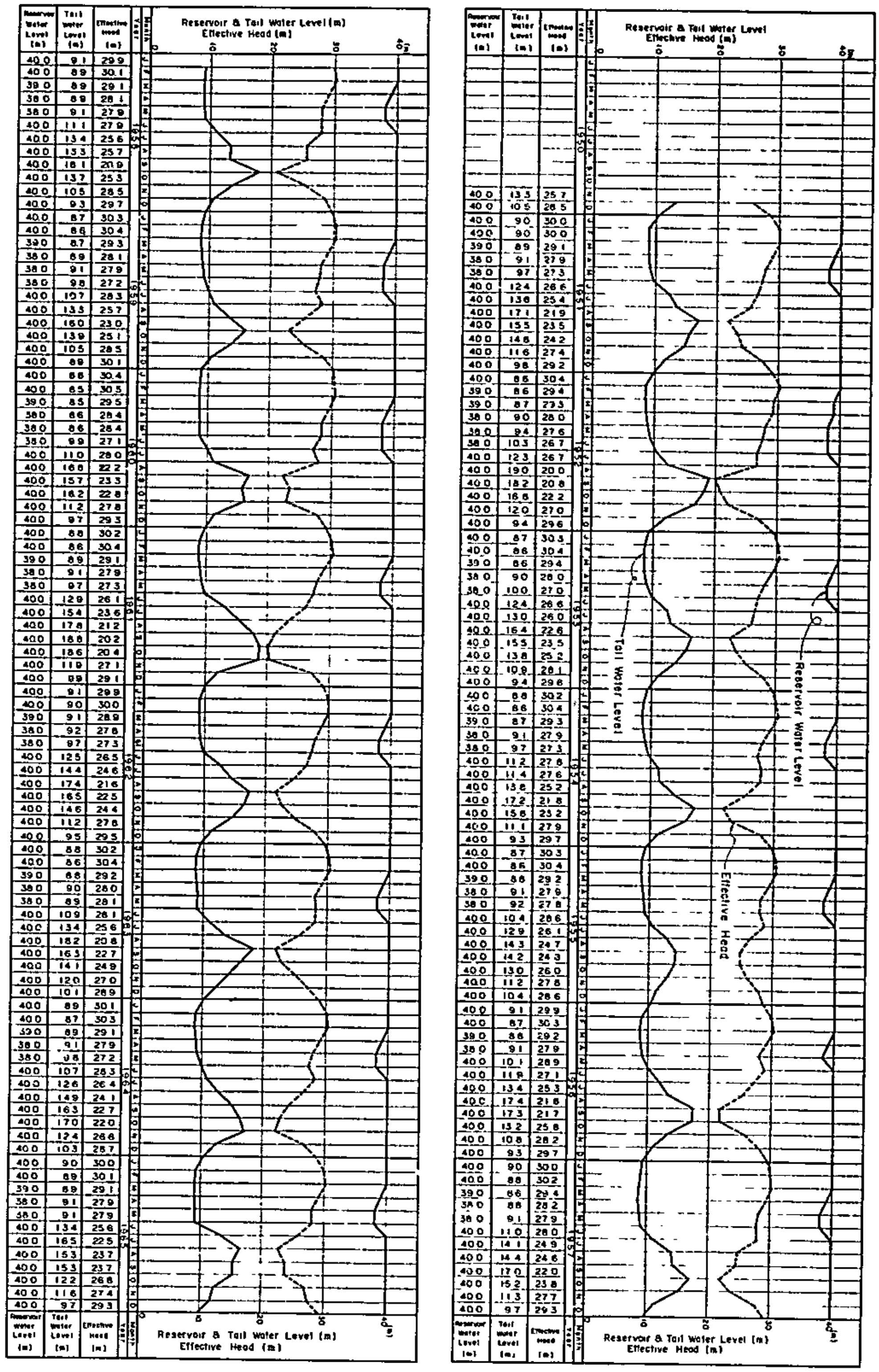


Fig. D-12 Change in the Reservoir Water Level, Effective Power Head and Tail Water Level

Fig. D-13 Power Output and Energy

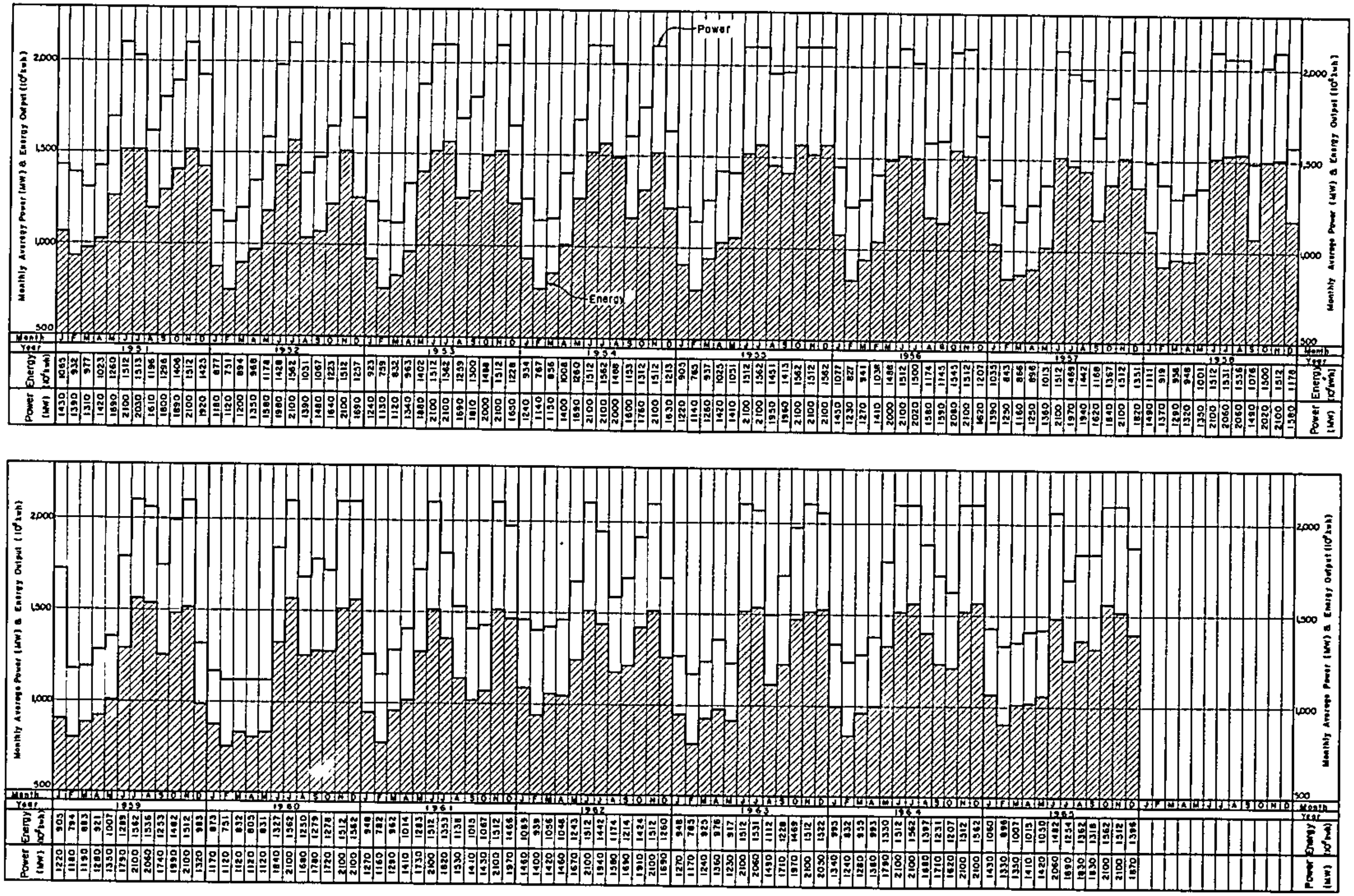


Table D-4 Available Power and Energy in Various Stages of the Development Work

Type	Year Elapsed	No. of Units	Installed Capacity (MW)	Available Annual Energy (million kWh)
I'-1	1-2	4	600	5,868
	3-5	5	875	7,333
	6	8	1,400	11,317
	7-8	9	1,575	12,273
	9	10	1,750	13,116
	10	11	1,925	13,887
	11	12	2,100	14,604
I'-2	1	4	600	5,868
	3	5	875	7,333
	5	6	1,050	8,806
	6	9	1,575	12,273
	7	10	1,750	13,116
	8	11	1,925	13,887
	10	12	2,100	14,604
III'-1	1-2	1	175	
	3-4	2	350	
	5-6	3	525	
	7-8	4	700	
	9	5	875	
	10	6	1,050	
	11	7	1,325	
	12	8	1,400	
	13	9	1,575	
	14	10	1,750	
	15	11	1,925	
	16	12	2,100	
III'-2	1	1	175	
	2	2	350	
	4	3	525	
	5	4	700	
	7	5	875	
	8	6	1,050	
	9	7	1,225	
	10	9	1,575	
	11	10	1,750	
	12	11	1,925	
	13	12	2,100	

CHAPTER E. POWER TRANSMISSION AND SUBSTATION

CHAPTER E. POWER TRANSMISSION AND SUBSTATION

E-1 Power Transmission

The electric power generated at the Sambor Power Plant is assumed to be transmitted to satisfy the general demand in Phnom Penh and Saigon, and the demand of power-oriented industries in Sihanouk Ville.

The load at the generating end in case of Type I' is as follows:

	(Type I'-1)		(Type I'-2)	
	Initial stage	Final stage	Initial stage	Final stage
Phnom Penh	71	445 MW	75	445 MW
Sihanouk Ville	485	970 MW	485	970 MW
Saigon	30	685 MW	46	685 MW

The load at the generating end in case of Type III' is as follows: (see Table E-1)

	(Type III'-1)		(Type III'-2)	
	Initial stage	Final stage	Initial stage	Final stage
Phnom Penh	8	490 MW	12	490 MW
Saigon	30	1,610 MW	6	1,610 MW

At the start of operations of the Sambor Power Plant, transmission networks of 115 kV system in Phnom Penh and 220 kV system in Saigon will have been completed, and the transmission line from Sambor will be interconnected to these systems.

The route of the transmission line will be the same as determined in the isolated case, and its length for the Sambor-Phnom Penh-Sihanouk Ville system will be 350 km and that for the Sambor-Saigon system of 230 km with total 580 km.

The voltage will be 345 kV. The number of circuits will be as follows for the time being. It will be increased in proportion to the load increase, (see Table E-1). In the case of Type I' two circuit transmission lines were considered from the beginning to supply power to the aluminum industry in Sihanouk Ville with consideration for supply reliability.

	Length (km)	Type I'		Type III'	
		1980	Final stage	1980	Final stage
Sambor-Phnom Penh	190	2	3	1	1
Phnom Penh-Sihanouk Ville	160	2	2	–	–
Sambor-Saigon	230	1	2	1	3

E-2 Substations

Primary substations will be constructed in Phnom Penh, Saigon and Sihanouk Ville (if power-oriented industries are to be established in Sihanouk Ville). The primary side of the transformers will be the 345 kV system.

The secondary side will be the 115 kV system in both Phnom Penh and Sihanouk Ville, and the 220 kV system in Saigon. The substation capacity has been planned as follows with a 90% load factor (see Figs. E-1 (1) & (2)).

Fig. E-1 (1) Transmission System Diagram (Type I'-1)

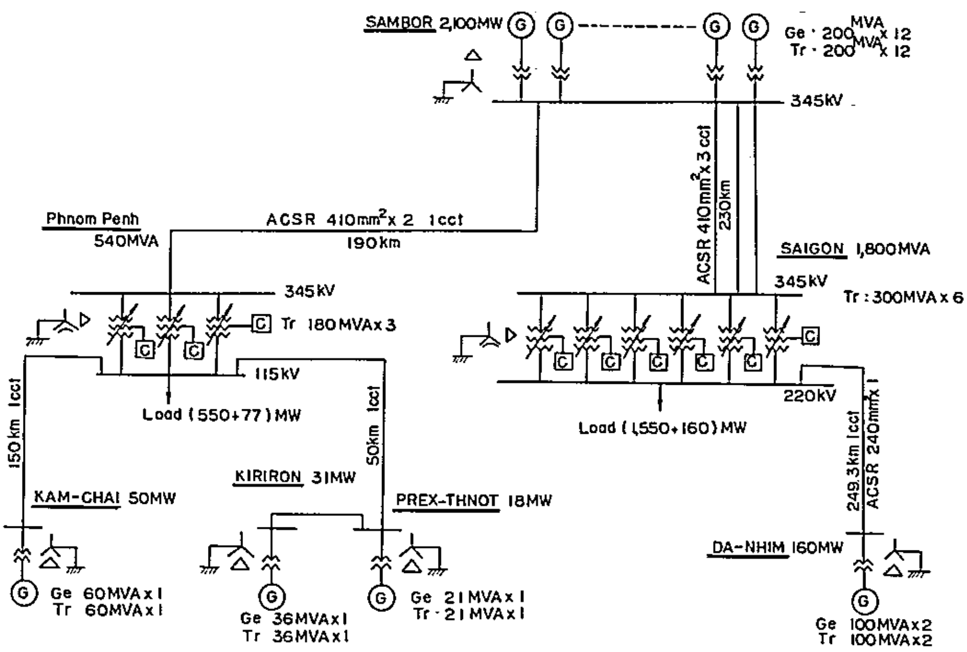


Fig. E-1 (2) Transmission System Diagram (Type III'-1)

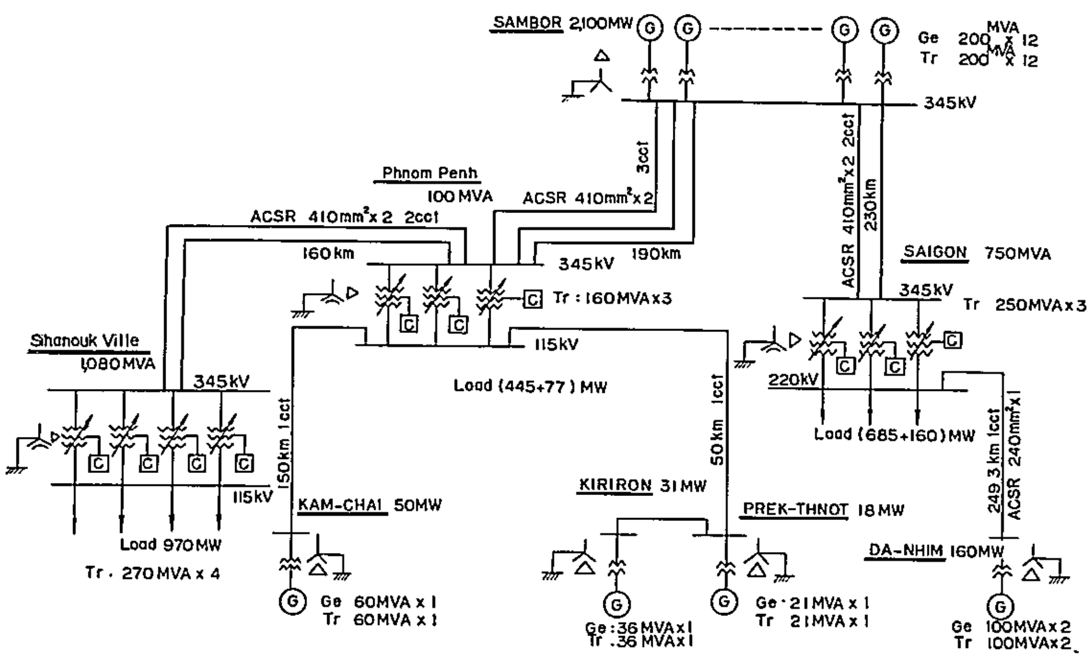


Table E-1 (1) Equipment Plan for the Sambor Project (Type I'-1)

Year	1980 1st	1981 2nd	1982 3rd	1983 4th	1984 5th	1985 6th	1986 7th	1987 8th	1988 9th	1989 10th	1990 11th	1991 12th	1992 13th	1993 14th	1994 15th	1995 16th	1996 17th	1997 18th
Demand (Generating end: MW)																		
Saigon S.S	30	65	105	148	190	238	294	352	418	480	548	634	685	685	685	685	685	685
Phnom Penh S.S	71	91	113	135	159	183	208	236	264	301	333	369	394	405	415	426	437	445
Sihanouk Ville S.S	485	485	485	485	485	970	970	970	970	970	970	970	970	970	970	970	970	970
Total	586	641	703	768	834	1,391	1,472	1,558	1,652	1,751	1,851	1,973	2,049	2,060	2,070	2,081	2,092	2,100
No. of Generator	4	4	5	5	5	8	9	9	10	11	11	12	12	12	12	12	12	12
No. of circuits for transmission line (345 kV)																		
Sambor–Saigon	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2
Sambor–P.Penh	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3
P.Penh-S.Ville	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
No. of banks at substation																		
Saigon S.S (250 MVA)	1	1	1	1	1	2	2	2	2	3	3	3	3	3	3	3	3	3
P.Penh S.S (160 MVA)	1	1	1	1	2	2	2	2	2	3	3	3	3	3	3	3	3	3
S. Ville S.S (270 MVA)	2	2	2	2	2	4	4	4	4	4	4	4	4	4	4	4	4	4

Table E-1 (2) Equipment Plan for the Sambor Project (Type I'-2)

Year	1980 1st	1981 2nd	1982 3rd	1983 4th	1984 5th	1985 6th	1986 7th	1987 8th	1988 9th	1989 10th	1990 11th	1991 12th	1992 13th	1993 14th	1994 15th	1995 16th	1996 17th	1997 18th
Demand (Generating end: MW)																		
Saigon S.S	46	96	159	222	285	357	440	528	625	685	685	685	685	685	685	685	685	685
Phnom Penh S.S	75	100	126	155	186	216	250	286	324	363	373	384	394	405	415	426	437	445
Sihanouk Ville S.S	485	485	485	485	485	970	970	970	970	970	970	970	970	970	970	970	970	970
Total	606	651	770	862	956	1,543	1,660	1,784	1,919	2,018	2,028	2,039	2,049	2,060	2,070	2,081	2,092	2,100
No. of Generator	4	4	5	5	6	9	10	11	11	12	12	12	12	12	12	12	12	12
No. of Circuits for transmission line (345 kV)																		
Sambor–Saigon	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2
Sambor–P.Penh	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3
P.Penh-S.Ville	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
No. of banks at substation																		
Saigon S.S (250 MVA)	1	1	1	1	2	2	2	3	3	3	3	3	3	3	3	3	3	3
P.Penh S.S (160 MVA)	1	1	1	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3
S.Ville S.S (270 MVA)	2	2	2	2	2	4	4	4	4	4	4	4	4	4	4	4	4	4

Table E-1 (3) Equipment Plan for Sambor Project (Type III'-1)

Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th	16th	17th	18th	19th	20th	21st
Demand (Generating end: MW)																					
Saigon S.S	30	65	106	148	190	238	293	352	417	479	548	634	734	833	930	1,035	1,150	1,280	1,420	1,570	1,610
Phnom Penh S.S	8	17	28	40	54	67	83	99	118	144	165	190	219	264	294	328	363	396	433	475	490
Total	38	82	134	188	244	305	376	451	535	623	713	824	953	1,097	1,224	1,363	1,513	1,676	1,853	2,045	2,100
No. of Generator	1	1	2	2	3	3	4	4	5	6	7	8	9	10	11	12	12	12	12	12	12
No. of circuits for transmission line (345 kV)																					
Sambor - Saigon	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	3	3	3	3	3	3
Sambor - P.Penh	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
No. of banks at substation																					
Saigon S.S (300 MVA)	1	1	1	1	1	1	2	2	2	2	3	3	3	4	4	5	5	5	6	6	6
P.Penh S.S (180 MVA)	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	3	3	3	3

Table E-1 (4) Equipment Plan for the Sambor Project (Type III'-2)

Year	1980 1st	1981 2nd	1982 3rd	1983 4th	1984 5th	1985 6th	1986 7th	1987 8th	1988 9th	1989 10th	1990 11th	1991 12th	1992 13th	1993 14th	1994 15th	1995 16th	1996 17th
Demand (Generating end: MW)																	
Saigon S.S	46	96	159	222	285	357	440	528	625	719	823	950	1,100	1,270	1,410	1,570	1,610
P.Penh S.S.	12	26	42	60	81	100	124	149	177	215	247	287	330	375	426	474	490
Total	58	122	201	282	366	457	564	677	802	834	1,070	1,237	1,430	1,645	1,836	2,044	2,100
No. of Generator	1	2	2	3	4	4	5	6	7	9	10	11	12	12	12	12	12
No. of circuits for transmission line (345 kV)																	
Sambor–Saigon	1	1	1	1	1	1	1	2	2	2	2	2	3	3	3	3	3
Sambor–P. Penh	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
No. of banks at substation																	
Saigon S.S (300 MVA)	1	1	1	1	2	2	2	2	3	3	4	4	5	5	6	6	6
P. Penh S.S (180 MVA)	1	1	1	1	1	1	1	1	2	2	2	2	2	3	3	3	3

To meet the load of Type I'

	Capacity (MVA)	Number	
		1980	Final stage
Phnom Penh	160	1	3
Sihanouk Ville	270	2	4
Saigon	250	1	3

To meet the load of Type III':

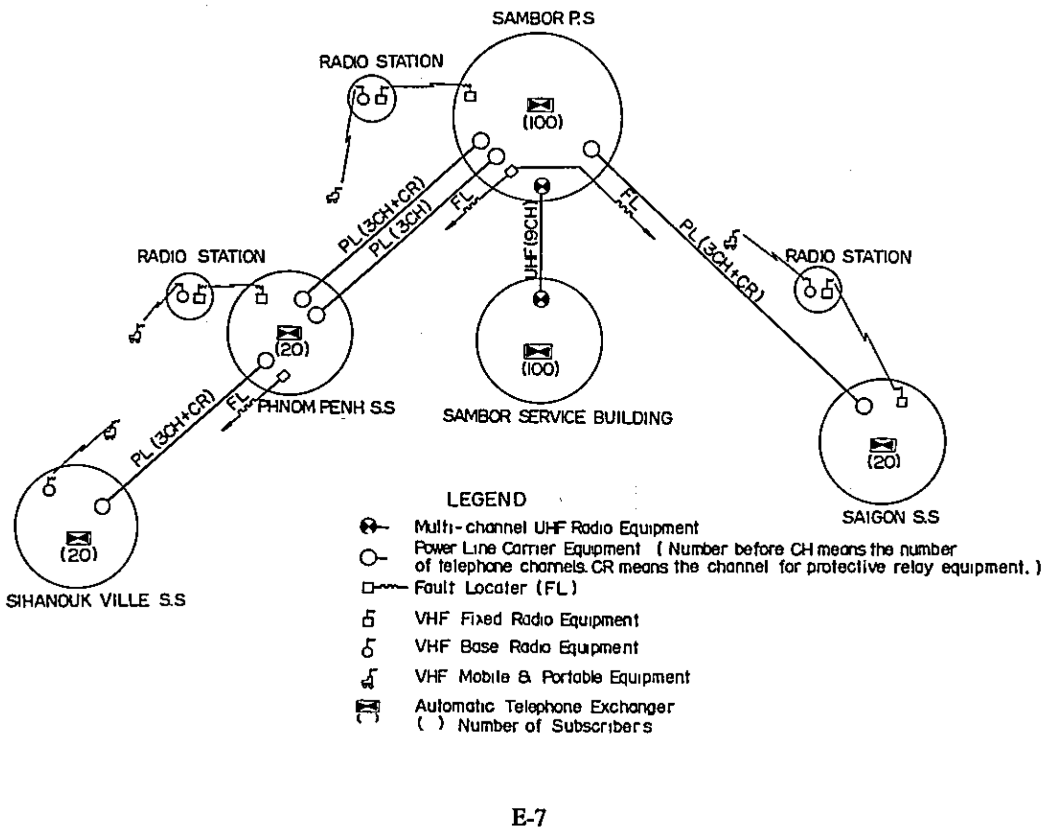
	Capacity (MVA)	Number	
		1980	Final stage
Phnom Penh	180	1	3
Saigon	300	1	6

The program of additional installation in proportion to the load increase is shown in Table E-1.

E-3 Telecommunication

Direct telephone lines for power supply instruction will be installed between the power supply control center and the power plant, and security ultra high frequency (UHF) multichannel equipment will be installed between the Sambor Service Building and the power plant. Between the Sambor Power Plant and the sub-stations there will be a system of power line carrier terminal equipment and automatic switching devices. The power line carrier terminal equipment will also be used as the protective relay equipment for the power system. (See Fig. E-2) Mobile wireless equipment will also be provided for maintenance of transmission lines.

Fig. E-2 Telecommunication System Diagram



CHAPTER F. MAIN STRUCTURES AND PLAN CONSTRUCTION

CHAPTER F. MAIN STRUCTURES AND PLAN CONSTRUCTION 1/

F-1 Description of Main Structures

F-1-1 Hydraulic Structure

The location and the dimension of hydraulic structure will be the same as in the isolated case.

Description of these structures is as follows (see Dwgs. 1 to 4).

Table F-1 Hydraulic Structures

	Length	Volume
Right Bank Earth-fill Dam	11,730 m	8,160,000 cu.m
Left Bank Earth-fill Dam	14,350 m	9,020,000 cu.m
Rock-fill Dam	2,350 m	8,720,000 cu.m
Concrete		
Spillway	1,471 m	900,000 cu.m
Intakes	763 m	530,000 cu.m
Net Length of Spillway	1,003 m	
Effective Length of Spillway	795 m	
Gates	Roller Gates	
	14 m (H) x 15 m (W), 53 Gates	
Design Flood	90,000 cu.ms (Flood water level EL 42m)	
Power Plant		
Length	560 m	
Width	45 m	
Concrete Volume (excluding Intakes)	801,000 cu.m	

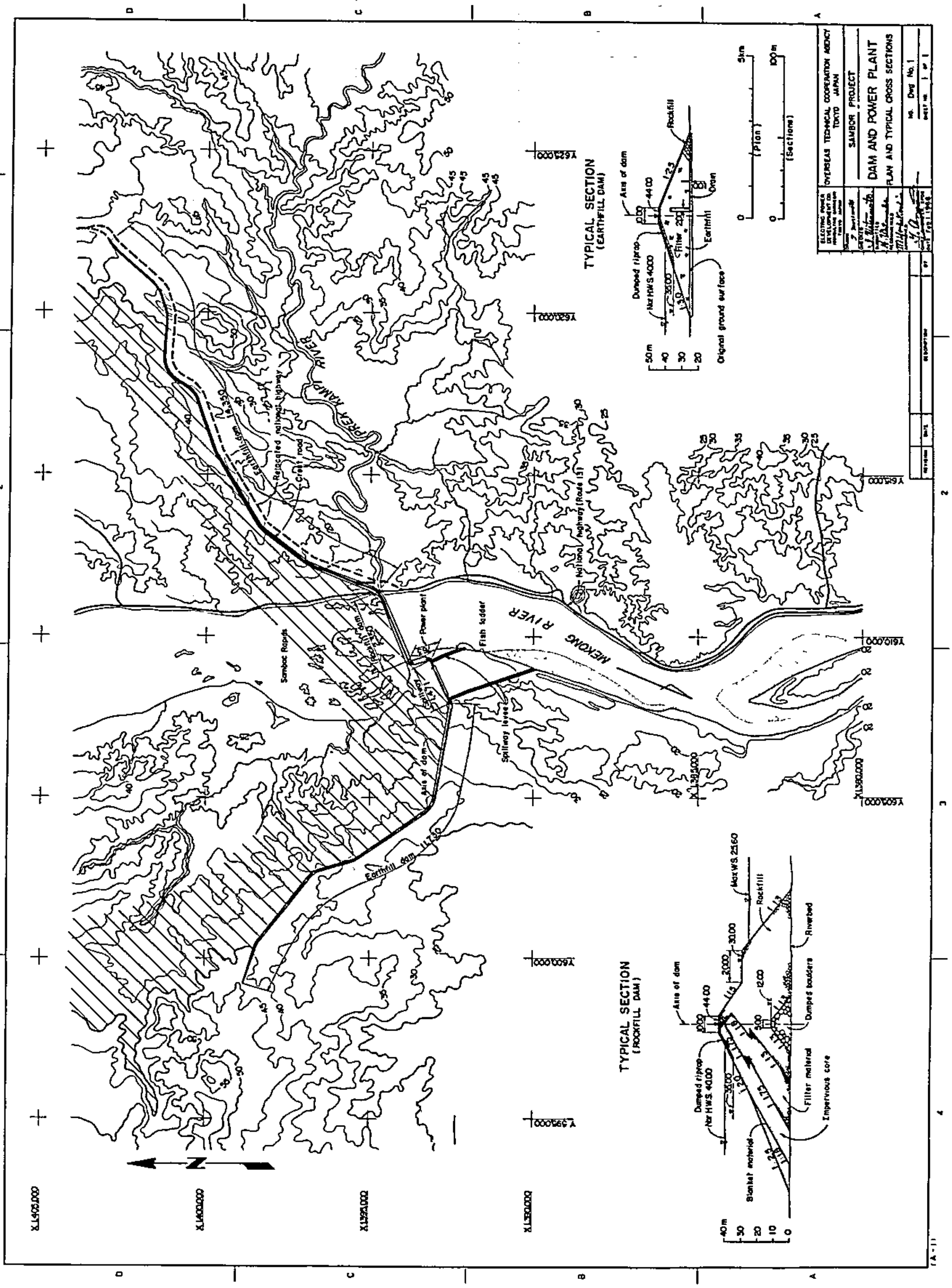
As stated in section D-4, there is no need to install all of the twelve generators from the beginning, and four units are to be installed for Type I' and one unit for Type III'. However, in order to use as a diversion channel at the time of construction of the rock-fill dam in the river, all of the intake and the power plant foundation (portion less than EL 4 m) will be constructed simultaneously in the first phase construction work. Though the construction of intakes for seven units and extra power plant foundations alone may be adequate for the diversion, as described in Chapter I-3-1 of Vol. III, but with the consideration of difficulties anticipated in the future expansion work all of the remainder (intakes and power plant foundations for eight units under Type I') were also planned for construction in the first phase.

