SAMBOR PROJECT REPORT

Lower Mekong River Basin

Volume III

Dam and Hydroelectric Power

Supplementary Material to Volume I

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

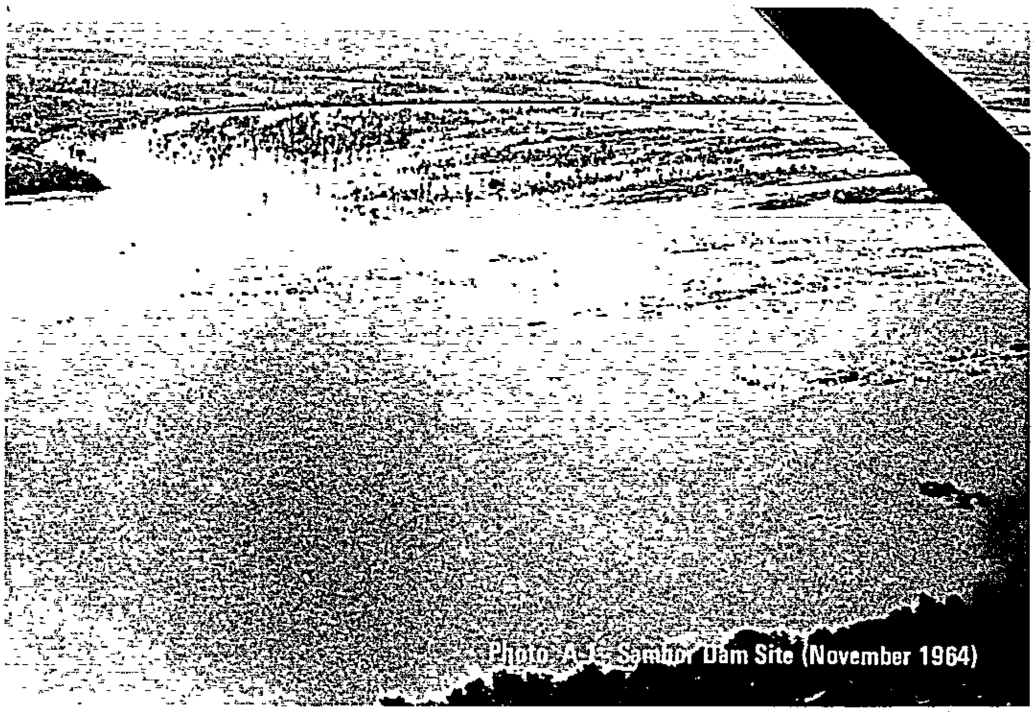


Photo. A-1 Sambor Dam Site (November 1964)