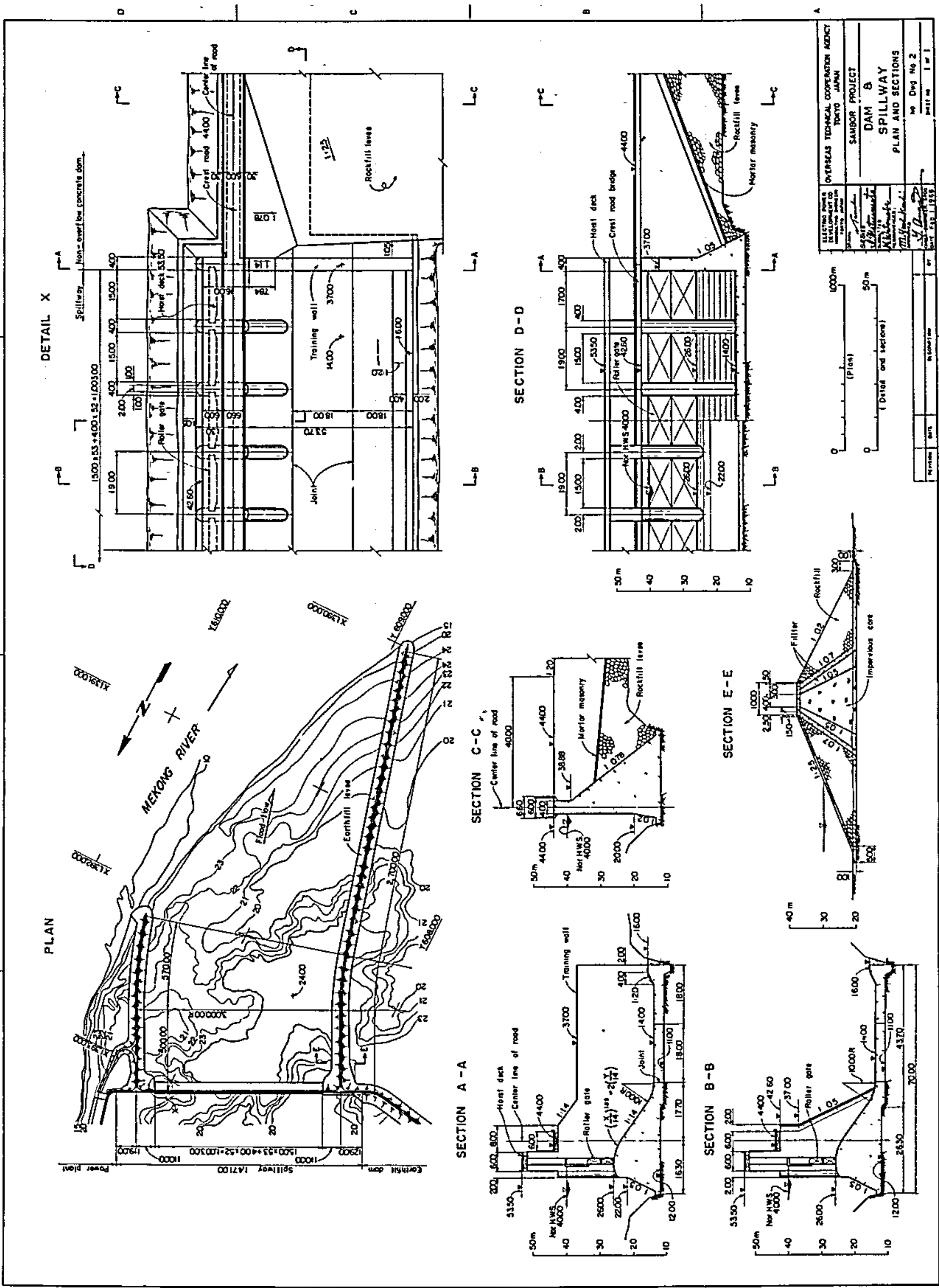
The fish ladders, when required, will be installed at both sides of the spillway. Outline of fish ladders is as follows:

Table F-2 Description of Fish Ladder

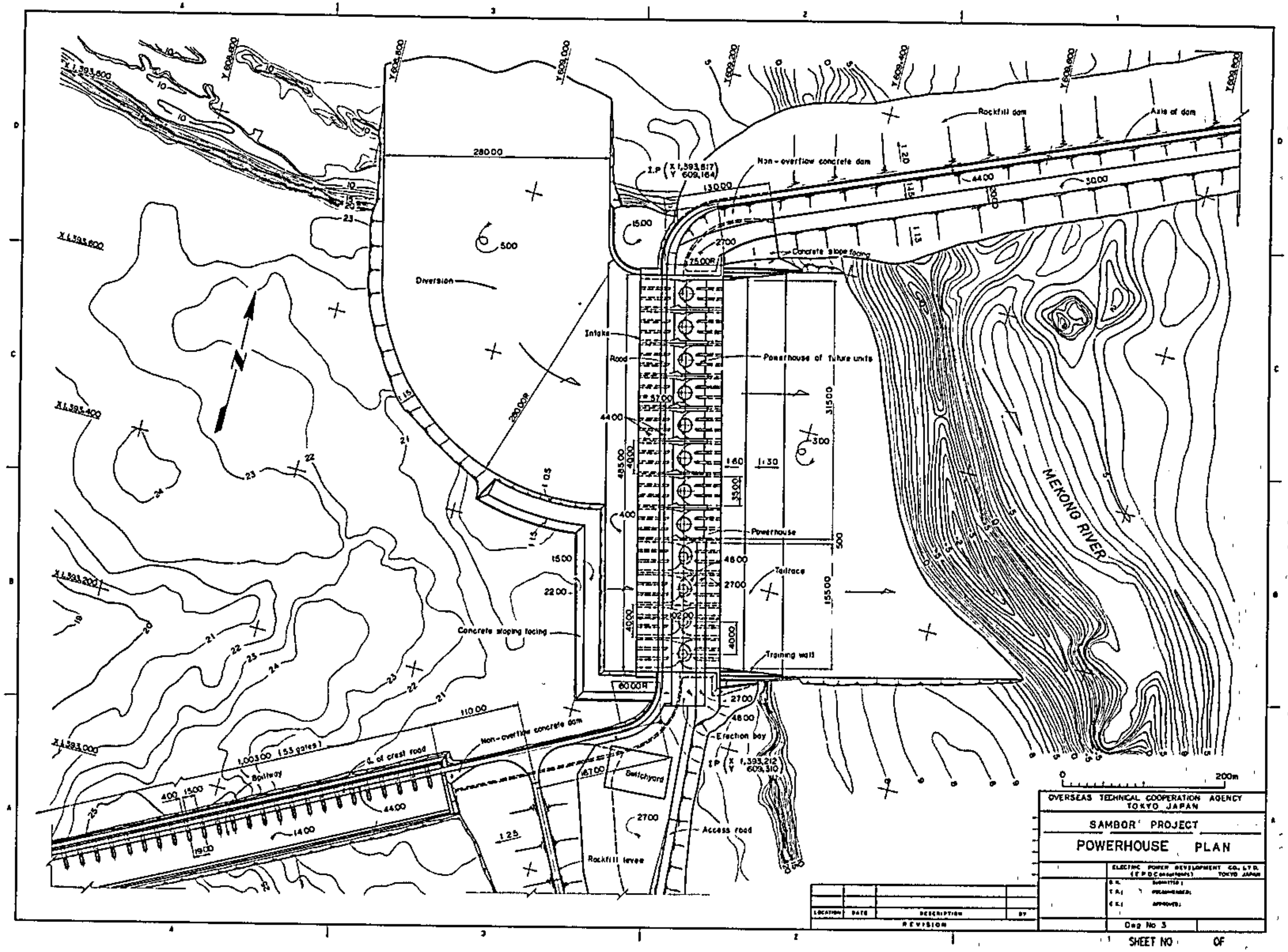
Length	Right	2,830 m
	Left	960 m
Width		40 m each (effective width 30 m)
Elevation of Top of Spill		39.0 m, 39.4 m, 39.8 m
		(3 sections for each ladder)
Concrete Volume		93,000 cu.m
Gate		4.5 m (H) x 5.0 m (W), 6 gates each

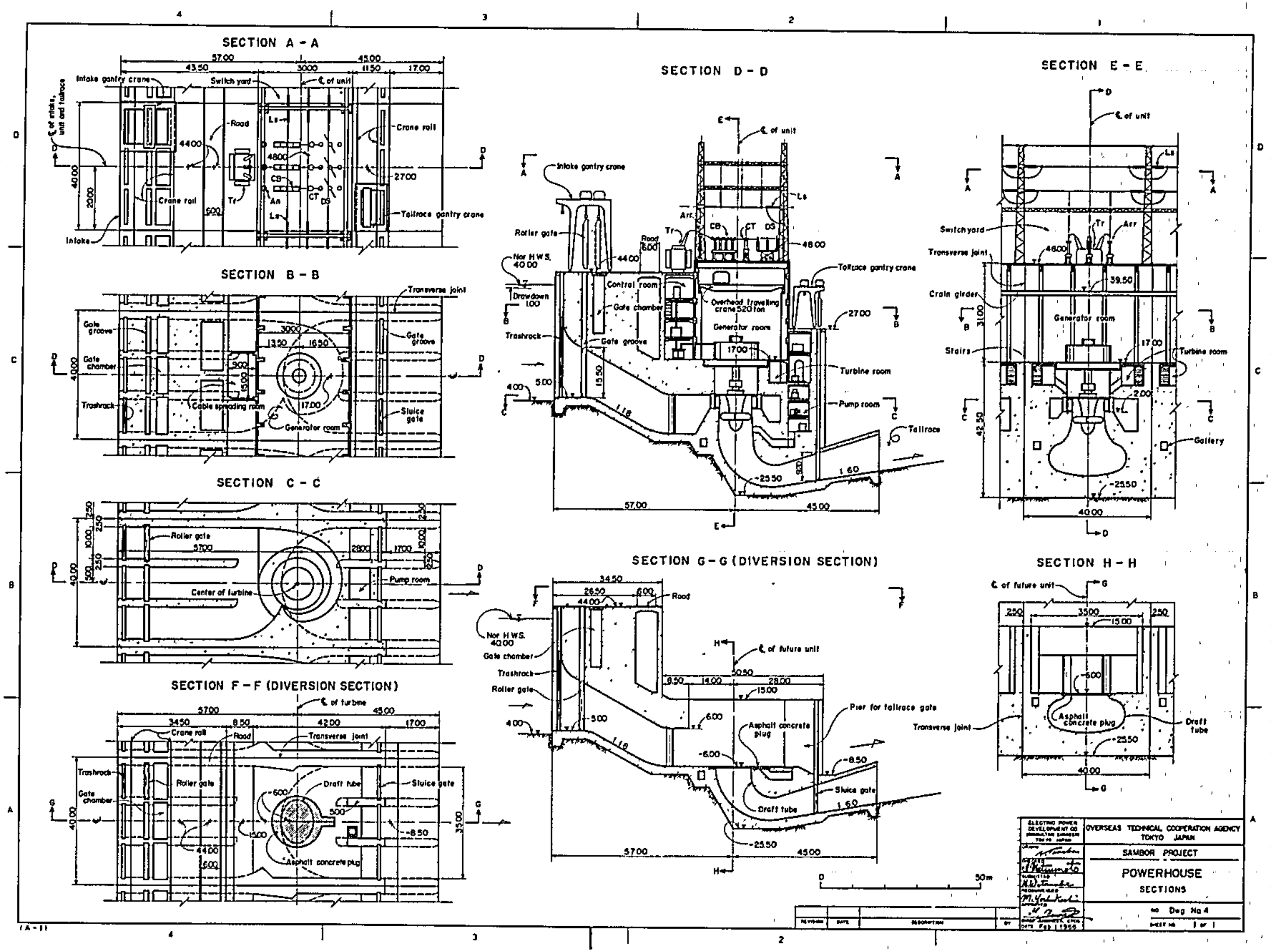
1/ This chapter is described mainly assuming that Type I' power consumption pattern is adopted.


TYPICAL SECTION
(EARTHFILL DAM)
TYPICAL SECTION
(ROCKFILL DAM)
MEKONG RIVER
Sambor Rapids
Power plant
Fish ladder
Spillway
Axis of dam
Earthfill dam
Rockfill
Dumped riprap
Filter material
Impervious core
Blanket material
Dumped boulders
Riverbed
Original ground surface
OVERSEAS TECHNICAL COOPERATION AGENCY TOKYO JAPAN
SAMBOR PROJECT
DAM AND POWER PLANT
PLAN AND TYPICAL CROSS SECTIONS


PLAN
MEKONG RIVER
DETAIL X
SECTION A-A
SECTION B-B
SECTION C-C
SECTION D-D
SECTION E-E
OVERSEAS TECHNICAL COOPERATION AGENCY TOKYO JAPAN
SAMBOR PROJECT
DAM & SPILLWAY
PLAN AND SECTIONS

Dwg. No. 3 Powerhouse
(Plan)




SECTION A - A
SECTION B - B
SECTION C - C
SECTION F - F (DIVERSION SECTION)
SECTION D - D
SECTION G - G (DIVERSION SECTION)
SECTION E - E
SECTION H - H
Intake gantry crane
Switch yard
Crane rail
Tailrace gantry crane
Intake
Road
Gate groove
Gate chamber
Trashrack
Transverse joint
Sluice gate
Cable spreading room
Generator room
Roller gate
Center of turbine
Pump room
Draft tube
Asphalt concrete plug
Control room
Overhead travelling crane 520 ton
Turbine room
Tailrace
Nor H.W.S. 40.00
Drawdown 1.00
Pier for tailrace gate
Gallery
Stairs
Crain girder
ELECTRIC POWER DEVELOPMENT CO.
OVERSEAS TECHNICAL COOPERATION AGENCY TOKYO JAPAN
SAMBOR PROJECT
POWERHOUSE
SECTIONS
Dwg No. 4
Feb. 1956

F-1-2 Electric Equipment

Table F-3 Description of Electric Equipment

Turbine:		
Type		Vertical Kaplan Type
Output		180 MW
No. of Units		12
Effective Head		20.0 m–30.5 m
Rated Head		26 m
Maximum Power Discharge		800 cu.ms
Generator:		
Type		Three-phase Alternating Current
Capacity		200 MVA
Frequency		50 c/s
Voltage		15,400 V
Power Factor		0.9
No. of Units		12
Transformer:		
Type		Outdoor, Three-phase, Forced Oil, Air-cooled
Capacity		200 MVA
Frequency		50 c/s
Voltage	Primary	15,400 V
	Secondary	345,000 V
No. of Units		12

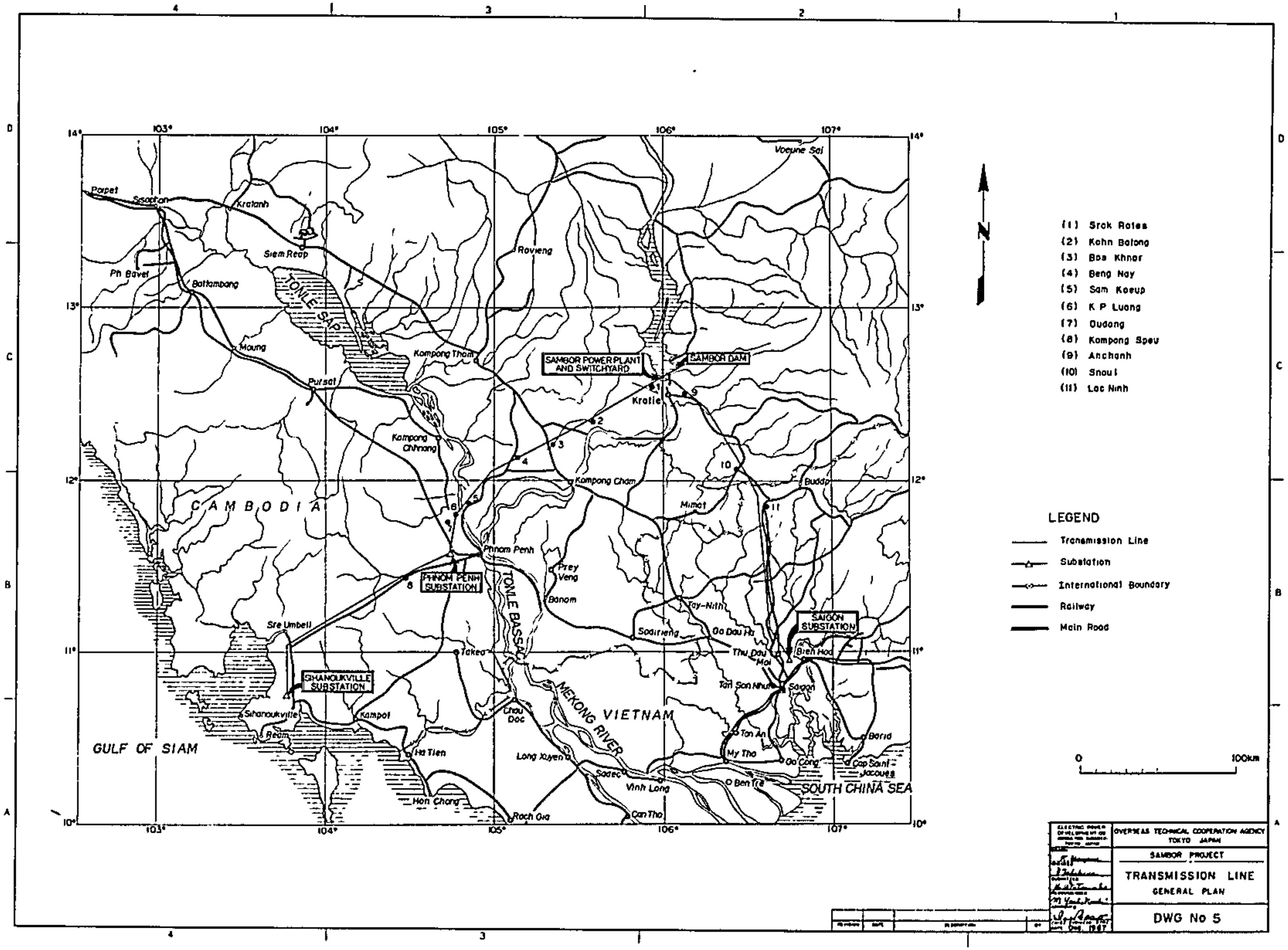
The type of turbine adopted was the vertical shaft Kaplan turbine. Even when the two upstream projects are completed, fluctuation of discharge water level at the Sambor Power Plant will still be great. The effective head will fluctuate in the range of 20 m to 30.5 m even when the average monthly discharge is taken into account. If the average daily discharge (the data is not available) might be taken into account, it is expected that the water level on the downstream side of the power plant rises higher and the effective head becomes smaller, then the range of fluctuation would become greater than the above figures. For this reason, the appropriate type of turbine to be used will be the Kaplan type from which relatively high efficiency may be obtained even though there might be greater fluctuation of head. Rated discharge water of the turbine will be 800 cu.ms per unit at the maximum, and this figure is one of the greatest for lower head.

Its characteristic curve is shown in Fig. F-1. This turbine will be fabricated with the rated head of 26 m, and when the effective head exceeds this level it will be operated with the adjustment of the volume of water with the guide vane. Therefore, if the head become 30 m and available water at that time is 800 cu.ms, the maximum output attainable by a single unit may be 200 MW. The generator selected was the three-phase alternating current synchronized type 200 MVA. This type of generator has been fabricated and put into operation with satisfactory results in various countries, and there should be no problem.

As for the main transformer, the unit system, which calls for the installation of one unit for every turbine generator, was adopted. The bus adopted is the double bus system. Since there is no power plant of large output in the neighborhood of the Sambor Power Plant, it is expected that the plant will be operated as a single plant. Therefore its position in the system is considered to be extremely important. For this reason, the above system has been adopted in order to promote operational reliability and flexibility. Besides, a switching station will be installed on the roof of the power plant.

F-1-3 Transmission Line

The route and various design conditions of the transmission line are the same as in the isolated case except for the number of circuits (see Dwgs. No. 5, 6). Outline of transmission line is as follows:



(1) Srok Rolea
(2) Kohn Balong
(3) Boa Khnar
(4) Beng Nay
(5) Sam Koeup
(6) K P Luang
(7) Oudong
(8) Kompong Speu
(9) Anchanh
(10) Snoul
(11) Loc Ninh
LEGEND
Transmission Line
Substation
International Boundary
Railway
Main Road
0
100km
N
SAMBOR POWER PLANT AND SWITCHYARD
SAMBOR DAM
PHNOM PENH SUBSTATION
SIHANOUKVILLE SUBSTATION
SAIGON SUBSTATION
CAMBODIA
VIETNAM
TONLE SAP
TONLE BASSAC
MEKONG RIVER
GULF OF SIAM
SOUTH CHINA SEA
Poipet
Sisophon
Kralanh
Siem Reap
Ph Bavel
Battambang
Moung
Pursat
Kompong Thom
Kompong Chhnang
Kratie
Kompong Cham
Rovieng
Voeune Sai
Buddp
Mimot
Phnom Penh
Prey Veng
Banom
Tay-Ninh
Soairieng
Go Dau Ha
Thu Dau Mot
Bien Hoa
Tan Son Nhut
Saigon
Tan An
My Tho
Go Cong
Ben Tre
Barid
Cap Saint-Jacques
Sre Umbell
Takeo
Chau Doc
Long Xuyen
Sadec
Vinh Long
Can Tho
Rach Gia
Ha Tien
Hon Chong
Kampot
Sihanoukville
Ream
OVERSEAS TECHNICAL COOPERATION AGENCY TOKYO JAPAN
SAMBOR PROJECT
TRANSMISSION LINE
GENERAL PLAN
DWG No 5

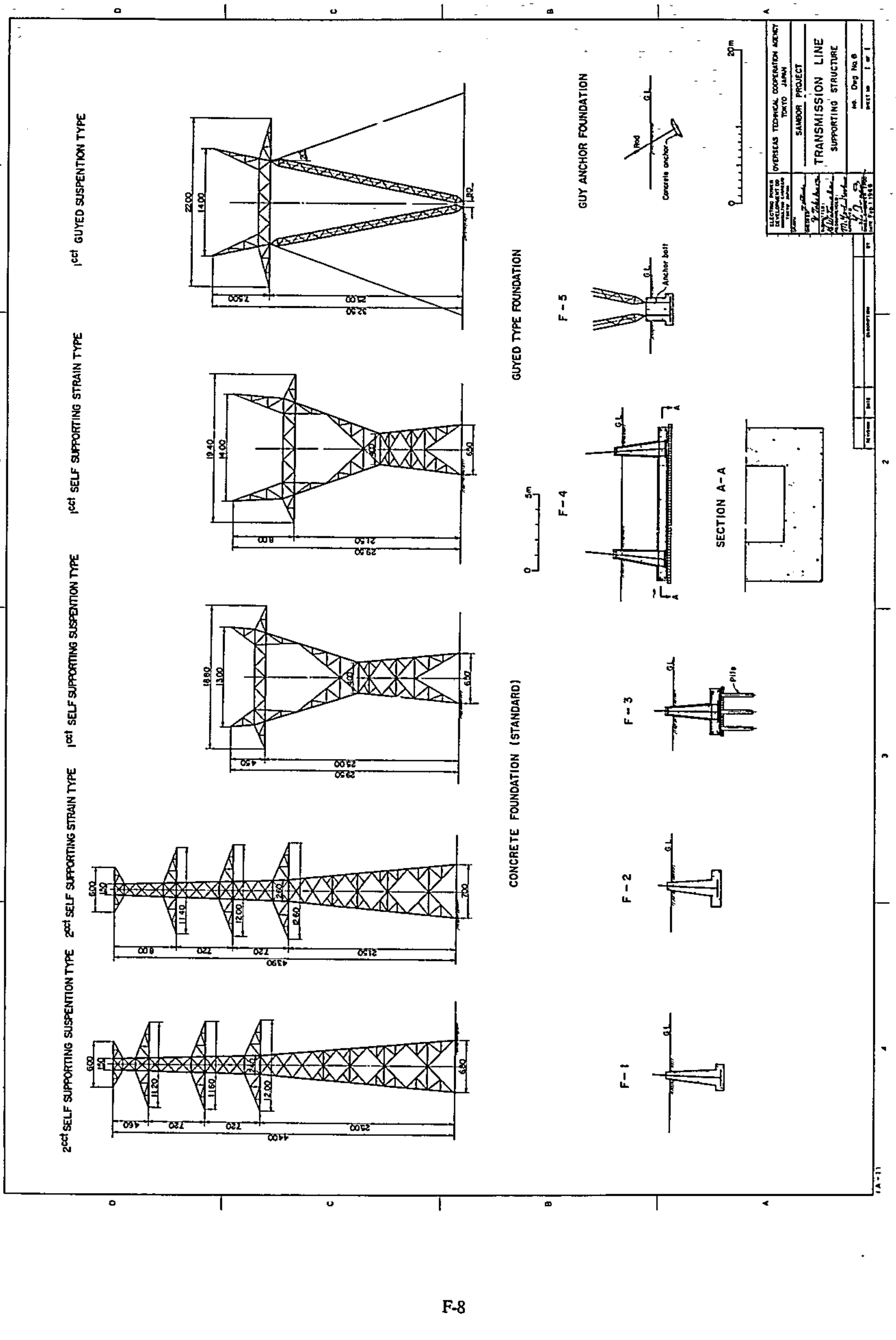

2cct SELF SUPPORTING SUSPENTION TYPE
2cct SELF SUPPORTING STRAIN TYPE
1cct SELF SUPPORTING SUSPENTION TYPE
1cct SELF SUPPORTING STRAIN TYPE
1cct GUYED SUSPENTION TYPE
CONCRETE FOUNDATION (STANDARD)
GUYED TYPE FOUNDATION
GUY ANCHOR FOUNDATION
F-1
F-2
F-3
F-4
F-5
SECTION A-A
G.L
Pile
Anchor bolt
Rod
Concrete anchor
5m
20m
OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO JAPAN
SAMBOR PROJECT
TRANSMISSION LINE
SUPPORTING STRUCTURE
Dwg No. 6

Fig. F-1 Curves for Efficiency, Installed Capacity and Plant Capacity

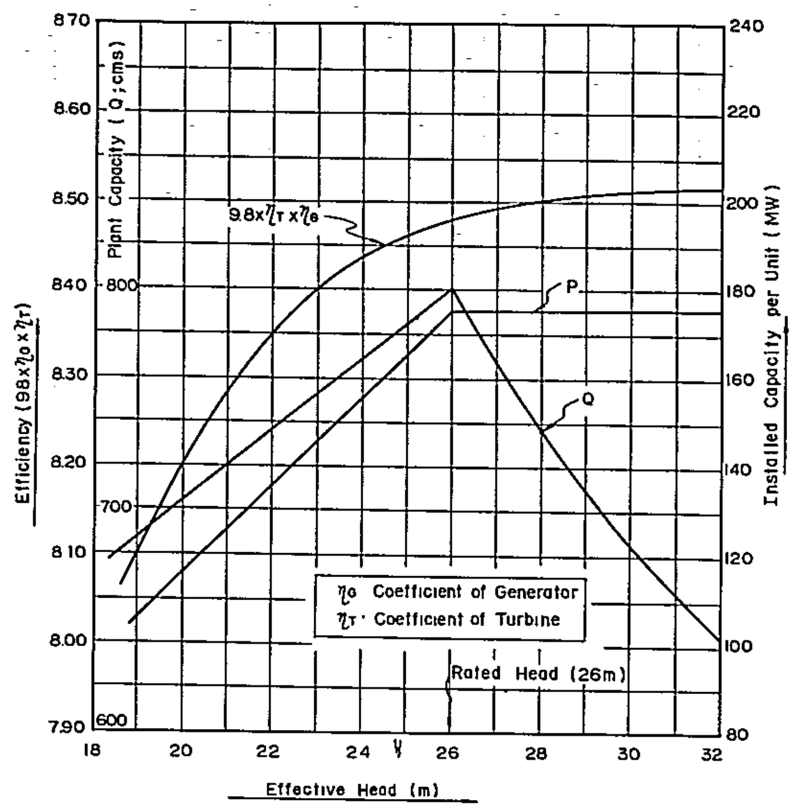


Table F-4 Description of Transmission Line

	Sambor–Phnom Penh	Phnom Penh– Sihanouk Ville	Sambor –Saigon
Length (km)	190	160	230
Voltage (kV)	345	345	345
No. of cct	1 cct x 3 (2)[1/] route	1 cct x 2 (–)[1/] route	2 (3)[1/] cct
Conductor	410 sq.mm ACSR x 2 (Al 26/4.5 mm, St 7/3.5 mm)	410 sq.mm ACSR x 2 (Al 26/4.5 mm, St 7/3.5 mm)	410 sq.mm ACSR x 2 (Al 26/4.5 mm, St 7/3.5 mm)
Ground Wire	90sq.mm GSC(7/3.5mm)	90sq.mm GSC(7/3.5mm)	90sq.mm GSC(7/3.5mm)
No. of Wire	2	2	2
Insulator:			
Kind	250 mm Suspension 35,000lb, Ball & Socket	250 mm Suspension 35,000lb, Ball & Socket	250 mm Suspension 35,000lb, Ball & Socket
Number	19	19	19
Support	Steel Tower	Steel Tower	Steel Tower
Min. Clearance (m)	8.5	8.5	8.5

Note: 1/ : Parenthesized figures show that of Type III'.

cct : circuit
ACSR : aluminum conductor steel reinforced
Al : aluminum
St : steel
GSC: galvanized steel cable

Supporting structures to be used will be the Guyed-Suspension Type Single Circuit Steel Tower, the number of which will be increased in proportion to the increase in load. Reasons for paralleling single circuit steel towers are that there is less occurence of corona than with the two or three circuits steel towers and that there is less possibility of failure with high stability, because each route of line is independent to each other.

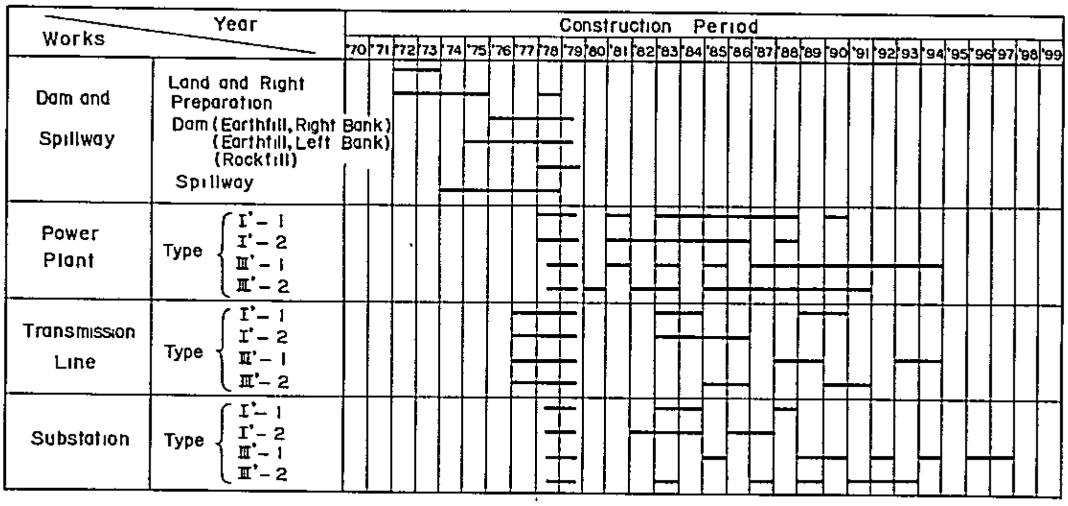
F-2 Construction Work

F-2-1 Construction Schedule

Construction work required does not differ significantly from that of the isolated case, but here it is reiterated or supplemented briefly.