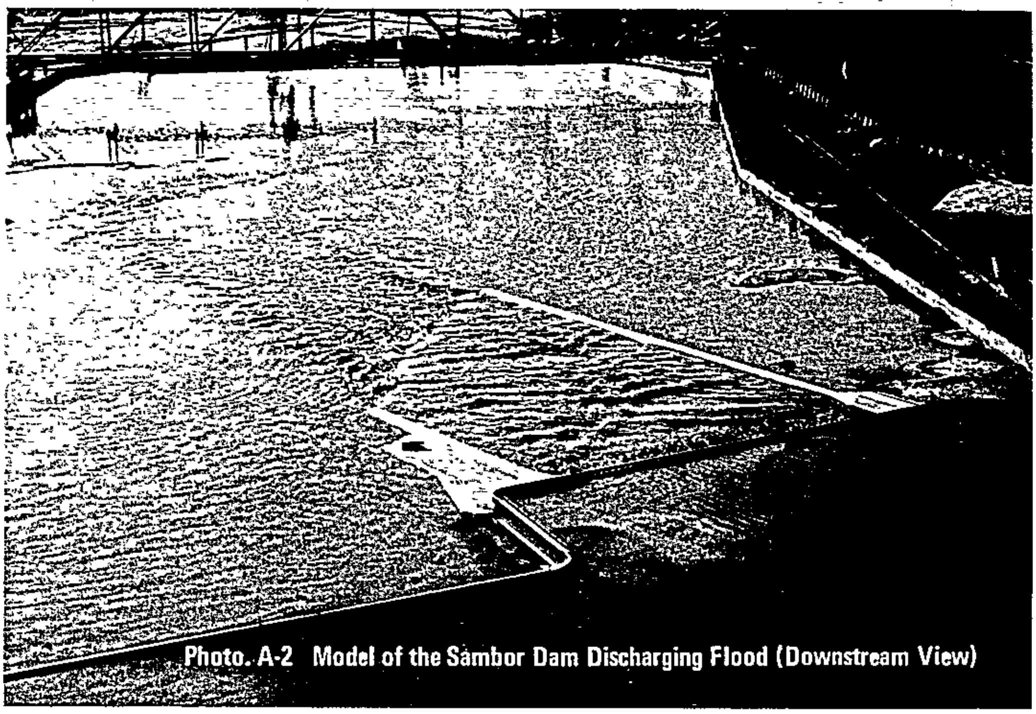
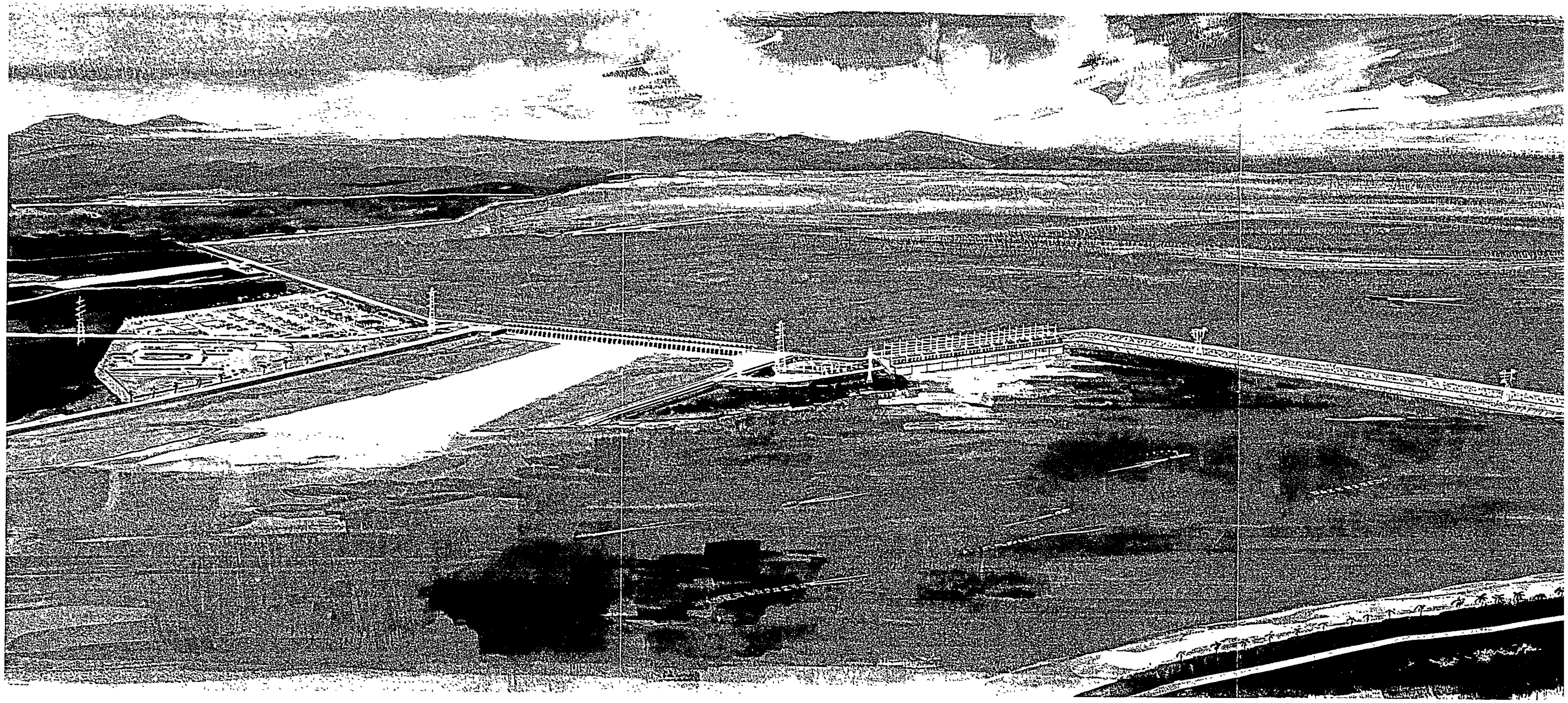