As indicated by the construction schedule in Fig. F-2, the work requires 8 years from 1972 for the first stage and the work in the second stage will continue for approximately 10 to 15 years after the initial operation of the power plant, though it may differ depending on the type of power consumption.

Fig. F-2 Construction Schedule



F-2-2 Preparatory Work for Construction

Transportation: Bulk materials such as turbine generators and cement will be transferred from ocean-going vessels to barges at the Phnom Penh Port, and transported to the project site. For this purpose, a special unloading dock will be constructed on the right bank downstream from the dam site (see Dwg. No. 7).

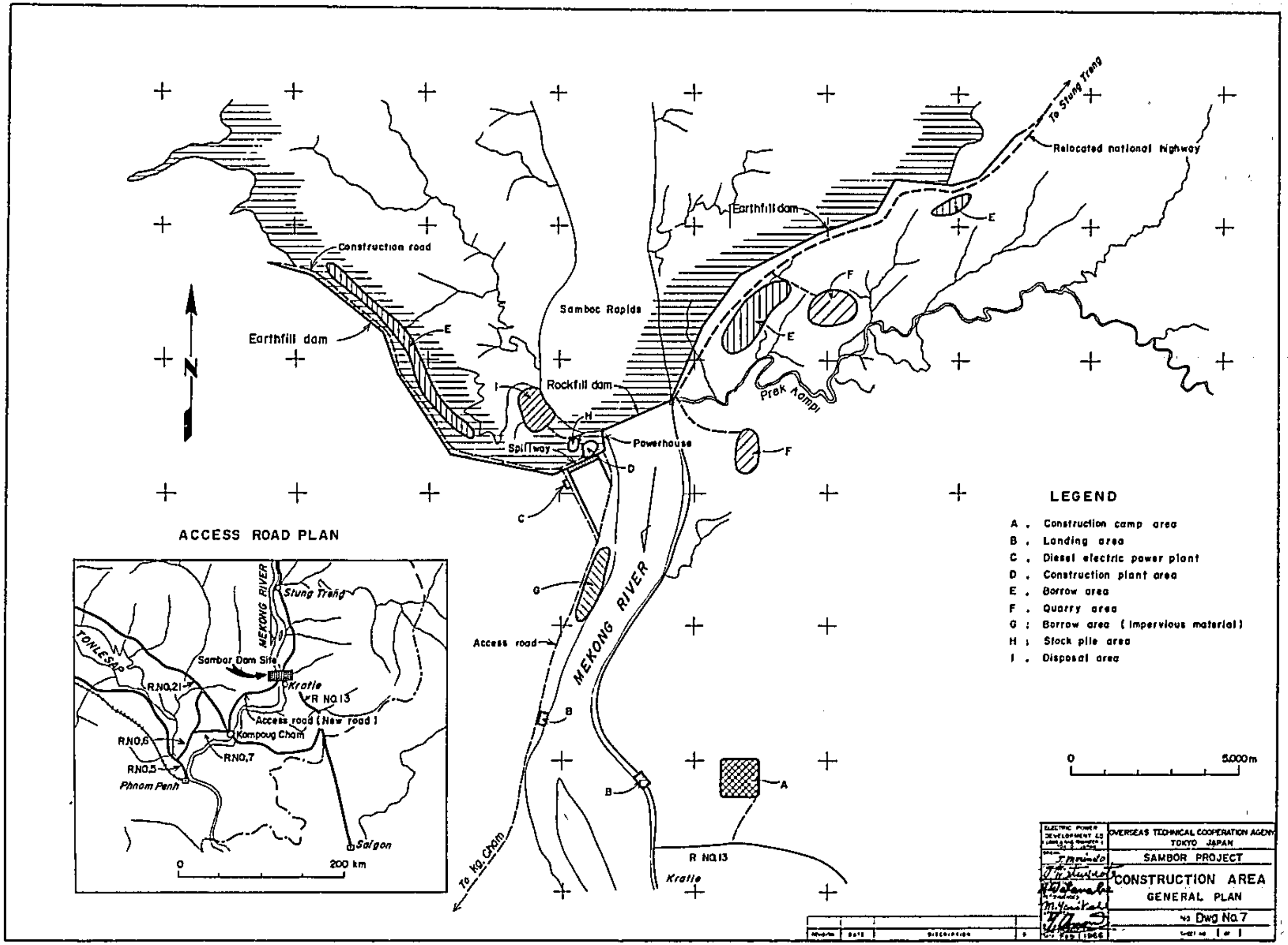
The other materials will be transported over land from Phnom Penh. The transportation route will be mainly National Roads No. 5 and No. 6 to Kompong Cham, and from there an access road will be built along the bank of the Mekong up to the dam site.

National Road No. 13 on the left bank of the Mekong will also be used, and the bridge between Kompong Cham and Kratie will have to be improved.

Construction Base: A construction base will be newly built in the neighborhood of Kratie. The total floor area of the buildings directly related to the work will be about 100,000 sq.m, and land covering an area of 700,000 sq.m – 1,000,000 sq.m will be required. Facilities such as roads, water and sewerage systems, power distribution lines, telecommunication systems, recreation centers, etc., will have to be provided in this area.

Power Source for Construction Work: As there is no available power source for construction work at present, internal combustion engines will be used to the fullest extent possible. However, power generating equipment of 5,500 kW – 6,000 kW capacity will be required in this case.

Replacement Road: As National Road No. 13 will be submerged in the reservoir to about 16 km north from the Prek Kampi Bridge, replacement of the road will be required. The new road will be located at an elevation of more than EL 42 m on the left bank of the reservoir, as shown in Dwg. No. 7.


To Stung Treng
Relocated national highway
Earthfill dam
Construction road
Earthfill dam
Samboc Rapids
Rockfill dam
Spillway
Powerhouse
Prek Aampi
MEKONG RIVER
Access road
To Kg. Cham
R NO.13
Kratie
LEGEND
A . Construction camp area
B . Landing area
C . Diesel electric power plant
D . Construction plant area
E . Borrow area
F . Quarry area
G : Borrow area (impervious material)
H : Stock pile area
I . Disposal area
0
5,000m
ACCESS ROAD PLAN
MEKONG RIVER
Stung Treng
TONLESAP
Sambor Dam Site
Kratie
R NO.13
R.NO.21
Access road (New road)
Kompoug Cham
R.NO.6
R.NO.7
R.NO.5
Phnom Penh
Saigon
0
200 km
OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO JAPAN
SAMBOR PROJECT
CONSTRUCTION AREA
GENERAL PLAN
Dwg No.7

F-2-3 Dam and Spillway

Earth-fill Dam on Both Sides: Embankment materials for the dam will be available in the vicinity of the dam (see Dwg. No. 7). Therefore, a large part of the embankment materials may be hauled by motor scrapers. For coarse materials such as filter and intercepter, excavated rocks at the power plant or the spillway may be used on the right bank. As these earth-fill dams may be constructed without being influenced considerably by the flow of the river, no specific problem is expected as far as construction work is concerned.

Rock-fill Dam in the River Bed: For this work, a plan to construct the dam without building a coffer dam has been adopted. For diversion purposes during construction work, power plant intake and power plant foundation (bays for eight units), in all of which units are scheduled to be additionally installed in the future, and spillway will be utilized. Therefore, in order to lead the flow to the intake prior to the start of rock-fill work, it will be necessary to excavate a diversion sluiceway having a width of 280 m with bottom elevation of 5 m corresponding to the completion of the power plant intake, foundations (EL less than 4 m) and spillway.

Dam embankment work will be begun by filling a portion of the center of the dam with gigantic rocks to a height EL 12 m which will allow the discharge of the river flow from the diversion channel during the dry season and then by building the embankment gradually from both banks when the flood begins to decrease (see Fig. F-3). When the water level of the river rises corresponding to the raising of embankment height, discharge will also be made from spillway. The water level versus discharge is shown in Fig. F-4. The final closure will be made in the dry season in 1979.

Materials for embankment work include fine sand for water intercepting wall material, which may be obtained at a point 4 km downstream of the dam; weathering rocks for filtering material, which may be obtained at a point 5 km from the left bank; sand layer found 2 km downstream and excavated rocks at the power plant for use as rock material. As rock material must be dumped into the water for embankment work, particular attention would be paid to the handling of it.

As for the dam in the river bed, there are several alternative plans on which a study has been made in addition to the original plan. (see Chapter H-1-1, Vol. III).

Though it might be necessary to give further study to this problem in the future, the original plan excells the other plans in respect to the economics and safety aspects. The adoption of this type of dam might be also justified from the experience of Dalles Dam in the USA. 1/

Spillway: The work on the spillway will have to be started a year earlier than the work on the power plant, This is due to the considerably lengthy time (about one month per gate) required for the installation of gates and also in order to avoid excessive concentration of work volume at the peak of construction.

Excavated rocks will be utilized for the embankment of the training levee of the spillway.

F-2-4 Power Plant

For the construction of the power plant a large volume of excavation work (6,900,000 cu.m) are required, and approximately three years will be needed before turbines can be installed.

Excavated rocks are to be used for concrete aggregate, rock-fill embankment material, and for embankment material for the spillway training levee. Therefore a spacious area will be needed for the storage of these materials. During excavation of the diversion sluiceway in the river side will have to be left unexcavated until the placement of concrete at the power plant is finished and the installation of the draft gate is completed in order to prevent the river discharge from flowing into the power plant. However, in view of the fact that the excavation at this place amounts to an enormous volume (sand and earth 600,000 cu.m and rock 1,000,000 cu.m) and that both the transportation of large construction equipment to this site and the large-scale blasting are expected to be very difficult, it will require three dry seasons to complete this excavation work. Giving due consideration to the volume and quality of concrete aggregate (including the spillway) required, it will be more economical to use crushed excavated rocks obtained at the power plant site than to use naturally deposited gravels. The layout of the aggregate plant is shown in Dwg. No. 7.

A further study on these problems should be made in preparation for a definite planning.

1/ *Transactions of the American Society of Civil Engineers,* Vol. 125, 1960 Part II, P. 473. "Rock-fill Dams. Dalles Closure Dam" by Robert J. Pope.

Fig. F-3 Study on Embankment of River Channel
(Proposed Plan)

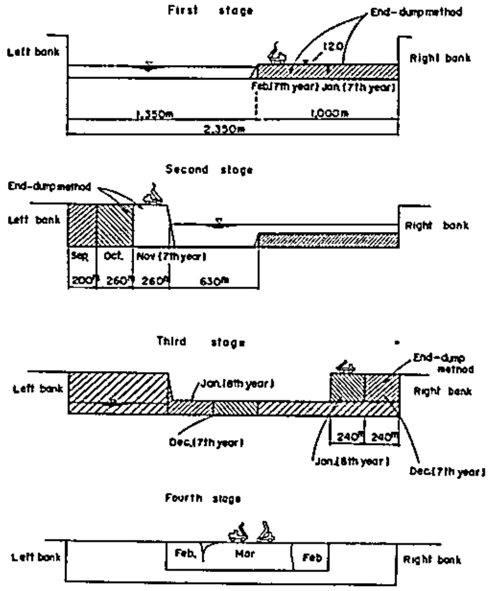
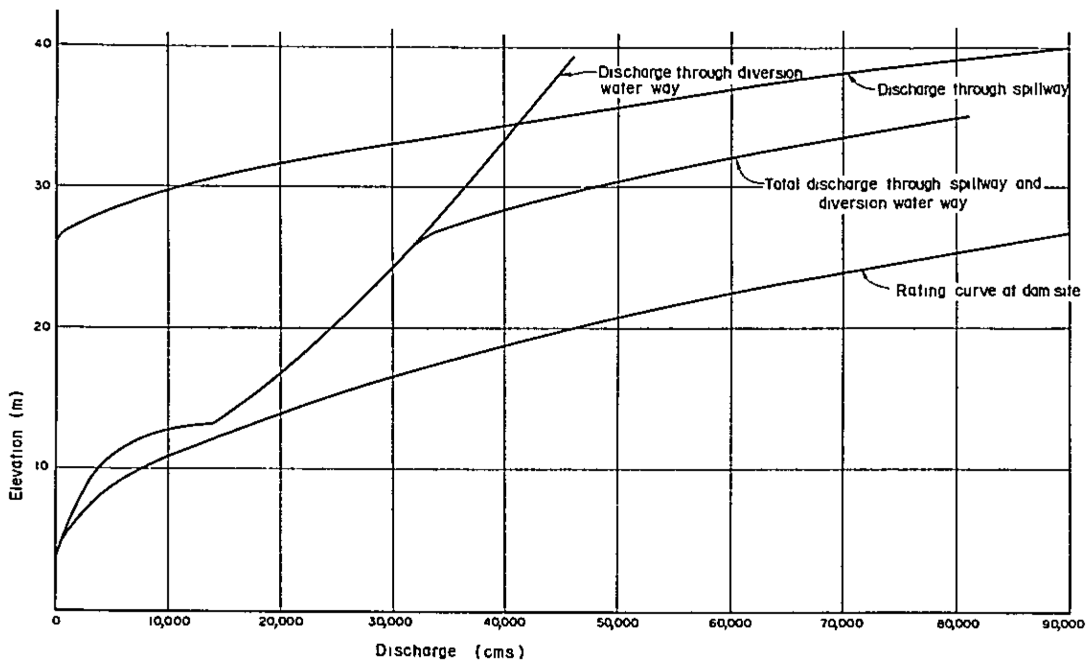


Fig. F-4 Rating Curve of Diversion



CHAPTER G. CONSTRUCTION COST

CHAPTER G. CONSTRUCTION COST

Total construction cost for the power development work including the dam is estimated as follows:

(1) Type I'

Total construction cost:	$437.6 million
Foreign currency	$342.7 million
Equivalent local currency:	$94.9 million

Details of construction cost are shown in Table G-1. The breakdown of required funds by year is shown in Table G-2; the funds required will be:

First stage construction work:	$293.1 million
Second stage construction work:	$144.5 million

Funds required for the construction of an industrial complex for power-oriented industries are estimated at $354 million (see Table G-3).

(2) Type III'

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

The details of the construction cost are shown in Table G-1.

The breakdown of required funds by construction stage is as follows:

First stage:	$240.4 million
Second stage:	$179.1 million

In addition to the above funds, $82.5 million will be required for construction of supplemental thermal power plant.

Besides, an additional $5 million will be required for a fish ladder, if it is to be provided (see Table G-4).

Calculation of these costs was based on the following criteria.

Calculation of construction cost was based on the commodity prices as of January 1967.

Land and right-of-way costs include the cost of acquisition of land and the cost of relocation of houses and public buildings in reservoir area based on information provided by air photographs and on the spot investigation. (Only the cost or relocation will be paid to those expected to be relocated to the reclaimed land on the downstream.)

The costs of civil and architectural works are based on the assumption that the works will be performed by contractors, all materials to be used in the project other than those available in Cambodia are assumed to be imported from Japan and required funds were set aside.

Each item under the construction cost includes indirect cost for construction or transport facilities and the base camp required for the accomplishment of the project as well as direct cost required for construction of structures and facilities.

Contingencies of approximately 15% for civil and architectural works and approximately 5% for equipment items are included.

Engineering fees of approximately 4.5% of the above construction costs is included for preparation of detail designs, specifications and for supervision of construction work.

However, the following are not included:

(1) Personnel expenses of the owner organization of the project.
(2) Personnel expenses disbursed or the Royal Government of Cambodia employees in connection with this project.
(3) Custom duties, business taxes, sales taxes, etc.
(4) Other costs connected with the project to be borned by the Royal Government of Cambodia or local autonomous bodies.
(5) Interest during construction (Included in the economic analysis and financial analysis.)

Domestic Curency and Foreign Currency: Wages of engineers labor cost of acquisition of land and the cost of compensation, local living expenses of construction supervisors and technical instructors, lumber, oil and lubricants and other materials procurable in Cambodia are listed under domestic currency in the breakdown of construction costs. All other items will be paid for in foreign currency.

Table G-1 (1) Summary of Estimated Construction Cost

(Unit: $ Million)

Structure and Pay Item	Project Cost for Type I' (Type III')		
	Total	Foreign Currency	Local Currency
(1) Reservoir and Dam	104.3 (104.3)	69.1 (69.1)	35.2 (35.2)
(2) Power Plant	249.8 (249.8)	198.8 (198.8)	51.0 (51.0)
(3) Transmission Line and Substation	83.5 (65.4)	74.8 (58.5)	8.7 (6.9)
(4) Total	437.6 (419.5)	342.7 (326.9)	94.9 (92.6)

Note: General Property and Engineering Fee were included in Items 1 to 3.

Table G-1 (2) Breakdown of Estimated Construction Cost

(Unit: $1,000)

Structure and Pay Item	Construction Cost Type I'	Construction Cost (Type III')
(1) Reservoir and Dam		
(1 - 1) Land and Right	3,240	(3,240)
(1 - 2) Relocation of Existing Property	2,140	(2,140)
(1 - 3) Earth-fill Dam on Left Side Bank	12,400	(12,400)
(1 - 4) Rock-fill Dam in River Bed	14,000	(14,000)
(1 - 5) Eath-fill Dam on Right Side Bank	10,900	(10,900)
(1 - 6) Spillway	53,000	(53,000)
(1 - 7) Spillway Channel	4,020	(4,020)
Subtotal	99,700	(99,700)
(2) Power Plant		
(2 - 1) Civil Works	115,300	(115,300)
(2 - 2) Electric Equipment	122,100	(122,100)
Subtotal	237,400	(237,400)
(3) Transmission Line and Substation		
(3 - 1) Sambor - Phnom Penh	21,500	(8,700)
(3 - 2) Phnom Penh - Sihanouk Ville	10,700	(-)
(3 - 3) Sambor - Saigon	21,200	(31,500)
(3 - 4) Substation	26,400	(22,200)
Subtotal	79,800	(62,400)
(4) General Property		
(4 - 1) Telecommunication Facilities	1,400	(1,400)
(4 - 2) Maintenance Facilities for Transmission Line	500	(500)
Subtotal	1,900	(1,900)
(5) Engineering Fee	18,800	(18,100)
Total	437,600	(419,500)

Table G-1 (3) Breakdown of Estimated Construction Cost

Structure and Pay Item	Unit	Quantity	Unit Cost ($)	Amount Type I' & III' ($1,000)
(1) Reservoir and Dams				
(1 - 1) Land and Right				
Acquisition House	house	2,500	280	700
Acquisition Arable Land	ha	3,000	170	510
Acquisition Forest and Others	L.S	1		1,600
Contingency	L.S	1		430
Subtotal				3,240
(1 - 2) Relocation of Existing Property				
Road in Upstream of Reservoir	m	18,000	64	1,152
Road in Downstream of Reservoir	m	14,000	50	700
Contingency	L.S	1		288
Subtotal				2,140
(1 - 3) Earth-fill Dam on Left Side Bank				
Earth-fill	cu.m	7,500,000	1	7,500
Filter under Riprap	cu.m	230,00	1.4	322
Sluice Zone	cu.m	390,000	1.4	546
Rock-fill in Toe Protection	cu.m	260,000	1.4	364
Riprap on Upstream Slope	cu.m	280,000	2.2	616
Riprap on Downstream Slope	cu.m	200,000	2.2	440
Surfacing on Crest	cu.m	160,000	3.8	608
Miscellaneous Works	L.S	1		404
Contingency				1,600
Subtotal				12,400
(1 - 4) Rock-fill Dam in River Bed				
Giantic Rock-fill	cu.m	160,000	2.7	432
Rock-fill	cu.m	3,000,000	1.5	4,500
Rock-fill, with Usable Materials Excavated for Power Plant	cu.m	1,840,000	0.8	1,472
Filter (Semi-pervious Zone)	cu.m	1,820,000	1.0	1,820
Impervious Zone	cu.m	1,560,000	1.4	2,184
Blanket	cu.m	310,000	1.4	434
Surfacing on Crest	cu.m	30,000	3.8	114
Miscellaneous Works	L.S	1		1,244
Contingency				1,800
Subtotal				14,000
(1 - 5) Earth Dam on Right Side Bank				
Earth-fill	cu.m	6,550,000	1.0	6,550
Filter under Riprap	cu.m	260,000	0.8	208
Sluice Zone	cu.m	400,000	0.8	320
Rock-fill in Toe	cu.m	320,000	0.8	256
Riprap on Upstream Slope	cu.m	310,000	2.2	682
Riprap on Downstream Slope	cu.m	180,000	2.2	396
Surfacing on Crest	cu.m	140,000	3.8	532
Miscellaneous Works	L.S	1		556
Contingency				1,400
Subtotal				10,900

(to be continued)

(continued)

Structure and Pay Item	Unit	Quantity	Unit Cost ($)	Amount Type I' & III' ($1,000)
(1 - 6) Spillway				
Excavation, Common	cu.m	500,000	0.6	300
Excavation, Common (Care of River)	cu.m	800,000	0.3	90
Excavation, Rock	cu.m	580,000	2.4	1,392
Concrete in Wings	cu.m	238,000	14	3,332
Concrete in Spillway Walls	cu.m	19,000	20	380
Concrete in Spillway Floor and Crest	cu.m	530,000	15	7,950
Concrete in Piers	cu.m	90,000	31	2,790
Concrete in Slab of Bridge	cu.m	3,000	42	126
Cement	ton	227,000	45	10,215
Reinforcement	ton	6,000	240	1,440
Grouting	m	8,000	39	312
Gate	ton	11,400	1,230	14,000
Bridge	ton	2,120	1,000	2,120
Miscellaneous Works	L.S	1		3,053
Contingency				5,500
Subtotal				53,000
(1 - 7) Spillway Channel				
Embankment	cu.m	3,170,000	0.2	634
Wet Masonry	sq.m	160,000	7.8	1,248
Concrete in Base	cu.m	20,000	24	480
Cement	ton	13,000	45	585
Miscellaneous Works	L.S	1		543
Contingency				530
Subtotal				4,020
Total - (1)				99,700
(2) Power Plant				
(2 - 1) Civil Work				
Excavation, Common (A)	cu.m	1,400,000	0.6	840
Excavation, Common (B)	cu.m	200,000	1.0	200
Excavation, Common (C)	cu.m	420,000	1.5	630
Excavation, Rock (A)	cu.m	3,900,000	1.7	6,630
Excavation, Rock (B)	cu.m	600,000	2.5	1,500
Excavation, Rock (C)	cu.m	380,000	3.6	1,368
Concrete in Intake	cu.m	530,000	18	9,540
Concrete in Draft	cu.m	260,000	21	5,460
Concrete in Casing Barrel	cu.m	405,500	28	11,354
Concrete in Outlet	cu.m	120,000	22	2,640
Concrete in Building	cu.m	48,000	36	1,728
Concrete in Retaining Wall	cu.m	20,000	19	380
Concrete in Wing Dam	cu.m	150,000	13	1,950
Cement	ton	436,500	45	19,643
Reinforcement	ton	41,000	240	9,840
Furnishing in Main Building	L.S	1		5,220
Access Road	L.S	1		145
Foundation Works for Outdoor Switchyard	L.S	1		108

(to be continued)

(continued)

Structure and Pay Item	Unit	Quantity	Unit Cost ($)	Amount Type I' & III' ($1,000)
Intake Gates	L.S	1		10,600
Outlet Gates	L.S	1		3,340
Miscellaneous Works	L.S	1		8,104
Contingency				15,080
Subtotal				115,300
(2 - 2) Electric Equipment				
Turbines	unit	12		43,500
Generators	unit	12		51,300
Transformers	unit	12		11,100
Switch Board, Cubicles, etc.	L.S	1		8,500
Accessories	L.S	1		1,900
Contingency				5,800
Subtotal				122,100
Total - (2)				237,400
(3) Transmission Line and Substation				
(3 - 1) Transmission Line (Sambor-Phnom Penh 190 km)				
Lands and Rights	L.S	1	200	(100)
Materials	L.S	1	11,200	(4,500)
Transportation	L.S	1	1,500	(600)
Installation	L.S	1	6,600	(2,700)
Contingency			2,000	(800)
Subtotal			21,500	(8,700)
(3 - 2) Transmission Line (Phnom Penh - S. Ville 160 km)				
Lands and Rights	L.S	1	100	(100)
Materials	L.S	1	5,600	(5,600)
Transportation	L.S	1	700	(700)
Installation	L.S	1	3,300	(3,300)
Contingency			1,000	(1,000)
Subtotal			10,700	(10,700)
(3 - 3) Transmission Line (Sambor-Saigon 230 km)				
Lands and Rights	L.S	1	600	(900)
Materials	L.S	1	10,400	(15,500)
Transportation	L.S	1	1,300	(1,900)
Installation	L.S	1	7,000	(10,400)
Contingency			1,900	(2,800)
Subtotal			21,200	(31,500)
(3 - 4) Substation				
Transformers	L.S	1	9,900	(9,300)
Circuit Breakers, Disconnecting Switches, etc.	L.S	1	9,700	(7,700)
Other Equipments	L.S	1	4,100	(2,900)
Transportation, Installation	L.S	1	1,400	(1,200)
Contingency			1,300	(1,100)
Subtotal			26,400	(22,200)
Total - (3)			79,800	(62,400)

(to be continued)

(continued)

Structure and Pay Item	Unit	Quantity	Amount Type I' & III' ($1,000)
(4) General Property			
(4 - 1) Telecommunication Facility			
Materials	L.S	1	850
Transportation	L.S	1	90
Installation	L.S	1	280
Contingency			180
Subtotal			1,400
(4 - 2) Maintenance Facility for Transmission Line			
Sambor - Phnom Penh	L.S	1	150
Phnom Penh - Sihanouk Ville	L.S	1	150
Sambor - Saigon	L.S	1	150
Contingency			50
Subtotal			500
Total - (4)			1,900

Table G-2 Annual Fund Requirement (Type I')

(Unit: Million Dollars)

	Currency	Grand Total	Cast for Detailed Design	First Stage 1972 1 st	'73 2 nd	'74 3 rd	'75 4 th	'76 5 th	'77 6 th	'78 7 th	'79 8 th	Subtotal
Reservoir and Dam	Foreign Currency	66.22		8.48	7.06	3.31	7.57	10.85	12.57	8.19	8.19	66.22
	Domestic Currency	33.48		3.40	3.01	2.30	4.92	6.34	6.29	3.63	3.59	33.48
	Subtotal	99.7		11.88	10.07	5.61	12.49	17.19	18.86	11.82	11.78	99.7
Power Plant	Foreign Currency	187.6		8.67	7.21	3.66	10.11	11.47	17.80	20.87	15.01	94.8
	Domestic Currency	49.8		3.22	2.67	1.35	3.74	4.25	6.60	7.74	5.43	35 0
	Subtotal	237.4		11.89	9.88	5.01	13.85	15.72	24.40	28.61	20.44	29.8
Transmission Line and Substation	Foreign Currency	71.4				3.12	1.54	5.55	6.54	14.20	11.25	43.2
	Domestic Currency	8.4				0.37	0.19	0.66	0.77	1.68	1.33	4 0
	Subtotal	79.8				3.49	1.73	6.21	7.31	15.88	12.58	47.2
General Property	Foreign Currency	1.4						0.12	0.18	0.80	0.30	1.40
	Domestic Currency	0.5						0.10	0.08	0.21	0.11	0.50
	Subtotal	1.9						0.22	0.26	1.01	0.41	1.90
Subtotal	Foreign Currency	326.62		17.15	14.27	10 09	19.22	27.99	37.09	44.06	35.75	205.62
	Domestic Currency	92.18		6.62	5.68	4.02	8.85	11.35	13.74	13.26	9.46	72.98
	Subtotal	418.8		23.77	19.95	14.11	28.07	39.34	50.83	57.32	45.21	278.6
Engineering Fee		18.8		0.72	0.61	0.41	0.84	1.16	1.51	1.67	1.32	8.24
Total		437.6	6.26	24.49	20.56	14.52	28.91	40.50	52.34	58.99	46.53	286 84

	Currency	Second Stage '80 9 th	'81 10th	'82 11tl	'83 12th	'84 13th	'85 14th	'86 15th	'87 16th	'88 17th	'89 18th	'90 19th	Subtotal
Reservoir and Dam	Foreign Currency												
	Domestic Currency												
	Subtotal												
Power Plant	Foreign Currency		9.3		19.2	19.2	9.3	8.6	8.6	9.3		9.3	92.8
	Domestic Currency		0.3		4.0	4.0	0.3	2.8	2.8	0.3		0.3	14.8
	Subtotal		9.6		23.2	23.2	9.6	11.4	11.4	9.6		9.6	107.6
Transmission Line and Substation	Foreign Currency				8.8	6.0				3.9		9.5	28.2
	Domestic Currency				1.1	1.7				0.5		1.1	4.4
	Subtotal				9.9	7.7				4.4		10.6	32.6
General Property	Foreign Currency												
	Domestic Currency												
	Subtotal												
Subtotal	Foreign Currency		9.3		28.0	25.2	9.3	8.6	8.6	13.2		18.8	121.0
	Domestic Currency		0.3		5.1	5.7	0.3	2.8	2.8	0.8		1.4	19.2
	Subtotal		9.6		33.1	30.9	9.6	11.4	11.4	14 0		20.2	140.2
Engineering Fee			0.3		1.1	0.9	0.3	0.4	0.3	0.4		0.6	4.3
Total			9.9		34.2	31.8	9.9	11.8	11.7	14.4		20.8	144.5

Table G-3 Summary of Construction Cost for Power-oriented Industries

Power-oriented Industries	Annual Production (Normal Year) (ton)	Basic Unit (kWh/ton)	Construction Cost (Type I') ($1,000)
Aluminum	250,000 (125,000)	16,100	250,000 (125,000)
Caustic Soda	230,000 (115,000)	3,700	104,000 (52,000)
Vinyl Chloride	240,000 (120,000)	1,000	
Calcium Carbide	380,000 (190,000)	3,150	
Ferro-silicon	33,000 (17,000)	10,000	
Silicon Carbide	33,000 (17,000)	10,000	
Total			354,000 (177,000)

Note: Figures in parentheses in column of annual production show annual production in years from 1980 to 1984 when the installed capacity remains 175 MW x 4 units, and figures in parentheses in column of construction cost show construction cost of power-oriented industries for that scale.