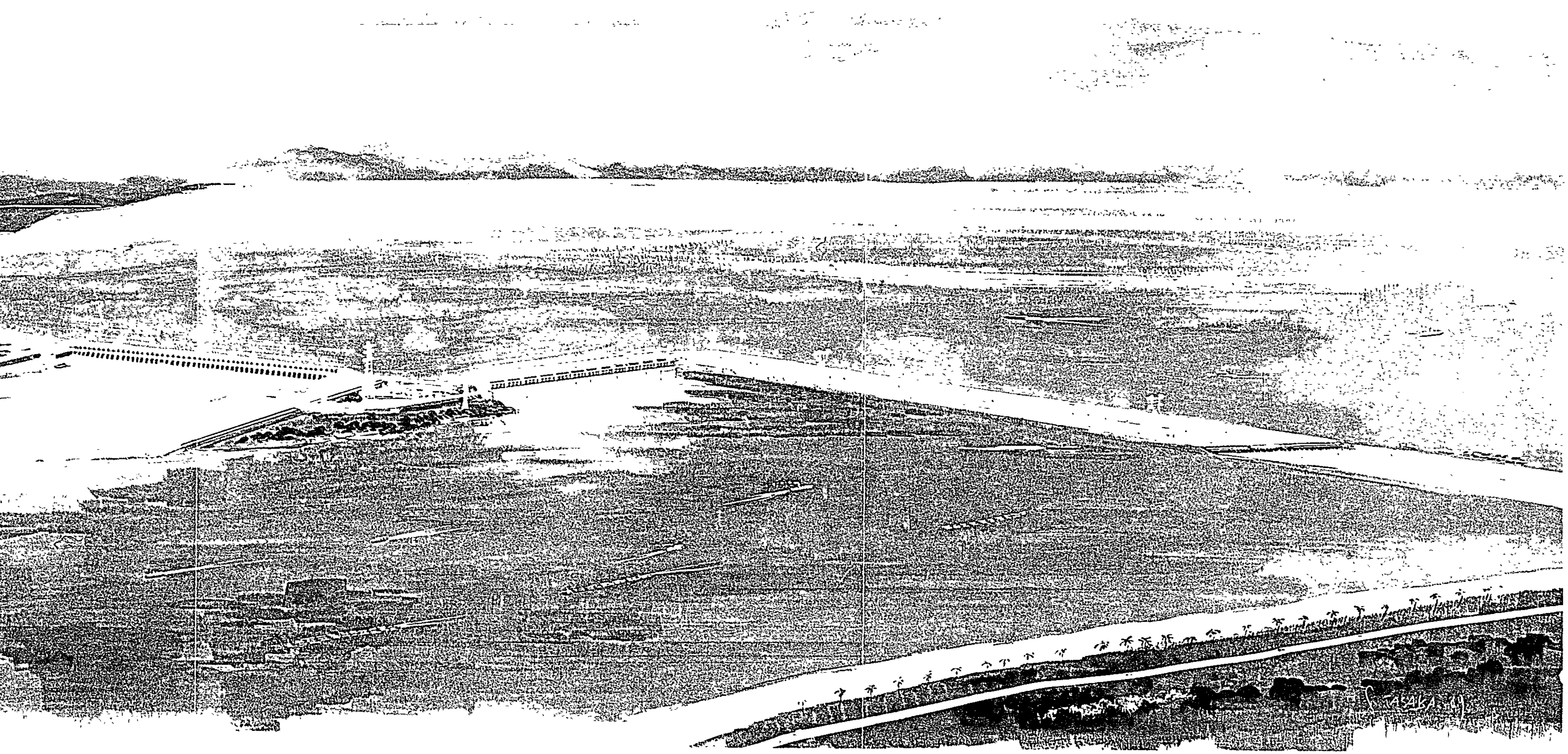