Table G-4 Construction Cost for Fish Ladder

	Unit	Amount	Unit Cost ($)	Construction Cost ($)
Excavation, Common	cu.m	860,000	0.6	516,000
Embankment of Rock-fill	cu.m	730,000	0.2	146,000
Concrete	cu.m	93,000	20	1,860,000
Cement	ton	25,000	45	1,125,000
Reinforcement	ton	400	240	96,000
Gate	ton	80	1,230	98,400
Bridge	ton	230	1,000	230,000
Miscellaneous Works	L.S	1		100,000
Contingency	L.S			628,600
Subtotal				4,800,000
Engineering Fee				200,000
Total				5,000,000

CHAPTER H. ECONOMIC ANALYSIS

CHAPTER H. ECONOMIC ANALYSIS

H-1 Method Adopted for Economic Analysis

The method adopted for the economic analysis was the internal rate of return method.

Essentially, the Sambor Power plant Project should be considered as an integral part of a great project which aims at the development of the economy and the community in the Mekong Basin Area. Evaluation of the project, therefore, must be made comprehensively by considering the position of the Sambor Development Project in the regional economic and social development project and in correlation with other future investments other than investment for Sambor development in such fields as education and public enterprises. Economic analysis by the internal rate of return method must be recognized as a reference for such a comprehensive evaluation.

H-2 Benefit

H-2-1 Approach

Benefit for electric power was based on the same conception as considered under the Sambor Isolated Project, as described in detail in Vol. III. The value of benefit for electric power, which is derived from the conception of attractive electricity rate from a consumer's point of view and the cost of substitute power changes, as a matter of course, according to the degree and the attitude toward the attractiveness or with the change in the cost of substitute power sources. In this project, therefore, the internal rate of return was estimated on the basis of unit cost of benefit which is considered to be the standard. However, in consideration of increased attractiveness for electric power from a comprehensive point of view or decrease in the cost of substitute power sources as the result of technical renovation of the future, a study was also made in the case in which unit cost of benefit is changed with corresponding internal rate of return.

H-2-2 Unit Cost of Benefit for General Demand

Standard value for the unit cost of benefit for general demand was estimated at 9 mills/kWh. This value, as described in detail in Vol. III, may be said to be a very attractive electricity rate when a comprehensive study is made on the present level of electricity rates in both Cambodia and Vietnam or the unit cost of benefit per kWh of substitute thermal power with the premise of maintaining stability in the supply of power. In addition, with the consideration of possible political measures which may promote the living standards of the people and which may accelerate the increase in demand for power energy, a study was made also in the case in which the unit cost of benefit is set at 7 mills/kWh.

H-2-3 Unit Cost of Benefit for Power-oriented Industries

Unit cost of benefit for power-oriented industries was set as follows:

Demand in aluminum refining industry	2.5 mills/kWh
Demand in other power-oriented industries	2.0 mills/kWh

This value, as described in detail in Vol. III, may be said to be a very attractive rate judging from the actual tendencies of electricity rates for the present power-oriented industries.

For further reference, estimate was made also on the change of internal rate of return for the case when the unit cost of benefit was changed by 1 mill/kWh. (See section H-4)

H-2-4 Unit Cost of Benefit for Demand in the Agricultural Sector for Power

Unit cost of benefit for demand in the agricultural sector for power is seasonal in nature and occurs in the dry season (November-March). The supply conditions are such that the load supply may be stopped during the peak hours of 18–22 for general demand. Therefore, it is of the same nature as that of the power-oriented industries with the exception of aluminum refining.

In view of this demand nature and also with the aim of accelerating increase in agricultural production, the unit cost of benefit was estimated at 2 mills/kWh the same for the demand in power-oriented industries with the exception of aluminum refining.

H-2-5 Annual Benefit

(1) Type I'

Table H-1 (1) shows annual supply of power energy to the demand of various types for Type I' and the benefit which is the multiplication of the foregoing figures by the following standard unit cost of benefit.

General demand:	9 mills/kWh
Aluminum refining:	2.5 mills/kWh
Others:	2.0 mills/kWh

Benefit for Type I' in 1980 is estimated to be $11,042,000 but it will increase every year thereafter with the increase of demand and will reach $57,365,000 in 1992. Thereafter it will increase little by little every year with the increase of demand in the agricultural sector for power. Benefit for Type I'-2, because of greater demand compared with that for Type I'-1 is estimated to be $11,930,000 in 1980 and is expected to reach $57,329,000 in 1990.

(2) Type III'

Table H-1 (2) shows the annual increase in the supply of power energy and that of benefit for Type III' (where only general demand is considered). Benefit in 1980 is estimated to be $1,746,000 for Type III'-1 and $2,664,000 for Type III'-2. In both cases the benefit is smaller than that for the Type I'. However, it is expected that the benefits for Type III'-1 and that for Type III'-2 are expected to exceed the benefit for Type I' in 1995 and 1992 respectively.

H-3 Cost

Annual costs are estimated as follows:

Salaries and Wages:	120 employees (For 2,100 MW upon completion)
Maintenance and repair of civil structures and transmission lines:	0.75% of the total construction cost of these facilities.
Maintenance and repair of equipment:	0.6% of the total cost of the equipment.
Other expenses:	10% of the total expenses above.

The results of calculations are shown in Tables H-2.

Expenses for auxiliary thermal power plants for Type III' are estimated to be fixed cost $825,000 (1% of the construction cost) and variable cost 5.36 mills/kWh. Extremely high unit price per kWh shown is due to extremely low working ratio of facilities.

Service life of facilities was determined as follows for the determination of replacement cost.

Dam and other civil structures:	50 years	50 years
Equipment including trurbines, generators and transformers:		35 years
Transmission lines:		50 years

Residual value of these facilities was considered to be nil and appropriation was made for these (equipment, etc.) which require replacement during the economic life of 50 years. (See Table H-2)

H-4 Internal Rate of Return

Internal rate of return for each power consumption type was obtained by using construction cost, annual benefit and cost (annual cost and replacement cost), which were obtained in sections I-2 and I-3 in the formula below.

Formula:

$$K = \sum_{t=1}^{n} \frac{Rt}{(1+i)^t}$$

Where:

K: Construction cost and replacement cost calculated by initial investment (Chapter G) with the addition of interest during construction (construction cost x 0.4 x construction period x i), further converted to the price as of 1980.

Rt: Cash flow in the corresponding year of t, "Annual benefit minus annual cost."

n: Period of analysis

i: Internal rate of return

Variation of internal rate of return when unit cost of benefit is changed by 1 mill/kWh in the neighborhood of internal rate of return and of standard unit cost of benefit under Type I', which were obtained as the result of the above formula, will be as follows:

Case		Type I'-1	Type I'-2
For Standard Unit Cost of Benefit:			
for General Demand:	9.0 mills/kWh	7.2%	7.6%
for Aluminum Refining:	2.5 mills/kWh		
for Other Industries:	2.0 mills/kWh		
Variation of Unit Cost of Benefit:			
for General Demand:	9.0 – 1.0 mills/kWh	– 0.5	– 0.6
for Aluminum Refining:	2.5 – 1.0 mill/kWh	– 0.6	– 0.6
for Other Industries:	2.0 – 1.0 mill/kWh	– 0.1	– 0.1

The fact that Type I'-2 has a greater effect of the variation of 1 mill/kWh in the unit cost of benefit for general demand than that of under Type I'-1 is that the ratio of general demand in the benefit is higher under Type I'-2. The effect of variation of unit cost of benefit for aluminum refining and for the demand in the agricultural sector is slightly greater under Type I'-1 but the difference (between the two) is negligible.

As a result of the above fact, even with the unit cost of benefit for general demand set at 7 mills/kWh, the internal rate of return will exceed the 6% level under both Type I'-1 and Type I'-2. Effect of the variation in per 1 mill/kWh in the internal rate of return and the unit cost of benefit on the internal rate of return under Type III' will be as follows:

Case	Type III'-1	Type III'-2
When unit cost of benefit is 9 mills/kWh	7.8%	8.6%
Change in per 1 mill/kWh in the unit cost of benefit	0.7%	0.8%

The fact that this type has a greater effect of the variation in per 1 mill/kWh in the unit cost of benefit on the internal rate of return compared with Type I' is because of the higher ratio of general demand under this type. The reason for a slightly greater effect under Type III'-2 compared with Type III'-1 is that the demand to be satisfied is greater under Type III'-2 with a greater total power energy to be supplied in the calculated 50-year period.

H-5 Comprehensive Evaluation

Internal rate of return with standard unit cost of benefit will be as follows:

Type I'	7.2%
Type I'-2	7.6%
Type III'-1	7.8%
Type III'-2	8.6%

Even with the unit cost of benefit for general demand set at 7 mills/kWh as a result of decreases in the unit cost of substitute power source following technical innovation or due considerations, the internal rate of return will exceed the 6% level in each case. These rates are considered to be within reasonable range from the standpoint of international levels of money interest rates also.

In addition, the benefit obtained thus far is of primary benefit only with power energy. It should be noted that no consideration whatsoever has been given to the secondary benefit which a large scale project such as the Sambor Project will bring to the economy and the communities of developing countries.

Though the internal rate of return is slightly lower under Type I' compared with Type III', the Type I' power consumption plan is considered more advisable (than Type III') in view of the fact that under this type it is expected that demand for power is also brought about in parallel with the construction of the Sambor Power Plant, thus providing a greater benefit from the early stage and that well balanced greater secondary benefit is brought to the economy and communities of the countries.

Table H-1 (1) Annual Benefit (Type I')

Year	Type I'-1 (For 60% of General Demand in Sambor Interconnected System)								Type I'-2 (For 90% of General Demand in Sambor Interconnected System)							
	Salable Energy (million kWh)				Gross Income ($1,000)				Salable Energy (million kWh)				Gross Income ($1,000)			
		Power-oriented Industries			General	Power-oriented Industries				Power-oriented Industries			General	Power-oriented Industries		
	General Demand	Aluminum	Others	Total	Demand (9 mills/kWh)	Aluminum (2.5 mills/kWh)	Others (2 mills/kWh)	Total	General Demand	Aluminum	Others	Total	Demand (9mills/kWh)	Aluminum (2.5 mills/kWh)	Others (2 mills/kWh)	Total
1980	194	2,016	2,128	4,338	1,746	5,040	4,256	11,042	296	2,016	2,113	4,425	2,664	5,040	4,226	11,930
'81	419	2,016	2,142	4,577	3,771	5,040	4,284	13,095	623	2,016	1,990	4,629	5,607	5,040	3,980	14,627
'82	684	2,016	3,226	4,926	6,156	5,040	4,452	15,648	1,025	2,016	2,157	5,198	9,225	5,040	4,314	18,579
'83	959	2,016	2,228	5,203	8,631	5,040	4,456	18,127	1,439	2,016	2,128	5,583	12,951	5,040	4,256	22,247
'84	1,245	2,016	2,211	5,472	11,205	5,040	4,422	20,667	1,868	2,016	2,232	6,116	16,812	5,040	4,464	26,316
'85	1,556	4,032	3,873	9,461	14,004	10,080	7,746	31,830	2,332	4,032	3,743	10,107	20,988	10,080	7,486	38,554
'86	1,918	4,032	3,897	9,847	17 262	10,080	7,794	35,136	2,877	4,032	3,714	10,623	25,893	10,080	7,428	43,401
'87	2,301	4,032	3,848	10,181	20,709	10,080	7,696	38,485	3,454	4,032	3,574	11,060	31,086	10,080	7,148	48,314
'88	2,729	4,032	3,796	10,557	24,561	10,080	7,592	42,233	4,091	4,032	3,199	11,322	36,819	10,080	6,398	53,297
'89	3,179	4,032	3,751	10,962	28,611	10,080	7,502	46,193	4,541	4,032	2,653	11,226	40,869	10,080	5,306	56,255
'90	3,637	4,032	3,508	11,177	32,733	10,080	7,016	49,829	4,541	4,032	3,190	11,763	40,869	10,080	6,380	57,329
'91	4,204	4,032	3,407	11,643	37,836	10,080	6,814	54,730	4,541	4,032	3,201	11,774	40,869	10,080	6,402	57,351
'92	4,541	4,032	3,208	11,781	40,869	10,080	6,416	57,365	4,541	4,032	3,208	11,781	40,869	10,080	6,416	57,365
'93	4,541	4,032	3,219	11,792	40,869	10,080	6,438	57,387	4,541	4,032	3,219	11,792	40,869	10,080	6,438	57,387
'94	4,541	4,032	3,225	11,798	40,869	10,080	6,450	57,399	4,541	4,032	3,225	11,798	40,869	10,080	6,450	57,399
'95	4,541	4,032	3,233	11,806	40,869	10,080	6,466	57,415	4,541	4,032	3,233	11,806	40,869	10,080	6,466	57,415
'96	4,541	4,032	3,240	11,813	40,869	10,080	6,480	57,429	4,541	4,032	3,240	11,813	40,869	10,080	6,480	57,429
'97	4,541	4,032	3,484	12,057	40,869	10,080	6,968	57,917	4,541	4,032	3,484	12,057	40,869	10,080	6,968	57,917

Table H-1 (2) Annual Benefit (Type III')

Year	Type III'-1 (For 60% of General Demand in Sambor Interconnected System)		Type III'-2 (For 90% of General Demand in Sambor Interconnected System)	
	Salable Energy (million kWh)	Gross Income ($1,000) (9 mills/kWh)	Salable Energy (million kWh)	Gross Income ($1,000) (9 mills/kWh)
1980	194	1,746	296	2,664
'81	419	3,771	623	5,607
'82	684	6,156	1,025	9,225
'83	959	8,631	1,435	12,951
'84	1,245	11,205	1,868	16,812
'85	1,556	14,004	2,332	20,988
'86	1,918	17,262	2,877	25,893
'87	2,301	20,709	3,454	31,086
'88	2,729	24,561	4,091	36,819
'89	3,179	28,611	4,765	42,885
'90	3,637	32,733	5,459	49,131
'91	4,204	37,836	6,311	56,799
'92	4,862	43,758	7,296	65,664
'93	5,597	50,373	8,393	75,537
'94	6,245	56,205	9,367	84,403
'95	6,954	62,586	10,428	93,852
'96	7,719	69,471	10,713	96,417
'97	8,551	76,959		
'98	9,454	85,086		
'99	10,433	93,897		
2000	10,713	96,417		

Table H-2 Replacement Cost

(Unit: $1,000)

Year	Type I'		Type III'	
	I'-1	I'-2	III'-1	III'-2
2015	61,200 (T.G) 4 (S.S)	61,200 (T.G) 4 (S.S)	25,000 (T.G) 1 (S.S)	25,000 (T.G) 1 (S.S)
'16				10,000 (T.G) 1
'17	10,000 (T.G) 1	10,000 (T.G) 1	10,000 (T.G) 1	
'18		2,400 (S.S)		10,000 (T.G) 1
'19	2,400 (S.S)	12,150 (T.G) 1 (S.S)	10,000 (T.G) 1	12,400 (T.G) 1 (S.S)
2020	36,800 (T.G) 3 (S.S)	34,600 (T.G) 3 (S.S)		
'21	10,000 (T.G) 1	10,000 (T.G) 1	12,400 (T.G) 1 (S.S)	10,000 (T.G) 1
'22		12,150 (S.S)		10,000 (T.G) 1
'23	10,000 (T.G) 1	2,400 (S.S)	10,000 (T.G) 1	14,300 (T.G) 1 (S.S)
'24	14,500 (T.G) 1 (S.S)	10,000 (T.G) 1	10,000 (T.G) 1	20,000 (T.G) 2
2025			12,400 (T.G) 1 (S.S)	12,400 (T.G) 1 (S.S)
'26	10,000 (T.G) 1		11,900 (T.G) 1 (S.S)	10,000 (T.G) 1
'27			10,000 (T.G) 1	12,400 (T.G) 1 (S.S)
'28			12,400 (T.G) 1 (S.S)	1,900 (S.S)
'29			10,000 (T.G) 1	2,400 (S.S)
2030			12,400 (T.G) 1 (S.S)	
'31				
'32			1,900 (S.S)	
'33			2,400 (S.S)	
'34				
2035				
Total	154,900	154,900	150,800	150,800

Note: (1) As the above figures do not include interest during construction, a profitability study should include interest which is calculated with the formula (construction cost x 0.4 x construction period x i).

(2) (T.G)4 = Four Units of Turbine and Generator

(3) (S.S) = Substation

CHAPTER I. FINANCIAL PROGRAM

CHAPTER I. FINANCIAL PROGRAM 1/

I-1 Financing of Funds

The total funds required for power portion (including navigation) amount to $442.63 million comprising of $296.85 million for the first phase and $145.78 million for the second phase. Of this amount, $345.56 million is required in foreign currency and $97.07 in local currency. In preparing the financial program the required foreign currency was considered to be financed by various international financial organizations and other financial institutions of the cooperating countreis, and the local currency was assumed to be made available from the national treasury of the Royal Government of Cambodia and the loan from Fonds National de l' Equipement.

I-2 Interest and Term of Repayment

First, with the conditions for foreign currency, the World Bank, for example, is currently charging on interest rate of 6.5% and a commitment charge of 0.375% with the term of rapayment set at 15 to 25 years and the International Development Association is charging no interest other than 0.75% loan handling charge with the term of repayment set at 50 years including a 10-year grace period. Recent practice with the financial institutions in various countries show, for example, an interest rate of 6% set by AID of the United States and in some cases the loans bearing an annual interest rate of around 4.5% to 5.75% depending on the country. The term of repayment for these loans is around 20 years for civil work and 18 years for equipment, at the longest.

Next for the local currency, two cases were considered. One is that the total required fund is to be made available from the national treasury of the Royal Government of Cambodia (Case I) and the other is that a half of the total amount is to be financed by the government and the remainder is to be financed by Fonds National de l' Equipement. In this case, the annual interest rate set by Fonds National de l' Equipement is 3.5%. Though the term of repayment varies with each case, it was presumed for the time being that the payment was to be made in 50 years, a full serviceable life.

Assuming that the type of funds to be appropriated for each work of the Sambor Project will be as follows, the weighted average interest rate will be 4% with the term of repayment set at 24 years after initial operation for the first stage and 6.4% for the second stage, in Case I.

In the Case II, the weighted average interest rate will be 4% with the term of repayment set at 29 years after initial operation for the first stage and 6.2% with the term of repayment set at 18 years for the second stage. In either cases, however, a grace period of about four years will be required after initial operation for the first stage in corresponding to the operating revenue at the initial stage of the operation.

Description of Work	Source of Fund
Foreign currency:	
Dam, reservoir:	International Development Association
Civil works for power stations:	Financial institutions in various countries
Power station equipment:	Financial institutions in various countries
Transmission lines, substations, communication system and navigation facilities:	World Bank, AID, maker's credit in various countries
Local currency:	
A half of the required fund for the project	Fonds National de l' Equipement

1/ Study is being made with the expectation that Type I'-1 consumption plan will be adopted

I-3 Debt Financing

Operating revenue consist of the revenue from the sale of electricity and the inclined passage tolls. The inclined passage tolls have already been discussed in Vol. I Chapter G-3-1. In preparing the financial program, the revenue from the sale of electricity was calculated with the unit rate of 2.5 mills/kWh for aluminum refining and 2 mills/kWh for other power-oriented industries, but a rate of 7 mills/kWh was applied to general demand.

Operation and maintenance costs are described in paragraph H-3 of this report. As for depreciation cost, the straight line method with a 10% residual value was adopted. The serviceable life of turbine, generator and substation facilities was determined to be 35 years and that of other facilities 50 years.

I-4 Findings

Based on the above premise, the results are summarized in the following:

Amortization schedule is shown by Table I-1 (1, 2);
Statement of income is shown in Table I-2 (1, 2);
Statement of cash flow is shown in Table I-3 (1, 2)

According to these tables, the cash balance take a favorable turn from the sixth year after initial operation in Case I and from the seventh year after initial operation in Case II, and the repayment of borrowings will be made smoothly thereafter. There will also be flexible reserve accumulated exceeding the amount of the fund financed by the government in 17 years after initial operation in Case I and in 15 years in Case II. It is concluded, therefore, that the feasibility of the Sambor Project is fully justified also from the financial point of view.

Table I-1 (1) Amortization Schedule (Case I)

(Unit:$1 million)

	Year	Procurement of funds for the project: Borrowings: Foreign Currency	Local Currency	Subtotal	Interest during construction	Subtotal	Government Investment	Total	Repayment of borrowings: First Stage: Principal	Interest	Total	Balance	Second Stage: Principal	Interest	Total	Balance	Total: Principal	Interest	Total
-9	1971	5.21			0 08	5.29	1.05	6.34											
-8	2	17 77			0 49	18 26	6.72	24 98											
-7	3	14,80			1.16	15.96	5.76	21.72											
-6	4	10 45			1 68	12.13	4.07	16.20											
-5	5	19.95			2.25	22.20	8 96	31.16											
-4	6	29 00			3 19	32.19	11.50	43.69											
-3	7	38.44			4.51	42.95	13.93	56.88											
-2	8	46.50			6.16	52.66	14.16	66 82											
-1	9	38.08			7.89	45 97	10.50	56 47				247 61							
1	1980								–	9.90	9.90	247 61				–	–	9.90	9.90
2	1	9.55			0.24	9 79	0 35	10 14	–	9.90	9.90	247.61				9.79	–	9.90	9.90
3	2								–	9 90	9.90	247.61	0.31	0 62	0 93	9 48	0 31	10.52	10.83
4	3	28,93			0.72	29.65	5.27	34 92	–	9.90	9 90	247 61	0 33	0 60	0 93	9.15	0.33	10.50	10.83
5	4	25.96			2 44	28 40	5 84	34 24	8 32	9.90	18.22	239.27	0.35	0.58	0 93	66 85	8 67	10 48	19.15
6	5	9.55			0.24	9.79	0.35	10.14	8 65	9.57	18 22	230 64	2.18	4.27	6.45	74.46	10.83	13 84	24 67
7	6	8.94			0.22	9.16	2 86	12.02	8.99	9.23	18 22	221.65	2.62	4.76	7.38	71.84	11 61	13.99	25 60
8	7	8 85			0.78	9 63	2 85	12.48	9.35	8 87	18 22	212 30	2.79	4.59	7.38	87.84	12.14	13.46	25.60
9	8	13.91			0 34	14.25	1.13	15.38	9.73	8 49	18.22	202.57	3.54	5 62	9 16	98 55	13.27	14.11	27.38
10	9								10.12	8 10	18 22	192.45	4.21	6.30	10.51	94.34	14.33	14.40	28.73
11	1990	19.30			0 48	19.78	1.50	21.28	10.52	7.70	18.22	181.93	4 48	6 03	10 51	109 64	15 00	13.73	28.73
12	1								10.94	7.28	18 22	170 99	5 38	7.01	12.39	104 26	16 32	14.29	30.61
13	2								11.38	6.84	18.22	159 61	5.72	6 67	12 39	98 54	17 10	13.51	30.61
14	3							(0 65)	11 84	6 38	18.22	147.77	6 09	6.30	12.39	92 45	17.93	12 68	30 61
15	4								12.31	5.91	18 22	135.46	6.48	5.91	12.39	85.97	18.79	11.82	30 61
16	5								12.80	5.42	18.22	122 66	6.91	5 48	12 39	79 06	19 71	10.90	30.61
17	6								13.31	4.91	18 22	109 35	7.36	5.0:	12.39	71.70	20 67	9.94	30 61
18	7								13.85	4.37	18.22	95.50	7.84	4.55	12.39	63.86	21 69	8.92	30 61
19	8								14 40	3 82	18 22	81.10	8.36	4 03	12 39	55.50	22.76	7.85	30 61
20	9								14.98	3.24	18 22	66 12	8 89	3 50	12 39	46.61	23 87	6 74	30 61
21	2000								15.57	2.65	18 22	50.55	8.54	2.92	11.46	38 07	24.11	5.57	29 68
22	1								16.20	2 02	18 22	34 35	9 06	2 40	11.46	29 01	25 26	4.42	29.68
23	2								16 84	1.38	18 22	17.51	9 64	1 82	11 46	19.37	26.48	3 20	29.68
24	3								17.51	0 71	18 22	0	4.72	1 22	5.94	14 65	22.23	1.93	24.16
25	4												4 08	0 93	5.01	10.57	4.08	0 93	5.01
26	5												4.34	0.67	5 01	6.23	4.34	0 67	5 01
27	6												2 84	0.39	3.23	3.39	2.84	0.39	3.23
28	7												1 67	0 21	1 88	1 72	1 67	0.21	1.88
29	8												1.72	0 16	1.88	0	1.72	0.16	1.88
Total		345.19			32 87	378 06	96 80	(475.51) 474 86	247.61	156 39			130 45	92.57			378.06	248.96	

Table I-1 (2) Amortization Schedule (Case II)

(Units: $1 million)

	Year	Procurement of funds for the project: Borrowings: Foreign Currency	Local Currency	Subtotal	Interest during construction	Subtotal	Government investment	Total	Repayment of borrowings: First Stage: Principal	Interest	Total	Balance	Second Stage: Principal	Interest	Total	Balance	Total: Principal	Interest	Total
-9	1971	5.21	0.53	5.74	0 09	5 83	0.52	6.35											
-8	2	17.77	3 36	21.13	0.57	21.70	3.36	25 06											
-7	3	14 80	2.88	17 68	1.35	19 03	2 88	21.91											
-6	4	10 45	2 03	12 48	1.98	14.46	2 04	16.50											
-5	5	19.95	4.48	24 43	2 67	27.10	4.48	31.58											
-4	6	29,00	5.75	34.75	3 82	38.57	5.75	44.32											
-3	7	38.44	6.96	45.40	5.34	50.74	6.97	57.71											
-2	8	46.50	7 08	53.58	7.28	60 86	7.08	67.94											
-1	9	38 08	5.25	43.33	9 26	52.59	5.25	57 84				290.88							
1	1980								–	11.64	11 64	290.88				–	–	11.64	11 64
2	1	9.55	0.17	9.72	0 24	9.96	0.18	10 14	–	11.64	11 64	290.88				9.96	–	11.64	11.64
3	2								–	11.64	11 64	290.88	0.32	0.61	0.93	9 64	0.32	12.25	12.57
4	3	28.93	2 63	31.56	0.78	32.34	2 64	34 98	–	11.64	11 64	290.88	0.34	0.59	0.93	9.30	0.34	12.23	12.57
5	4	25 96	2.92	28 88	2.66	31.56	2 92	34.48	6 98	11.64	18.62	283.90	0.36	0 57	0.93	72.84	7.34	12.21	19.55
6	5	9.55	0.18	9.73	0 24	9.97	0.17	10.14	7.27	11.35	18 62	276.63	2 41	4.51	6.92	80 40	9 68	15.86	25.54
7	6	8 94	1.43	10 37	0.26	10 63	1.43	12.06	7.56	11 06	18 62	269 07	2.87	4.98	7.85	77.53	10.43	16.04	26 47
8	7	8.85	1.42	10.27	0 89	11.16	1.43	12.59	7 86	10.76	18.62	261.21	3.05	4 80	7.85	96.27	10.91	15 56	26 47
9	8	13.91	0.57	14 48	0.36	14.84	0.56	15.40	8.18	10 44	18.62	253 03	3 93	5.96	9.89	107.18	12.11	16.40	28.51
10	9								8.50	10.12	18.62	244.53	4.64	6.64	11 28	102.54	13.14	16 76	29.90
11	1990	19.30	0.75	20 05	0.50	20.55	0.75	21.30	8.84	9 78	18.62	235 69	4 93	6.35	11.28	118 16	13 77	16.13	29.90
12	1								9.20	9.42	18 62	226.49	5.89	7.32	13 21	112 27	15 09	16.74	31 83
13	2								9.57	9.05	18 62	216 92	6.25	6 96	13 21	106.02	15.82	16 01	31 83
14	3							(0 65)	9.95	8.67	18 62	206.97	6 64	6 57	13 21	99.38	16.59	15 24	31 83
15	4								10 35	8.27	18.62	196 62	7.05	6.16	13.21	92.33	17 40	14.43	31.83
16	5								10.76	7.86	18 62	185.86	7 49	5 72	13.21	84 84	18 25	13.58	31.83
17	6								11.19	7.43	18 62	174 67	7.95	5.26	13 21	76.89	19.14	12.69	31 83
18	7								11 64	6.98	18 62	163.03	8 45	4.76	13.21	68 44	20.09	11.74	31.83
19	8								12.10	6.52	18 62	150.93	8.97	4 24	13.21	59.47	21.07	10.76	31.83
20	9								12.59	6 03	18.62	138.34	9.52	3 69	13.21	49.95	22.11	9.72	31.83
21	2000								13 09	5.53	18 62	125.25	9.19	3.09	12.28	40 76	22.28	8 62	30 90
22	1								13 61	5.01	18 62	111.64	9.76	2.52	12.28	31 00	23 37	7.53	30.90
23	2								14.16	4 46	18 62	97.48	10.36	1 92	12.28	20 64	24.52	6.38	30 90
24	3								14.73	3.89	18 62	82.75	5 02	1.27	6 29	15.62	19.75	5 16	24 91
25	4								15.31	3.31	18.62	67 44	4.40	0.96	5.36	11 22	19.71	4.27	23.98
26	5								15.93	2 69	18 62	51.51	4 68	0 68	5.36	6.54	20 61	3.37	23.98
27	6								16.56	2.06	18.62	34 95	2.92	0.40	3.32	3.62	19.48	2.46	21.94
28	7								17.23	1.39	18.62	17.72	1.71	0.22	1.93	1.91	18.94	1.61	20.55
29	8								17.72	0.90	18.62	0	1 91	0.02	1.93	0	19 63	0.92	20.55
Total		345.19	48.39	393.58	38.31	431.89	48 41	(480 95) 480.30	290 88	221.18			141.01	96.77			431.89	317.95	

Table I-2 (1) Statement of Income (Case I) (Unit. $ Million)