Photo. A-2 Model of the Sambor Dam Discharging Flood (Downstream View)



Aerial View of the Projected Sambor Dam



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JUNE 1969

CONTENTS

LIST OF FIGURES

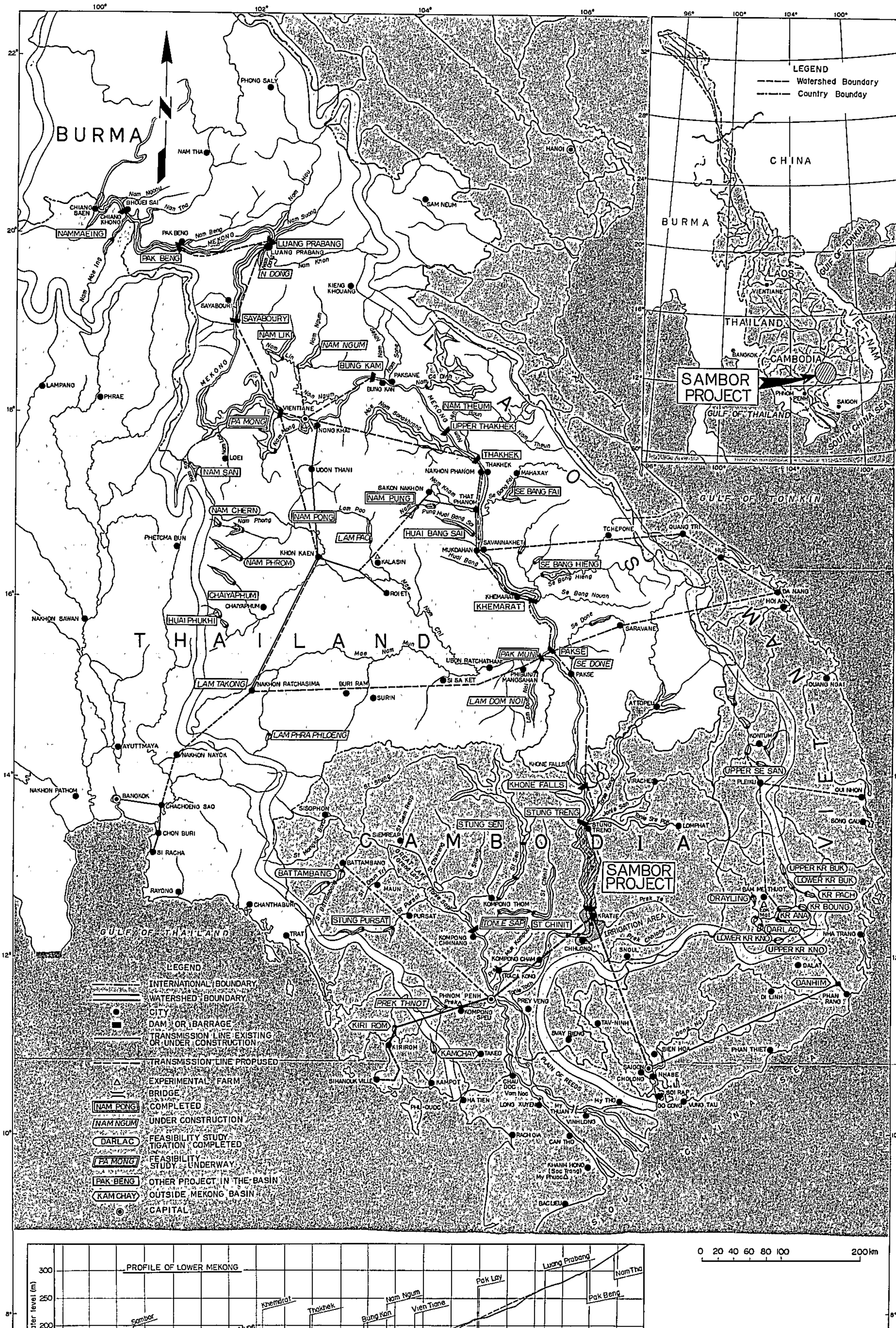
LIST OF DRAWINGS

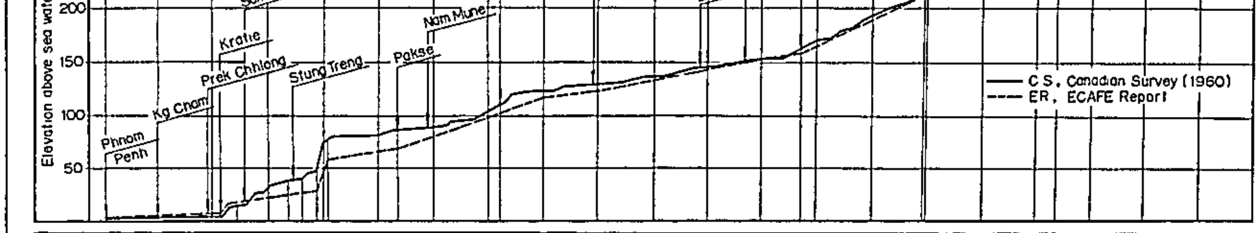
LIST OF TABLES

UNITS AND CONVERSIONS

mm	millimeter	kg	kilogram
cm	centimeter	ton	metric ton
m	meter	m/sec	meter per second
km	kilometer	kW	kilowatt
sq.mm	square millimeter	MW	megawatt
sq.cm	square centimeter	kV	kilovolt
sq.m	square meter	kVA	kilovolt-ampere
sq.km	square kilometer	kWh	kilowatt-hour
ha	hectare	mill	U.S. mill
cu.m	cubic meter	$	U.S. dollar
cu.ms	cubic meter per second	p.p.m.	parts per million
cu.ms/day	cubic meter per second per day	EL	the height above mean sea level
gr	gram	°C	centigrade