	Year	Operating revenue			Operating cost					Operation revenue (C)=(A)-(B)	Financing cost (interest payable)	Net Income (C)-(D)	Remarks
		Revenue from the sale of electricity	Inclined Passage tolls	Total (A)	Operating & maintenance cost			Depreciation	Total (B)				
					Power	Navigation	Total						
1	1980	10.65	0.002	10.65	2.92	0.09	3.01	6.66	9.67	0.98	9.90	(−)8.92	
2	1	12.23	0.002	12.23	2.92	0.09	3.01	6.66	9.67	2.56	9.90	(−)7.34	
3	2	14.28	0.003	14.28	2.98	0.09	3.07	6.92	9.99	4.29	10.52	(−)6.23	
4	3	16.21	0.003	16.21	2.98	0.09	3.07	6.92	9.99	6.22	10.50	(−)4.28	
5	4	18.18	0.003	18.18	3.00	0.09	3.09	6.92	10.01	8.17	10.48	(−)2.31	
6	5	28.72	0.004	28.72	3.42	0.09	3.51	8.70	12.21	16.51	13.84	2.67	
7	6	31.30	0.004	31.30	3.49	0.09	3.58	8.96	12.54	18.76	13.99	4.77	
8	7	33.88	0.005	33.89	3.49	0.09	3.58	8.96	12.54	21.35	13.46	7.89	
9	8	36.78	0.006	36.78	3.65	0.09	3.74	9.59	13.33	23.45	14.11	9.34	
10	9	39.84	0.007	39.84	3.74	0.09	3.83	9.99	13.82	26.02	14.40	11.62	
11	1990	42.56	0.007	42.56	3.74	0.09	3.83	9.99	13.82	28.74	13.73	15.01	
12	1	46.32	0.008	46.33	3.88	0.12	4.00	10.54	14.54	31.79	14.29	17.50	
13	2	48.28	0.009	48.29	3.88	0.12	4.00	10.54	14.54	33.75	13.51	20.24	
14	3	48.31	0.01	48.32	3.88	0.12	4.00	10.54	14.54	33.78	12.68	21.10	
15	4	48.32	0.01	48.33	3.88	0.12	4.00	10.54	14.54	33.79	11.82	21.97	
16	5	48.33	0.01	48.34	3.88	0.15	4.00	10.54	14.54	33.80	10.90	22.90	
17	6	48.34	0.02	48.36	3.88	0.15	4.03	10.54	14.57	33.79	9.94	23.85	
18	7	48.84	0.02	48.86	3.88	0.15	4.03	10.54	14.57	34.29	8.92	25.37	
19	8	48.84	0.02	48.86	3.88	0.15	4.03	10.54	14.57	34.29	7.85	26.44	
20	9	48.84	0.02	48.86	3.88	0.15	4.03	10.54	14.57	34.29	6.74	27.55	
21	2000	48.84	0.02	48.86	3.88	0.15	4.03	10.54	14.57	34.29	5.57	28.72	
22	1	48.84	0.02	48.86	3.88	0.15	4.03	10.54	14.57	34.29	4.42	29.87	
23	2	48.84	0.02	48.86	3.88	0.15	4.03	10.54	14.57	34.29	3.20	31.09	
24	3	48.84	0.02	48.86	3.88	0.15	4.03	10.54	14.57	34.29	1.93	32.36	
25	4	48.84	0.02	48.86	3.88	0.15	4.03	10.54	14.57	34.29	0.93	33.36	
26	5	48.84	0.02	48.86	3.88	0.15	4.03	10.54	14.57	34.29	0.67	33.62	
27	6	48.84	0.02	48.86	3.88	0.15	4.03	10.54	14.57	34.29	0.39	33.90	
28	7	48.84	0.02	48.86	3.88	0.15	4.03	10.54	14.57	34.29	0.21	34.08	
29	8	48.84	0.02	48.86	3.88	0.15	4.03	10.54	14.57	34.29	0.16	34.13	

Table I-2 (2) Statement of Income (Case 2) (Unit $ Million)

	Year	Operating revenue			Operating cost					Operating revenue (C)=(A)-(B)	Financing cost (interest payable)	Net Income (C)-(D)	Remarks
		Revenue from the sale of electricity	Inclined Passage tolls	Total (A)	Operating & maintenance cost			Depreciation	Total (B)				
					Power	Navigation	Total						
1	1980	10 65	0 002	10 65	2.92	0 09	3.01	6.76	9.77	0.88	11.64	(–)10.76	
2	1	12.23	0 002	12 23	2.92	0 09	3 01	6.76	9.77	2 46	11 64	(–) 9.18	Depreciation cost for navigation portion included in the total depreciation cost is negligible.
3	2	14 28	0.003	14.28	2 98	0.09	3.07	7 02	10 09	4.19	12 25	(–) 8.06	
4	3	16.21	0.003	16 21	2 98	0 09	3 07	7.02	10 09	6.12	12 23	(–) 6.11	
5	4	18.18	0 003	18.18	3 00	0.09	3.09	7.02	10.11	8 07	12 21	(–) 4.14	
6	5	28.72	0 004	28 72	3.42	0 09	3 51	8 81	12.32	16 40	15.86	0.54	
7	6	31.30	0.004	31.30	3.49	0.09	3.58	9 07	12.65	18 65	16 04	2.61	
8	7	33 88	0.005	33.89	3 49	0 09	3.58	9 07	12.65	21 24	15.56	5 68	
9	8	36.78	0 006	36.78	3 65	0 09	3.74	9.71	13.45	23 33	16 40	6.93	
10	9	39.84	0 007	39.84	3.74	0 09	3 83	10.11	13 94	25 90	16.76	9 14	
11	1990	42.56	0 007	42 56	3.74	0 09	3.83	10 11	13.94	28 62	16 13	12.49	
12	1	46.32	0 008	46 33	3.88	0 12	4 00	10 66	14.66	31 67	16 74	14 93	
13	2	48.28	0 009	48 29	3 88	0.12	4.00	10 66	14 66	33 63	16.01	17.62	
14	3	48 31	0.01	48.32	3 88	0.12	4 00	10.66	14 66	33.66	15.24	18.42	
15	4	48 32	0 01	48.33	3.88	0 12	4 00	10 66	14.66	33.67	14 43	19.24	
16	5	48 33	0 01	48 34	3.88	0.12	4 00	10 66	14 66	33.68	13.58	20 10	
17	6	48 34	0.02	48.36	3 88	0 15	4 03	10 66	14.69	33 67	12 69	20 98	
18	7	48 84	0 02	48 86	3 88	0.15	4 03	10 66	14 69	34 17	11.74	22.43	
19	8	48.84	0 02	48 86	3 88	0.15	4 03	10 66	14.69	34.17	10 76	23 41	
20	9	48.84	0 02	48 86	3 88	0 15	4 03	10 66	14.69	34.17	9 72	24 45	
21	2000	48.84	0 02	48 86	3 88	0 15	4 03	10 66	14.69	34.17	8 62	25 55	
22	1	48 84	0.02	48.86	3.88	0 15	4 03	10 66	14 69	34 17	7.53	26.64	
23	2	48 84	0 02	48.86	3,88	0 15	4 03	10 66	14 69	34 17	6.38	27.79	
24	3	48.84	0 02	48.86	3.88	0 15	4 03	10 66	14.69	34.17	5.16	29 01	
25	4	48 84	0.02	48 86	3 88	0 15	4 03	10 66	14.69	34.17	4.27	29.90	
26	5	48 84	0.02	48 86	3.88	0.15	4 03	10 66	14 69	34 17	3.37	30.80	
27	6	48 84	0.02	48.86	3.88	0 15	4.03	10 66	14.69	34.17	2.46	31.71	
28	7	48 84	0 02	48 86	3 88	0.15	4.03	10 66	14 69	34 17	1.61	32.56	
29	8	48.84	0 02	48 86	3 88	0.15	4 03	10.66	14 69	34.17	0.92	33.25	

Table I-3 (1) Statement of Cash Flow (Case I)

(Unit· $ Million)

Year		Cash from Income: Net Income	Cash from Income: Depreciation	Cash from Income: Subtotal	Receipt of Project Fund: Borrowings	Receipt of Project Fund: Government Investment	Receipt of Project Fund: Subtotal	Total Fund	Construction Cost Expensed	Borrowings repaid (principal)	Total expen-diture	Cash Balance: Currency Year (A)-(B)	Cash Balance: Cumulative
-9	1971				5.29	1.05	6 34		6.34				
-8	2				18.26	6.72	24.98		24.98				
-7	3				15 96	5 76	21 72		21 72				
-6	4				12.13	4.07	16.20		16.20				
-5	5				22.20	8.96	31.16		31.16				
-4	6				32 19	11.50	43.69		43 69				
-3	7				42.95	13.93	56.88		56.88				
-2	8				52.66	14.16	66 82		66 82				
-1	9				45 97	10 50	56 47		56.47				
1	1980	(–) 8.92	6.66	(–)2.26				(–) 2 26				(–) 2.26	(–) 2.26
2	1	(–) 7.34	6 66	(–)0 68	9.79	0.35	10.14	9.46	10.14		10.14	(–) 0.68	(–) 2.94
3	2	(–) 6 23	6.92	0.69				0 69		0 31	0 31	0.38	(–) 2.56
4	3	(–) 4.28	6 92	2.64	29 65	5.27	34.92	37.56	34.92	0.33	35.25	2.31	(–) 0.25
5	4	(–) 2.31	6.92	4.61	28.40	5.84	34.24	38.85	34.24	8.67	42.91	(–) 4.06	(–) 4.31
6	5	2.67	8.70	11.37	9.79	0.35	10 14	21 51	10.14	10.83	20 97	0.54	(–) 3.77
7	6	4.77	8.96	13 73	9.16	2.86	12 02	25.75	12.02	11.61	23.63	2.12	(–) 1.65
8	7	7.89	8.96	16.85	9.63	2.85	12 48	29.33	12 48	12 14	24.62	4.71	3.06
9	8	9.34	9.59	18.93	14.25	1.13	15.38	34 31	15.38	13 27	28.65	5 66	8.72
10	9	11.62	9.99	21.61				21 61		14.33	14.33	7.28	16 00
11	1990	15.01	9.99	25.00	19.78	1.50	21.28	46.28	21.28	15.00	36.28	10 00	26 00
12	1	17.50	10 54	28 04				28.04		16.32	16.32	11.72	37.72
13	2	20.24	10.54	30.78				30.78		17.10	17.10	13.68	51.40
14	3	21.10	10.54	31.64				31.64	0.65	17.93	18.58	13 06	64.46
15	4	21.97	10.54	32.51				32.51		18.79	18.79	13 72	78 18
16	5	22.90	10.54	33.44				33.44		19.71	19.71	13.73	91.91
17	6	23 85	10.54	34.39				34.39		20.67	20.67	13.72	105 63
18	7	25 37	10.54	35 91				35.91		21 69	21.69	14.22	119 85
19	8	26.44	10 54	36.98				36.98		22.76	22.76	14 22	134 07
20	9	27.55	10.54	38.09				38.09		23 87	23 87	14.22	148.29
21	2000	28.72	10.54	39.26				39 26		24.11	24.11	15.15	163 44
22	1	29 87	10 54	40 41				40.41		25 26	25.26	15.15	178.59
23	2	31.09	10.54	41 63				41 63		26.48	26.48	15.15	193.74
24	3	32.36	10 54	42.90				42.90		22.23	22.23	20 67	214.41
25	4	33 36	10 54	43.90				43.90		4.08	4 08	39 82	254.23
26	5	33 62	10 54	44.16				44.16		4 34	4.34	39 82	294.05
27	6	33.90	10 54	44.44				44.44		2 84	2 84	41.60	335.65
28	7	34 08	10.54	44.62				44 62		1.67	1.67	42.95	378 60
29	8	34 13	10 54	44 67				44 67		1.72	1.72	42.95	421.55
Total				800 26				950 86		378.06	529.31		

Table I-3 (2) Statement of Cash Flow (Case II)

(Unit: $ million)

Year		Cash from Income			Receipt of Project Fund			Total Fund	Construction cost Expensed	Borrowings repaid (principal)	Total Expenditure	Cash Balance	
		Net Income	Depreciation	Subtotal	Borrowings	Government Investment	Subtotal					Current Year (A) - (B)	Cumulative
-9	1971				5.83	0.52	6.35		6.35				
-8	2				21.70	3.36	25 06		25 06				
-7	3				19.03	2.88	21.91		21.91				
-6	4				14.46	2.04	16 50		16.50				
-5	5				27.10	4 48	31.58		31.58				
-4	6				38 57	5.75	44.32		44.32				
-3	7				50.74	6.97	57.71		57.71				
-2	8				60.86	7.08	67.94		67.94				
-1	9				52.59	5 25	57.84		57.84				
1	1980	(–) 10.76	6.76	(–)4.00				(–)4.00				(–) 4 00	(–) 4.00
2	1	(–) 9.18	6.76	(–)2.42	9.96	0.18	10.14	7.72	10.14		10 14	(–) 2.42	(–) 6 42
3	2	(–) 8 06	7.02	(–)1.04				(–)1.04		0 32	0.32	(–) 1 36	(–) 7.78
4	3	(–) 6.11	7.02	0.91	32.34	2.64	34.98	35 89	34.98	0.34	35 32	0.57	(–) 7.21
5	4	(–) 4.14	7 02	2.88	31.56	2.92	34.48	37.36	34.48	7.34	41 82	(–) 4.46	(–)11.67
6	5	0.54	8.81	9.35	9.97	0 17	10.14	19.49	10.14	9.68	19.82	(–) 0.33	(–)12.00
7	6	2.61	9 07	11.68	10.63	1.43	12.06	23.74	12.06	10 43	22 49	1.25	(–)10.75
8	7	5.68	9.07	14.75	11.16	1.43	12.59	27.34	12.59	10.91	23 50	3.84	(–) 6 91
9	8	6.93	9.71	16.64	14.84	0.56	15.40	32 04	15.40	12 11	27.51	4 53	(–) 2.38
10	9	9.14	10.11	19.25				19.25		13.14	13 14	6.11	3.73
11	1990	12.49	10.11	22.60	20.55	0.75	21 30	43.90	21.30	13.77	35.07	8.83	12.56
12	1	14.93	10 66	25.59				25.59		15.09	15.09	10.50	23.06
13	2	17 62	10.66	28.28				28.28		15.82	15 82	12.46	35.52
14	3	18.42	10 66	29 08				29.08	0.65	16.59	17.24	11 84	47.36
15	4	19 24	10.66	29 90				29.90		17.40	17.40	12.50	59 86
16	5	20.10	10 66	30.76				30.76		18.25	18.25	12.51	72 37
17	6	20.98	10.66	31.64				31.64		19.14	19.14	12.50	84.87
18	7	22.43	10 66	33.09				33 09		20.09	20.09	13.00	97 87
19	8	23.41	10.66	34.07				34 07		21.07	21.07	13.00	110 87
20	9	24.45	10.66	35.11				35.11		22 11	22.11	13 00	123.87
21	2000	25.55	10.66	36 21				36.21		22 28	22.28	13.93	137.80
22	1	26.64	10.66	37.30				37.30		23.37	23.37	13.93	151.73
23	2	27.79	10 66	38.45				38 45		24.52	24.52	13.93	165.66
24	3	29.01	10.66	39.67				39.67		19.75	19.75	19.92	185.58
25	4	29.90	10.66	40.56				40.56		19.71	19.71	20 85	206.43
26	5	30 80	10.66	41.46				41.46		20.61	20 61	20.85	227.28
27	6	31.71	10 66	42.37				42.37		19 48	19.48	22.89	250.17
28	7	32 56	10.66	43.22				43.22		18.94	18.94	24.28	274 45
29	8	33.25	10 66	43.91				43.91		19.63	19.63	24.28	298.73
Total				731.27				882.36	480.95	431.89	583.63		

CHAPTER J. NAVIGATION AND IRRIGATION

CHAPTER J. NAVIGATION AND IRRIGATION

J-1 Navigation Plan

J-1-1 General

With the construction of dams at Nam Ngum and Pa Mong, there will be a change in the discharge and water levels in the lower reaches of the Mekong River. Due to the functions of both the Nam Ngum and the Pa Mong Dams, discharge in the wet season will decrease with the regulation of flood discharge and the flow in the dry season will increase. As a result, the velocity of river flow will decrease in the wet season and the water level of the river will rise in the dry season, which is expected to bring favorable effect for navigation in the lower reaches.

Construction of the Sambor Dam should also bring about the same effects for navigation, however, because of a relatively smaller effective storage capacity of the Sambor Dam, the effects may not be too great. Nevertheless, with the completion of the Nam Ngum and the Pa Mong Dams in addition to the Sambor Dam, a distinct change will occur in the lower reaches and a favorable result may be expected.

J-1-2 Changes in the Discharge and Water Levels

Changes in the discharge and water levels as the result of construction of the two dams. Monthly mean discharge and monthly mean water levels of the Sambor Dam with and without the Nam Ngun and the Pa Mong Dams are shown in Table J-1 (1) and Table J-1 (2). Table J-1 (1) is for the dry season (February - April) and Table J-1 (2) is for the wet season (August - October).

Table J-1 (1) Change in Discharge and Water Level with or without the Upper Projects
(For the three-month period of the dry season)

	Discharge (cu.ms)				Water Level (m)				Discharge (cu.ms)				Water Level (m)		
	Original	With Pa Mong	Difference	Ratio	Original	With Pa Mong	Difference		Original	With Pa Mong	Difference	Ratio	Original	With Pa Mong	Difference
1951 Feb	3,099	5,421	2,322	1 74	5.5	7 1	1 6	1960 Feb	2,296	4,376	2,080	1 90	4.8	6.4	1.6
Mar	2,082	5,206	3,124	2.50	4 5	7.0	2.5	Mar	1,827	4,439	2,612	2.43	4.3	6 4	2.1
Apr	2,026	5,770	3,744	2.85	4 5	7.3	2.8	Apr	1,357	4,548	3,191	3.35	3 8	6.5	2.7
1952 Feb	1,961	4,393	2,432	2.24	4.5	6.4	1 9	1961 Feb	2,388	4,555	2,167	1 90	4 8	6.5	1.7
Mar	1,762	4,786	3,068	2 72	4.2	6 6	2.4	Mar.	2,004	5,128	3,124	2.56	4.5	7.0	2.5
Apr	1,718	5,462	3,744	3.18	4 2	7 1	2.9	Apr	1,972	5,716	3,744	2.90	4.5	7.3	2.8
1953 Feb	2,206	4,415	2,209	2.00	4 7	6.4	1 7	1962 Feb	3,137	5,459	2,322	1.74	5.5	7 2	1 7
Mar	1,828	4,440	2,612	2.42	4.3	6 4	2.1	Mar	2,503	5,627	3,124	2.25	5.0	7.3	2.3
Apr	1,833	5,432	3,599	2.96	4.3	7 2	2.9	Apr.	2,166	5,910	3,744	2.72	4 6	7 4	2.8
1954 Feb	2,110	4,470	2,360	2 12	4.6	6 4	1.8	1963 Feb	2,372	4,572	2,200	1 93	4 8	6.5	1 7
Mar	1,689	4,562	2,873	2.70	4 1	6.5	2.4	Mar	1,929	4,930	3,001	2.56	4.3	6 6	2.3
Apr	1,967	5,682	3,715	2.88	4 5	7 2	2.7	Apr	1,757	5,501	3,744	3 13	4 2	7 2	3.0
1955 Feb	2,237	4,459	2,222	1 99	4 7	6 4	1 7	1964 Feb	2,520	4,842	2,322	1 92	5 0	6 8	1 8
Mar	1,864	4,993	3,129	2.68	4.3	6 9	2.6	Mar	1,965	5,089	3,124	2.58	4.5	6 9	2.4
Apr.	2,038	5,782	3,744	2.84	4.5	7.3	2.8	Apr	1,854	5.598	3,744	3.02	4.3	7 2	2.9
1956 Feb	2,506	4,814	2,308	1 94	5 0	6 7	1 7	1965 Feb	2,890	5,212	2,322	1 80	5.3	7 1	1.8
Mar	1,934	5,016	3,082	2.59	4 4	6 9	2.5	Mar	2,243	5,317	3,074	2.36	4 7	7 1	2.4
Apr	1,991	5,727	3,736	2.88	4.5	7.2	2.7	Apr	1,980	5,724	3,740	2.88	4 5	7 3	2.8
1957 Feb	2,600	4,904	2,304	1 89	5 1	6 9	1.8								
Mar	2,093	4,618	2,525	2.21	4 5	6.6	2.1								
Apr	2,103	5,058	2,955	2.40	4 6	6.9	2.3								
1958 Feb	2,510	5,345	2,835	2.13	5.0	7 1	2 1								
Mar	1,919	5,103	3,184	2.68	4 40	7 0	2.6								
Apr	1,733	5,349	3,616	3.08	4 20	7 1	2.9								
1959 Feb	1,945	4,623	2,678	2.38	4.4	6.6	2.2								
Mar	1,730	4,710	2,980	2.72	4.2	6 7	2.5								
Apr	1,648	5,197	3,649	3 15	4 1	7.0	2.9								

Table J-1 (2) Change in Discharge and Water Level with or without the Upper Projects
(For the three-month period of the dry season)

	Discharge (cu.ms)				Water Level (m)		
	Original	With Pa Mong	Difference	Ratio	Original	With Pa Mong	Difference
1951 Aug.	36,403	32,401	4,002	89.0	16.9	16.1	0.8
Sep	34,443	25,874	8,569	75.1	16.6	14 6	2.0
Oct.	23,716	22,869	847	96.4	14.0	13.8	0.2
1952 Aug.	44,445	40,734	3,711	91 7	18.6	17.8	0.8
Sep.	46,197	36,995	9,202	80.1	18.8	17.0	1.8
Oct.	30,817	30,728	85	99 7	15.9	15.9	0
1953 Aug.	33,100	28,789	4,311	87.0	16.3	15.1	1.2
Sep.	33,687	25,511	8,176	75 7	16.4	14.5	1 9
Oct.	20,771	19,576	1,195	94.2	13 1	12.9	0.2
1954 Aug.	25,416	19,369	6,047	76.2	14 5	12.9	1.6
Sep.	41,856	32,558	9,299	77.9	18.0	16.2	1.8
Oct.	26,758	26,683	75	99 7	14 8	14.8	0
1955 Aug	25,378	21,296	4,082	83.9	14.4	13.3	1 1
Sep.	30,233	20,966	9,267	69.3	15 7	13.2	2.5
Oct	17,091	17,012	79	99.5	12.0	12.0	0
1956 Aug	39,341	33,451	5,890	85.0	17.6	16.4	1.2
Sep	41,350	33,083	8,267	80.0	17.9	16.3	1.6
Oct	18,431	17,398	1,033	94.4	12.5	12.1	0.4
1957 Aug	24,733	22,452	2,281	90.8	14.4	13.7	0.7
Sep.	34,844	31 174	3,670	89.5	16.7	15.9	0.8
Oct.	27,683	24,543	3,140	88.7	15.0	14 4	0.6
1958 Aug.	25,077	17,837	7,240	71 1	14.5	12.2	2.3
Sep	42,717	36,875	5,842	86.3	18.2	17 1	1.1
Oct	19 780	19,026	754	96.2	13.0	12.7	0.3
1959 Aug.	26,128	17,885	8,243	68.5	14.6	12.2	2.4
Sep.	37,304	27 705	9,599	74.3	17.2	15.0	2.2
Oct.	24,029	19,672	4,357	81 9	14.2	12.9	1.3

	Discharge (cu.ms)				Water Level (m)		
	Original	With Pa Mong	Difference	Ratio	Original	With Pa Mong	Difference
1960 Aug.	39,539	30,757	8,782	77.8	17 7	15.8	1.9
Sep.	36,117	26,393	9,724	73.1	16.9	14.6	2.3
Oct	28,394	28,309	85	99 7	15.0	15.0	0
1961 Aug.	40,039	35,513	4,526	88.7	17 7	16.8	0.9
Sep.	49 790	40,261	9,529	80.9	19.5	17.8	1 7
Oct.	39,371	39 164	207	99.5	17.6	17.5	0.1
1962 Aug.	37,658	33,522	4,136	89.0	17.3	16.4	0.9
Sep.	36,408	29,458	6,950	80.9	16.9	15 4	1.5
Oct.	24,662	22,372	2,290	90.7	14 4	13.7	0.7
1963 Aug.	41,603	37,437	4,166	90.0	17 9	17.2	0.7
Sep.	36,657	28,728	7,929	78.4	16.9	15.1	1.8
Oct.	21,745	20,424	1,321	93.9	13 5	13 1	0 4
1964 Aug.	27,358	23,643	3,715	86.4	14 9	14.0	0.9
Sep.	37,897	28,502	9,395	75.2	17.3	15 1	2.2
Oct.	31,845	31 760	85	99 7	16.1	16.1	0
1965 Aug	28,629	24,841	3,788	86.8	15 1	14.4	0.7
Sep.	32,463	25,083	7,380	77.3	16.1	14.5	1.6
Oct.	16,158	14,250	1 908	88.2	11 7	11.0	0.7

J-1-2-1 Changes in the Discharge in the Dry Season

Change in the discharge for a three-month period of the dry season (February-April), as shown in Table J-1 (1), indicates an increase from the original discharge of 1,360 cu.ms – 3,140 cu.ms to 4,380 cu.ms – 5,910 cu.ms with the Pa Mong and the Nam Ngum Dams, with the difference in the discharge being 2,080 cu.ms – 3,740 cu.ms and the ratio of discharge being 1.74 – 3.35. Study by monthly classification indicates the greatest effect would be in April when the annual water level is the lowest of the year.

Table J-2 Changes in Discharge during the Dry Season

Month	Original flow (1) (cu.ms)	Regulated flow with Pa Mong and Nam Ngum projects (2) (cu.ms)	Difference (cu.ms)	(2)/(1)
Feb.	1,950-3,140	4,380-5,460	2,080-2,840	1.74-2.38
Mar.	1,690-2,500	4,440-5,630	2,530-3,180	2.21-2.72
Apr.	1,360-2,170	4,550-5,910	2,960-3,740	2.44-3.35

J-1-2-2 Changes in Water Level during the Dry Season

With the completion of dams, the discharge will increase and the water level will rise during the dry season but the discharge will decrease and the water level will drop during the wet season.

A study was made on the change in the water level by using the data [1] on water level compiled from observations made by the Japanese Survey Team at a point between the Sambor dam site and Kratie since 1961.

Changes in the water level for a three-month period of the dry season (February-April), as shown in Table J-3, indicate an increase from the original water level of 3.8 m – 5.5 m to 6.4 m – 7.4 m, and the difference in the water level is 1.6 m – 3.0 m with the average of 2.3 m. Study by monthly classification indicates the greatest rise in the water level is in April.

1/ *Sambor Project Report on Preliminary Investigation for Development of the Lower Mekong River Basin, Cambodia,* Oct. 1912. The Japanese Preliminary Survey Team for the Sambor Project
The First Progress Report on Investigations of the Sambor Project, Oct. 1963, OTCA, Tokyo, Japan.
The Second Progress Report on Investigations of the Sambor Project, Sept. 1964, OTCA, Tokyo, Japan.

Table J-3 Changes in Water Level during the dry season

Month	Original (EL m)	With Pa Mong and Nam Ngum (EL m)	Difference (m)
Feb.	4.4-5.5	6.4-7.2	1.6-2.2
Mar	4.1-5.0	6.4-7.3	2.1-2.6
Apr.	3.8-4.6	6.5-7.4	2.3-3.0
Average			2.3

J-1-2-3 Changes in Discharge during the Wet Season

Changes in discharge for a three-months period (August-October) of the wet season shown in Table J-1 (2) were summarized in Table J-4.

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Table J-4 Changes in Discharge during the Wet Season

Month	Original (cu.ms)	With Pa Mong and Nam Ngum (cu.ms)	Difference (cu.ms)
Aug.	24,700 - 44,400	17,800 - 40,700	2,300 - 8,800
Sep.	30,200 - 49,800	21,000 - 40,300	2,300 - 9,700
Oct.	16,200 - 39,400	14,300 - 39,200	80 - 4,400

Against the original discharge of 16,200 cu.ms - 49,800 cu.ms, discharge with the completion of the Pa Mong Dam will decrease to 14,300 cu.ms - 40,700 cu.ms during the wet season and the difference in discharge (between the two cases) is 90 cu.ms - 9,700 cu.ms. Discharge ratio is 68.5 % - 99.7 %, which is not a significant difference as compared with that for the dry season.

Study by monthly classification indicates a greater difference for September and less effect for October.

J-1-2-4 Changes in the Water Level during the Wet Season

Changes in the monthly water level for the August - October period of the wet season, as shown in Table J-5, indicate a decrease from the original water level of 11.7 m - 19.5 m to 11.0 m - 17.8 m after the completion of dams. The difference in the water level (between the two cases) is 1.1 m on the average, which is smaller when compared with that for the dry season. Study by monthly classification indicates a greater effect for September.

Table J-5 Changes in Monthly Water Level during the Wet Season

Month	Original (EL m)	With Pa Mong and Nam Ngum (EL m)	Difference (m)
Aug.	14.4 - 18.6	12.2 - 17.8	0.7 - 2.4
Sep.	15.7 - 19.5	13.2 - 17.8	0.8 - 2.5
Oct.	11.7 - 17.6	11.0 - 17.5	0 - 1.3
Average			1.1

J-1-3- Effect of Change in Discharge on Navigation

Construction of the Nam Ngum and the Pa Mong Dams in addition to the Sambor Dam will result in an increase in discharge by 2,080 cu.ms - 3,700 cu.ms and an increase in the water level by 1.6 m - 3.0 m during the dry season, as described in the foregoing section. Also during the wet season, discharge will decrease by 80 cu.ms - 9,700 cu.ms and the water level will drop by 0 m - 2.5 m.

Decrease in discharge during the wet season will in turn decrease the flow velocity with favorable results for navigation, however, due to limited data on observation of flow velocity, estimate on the change in the value of flow velocity would be rather difficult. Because of the decrease in the water level, inundation of land area, which at present is frequent during the wet season, will be greatly reduced in the future, but on the other hand it is conceived that the amount of discharge of the river during the flood season might remain almost as large as for the present time. The decrease in the flow velocity, therefore, is considered insignificant.

During the dry season, a rise of water level on the monthly average of 1.6m–3.0m is expected at Kratie and this change in the water level will have a considerable effect on navigation.

Under the project for Sambor only, against the initial navigation plan calling for a minimum depth of 3.6 m for the navigation of a vessel of 122 tons dead weight, the minimum depth had to be reduced to 2.0 m at the downstream side of the inclined passage facility in order to reduce the cost of dredging work.

Under the Isolated Project, therefore, when the water level is low during the dry season, though it may be a short period restriction must be made on the draft of vessels, which will prevent the navigation of large ships. With the construction of the Nam Ngum and the Pa Mong Dams, such a need for the restriction on the draft of ships will be almost eliminated.

As is evident from the above discussion even with the addition of the Nam Ngum and the Pa Mong Dams, details of the work under the navigation plan will still be the same as under the Isolated Sambor Project and no change in the construction cost will be required.

On the assumption that the project will impose a restriction on the draft of ships during the dry season as under the Isolated Sambor Project, a saving of $ 1,000,000 for dredging work will be materialized.