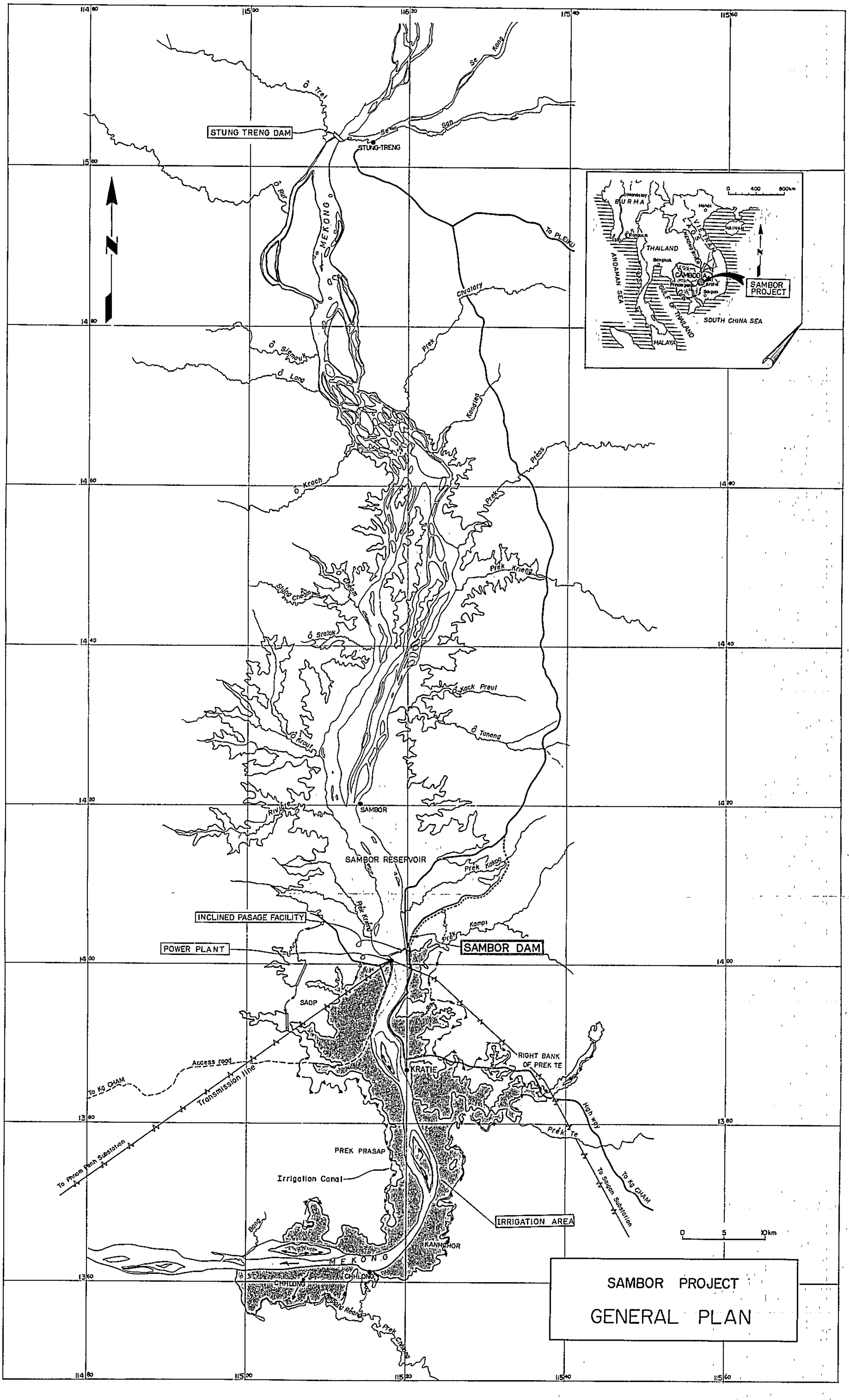
1 m	39.37 inches	3.2808 feet
1 km	0.6214 mile	3,280.8 feet
1 n.m.	(1 nautical mile)	1,852 m
1 sq.m	1.196 sq.yards	10.764 sq.feet
1 sq.km	100 hectares	247.1 acres
1 ha	10,000 sq.m	2,471 acres
1 cu.m	1,000 liters	35.31 cu.feet
1 kg	2.2046 pounds	
1 ton	1,000 kilogram	2,204.6 pounds
1 cu.ms	35.31 cu.ft/sec	
°C	5/9 (°F-32°)	