With the construction of the Pa Mong Dam a rise of approximately 2 m in the water level will occur during the dry season not only in the vicinity of the Sambor Dam but between Kratie and Phnom Penh with the accompaning advantage of safer navigation. The maximum tonnage presently allowed for navigation is 300 tons for vessels and 500 tons for barges. Shallow river beds located at Chhlong and several other points downstream of Kratie makes it necessary to have vessels of smaller size than those mentioned above operation with extreme caution in navigation. The advantage of this project is that ships will be able to pass through such points without restriction on draft and with ease in navigation.

J-2 Irrigation Plan

J-2-1 Introduction

A plan to develop the land covering an area of 34,000 ha downstream of the Sambor Dam by gravity-irrigation from the Sambor Reservoir upon its completion and from tributaries, lakes and swamps, has been discussed in detail in the Isolated Project (see Vol. I and IV).

When the Nam Ngum and the Pa Mong upstream projects materialized, downstream of the Mekong River will be greatly improved and discharge during the dry season will also be increased. The menace of floods is expected to be mitigated to some extent. Also because of the large volume of power energy generated at the Sambor Power Plant at low cost, development of the Lower Mekong Delta may also be considered in addition to the foregoing 34,000 ha. For the development of the delta there still remains many points which must be studied and investigated in the future. In this report, however, a preliminary study was made tentatively on the land covering an area of 587,000 ha in Cambodia, for which pumping from the Mekong River making use of Sambor electricity is considered to be easily accomplished and for which most effective irrigation is considered to be carried out (see Fig. J-1)

J-2-2 Present Condition

A rough soil investigation was made in the nine provinces situated along the Mekong and the Tonle Sap, namely; Kompong Cham, Prey Veng, Kandal, Kompong Chhnang, Pursat, Battambang, Kompong Speu, Takeo and Kampot Provinces. The soils of these area are classified into the following groups.

Alluvial Soils of the Mekong: The fresh supplementary muddy soil from the Mekong and the Tonle Sap inundation during the rainy season is alluvial soil and this type of soil belongs to the most fertility soil in Cambodia. Soil texture is either silt or light clay. During the period before and after inundation this soil is utilized to cultivate maize, tobacco, mung bean and peanut, and is called the "treasure house of upland field."

In a certain place, floating rice and dry seasonal rice are cultivated utilizing the water resources of ponds and swamps.

Sandy Alluvial Soils: This soil is the paddy field soil which is widely spread along the low land of the back slope in the natural levee of the Mekong and is distributed in the most of the area in the southern portion of Kampong Cham Province, Kandal, Prey Veng and Takeo Provinces.

This soil has a rather high water retention factor, but its productivity is low.

During the dry season it dries and solidifies, and aside from the area around the water resource, this land is utilized for rainy seasonal rice cultivation only, but most of this land is inundated every year, and the inundation depth is great and these deep area cannot be used.

Hydromorphic Soils: This soil is found at the places higher than the sandy alluvial soil and is utilized mainly in the paddy field during the rainy season. Hilly-lands of Prey Veng, Kompong Speu, Takeo and Kampot Provinces are of this soil. This type of soil is unfertile one and the mobile iron solidification occurs due to dryness during the dry season and at 40 cm - 50 cm below the ground surface, laterite layer affected by ground water is sometimes found.

Clayey Alluvial Soils: This soil formulated by the alluvial clayey soil of Tonle Sap Lake is widely found in Battambang Province, and it is a comparatively fertile and is mainly used for paddy field in the rainy season.

Podzolic Soils: This soil is a low fertility sandy soil found in the upland of Kompong Chhnang, Kompong Speu, Takeo and Kampot Provinces. In a certain place, this soil is used for mung bean, peanut and other field products as well as paddy fields.

Others: In the hilly-lands of Kompong Cham Province, the terrace residual soil, red and blackish fertile soil made of basalt can be seen.

The red soil knowm as terre-rouge is forming the aggregate structure with agglutinative materials of the metallic iron, and the physical properties such as aeration, water penetration, and water retention are well developed.

For these reasons this soil is suitable for rubber and banana plantations and also for field crops such as cotton and bean. The black soil is used for paddy fields. Along the seashores of Kampot and Takeo, the coastal complex, acid lithsols, alumisols are found.

Table J-6 shows the land classification according to land tax, soil productivity and three essential elements of topography, and the standard classification by Srok of each province is shown as follows:

Land Tax:	Class I;	1.0 $/ha and over
	Class II;	1.0 - 0.5 $/ha
	Class III;	0.5 $/ha and less
Soil productivity:	Class I;	Mekong alluvial soil (red soil and black soil)
	Class II;	Sandy and clayey alluvial soil
	Class III;	Hydromorphic soil
	Class IV;	Podzolic soil
Topography:	Class I;	Flat land
	Class II;	Marshy land
	Class III;	Upland slope, hilly-lands

J-2-3 Development Plan

J-2-3-1 Selection of the Project Area

Fig. J-1

General Plan of Agricultural Development in
Downstream Project Area

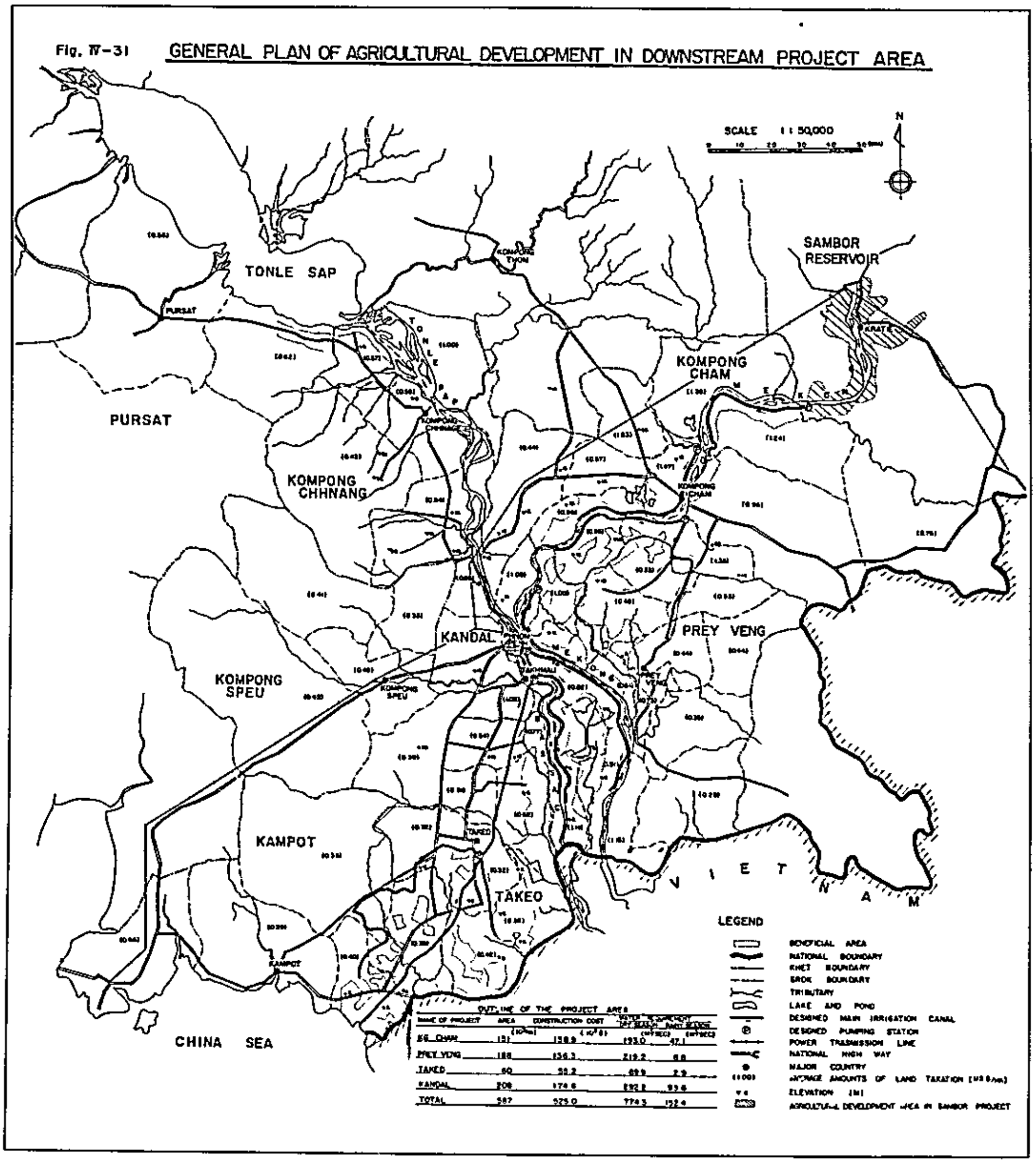


Table J-6 Criteria for Land Classification

Province	Srok	Taxation	Soil	Topography
Kompong Cham:	Koh Sautin	I	I	II - III
	Krauch Chhmar	I	II	I
	Kompong Siem	I	I	I
	Srei Santhor	I	I - II	I
	Prey Chhour	II	II	I
	Cheung Prey	III	I	II
	Kang Meas	II	II	II
Prey Veng:	Sithor Kandal	III	III	I
	Peareang	II	II - III	II
	Prey Veng	III	II - III	I - II
Kandal:	Dang Kor	III	III	I
	Pon Hea Leu	II	III	I
	Khsach Kandal	I	I - III	II
	Muk Kanpul	I	I - II	I - II
	Kandal Stung	I	II	I
	Koki Thom	I	I - II	I - II
	Leyk Dek	I	I - II	I - II
	Saang	II	I - II	I - II
	Lovea Em	II	I	I - II
	Kien Svay	II	I	I - II
Kampot:	Kompong Track	III	IV	I
	Bantay Meas	III	III	I
	Chhuk	III	III-IV	I - III
Takeo:	Bati	II	III	I
	Prey Krabas	II	II - III	I III
	Samrong	III	III	I
	Treang	III	III	I
	Koh Ardet	III	II	II
	Kirivong	III	III	I III

The project area of 628,000 ha is finally selected as shown in Table J-7 and out of this project area, 587,000 ha is the irrigable area which will be explained later. The districts shown in the remarks column in Table J-7 are representative provincial names:

(1) These areas are established depending on the following factors.
   (a) To be capable of the irrigation during the dry season.
   (b) To be capable of the supplemental irrigation effectively during the rainy season.
   (c) To rely on the pumping irrigation solely from the Mekong.

These areas are a vast delta spread widely along the Mekong, Tonle Sap and the Bassac Rivers at the downstream of Kompong Cham. Elevation of this area is less than 10 m and the pumping head is about 10m.

(2) The environments of the Great Lake is not included in this project area. The reason for this is that another development project will be formulated, such as pumping project using the Great Lake as the water resource and also the tributaries that pours into the Great Lake. Actually during 1966-67, the Mekong Committee conducted a reconnaissance survey on the 13 million ha located in the northern area of the Great Lake, and a basic plan was formulated. Several favorable project were discovered, and the further survey on the southern area of the Great Lake will be continued, but the electric power required for lifting the irrigation Water from the Great Lake and other reservoir will be supplied from the hydroelectric plant of Sambor Dam.

(3) North west plateau area of the Kompong Cham, Kompong Thom and Kompong Speu Provinces are situated on a rather high-land and there are good tributaries that can be used for water resources. Therefore, it is decided that the development of the tributaries in these area are most appropriate and this area is eleminated from the project area.

The irrigation area of Prek Thnot Project situated in this area is excluded.

The arable land along the seashore of Kampot Province and the highly fertile land in Srok Prey Nap are excluded, because they are away from the central part of this project and it is decided that it will be better to rely on the tributaries as water resources.

The southern section of Prey Veng Province and the eastern area of Takeo are also excluded, because the inundation is great.

The area along the Tonle Sap in Kompong Chhlong Province is excluded by the following reasons:

The hillside elevation is rather high, the arable land stretches to a narrow strip, therefore, construction cost of pumping and canal works will be higher compared with that of the other area.

(4) Takeo and Kampot Province are included in this downstream project area considering the effective plan of the basin-wide canal, which has been proposed to the Mekong Committee. In this plan, an irrigation canal from the south of Phnom Penh to the China Sea through Takeo is planned to be provided in the future. This route is a similar to the proposed basin-wide canal, and also there is a possibility of utilizing this canal as a navigation route.

(5) From the land classification of J-2-2, the area capable of expecting high productivity is selected by considering many conditions as stated in sections (1) to (4).

The area selected on Table J-7 is planned to be the group irrigation area depending on the topographic and soil conditions.

J-2-3-2 Plan of Land Utilization

In this plan, the existing cultivated land will remain even in the future, and the uncultivated land along the river bank will be utilized as the upland fields, and the low-land as paddy fields. From the topography and other conditions. 20% of the uncultivated land is considered to be the non-usable area. Consequently, total irrigation area is estimated to be 587,000 ha. This is shown in Table J-8.

In this table the inundated and non-inundated area are classified. Since this project does not include flood control plan, the inundation condition after the completion of the construction is not likely to change.

Table J-7 Present Land Category of the Project Area (unit: 1,000 ha)

District	Surveyed Area	Lake and Swamp	Project Area: Paddy Field	Project Area: Upland Field	Project Area: Uncultivated Area	Total	Ratio of inundated Area (%)
Kompong Cham	210	40	51	24	95	170	65
Prey Veng	240	57	85	23	75	183	90
Kandal 1	115	50	15	25	25	65	90
Takeo	230	20	200	–	10	210	50
Total	795	167	351	72	205	628	70

Remarks:
Kompong Cham: Area between the Mekong and Tonle Sap
Prey Veng: Left bank of the Mekong
Kandal: Area between the Mekong and Bassac
Takeo: Right bank of the Bassac

Table J-8 Plan of Land Utilization

(Unit 1,0000 ha)

Item / District	Paddy Field: Existing Paddy Field	Paddy Field: Reclaimed Paddy Field	Paddy Field: Subtotal	Upland Field: Existing Paddy Field	Upland Field: Reclaimed Paddy Field	Upland Field: Reclaimed Upland Field from Paddy Field	Upland Field: Subtotal	Total	Non-use Area
Kompong Cham (inundated)	31	28	59	24	15	–	39	98	
Kompong Cham (inundated)	20	22	42	-	11	–	11	53	
Subtotal (non-inundated)			101				50	151	19
Prey Veng (inundated)	85	36	121	23	12	–	35	156	
Prey Veng (inundated)	–	–	-	–	12	-	12	12	
Subtotal (non-inundated)			121				47	168	15
Takeo (inundated)	96	5	101	–	3	-	3	104	
Takeo (inundated)	89	–	89	-	–	15	15	104	
Subtotal (non-inundated)			190				18	208	2
Kandal (inundated)	15	12	27	25	4	-	29	56	
Kandal (inundated)	–	–	–	-	4	–	4	4	
Subtotal (non-inundated)			27				35	60	5
Total	336	103	439	72	61	15	148	557	41

J-2-3-3 Agricultural Development

The objective of this project is; (1) introduce supplemental irrigation to the existing cultivated land during the rainy season (2) stabilize the production, (3) expand the cropping area by establishing the irrigation system during the dry season. Along with the introduction of irrigation, the present farming will change over to fertilized agriculture, hence stabilizing the production and increasing the unit yield. 60 kg/ha of the three essential elements of fertilization is required for rice and maize and about 30 kg/ha for the other crops, besides 10 t/ha of organic fertilizer.

Table J-9 Present Cropping Area (unit: 1,000 ha)

District	Paddy Field: Rainy Seasonal Rice	Paddy Field: Dry Seasonal Rice	Paddy Field: Total	Upland Field: Rainy Season	Dry Season: Maize	Dry Season: Mung bean	Dry Season: Peanut	Dry Season: Cotton	Dry Season: Tobacco	Dry Season: Total
Kompong Cham	47.9	3.1	51.0	–	15.6	–	1.2	1.2	3.6	21.6
Prey Veng	78.2	6.8	85.0	–	17.3	–	2.3	–	0.7	20.3
Takeo	183.0	2.0	185.0	–	–	–	–	–	–	–
Kandal	12.7	2.3	15.0	–	17.5	1.2	–	–	1.2	19.9
Total	321.8	14.2	336.0	–	50.4	1.2	3.5	1.2	5.5	61.8
Cropping Ratio	(96)	(4)	(100)		(70)	(2)	(5)	(2)	(8)	(87)

Cropping ratio increase must be considered, and also in the paddy field, double cropping should be adopted. In the upland field, the cropping area for maize, mung bean and peanut should be expanded. The present and the proposed cropping areas are as given in Table J-9 and Table J-10.

Table J-10 Designed Cropping Area

(unit: 1,000 ha)

District	Paddy Field					Upland Field									
	Rainy Season		Dry Season	Total	Fodder Crop	Rainy Season				Dry Season					Total
	Rice	Mung Bean	Rice			Maize	Mung Bean	Peanut	Sesame	Maize	Mung Bean	Peanut	Cotton	Tobacco	
Kompong Cham	47.9	27.0	101.0	175.9	5.2	3.5	19.5	19.5	2.3	31.1	–	2.0	3.9	7.8	94.8
Prey Veng	78.2	21.4	121.0	220.6	5.8	6.2	17.5	17.5	–	32.5	–	7.0	–	1.7	88.2
Takeo	183.0	7.0	190.0	380.0	–	15.0	1.5	1.5	–	13.3	1.0	1.0	–	2.7	36.0
Kandal	12.7	7.2	27.0	46.9	2.1	1.9	14.5	14.5	–	28.5	1.2	–	–	1.2	63.9*
Total	321.8	62.6	439.0	823.4	13.1	26.6	53.0	53.0	2.3	105.4	2.2	10.0	3.9	13.4	282.9
Cropping ratio	(73)	(14)	(100)	(187)	(8)	(17)	(34)	(34)	(67)	(67)	(1)	(6)	(2)	(8)	(178)

Remarks. Cropping ratio of paddy field is estimated according to the existing paddy fields of 439,000 ha, also that of upland fields the existing upland fields of 158,000 ha. (see Table J-8)

J-2-4 Water Requirement

Since an actual survey on the water requirement was not conducted, an assumption is made depending on the data obtained from the Kompong Cham Province. Table J-11 shows the water requirement calculated by Blaney-Criddle formula taking the average empirical coefficient K equals 0.7.

Table J-11 Water Requirement

Land Category	Water Requirement	Dry Season	Rainy Season	Remarks
Paddy Field	Percolation	3.0	1.0	1/ Average value from Dec. to Mar.
	Evapotranspiration	6.4 1/	5.0 2/	
	Total	9.4	6.0	2/ Average value from June to Oct.
Upland Field	Percolation	–	–	
	Evapotranspiration	4.5	3.5 3/	3/ The Average Empirical Coefficient K=0.7
	Total	4.5	3.5	

Unit water requirement is shown in Table J-12 and the total water requirement are shown in Table J-13. Loss of the irrigation water requirement at the paddy fields is decided at 25% as the conveyance loss and operation loss, and also at the upland fields 20% as the conveyance loss and 70% of irrigation efficiency.

The total water requirements during the dry season are an average 774 cu.ms for 578,000 ha of irrigation area and an average of 152 cu.ms for 173,000 ha of irrigation area during the rainy season.

Table J-12 Unit Water Requirement

Land Category	Dry Season		Rainy Season	
	Water Requirement in Depth (d: mm/day)	Unit Water requirement (q; cu.ms/ 1,000 ha)	Water Requirement in Depth (d: mm/day)	Unit water requirement (q; cu.ms/ 1,000 ha)
Paddy Field	9.4	1.45	6.0	0.93
Upland Field	4.5	0.93	3.5	0.73

Remarks: for paddy field; $q = \frac{d \times 10^{-3} \times A \times 10^4}{(1 - 0.25) \times 86,400}$

for upland field; $q = \frac{d \times 10^{-3} \times A \times 10^4}{(1 - 0.20) \times 0.70 \times 86,400}$

Where; A: irrigation area (ha)

Table J-13 Total Water Requirement

District	Land Category	Dry Season Irrigation Area (1,000 ha)	Dry Season Total Water Requirement (cu.ms)	Rainy Season Irrigation Area (1,000 ha)	Rainy Season Total Water Requirement (cu.ms)
Kompong Cham	Paddy Field	101	146.5	42	39.1
	Upland Field	50	46.5	11	8.0
Prey VEng	Paddy Field	121	175.5	–	–
	Upland Field	47	43.7	12	8.8
Kandal	Paddy Field	27	39.2	–	–
	Upland Field	33	30.7	4	2.9
Takeo	Paddy Field	190	275.5	89	82.7
	Upland Field	18	16.7	15	10.9
	Paddy Field	439	636.7	131	121.8
Total	Upland Field	148	137.6	42	30.6
	Total	587	774.3	173	152.4

J-2-5 Construction Plan and Cost

Major construction works are irrigation facilities, and its water resource will rely on the mainstream of the Mekong, Tonle Sap, and the Bassac Rivers. The irrigation method is a pumping system using the power from the Sambor Power Plant. The principal facilities are composed of pumps and main irrigation canals. All the main irrigation canals are provided so as to make gravity irrigation. Terminal irrigation canals to each field are also provided.

All the canals are designed to be the trapezoid earth canal having the side slopes of 1:2, and the longitudinal section is assumed at 1:10,000 - 1:15,000.

The upland field irrigation is to be introduced, therefore, land leveling must be done to make furrow irrigation to the existing upland fields.

Engineering fee, contingencies and associated cost are estimated as the same as the Isolated Project. The total construction cost of the entire beneficial area of 587,000 ha is $525 million and per ha is $894.

Table J-14 Construction Volume and Cost (Unit: $ million)

Construction Works	Construction Volume	Construction Cost
Reclamation Works	251,000 ha	102.6
Irrigation Canal Works	780 km	157.8
Pumping Station Works	211,600 kW	102.8
Accessory Works	Complete set	73.0
Subtotal		436.2
Engineering Fee		43.6
Contingencies		43.6
Associated Cost		1.6
Subtotal		88.8
Total	587,000 ha	$525.0 million

Table J-15 Main Construction Works by District

District	Area (1,000 ha)	Total Construction Cost ($ million)	Main Construction Works
Kompong Cham	151	158.9	Reclamation Works: 100,000 ha Irrigation Canal Works: 190 km Pumping Station Works: 55,900 kW
Prey Veng	168	136.3	Reclamation Works: 83,000 ha Irrigation Canal Works: 160 km Pumping Station Works: 53,700 kW
Kandal	60	55.2	Reclamation Works: 45,000 ha Irrigation Canal Works: 130 km Pumping Station Works: 14,400 kW
Takeo	208	174.6	Reclamation Works: 23,000 ha Irrigation Canal Works: 300 km Punping Station Works: 87,600 kW

J-2-6 Benefit and Economic Analysis

J-2-6-1 Benefit

Main objective of this project is to increase agricultural production with the introduction of irrigation, use of fertilizer, employment of improved varieties, and is to expand the cropping area by the reclamation and the introduction of dry seasonal crops. The following table shows the increased net benefit by each district.

Table J-16 Increased Net Benefit

District	Area (1,000ha)	Increased Net Benefit	
		Total Benefit ($1,000)	Net Benefit per ha ($/ha)
Kompong Cham	151	30,357	201.1
Prey Veng	168	29,251	174.2
Kandal	60	13,264	210.5
Takeo	208	32,553	156.5
Total	587	105,425	179.7

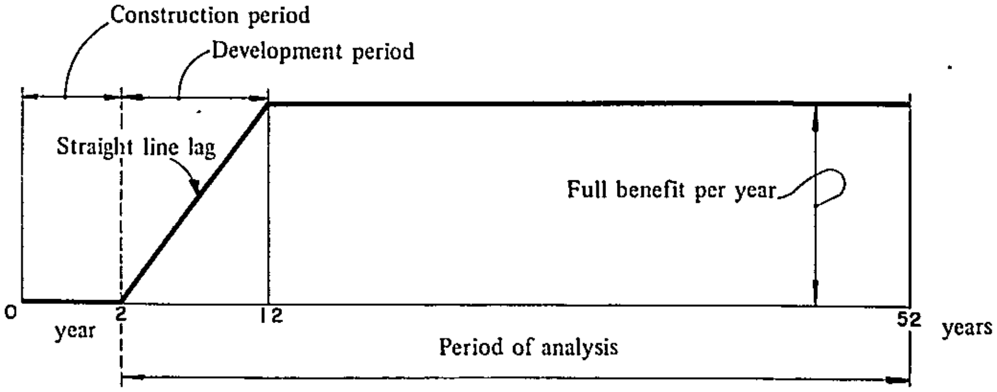
J-2-6-2 Annual Cost and Benefit

In the economic analysis of this project, the internal rate of return was calculated and used as an index to the economic evaluation in the same manner as for the Isolated Sambor Project.

For the realization of full benefit a total of ten years was considered to be required with gradual increase of its effect after the completion of the Project. Construction work was divided into districts, each of which requires a construction period of four years.

Calculation of cost and benefit with various interest rates for a 50-year period of economic analysis of the project is shown in Table J-17, 18, and Fig. J-2.

Fig. J-2 Target for construction and benefit



In compliance with the above target, as in the Isolated Sambor Project, the annual cost and annual benefit are estimated as shown in Table J-17 and J-18.

Table J-17 Annual Cost (S/ha)

District \ Interest Rate	5%	6%	7%	8%	9%	10%
Kompong Cham	96.1	106.8	119.2	130.5	143.0	156.3
Prey Veng	74.9	83.3	92.3	101.1	110.6	120.1
Kandal	81.7	91.6	101.8	113.5	123.5	136.7
Takeo	79.3	87.5	97.2	106.2	116.0	126.4
Average	82.7	92.7	101.1	111.3	122.1	133.1

Table J-18 Annual Benefit (S/ha)

District \ Interest Rate	5%	6%	7%	8%	9%	10%	Full Benefit
Kompong Cham	159.5	154.2	149.4	144.5	139.3	135.4	201.1
Prey Veng	138.1	133.6	129.4	125.1	120.3	117.4	174.2
Kandal	166.9	161.5	156.4	151.2	145.8	141.7	210.5
Takeo	124.1	120.0	116.3	112.4	108.4	105.4	156.5
Average	142.5	137.8	133.5	129.1	124.4	121.0	179.7

J-2-6-3 Economic Evaluation

Internal rate of return derived from the cost and benefit mentioned in the previous section is 10.1%. Internal rate of return by district is shown in Table J-19.

Note: Formula for the calculation of internal rate of return.

$$K = \sum_{t=1}^{50} \frac{Rt}{(1+i)^t}$$

Where: K = Initial Investment

i = Interest Rate (Internal Rate of Return)

Rt = Cash Flow in the Year of t (Revenue minus Annual Expense)

t = Period of Capital Recovery

Table J-19 Internal Rate of Return by District

District	Internal Rate of Return (%)
Kompong Cham	9.6
Prey Veng	10.7
Kandal	11.1
Takeo	9.3
Average	10.1

The internal rate of return of the four districts differs slightly, and the favorable rate is in order of Kandal, Prey Veng, Kompong Cham and Takeo. From the above table, project feasibility is favorable at each district, but since it requires a vast amount of water and electric power, the undertaking of this project will be realized after the water utilization adjustments of the Mekong is progressed to a certain extent.

Furthermore, the main irrigation canal in the Takeo District is the link for the shortest water route from the Mekong to the China Sea, and this is a similar to the route suggested by Mekong Committee on basin-wide canal study of the Lower Mekong River Basin. The internal rate of return of Takeo District is 9.3%, and therefore there is a possibility of construction execution. If the basin-wide canal is constructed in the future, the construction cost required for this canal should be allocated to both fields of agriculture and navigation.

CHAPTER K. FUTURE PLAN OF NAVIGATION (LOCK AND CANAL SYSTEM)

CHAPTER K. FUTURE PLAN OF NAVIGATION (LOCK AND CANAL SYSTEM)

K-1 Design Traffic Volume for Future Plan

The possible future traffic that will pass the Sambor dam and for which the future plan of navigation facilities shall be designed will mostly be composed of what result from industrial development and expansion of exports and imports when the Mekong should become navigable throughout from its mouth to Vientiane in Laos.

In an ECAFE report [1/] is presented an estimate of the possible future traffic flows that will result from the development of the Mekong Basin. Of those listed in the report, what might be expected to come to and pass the Sambor dam are shown in Table K-1.

Table K-1 Possible Traffic at Sambor Resulting from Industrial Development and Expansion of Exports and Imports

Item and Quantity of Traffic	Traffic Flow
Teak: 60,000 tons	From Laotian forests to seaport
Other Timber: 1,500,000 tons	From Laotian forests to seaport
Copper Concentrates: 10,000 tons	From Savannakhet to seaport
Ammonium Sulfate: 220,000 tons	From Savannakhet to seaport
Ammonium Sulfate: 300,000 tons	From Savannakhet to Cambodia and Vietnam
Dry Paper Pulp: 1,000,000 tons	From Khemarat to seaport
Soda Ash: 115,000 tons	From seaport to Khemarat
Coal: 590,000 tons	From seaport to Khemarat
Zinc and Lead: 10,000 tons	From Pakse to seaport
Aluminum: 45,000 tons	From Khone to seaport
Alumina: 90,000 tons	From seaport to Khone
Salt: 100,000 tons	From seaport to along the Mekong

The traffic listed in Table K-1 totals 4,040,000 tons a year, dividing into 3,145,000 tons of downstream traffic and 895,000 tons of upstream traffic. They are however, not the all items that constitute the future traffic at Sambor. As the Mekong would become navigable through its middle and lower reaches and the population, industries and economic activities would develop in these areas, the traffic of farm produce, construction materials and various goods that shall meet the population's daily needs will substantially increase.

Therefore, the volume of future traffic on which the future plan shall be based is set at 4,400,000 tons a year, an amount also estimated in the ECAFE report. Of these, 3,200,000 tons are assumed to move downstream and 1,200,000 tons, upstream.

As for the passenger traffic, 400,000 passengers a year are assumed, dividing them into halves in the downstream and upstream traffic.

K-2 Type and Size of Vessels

To handle a river traffic as large as 4,400,000 tons a year, it is generally economical and efficient to use large-sized vessels. But there are many cargoes for which small-sized vessels are rather suited, and part of timber will be carried by rafting. When these are excluded, the cargoes that shall be carried by large-sized vessels will amount to some 3,600,000 tons a year, of which 2,700,000 tons are to move downstream and 900,000 tons upstream.

Two kinds of large-sized vessels, ocean-going vessels and barge lines, seem suited for navigation on the Mekong. And after making studies on the size of these vessels with relation to the navigability of the river as well as the volume and kind of traffic, as stated in the following Appendix 1, it has been decided to consider the ocean-going vessel of 3,000-ton class and the barge line consisting of a 1,200-HP pusher tug and two 1,500-ton barges.

1/ *Development of Water Resources in the Lower Mekong Basin, Flood Control Series No. 12,* E/CN.11/457, ST/ECAFE/SER.F. 12, October 1957.

In order to know which of the tow kinds would be preferable and hence shall be based upon in designing the future plan facilities, a comparative study was made with respect to transport costs. The following are the gist of the study.

(1) Transport between Phnom Penh and Khemarat will cost $1.693 per ton by the ocean-going vessel as compared with $1.65 per ton by the barge.

(2) Most of the 3,600,000 tons of cargo that shall be carried by large-sized vessels will be those for foreign trade. Hence,when they are carried by barges, they must be transhipped at Phnom Penh or Kompong Cham to or from ocean-going vessels. Cost of transhipping and handling at Phnom Penh is estimated at $1.80 per ton. Therefore, a saving of $1.757 per ton will result from the use of the ocean-going vessel, the annual saving amounting to some $6.3 million.

(3) Navigation facilities to be built in the reach from the river mouth to Khemarat will cost about $60 million more for the ocean-going vessel than for the barge.

(4) Even if the increase in the interest of the construction cost is taken into account, the ocean-going vessel will still be more advantageous than the barge on account of the low transport cost.

From the above reasons, the ocean-going vessel of 3,000-ton class has been adopted as the vessel, for which locks and other construction in the future shall be designed.

It goes without saying that in addition to the ocean-going vessels there will come a large number of small-sized craft such as small barges, motorboats and naturally passenger cruisers as well as timber rafts as considered in the initial plan.

As stated above, the ocean-going vessel has been judged preferable to the barge. However, it will take a long period of time, possibly over half a century, before the future plan would be materialized. So, it is desired that the problem be reconsidered by studying and clarifying factors so far unknown or only roughly studied such as the kind and volume of the possible traffic, the river regime, and the geological and topographical features of the region upstream from Stung Treng.

K-3 Design Water Level

Although they are no more than rough estimates as the scale and operation plan of the dams proposed upstream from Sambor are yet to be definitely decided, the minimum discharge and the corresponding lowest water level of the Mekong that shall be expected at Kratie after the completion of these dams are given in Table K-2 as compared with those at present.

Table K-2 Minimum Discharge and Lowest Water Level at Kratie

Time	In Drought Year		In High Water Year	
	Minimum Discharge	Lowest Water Level	Minimum Discharge	Lowest Water Level
At present	1,250 a/	3.60 b/	2,000 a/	4.50 b/
After the completion of proposed dams	7,100	8.00	8,700	8.70

When estimated based on the results of the water level observation between Kratie and the Sambor dam site made by EPDC of Japan, 1/ the lowest water level at the site where the lower lock is to be built in the future plan will be 8.50 m above mean sea level after the completion of the upstream dams. Therefore, the design of lowest water level for the lower lock was set at EL 8.50 m, a rise of about 4.5 m from the present low water level.

Note: a/ In cubic meters per second. b/ In meters above mean sea level.

1/ *The First Progress Report on Investigations of the Sambor Project*, October 1963, and *The Second Progress Report on Investigations on the Sambor Project*, September 1964, OTCA, Tokyo, Japan.

Dredging will be planned based on the water levels that correspond to the estimated discharge of 7,100 cu.ms.

The maximum flood discharge ever recorded at Kratie in recent years was the 66,700 cu.ms of 1939. When computed from the past record, the 10,000-year probable flood discharge becomes 90,000 cu.ms. But, if it considered that the extraordinary flood discharge cited above would be moderated by the upstream dams in the future, a discharge of some 50,000 cu.ms may be considered as the probable flood discharge, and this has been taken as the design flood discharge for the future plan.

The water level at Sambor that corresponds to the above flood discharge is estimated at EL 20.00 m, and this has been taken as the design high water level of the future plan.

K-4 Outline of the Plan

(1) Location: As regards the location of the locks and other structures, three routes each on either bank were taken into consideration. They are routes Ⓓ, Ⓔ and Ⓕ on the right bank and routes Ⓖ, Ⓗ and Ⓘ on the left bank, shown in Fig. K-1. And after a comparative study, described in the following Appendix 1, in respect of geology, topography, construction work, navigability, effects on the surroundings, cost of construction and others, the route Ⓗ on the left bank has been selected and all the facilities have been planned on this route as shown in Fig. K-1.

(2) Principal Structures: Two ship locks will be built, one on the upper reach and one on the lower reach, connected with a 12 km canal. A movable weir will be built, one on the upper reach and one on the lower reach, totaling 22.2 km in length and three bridges will be built around the locks and the canal for the land traffic along and across the canal.

(3) Dredging of Navigation Course: Shallow places in the following sections shall be dredged to ensure a safe navigation course: from Kratie downstream to the Cambodian-Vietnamese border, between Kratie and Sambor, and around Stung Treng.

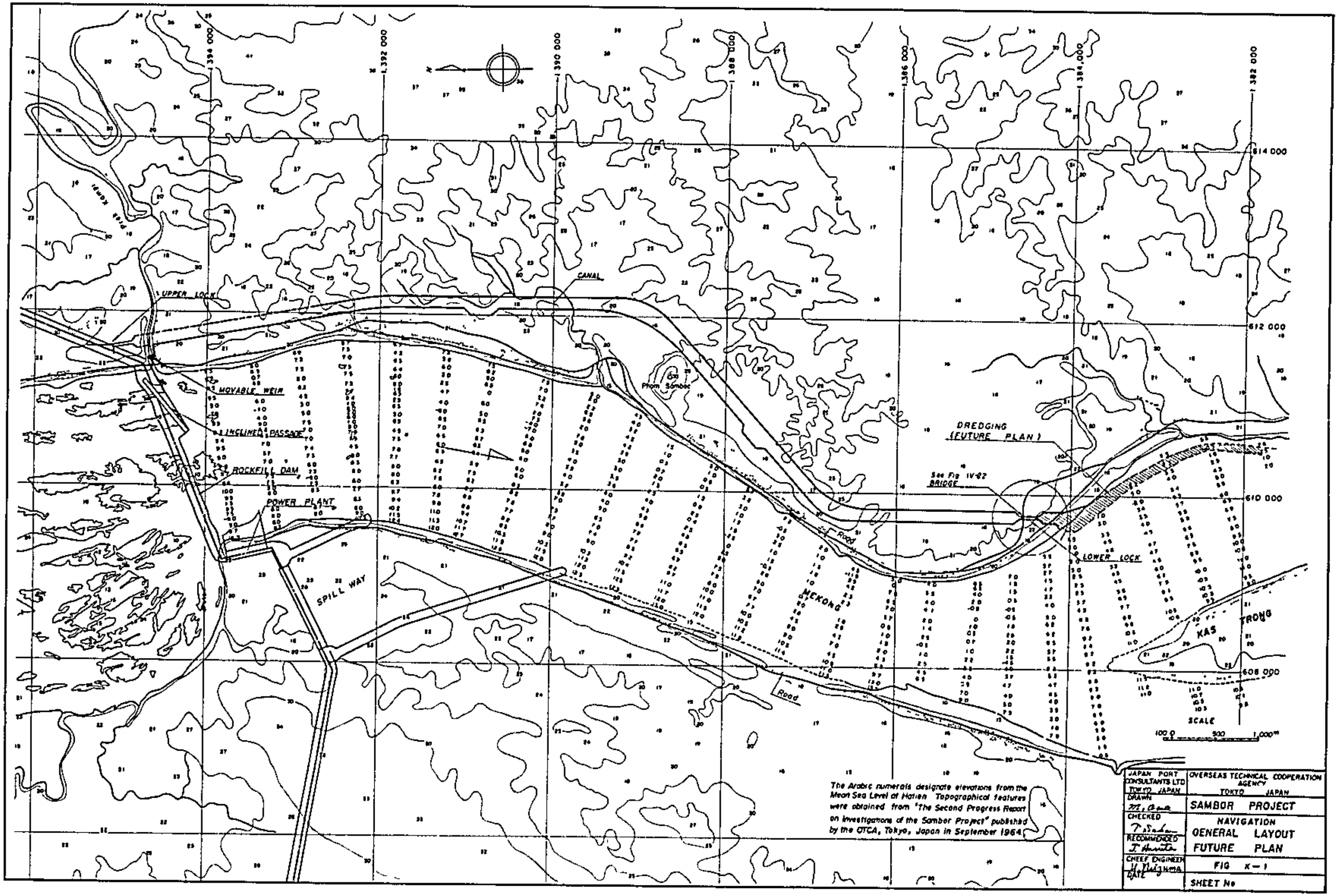
K-5 Upper Lock

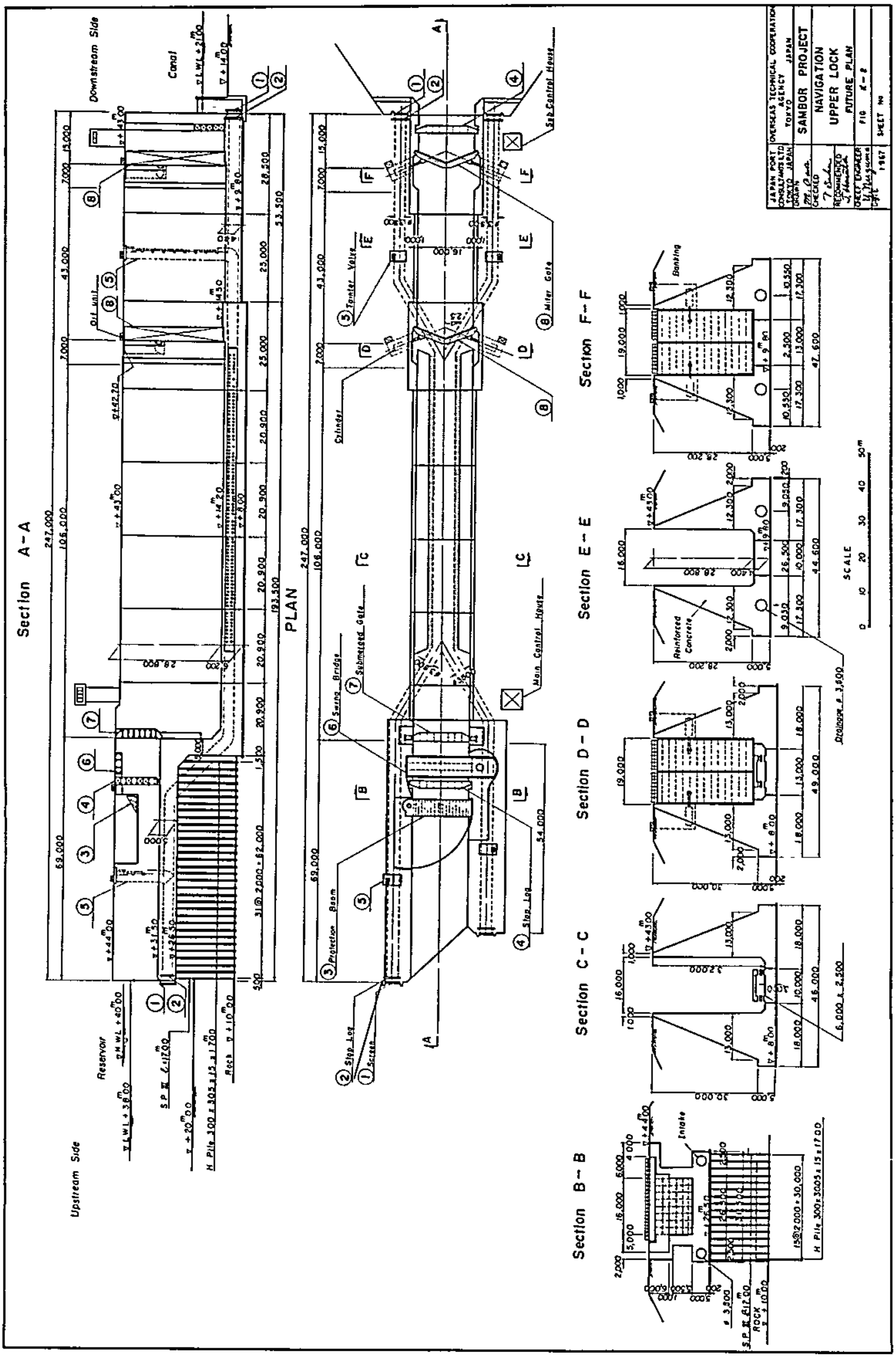
K-5-1 Location and Dimensions

Table K-3 Dimensions of Vessels to Pass the Lock (unit: m)

Vessel	Size	Length	Breadth	Draft
Freighter	3,000 tons	92.0	13.0	5.7
Cruiser	122 tons	32.5	6.6	2.75
Speedcraft	70 Passengers	20.0	7.5	2.7
Barge	150 tons	25.0	6.5	1.5
Timber Raft		100.0	12.0	2.0

The length of 150 m was so determined from the consideration that small-sized vessels such as fishery boats, motorboats and small tugs can be handled at the same time with a freighter or a timber raft when the traffic at the lock would become congested.


UPPER LOCK
MOVABLE WEIR
INCLINED PASSAGE
ROCKFILL DAM
POWER PLANT
SPILL WAY
CANAL
Phnom Sambor
DREDGING
(FUTURE PLAN)
See Fig IV-22
BRIDGE
Road
MEKONG
LOWER LOCK
KAS TRONG
SCALE
100 0 500 1,000m
The Arabic numerals designate elevations from the Mean Sea Level at Hatien. Topographical features were obtained from "The Second Progress Report on Investigations of the Sambor Project" published by the OTCA, Tokyo, Japan in September 1964.
JAPAN PORT CONSULTANTS LTD
TOKYO JAPAN
DRAWN
CHECKED
RECOMMENDED
CHIEF ENGINEER
DATE
OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO JAPAN
SAMBOR PROJECT
NAVIGATION
GENERAL LAYOUT
FUTURE PLAN
FIG K-1
SHEET No



Section A - A
PLAN
Section B - B
Section C - C
Section D - D
Section E - E
Section F - F
Upstream Side
Downstream Side
Reservoir
Canal
Main Control House
Sub Control House
Swing Bridge
Submerged Gate
Tainter Valve
Miter Gate
Protection Boom
Stop Log
Screen
Reinforced Concrete
SCALE
OVERSEAS TECHNICAL COOPERATION AGENCY TOKYO JAPAN
SAMBOR PROJECT
NAVIGATION
UPPER LOCK
FUTURE PLAN

K-5-2 Lock Chamber and Upper Head

The lock chamber with its upper head will be built of reinforced concrete. Its base shall be founded directly on the underlying firm bedrock. Side walls will be sided with earth embankments.

The chamber shall measure 16 m wide and 150 m long. The water level in the chamber will fluctuate between the elevations of EL 21.00 m and EL 40.00 m, and so the bottom surface and the gate sill are located at EL 14.20 m and EL 14.50 m, respectively, to maintain the planned minimum water depth of 6.5 m. The side-wall top will lie at EL 43.00 m.

As the bottom of the upper head, or the entrance, will be located at EL 31.50 m, or by 17.30 m higher than the chamber bottom, steel piles will be driven for its foundation to reach the firm bedrock layer. But at the waterside front of the foundation, steel sheet piles instead of steel piles shall be driven in order to prevent water seepage.

K-5-3 Gates

The lock chamber will be provided with a submerged lift gate and two miter gates.

The submerged lift gate is located at the upstream entrance. This type of gate was chosen with intent to minimize eventual damages from the collision of driftwood or incoming vessels and also as the sediments that would deposit on the channel bottom will be scoured off more easily than in the case of a miter gate.

One miter gate is located at the downstream end and another one at about 110 m from the upstream entrance. The latter will divide the lock chamber into two sections, one about 100 m long and the other about 50 m long. When only small-sized vessels are to be handled, instead of the full section of the chamber the 100 m section will be used in order to lessen the water consumption and also to shorten the handling time.

The gates will be made of steel. The submerged gate moves vertically guided by grooves built in the side walls. When lifted in position, its top will reach an elevation of EL 44.00 m.

The two leaves of the miter gates, when closed, will make an angle of 140 degrees. The top of the miter gates will be at EL 42.70 m.

K-5-4 Water Intake and Discharge

Two bellmouth-shaped water intakes will be built in the bottom of the upper head to let water flow in from the upper reach The water, flowing through two conduits of 3.5 m diameter, will stream out into the lock chamber horizontally from orifices set up distributedly in a 100 m section of the chamber bottom.

Tainter valves that shall be operated by oil pressure will be fitted up in the two intake conduits and in two discharge conduits, also 3.5 m diameter. When the intake valves are opened, the discharge valves having been closed, water will flow into the lock chamber, and if the intake valves are closed and then the discharge valves are opened, the water detained in the lock chamber will be discharged into the canal.

It will take about one minute to close or open the valve. The quantity of water that will be consumed in one operation is estimated at about 48,500 cu.m.

K-5-5 Accessories

A control house shall be built near the upper head and a sub-control house near the lower head.

Besides, the lock shall be provided with the following items: one rack screen each in front of the intakes and outlets of the conduits; one swing boom to guard the submerged gate; a protection chain at the lower head; stop-logs for use of repairing the lock gates or for eventual emergency; a truck-crane to handle the stop-logs or other items; six capstans; a drain pump, illumination, signals, communications systems and so forth.

K-6 Lower Lock

The lower lock is located on the left bank of the Mekong about 12 km downstream from the upper lock as shown in Fig. K-1.

It is essentially the same with the upper lock in its construction and in the way of its operation as shown in Fig. K-3. The lock chamber measure 16 m by 150 m. The bottom, gate sill and side-wall crest are located at elevations of EL 1.70 m, EL 2.00 m and EL 23.00 m, respectively, conforming to the canal water level of EL 21.00 m and the water level of the lower reach which will vary between EL 8.50 m and EL 20.00 m according to the season.

The lock chamber will be founded on a firm gravel ground underlain by bedrock. The upper head, or the entrance from the canal, will rest on foundation made by steel piles driven to reach the gravel layer. The bottom and side-wall crest will lie at EL 14.50 m and EL 24.00 m, respectively.

A submerged lift gate and two miter gates of the same construction will be installed at the same location as in the upper lock. The miter gate top will lie at EL 22.70 m and the top of the lift gate, when lifted in position, will reach EL 23.00 m.

The time required for filling or emptying the lock chamber varies according to the season. It is estimated at 7 minutes at the maximum.

The lower lock will be provided with the same accessories as the upper lock.

K-7 Canal

The canal that connects the upper and lower locks is located on the left bank of the river as shown in Fig. K-1 to conform to the topography and soil condition of the site as well as to various circumstances as considered in following Appendix I.

The channel water level is planned at EL 21.00 m, though it may rise by 1.5 m to EL 22.50 m in the high-water period. The channel bottom is planned at EL 14.00 m to maintain a water level of 7 m or more.

The channel shall measure 140 m wide at the surface and 80 m at the bottom. But where the channel turns in a curve, the radius of curvature shall not be less than 500 m and the channel must be widened. In the neighborhood of two densely populated hamlets, the channel will be widened to 170 m to provide bays for local traffic. And, near the upper and lower locks, there will be built lay-bays with a bottom width of 120 m. (Fig. K-4)

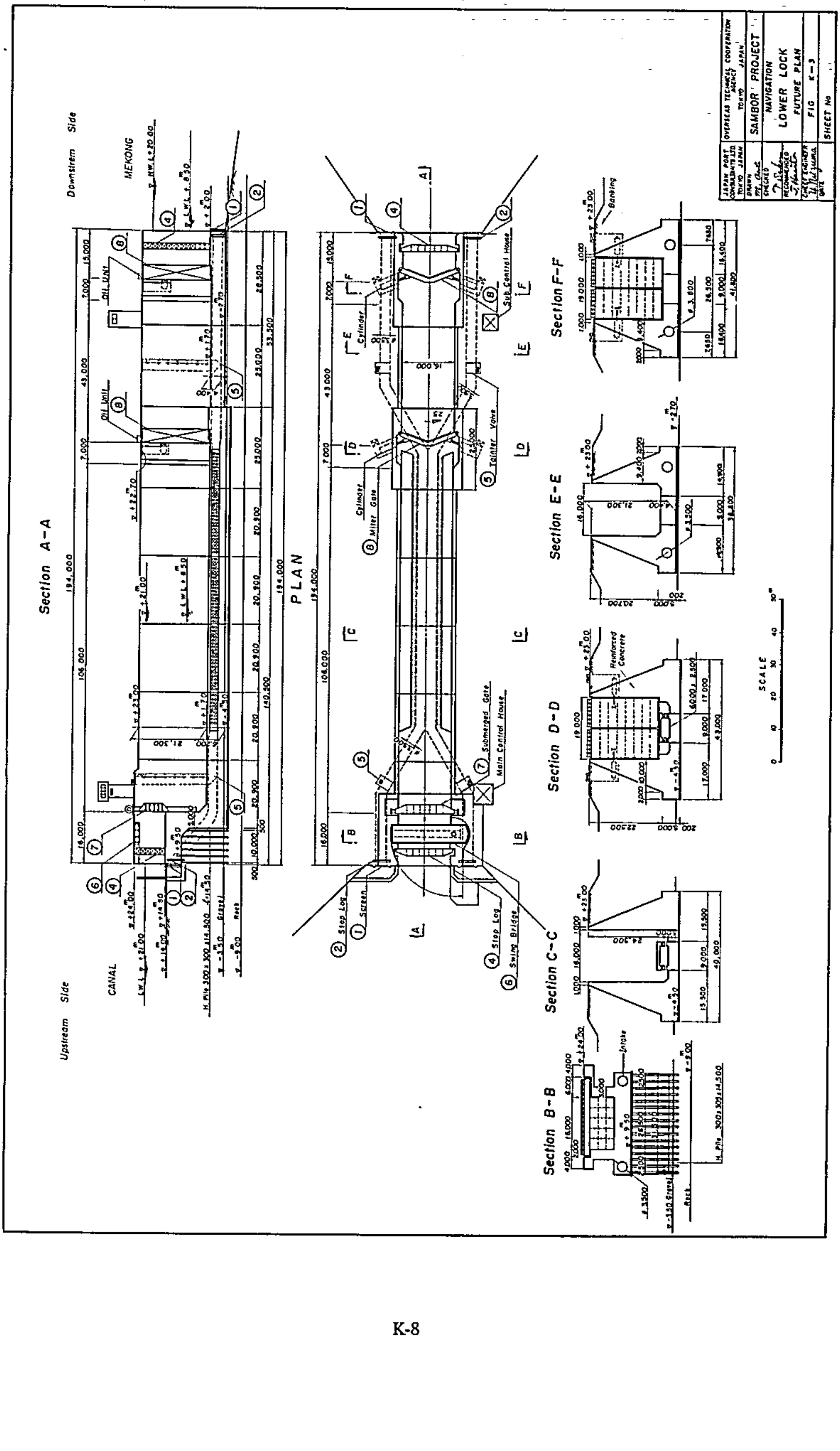
The soil of good quality, that will be obtained from the channel excavation will be utilized to build embankments on both sides of the channel, and spoils will be dumped on nearby swampy grounds to reclaim there. The bank crest will lie at EL 23.00 m and measures 8 m wide. The inner and outer slopes will be 2.5 to 1 and 2 to 1, respectively.

The side face of the channel will slope 4.3 to 1. It will be made continuous with the inner face of the embankment and will be pitched with stone from EL 19.00 m to EL 23.00 m to be guarded against waves that would be caused by passing vessels. The outer face of the embankment will be sodded.

K-8 Roads and Bridges

Atop each embankment will be built a 6 m wide paved road. Lighting will be installed along the roads, which will also illuminate the channel.

The upper heads of the upper and the lower lock will each be spanned by a swing bridge of steel plate-girder construction. The bridge will have a 6 m roadway and a total length of 26.1 m, measuring 24.64 m between centers of bearing. The leaf of the bridge will swing into position on one side wall when vessels will come to pass the lock.



Section A-A
PLAN
Section B-B
Section C-C
Section D-D
Section E-E
Section F-F
SCALE
Upstream Side
Downstream Side
CANAL
MEKONG
Oil Unit
Cylinder
Miter Gate
Tainter Valve
Sub Control House
Main Control House
Submerged Gate
Stop Log
Screen
Swing Bridge
Reinforced Concrete
Banking
Gravel
Rock
H. Pile 300 x 300 x 14,500
194,000
106,000
43,000
OVERSEAS TECHNICAL COOPERATION AGENCY TOKYO JAPAN
JAPAN PORT CONSULTANTS LTD. TOKYO JAPAN
SAMBOR PROJECT
NAVIGATION
LOWER LOCK
FUTURE PLAN
FIG K-3
SHEET No

As there are densely populated areas between Kratie and the dam sites, the completion of the dam and the lock will bring forth a great increase of local traffic such as those to and from the power station or for communication with vessels to pass the lock and motor traffic on the bank roads. On the other hand, the frequency of lock operation will also increase as the water traffic increases and the swing bridge will have become to be opened many times a day.

And, as it is considered that the swing bridges would not suffice for smoothly handling the increased local land traffic, a 1,365 m long viaduct is planned to cross the lower lock. The main bridge of this viaduct, which shall be built across the lower lock, will be a three-span continuous steel plate-girder bridge resting on reinforced concrete piers. It shall have a 6 m roadway and is 144.4 m in total length, dividing into a 55 m center span and two 44 m side spans.

A vertical clearance of 30 m is required for 3,000-ton vessels. Therefore, the girder bottom in the center span is set at EL 51.00 m, and consequently the roadway crown at midspan is set at EL 53.80 m.

From each end of the main bridge, the roadway runs at a grade of 3% over a 610.5 m viaduct and a 384.3 m access ramp, covering a total length of about 2 km. Each viaduct comprises 15 spans of 40-meter steel plate-girders simply supported on reinforced concrete piers. (Fig. K-4)

K-9 Movable Weir

The Prek Kampi that has a drainage area of about 915 sq. km crosses the canal and then flows into the Mekong in the neighborhood of the upper lock. In order to maintain the planned water level of the channel, a movable weir will be installed at an intermediate site between the existing Prek Kampi bridge and the junction of the river and the canal.

No reliable measurement has so far been made on the river's runoff and rainfall in its basin, and besides, little is known about the river regime. But, if estimated by the so-called rational formula, assuming probable values of the runoff coefficient and rainfall intensity, the peak runoff of the river becomes 732 cu.ms from which a runoff of 750 cu.ms has been adopted for designing the weir.

The weir will consist of two spans of roller gates. The weir pier and the service gangway will be of reinforced concrete construction.

The gates will remain closed at ordinary times, their crest lying at EL 21.00 m, the planned water level of the canal. But when a flood would come, the weir will be opened to discharge the flood water into the Mekong.

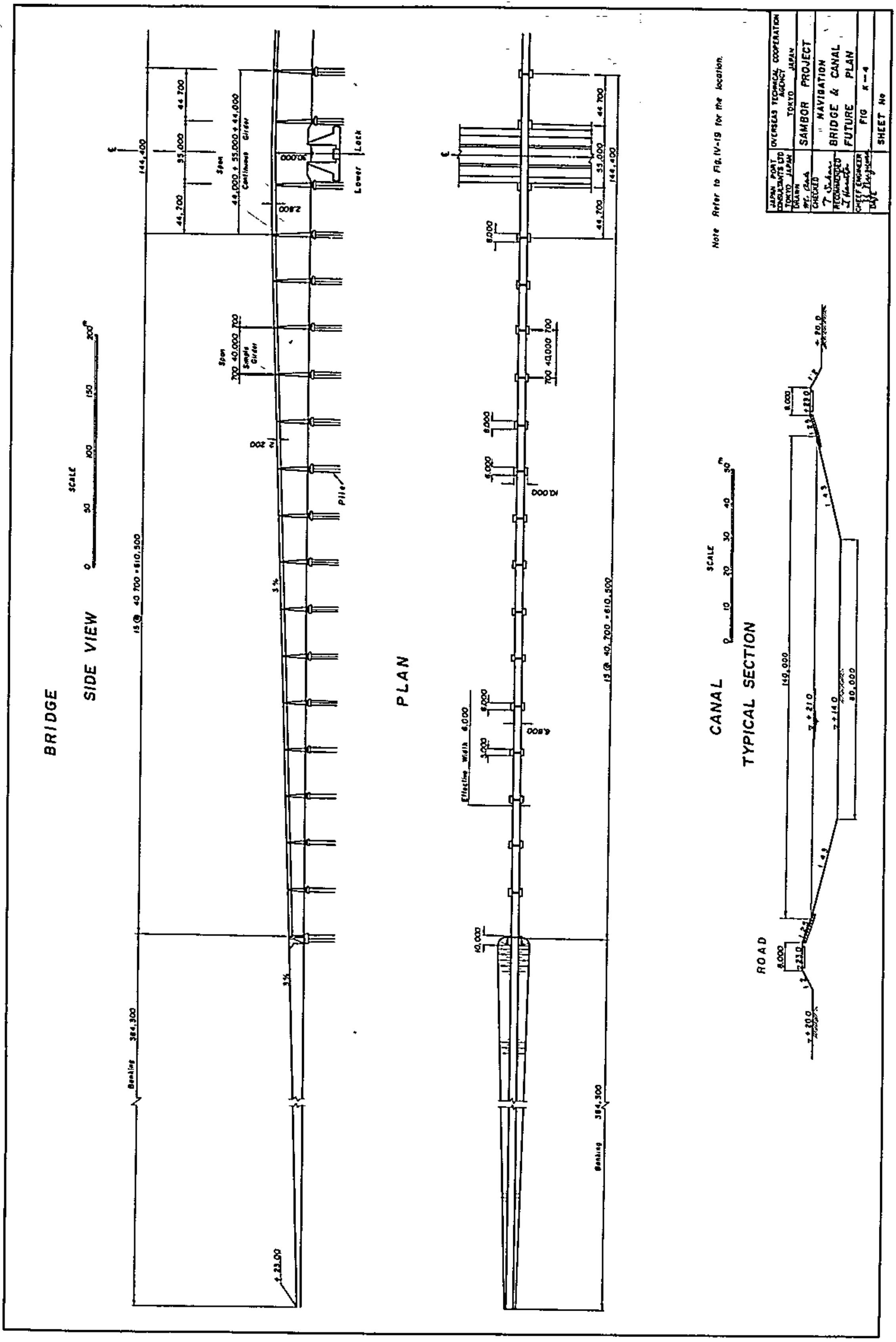
K-10 Dredging

For the navigation of 3,000-ton class vessels, a course of 150 m wide having a minimum depth of 7 m from the low water level shall be maintained. The dredging of the river bottom to materialize the above channel depth in the reach from Sambor downstream was studied based on the hydrographic chart of the reach from the Cambodian-Vietnamese border to Sambor prepared by the Royal Government of Cambodia, and the sounding chart around Stung Treng made by Mr. Dooleage sent by the United Nations.

After the completion of the Sambor Dam, the Mekong's water level will rise by about 4 m at Kratie and 3 m at Phnom Penh when the estimated minimum discharge at Sambor of 7,100 cu.ms is considered.

The dredging of the stretch between the border and Kratie was planned based on the above-noted water level rises. First, in the region downstream from Kompong Cham, no dredging is needed except for a dredging of a small quantity in the vicinity of Phnom Penh Port. As for the upstream reach from Kompong Cham, dredging is required around islands, Kas Toke, Kas Thmay and a shallow, lying about 10, 25, 50 and 70 km upstream from Kompong Cham, respectively. Also the shallow places in the vicinity of Chhlong and around Kas Cheeng about 10 km downstream from Kratie shall be dredged. The quantity of dredging is estimated at about 4,000,000 cu.m of sandy soil.

There is no need of dredging in the vicinity of Kratie. But there is a shallow near the downstream end of the lower lock as shown in Fig. K-1 where about 320,000 cu.m of sandy soil must be dredged.


BRIDGE
SIDE VIEW
PLAN
CANAL
TYPICAL SECTION
ROAD
Pile
Lower Lock
Continuous Girder
Simple Girder
Effective Width 6,000
13 @ 40,700 = 610,500
144,400
384,300
Note Refer to Fig. IV-19 for the location.
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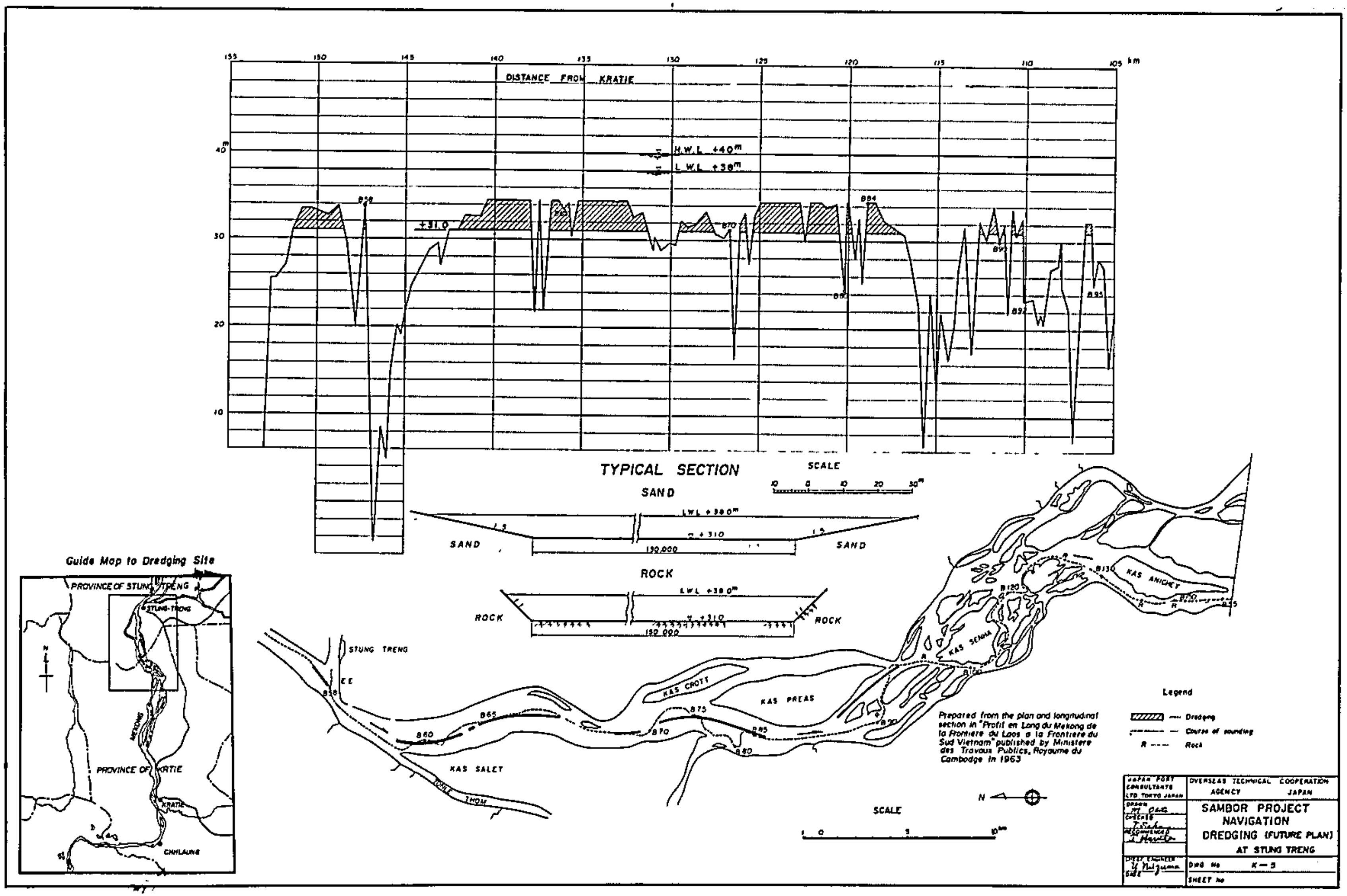
OVERSEAS TECHNICAL COOPERATION AGENCY TOKYO JAPAN
SAMBOR PROJECT
NAVIGATION BRIDGE & CANAL FUTURE PLAN
FIG K-4
SHEET No



DISTANCE FROM KRATIE
H.W.L +40m
L.W.L +30m
+31.0
TYPICAL SECTION
SAND
ROCK
SCALE
LWL +30.0m
150.000
Guide Map to Dredging Site
PROVINCE OF STUNG TRENG
PROVINCE OF KRATIE
MEKONG
KRATIE
CHHLAUNE
STUNG TRENG
KAS SALEY
KAS CROTT
KAS PREAS
KAS SENHA
KAS ANIGET
Prepared from the plan and longitudinal section in "Profil en Long du Mekong de la Frontiere du Laos a la Frontiere du Sud Vietnam" published by Ministere des Travaux Publics, Royaume du Cambodge in 1963
Legend
Dredging
Course of sounding
Rock
JAPAN PORT CONSULTANTS LTD TOKYO JAPAN
OVERSEAS TECHNICAL COOPERATION AGENCY JAPAN
SAMBOR PROJECT
NAVIGATION
DREDGING (FUTURE PLAN)
AT STUNG TRENG
DWG No K-5
SHEET No

The backwater of the dam will rise to an elevation of EL 38.00 m to EL 40.00 m, submerging many navigation obstacles. But there will still remain many rocky shallows that shall have to be dredged to a depth of EL 31.00 m, should the minimum water depth of 7 m be maintained.

According to Mr. Dooleage's survey, the river bottom must be dredged around Kas Salet and Kas Preas stretching from 5 km to 36 km downstream from Stung Treng as well as around Kas Senha, as shown in Fig. K-5. Judging from the topography, the former shallows will be of sandy soil and the latter of rock outcrops. The quantity of dredging in this section is estimated at 7,000,000 cu.m of sandy soil and 220,000 cu.m of rock.

K-11 Construction Costs of Future Plan

The costs of construction of the future plan have been estimated in the same way as of the initial plan. The direct or net costs of the locks, canal, movable weir, roads, bridges, dredging and other works are estimated to total $38.6 million. The estimated total cost including contingencies, engineering fees and others amounts to $48.05 million, dividing into $29.21 million in foreign currency and $18.84 million in local currency, as shown in Table K-4.

Table K-4 Construction Costs of the Future Plan (Unit: $1,000)

	Item	Total	In Foreign Currency	In Local Currency
1.	Direct Construction Cost	38,600	23,400	15,200
	Lock	19,800	12,000	7,800
	Canal	5,126	2,700	2,426
	Dredging	9,451	6,300	3,151
	Movable weir	1.400	820	580
	Bridge	2,020	1,300	720
	Road	450	180	270
	Others	353	100	253
2.	Contingencies	5,200	3,200	2,000
3.	Engineering Fee	2,125	1,305	820
4.	Other Expense	2,125	1,305	820
5.	Interest	3,150	1,890	1,260
	Grand Total	48,050	29,210	18,840

APPENDIX 1 TO CHAPTER K: LOCATION OF FUTURE PLAN PROJECT

1-1 General Remarks

As reasoned in Paragraph K-4 the Sambor Dam shall be provided with two locks, upper and lower, connected with a canal for navigation of large-sized vessels, if in the future the through navigation on the Mekong from its estuary upstream to Laos should be materialized. It remains yet to decide on which side of the Mekong and in what location the facilities at Sambor shall be built.

In the following are described the comparative study and the conclusion made on the location of the facilities.

1-2 Envisaged Routes

Studied are the following six routes: Routes Ⓓ, Ⓔ and Ⓕ on the right bank and Routes Ⓖ Ⓗ and Ⓘ on the left bank, shown in Fig. V-11 of Vol. V.

a) Route Ⓓ : Located on the right bank of the Mekong, the canal runs along and west of the earth levee of the dam spillway. The locks will be built at both ends of the canal. Route Ⓓ will measure about 2.8 km in length, the shortest of the envisaged six routes.

b) Route Ⓔ : The canal passes the same route as Route Ⓓ in its upstream section of about 2 km, and then, making a southward turn, runs parallel to the river-bank road keeping a distance of 150 m to 200 m to the west. The end of the canal, where the lower lock shall be built, is located about 9 km downstream from the dam.

c) Route Ⓕ . Route Ⓕ is essentially similar to Route Ⓔ. It differs from Route Ⓔ in that it is located further westward, at a distance of about 650 m from the bankside road. The lower lock is located about 1.8 km downstream from that of Route Ⓔ. Route Ⓔ will measure about 9 km long.

d) Route Ⓖ : Route Ⓖ starts from the left bank end of the dam crest, runs southward nearly parallel to the left bank of the river at a distance of 400 m to 500 m, passes through a saddle at the eastern foot of Phnom Samboc, then, making a turn to the southwest, finally reaches the Mekong's bank at about 11 km from the dam. The total length of the canal will be about 11.5 km. The canal crosses the Prek Kampi at a site a little downstream from the upper lock, where the Prek Kampi will be dammed up to form an artificial lake. Excepting this site, the canal will be sided with levees.

e) Route Ⓗ : In Route Ⓖ, the canal shall pass a hill of EL 26.00 m at about 1.5 km south of Phnom Samboc. In order to bypass this hill, Route Ⓗ makes a detour toward the river bank. The lower lock will be located at the same site as in Route Ⓖ. The total length is estimated at about 12 km.

f) Route Ⓘ : This route deviates southeastward from Route Ⓖ at about 4.7 km from the head lock and joins the Mekong at about 1 km north of Phnom Samboc, Route Ⓘ measures about 6.2 km in length, the shortest of the three routes on the left bank.

1-3 Comparative Study of Envisaged Routes

A comparative study of the above six routes has been done by considering the following factors: soil conditions; relative difficulty in construction; safety of navigation; influence on neighboring areas; and construction costs.

1-3-1 Soil Conditions

Strata of gravel or sand of good quality or bedrock lying at a suitable depth are highly desirable for the foundation of locks for these grounds are capable of withstanding the huge loads of locks.

As for the construction of the canal, however, if rock outcrops or rock strata are to be excavated, it will be far from easy and hence will cost much. A surface layer of laterite is more suited for canal construction than a sandy soil, because laterite allows less water seepage and the work can be done dry. Laterite is preferable to sand also in maintaining the canal water because of its low permeability.

Rock outcrops in the river bed are most undesirable for dredging. Rock removal, and that in a swift and turbid current, not only is very difficult and costs much but also cannot be done exactly.

The geological features and soil properties in areas where the envisaged routes are located are already explained in detail in Vol. V, paragraph E-5.

In the right bank area of the Mekong, where the upper lock and the upstream section of the canal along the dam spillway in Route Ⓓ , Ⓔ or Ⓕ are located, bedrock lies very shallow from the ground. This bedrock will be a good foundation for the lock, but will make the canal construction require a large amount of cost.

In the vicinity of the river bank site where Route Ⓓ joins the river, rock lies in a depth suited for the canal construction, but it must be excavated to build the lower lock.

Along the downstream section of the canal in Route Ⓔ and Ⓕ , sandy soil covers the ground. It will require a little much cost and is not advantageous in maintaining the canal water level because of its high perviousness to water. Bedrock in these routes becomes deeper seated to the south. For instance, at the lower-lock site of Route Ⓔ, rock lies very deep and will make the foundation cost much.

The ground formation along Routes Ⓖ and Ⓗ on the left bank is shown in Fig. V-12 of Vol. V.

In the area where the upper lock and the upstream section of the canal of Routes Ⓖ, Ⓗ and Ⓘ are located, bedrock lies at a depth suitable for the lock construction, and although a small quantity of rock shall be excavated, the canal will be built without any difficulty, because the ground in this section consists mostly of firm laterite clay.

Along the middle section of the canal of Routes Ⓖ and Ⓗ bedrock stratum generally lies deep and the canal can be excavated easily. It lies, however, relatively shallow in the vicinity of the eastern side of Phnom Samboc and a hill some 1.7 km south of Phnom Samboc, and here some quantities of rock must be excavated for the lock construction. Therefore, Route Ⓗ bypasses the hill.

At the lower-lock site of Route Ⓘ, bedrock lies shallow and must be excavated.

The downstream parts of Routes Ⓖ and Ⓗ are located on the laterite clay ground suited for the canal. The lower lock is located, common to the two routes, at a site where bedrock lies at a feasible depth as compared with the counterpart that lies too deep on the right bank.

As most of the river bed to be dredged consists of sandy soil, there will be no problem in dredging. But, rock removal is needed in the vicinity of the lower lock of Routes Ⓓ and Ⓘ.

1-3-2 Safety of Navigation

The reach in the vicinity of and a 5 km stretch downstream from the outlet of the dam spillway call for a special attention in regard to navigation because of the rapid current during the high-water period.

No at-site measurement has so far been made on the current velocity in the stream center in the above stretches. But, a hydraulic model experiment made by the EPDC of Japan showed that it will be 3 m/sec to 4 m/sec knots at a discharge of 30,000 cu.ms. This corresponds to about 5 knots to 8 knots. Hence, it will become extremely difficult and dangerous for small craft such as fishery boats, small-sized cruisers and barges to sail against the rapid current during the high-water period.

One rule in navigation is to keep to the right. Accordingly, if Route Ⓓ would be adopted, ships that will come from downstream to enter the lock will be compelled to cross not only the stream center but also the discharge flow from the spillway, which will flow in a large and rapid current especially during the flood season. This is very dangerous for small vessels.

If Route Ⓔ or Route Ⓕ would be adopted, small vessels that will move between Kratie and the lock will take a course, instead of east of, west of Kas Treng for the sake of navigation safety. This course is longer and will take more time than the course from Kratie to the lower lock of Route Ⓖ or Route Ⓗ on the left bank.

Route Ⓘ on the left bank, like Route Ⓓ on the right bank, will compel vessels to sail against the swift current of the river which flows deviated towards the left bank. Moreover, according to the above cited experiment, a current with a velocity of about 4 m/sec will strike on the left bank near the lower-lock site of Route Ⓘ, when the river's runoff is 30,000 cu.ms. This means that vessels will have to sail to and from the lower lock of Route Ⓘ exposing their sides askew to the discharge current from the dam spillway.

1-3-3 Influence on neighboring areas

The construction of the locks and canal will inevitably exert various influences, favorable and unfavorable, upon the neighboring areas. Beyond question, unfavorable influence such as land expropriation, house removal, interruption of local traffic and so forth shall be minimized.

In this respect, Route Ⓓ and Route Ⓘ are the most preferable, and there is little to choose among the rest.

1-3-4 Construction

Geology, topography, soil conditions and transport facilities around the site generally affects the relative difficulty or easiness, and consequently the cost of construction. The relative difficulty of construction envisaged routes in respect to soil conditions has already been noted in subparagraph I-3-1.

When compared from the viewpoint of the transport facilities, the routes on the left bank are preferable, because on the left bank lies the city of Kratie with a relatively well-developed traffic network and so transport of construction materials and workers can be done more conveniently and facilities for repair of equipment and for others may be available.

Route Ⓓ and Route Ⓘ, though they are preferable in respect of their little influence on neighboring areas, are excluded from the consideration that they seem decidedly unfeasible from the viewpoint of navigation.

The costs of construction of the remaining four routes, i.e., Route Ⓔ and Route Ⓕ on the right bank and Route Ⓖ and Route Ⓗ on the left bank, have been estimated and listed in Table K-5. The estimates have been made separately for the project to handle ocean-going freighters and for the project to handle large-sized barges. As can be seen from the table, Route Ⓖ will cost the largest in both cases.

1-4 Selection of Project Route

Each of the envisaged routes has its own merits and demerits. They are resumed as follows:

(1) In respect of soil conditions, the left-bank routes are preferable.

(2) In respect of the easiness of construction, the left-bank routes are preferable.

(3) From the viewpoint of navigation, Route Ⓓ and Route Ⓘ seem decidedly unfeasible, because it is very difficult and involves danger for small boats to sail against the stream during the high-water season in order to reach the lock. As for the remaining four routes, those on the left bank present less difficulty to navigation than those on the right bank.

(4) In respect of influence on neighboring areas, there is little to choose among Routes ⒺⒻⒼ and Ⓗ But, if Route Ⓖ or Route Ⓗ is adopted, some land area will be submerged under the backwater of the movable weir that shall be built at a site where the canal crosses the Prek Kampi.

(5) Routes on the left bank measure in general a little longer than those on the right bank.

(6) Routes on the left bank cost a little more than those on the right bank, Route Ⓖ costing the largest. But the difference between the maximum and minimum amounts to only 2.1% to 2.5%, and there is no sizable difference among Routes Ⓔ, Ⓕ and Ⓗ .

From the above comparison and especially from the viewpoint of navigation, a vital factor of the project, it was first decided that the project route shall be located on the left bank, and then Route Ⓗ has been selected as the project route because of its relative easiness and low cost of construction.

Table K-5 Estimates of Construction Costs of the Future Plan Routes

(Unit: $1,000)

Item	Route Ⓔ	Route Ⓕ	Route Ⓖ	Route Ⓗ
Plan for Large-sized Barges	24,200	24,500	24,800	24,460
Lock	20,750	20,750	19,400	19,400
Canal	1,750	2,110	2,400	2,056
Movable weir	–	–	1,400	1,400
Dredging	670	476	476	476
Bridge	291	291	291	291
Roads	296	427	467	490
Others	443	446	366	353
Plan for Ocean-going Vessels	38,700	38,500	40,300	38,600
Lock	21,400	21,400	19,800	19,800
Canal	4,120	4,600	6,850	5,126
Movable Weir	–	–	1,400	1,400
Dredging	10,400	9,600	9,451	9,451
Bridge	2,020	2,020	2,020	2,020
Roads	280	390	430	450
Others	480	490	349	353

APPENDIX 2 TO CHAPTER K: OCEAN-GOING FREIGHTERS vs PUSHER BARGES

2-1 General Remarks

It is stated in paragraph K-2 that the use of large-sized vessels such as ocean-going freighters and large barges is recommendable for transport of large quantities of goods that will become to be carried on the Mekong in the future when the river would become navigable from its estuary through to Laos. And the future plan described in Chapter K has been planned for ocean-going vessels of 3,000 tons or so, based on the comparative study made on the ocean-going freighter vs the barge, as described in the following.

2-2 Ocean-going Freighters

In its reach downstream from Kompong Cham, the Mekong generally maintains a depth enough deep for navigation of large ocean-going vessels. But, as noted in Vol. V, subparagraph E-3-1, there extend shallows off the estuary and at present only vessels of 2,000 tons to 3,000 tons are making port at Phnom Penh or Kompong Cham, and that by taking advantage of the high tide.

It might be technically well feasible to dredge these shallows for the passage of vessels of 5,000 tons or more. But it will require a tremendous cost, and moreover, a huge amount of expense will have to be provided for perennial dredging to maintain the depth of the navigation course as the offshore region is destined to become shallow on account of silt deposit and drift sand.

Situations being as stated above, it was decided that the future plan shall be made based on 3,000-ton class freighters similar to what are now coming to Phnom Penh and Kompong Cham, and the study has been made based on the following size of the freighter.

Length: 90 m, breadth: 13 m, and draft: 5.7 m.

2-3 Barge Transport

Transport of goods by barges towed by a tug is used since olden times. Barge transport has in general the following advantages as compared with freighter transport.

(1) A fleet of barges and a tug costs less and requires less crew than a comparable freighter, and hence barge transport costs less than freighter transport.

(2) A barge fleet draws much less than a freighter of the same capacity. Consequently, a large saving in the cost of construction of navigation and wharf facilities will result.

(3) Any number of barges in a fleet can readily be broken off and moored to the river bank or levee for exchange of cargo, and that without loss of time to the tug.

On large rivers or inland waterways in the world, however, barges are now pushed, linked closely together. It is called a barge-line system in the United States, where frequently more than 20 barges are pushed by one pusher tug. Pushing, as opposed to towing, reduces crew requirements and eliminates the adverse current that will be produced under the barges by the propellers. Accordingly, barge pushing requires less power and increases sailing speed.

Barge pushing is now popular not only in the United States but also in Europe and the U.S.S.R.

The size of barges varies according to situations. On the Mekong, barges of 1,500 tons to 2,000 tons seem suitable. If so, the numbers of barges required for carrying some of main items of the possible future traffic listed in Table K-1 will become as shown in Table K-6.

Table K-6 Required Number of Barges for Carrying Possible Future Traffic on the Mekong

Traffic Item Annual Volume Traffic Section	Required Number of Barges			
	1,500-ton Barges		2,000-ton Barges	
	Per Year	Per Day	Per Year	Per Day
Dry Paper Pulp: 1,000,000 tons from Khemarat to seaport	667	1.8	500	1.4
Coal: 590,000 tons from seaport to Khemarat	393	1.1	295	0.8
Soda Ash: 115,000 tons from seaport to Khemarat	76.5	0.21	57.5	0.16
Ammonium Sulfate: 520,000 tons from Savannakhet downstream	347	0.95	260	0.7

As can be seen from the table, two 1,500-ton barges a day on the average will suffice for each item. Consequently, it has been decided that the further study shall be made based on a fleet composed of two 1,500-ton barges and a pusher. To push these two barges at a speed of 7 knots to 8 knots, or 3.6 m/sec to 4.1 m/sec, a 1,200-HP pusher will be required. The dimensions of the barge and pusher are assumed as shown in Table K-7.

Table K-7 Assumed Dimensions of Barge and Pusher

Vessel	Capacity	Dimensions in meters			
		Length	Breadth	Depth	Draft
Barge	1,500 tons	60.0	12.0	3.2	2.7
Pusher	1,200-HP	25.0	7.5	3.6	2.4

2-4 Transport Costs

(1) Base of Estimation

The transport costs of the two types of carriers are estimated and compared on the following bases.

a) The ocean-going freighter can carry 3,000 tons of cargo; the barge fleet is composed of two 1,500-ton barges and a 1,200-HP pusher tug.

b) Estimates shall be made of transport between Phnom Penh and Khemarat, a stretch of about 750 km. Khemarat has been selected because it is situated just midway between Kratie and Vientiane and so the transport between Phnom Penh and Khemarat will represent the average future transport from Phnom Penh to Kratie and farther upstream to Vientiane.

c) All transports are assumed for foreign trade. Cargoes on ocean-going freighters will be carried, without transhipment at Phnom Penh, directly to or from foreign ports. On the other hand, those on barges shall be transhipped at Phnom Penh to or from ocean-going vessels.

d) The initial costs, carrying capacities, sailing speeds, load coefficients of vessels and other items are assumed as listed in Table K-8.

(2) Cost of Freighter Transport

Estimates have been made as follows:

Duration of Average Round Trip:

Sailing time per round trip (2 x 750/21 = 71.4 hr.)	3 days
Time for cargo handling per round trip (4,000/1,000)	4 days
Time for port entry and clearance per round trip	0.7 days
Duration of average round trip	7.7 days
Number of round trips per year (365/7.7 = 47.4)	47 times

Operation Cost of Round Trip:	
Fuel cost (190 x 3 + 30 x 4.7)	$711
Lubrication and others (20 x 7.7)	$154
Crew wages (25 x 5,400/47)	$2,872
Subtotal	$3,737
Cost of Maintenance and Repair, per Round Trip: (0.06 x $715,000/47)	$913
Depreciation, per round trip: (0.9 x $715,000/15/47)	$912
Administration and incidentals, per round trip: (0.3 x $3,737)	$1,211
Total transport cost, per round trip	$6,773
Average transport cost, per ton ($6,773/4,000)	$1,693

(3) Cost of Barge Transport

Duration of Average Round Trip:	
Sailing time per round trip (2 x 750/14 = 107 hours)	4.5 days
Time for cargo handling per round trip (2 x 4,500/1,000)	9.0 days
Time for port entry and clearance per round trip	1.0 day
Duration of average round trip	14.5 days
Number of round trips per year (365/14.5)	25 times
Operation Cost of Round Trip:	
Fuel cost (160 x 4.5 + 25 x 10)	$970
Lubrication and others (15 x 14.5)	$218
Crew wages (15 x 3,000/25)	$1,800
Subtotal	$2,988
Transshipment at Phnom Penh, per Round Trip: (1.8 x 4,500)	$8,100
Cost of Maintenance and Repair, per Round Trip: (0.06 x $550,000/25)	$1,480
Depreciation, per Round Trip: (0.9 x $330,000/15 + 0.9 x $220,000/10) /25	$1,760
Administration and Incidentals, per Round Trip: (0.4 x 2,988)	$1,195
Total transport cost, per round trip:	$15,523
Average transport cost, per ton ($15,523/4,500 tons):	$3,450

(4) Annual Transport Cost

The possible future traffic that will be carried by large-sized vessels is estimated in paragraph K-2 at 3,600,000 tons a year. Then the annual transport cost to carry this amount of traffic becomes:

When transported by ocean-going freighters ($1.693 x 3,600,000 tons):	$6,095,000
When transported by barge fleets ($3.450 x 3,600,000 tons):	$12,420,000

2-5 Cost of Construction

The direct cost of construction of the navigation facilities is estimated at about $39 million for ocean-going freighters and about $25 million for large-sized barges (Table K-5 in Appendix 1).

The cost for providing a through navigation route from the river mouth upstream to Laos cannot be estimated, even roughly, due to the lack of detailed information about the river regime, topography and soil conditions in areas upstream from Stung Treng and also because the projects of the dams to be built in these regions are not yet been definitely established.

Table K-8 Bases of Estimation

I t e m	Ocean-going Freighter	Barge Fleet
Cost of vessel ($)	715,000	550,000 1/
Rated engine horse-power (HP)	2,000	1,200
Average sailing speed (knots)	11.5	7.5
Ditto (km per hour)	21	14
Carrying capacity (tons)	3,000	3,000
Downstream load, average (tons)	3,000 2/	3,000 2/
Upstream load, average (tons)	1,000 2/	1,500 2/
Total load per round trip (tons)	4,000	4,500
Average load coefficient (%)	66.7	75.0
Time for port entry and clearance per round trip (days)	0.7	1.0
Cargo loading or unloading (tons per day)	1,000	1,000
Transhipment cost at Phnom Penh (per ton)	....	1.8 3/
Fuel cost during navigation (per day)	190	160
Ditto for the rest of time (per day)	30	25
Cost of lubrication and others (per day)	20	15
Annual cost of maintenance and repair (per cent of the initial cost)	6.0	6.0
Number of crew	25	15
Average crew wage (per person, per year)	5,400	3,000
Administration expense (per cent of operation cost)	30.0	40.0
Period of depreciation (in years)	15	15 (tug) 10 (barge)
Residual value of vessel (per cent of initial cost)	10.0	10.0

Note: 1/ $110,000 per barge, $330,000 for one pusher.

2/ Assumed from paragraph K-1.

3/ Cargoes that arrive at Phnom Penh port carried by barges may be transhipped directly from the barge into ocean-going vessels, or they will be discharged on shore and afterwards loaded onto an ocean-going vessel. The latter case costs more than the former. But, the cost has been estimated at $1.80 per ton on the average. The same holds to cargoes that arrive carried by ocean-going vessels and are transhipped onto barges.

However, in order to make a comparison between the freighter and barge transports, a rough estimate of the costs of navigation facilities from the river mouth to Thakhek has been made based the cost of the future plan project, taking account of the water levels and the projected dam heights at the proposed dam sites in the reach.

The estimated cost amounts to about $196 million for ocean-going freighters and $136 million for barge fleets. If these costs shall be entirely repaid in a uniform yearly installment at an annual interest of 5% or 6% over a period of 20, 30 or 50 years, the annual repayment will amount to as listed in Table K-9.

However, in order to make a comparison between the freighter and barge transports, a rough estimate of the costs of navigation facilities from the river mouth to Thakhek has been made based the cost of the future plan project, taking account of the waterlevels and the projected dam heights at the proposed dam sites in the reach.

The estimated cost amounts to about $196 million for ocean-going freighters and $136 million for barge fleets. If these costs shall be entirely repaid in a uniform yearly installment at an annual interest of five or six per cent over a period of 20, 30 or 50 years, the annual repayment will amount to as listed in Table K-9.

Table K-9 Annual Repayment of Construction Cost

(Unit: $)

Period of Repayment	For 196,000,000 for Freighter Transport at Annual Interest of		For 136,000,000 for Barge Transport At Annual Interest of	
	5%	6%	5%	6%
20 Years	15,726,000	17,089,000	10,912,000	11,858,000
30 Years	12,750,000	14,235,000	8,847,000	9,878,000
50 Years	10,736,000	12,434,000	7,450,000	8,628,000

2-6 Selection of Carriers for the Future Plan

The total annual cost, i.e., the sum of the transport cost and the annual repayment, becomes for each case as shown in Table K-10.

Table K-10 Comparison of Total Annual Costs

(Unit: $)

Period of Repayment	Annual Interest	Freighter Transport	Barge Transport	Difference
20 Years	5%	21,821,000	23,332,000	1,511,000
	6%	23,184,000	24,278,000	1,094,000
30 Years	5%	18,845,000	21,267,000	2,422,000
	6%	20,330,000	22,298,000	1,968,000
50 Years	5%	16,831,000	19,870,000	3,039,000
	6%	18,529,000	21,048,000	2,519,000

As can be seen from the above table, though it will require more cost in construction, the project for the freighter transport is distinctly more economical than the project for the barge transport. Besides, the freighter transport has a decisive advantage of time saving. Consequently, it has been decided that the future plan of the navigation facilities at Sambor shall be planned for the ocean-going freighter.