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

Key and Location Map


STUNG TRENG DAM
STUNG-TRENG
Se Kong
San
Ô Trel
Ô Rur
MEKONG
To PLEIKU
Chralary
Prek
Ô Siemouk
Ô Long
Kandieg
Preas
Ô Krach
Prek Krieng
Cham
Ô Sratok
Kack Preul
Ô Taneng
Ô Krout
SAMBOR
SAMBOR RESERVOIR
Prek Kakao
Kampi
INCLINED PASAGE FACILITY
POWER PLANT
SAMBOR DAM
SAOP
RIGHT BANK OF PREK TE
KRATIE
Access road
To Kg CHAM
Transmission line
To Phnom Penh Substation
High way
Prek Te
To Saigon Substation
PREK PRASAP
Irrigation Canal
IRRIGATION AREA
KANHCHOR
CHHLONG
Prek Chhlong
BURMA
THAILAND
ANDAMAN SEA
GULF OF THAILAND
CAMBODIA
SOUTH CHINA SEA
MALAYA
HAINAN
SAMBOR PROJECT
SAMBOR PROJECT
GENERAL PLAN

The Mekong in Cambodia

Photo. B-1 Inundation of Mekong Delta (March 1962)

Photo. B-2 Inundation in the Downstream Area of the Dam Site (March 1962)

Photo. B-3 Quatre Bras (Downstream View)

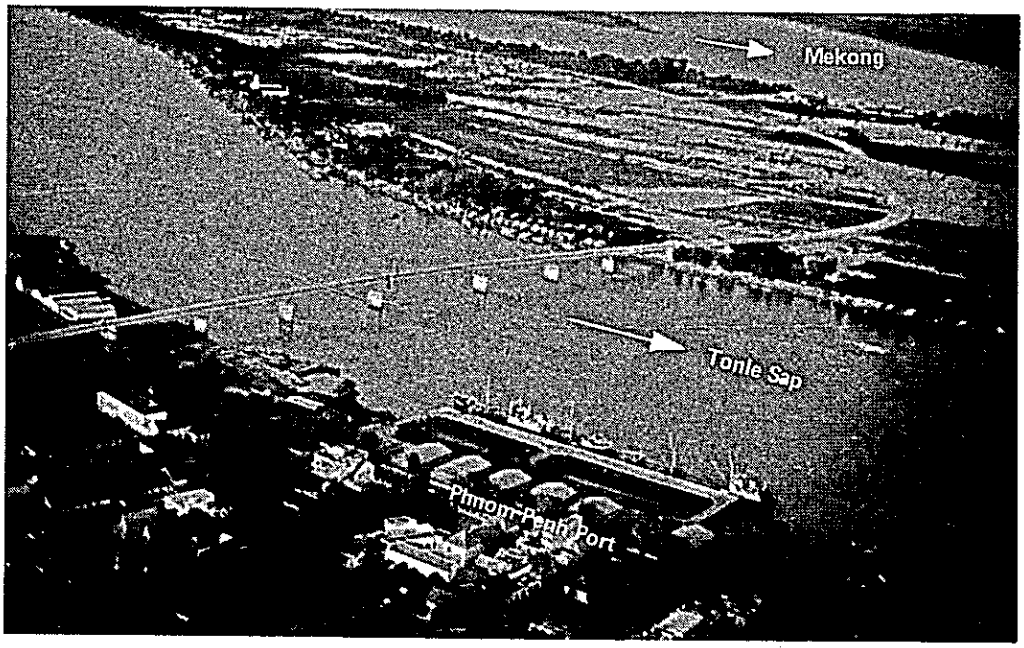


Photo. B-4 Mekong and Tonle Sap (Upstream View)

Photo. B-5 Island in front of Kratie (December 1964)

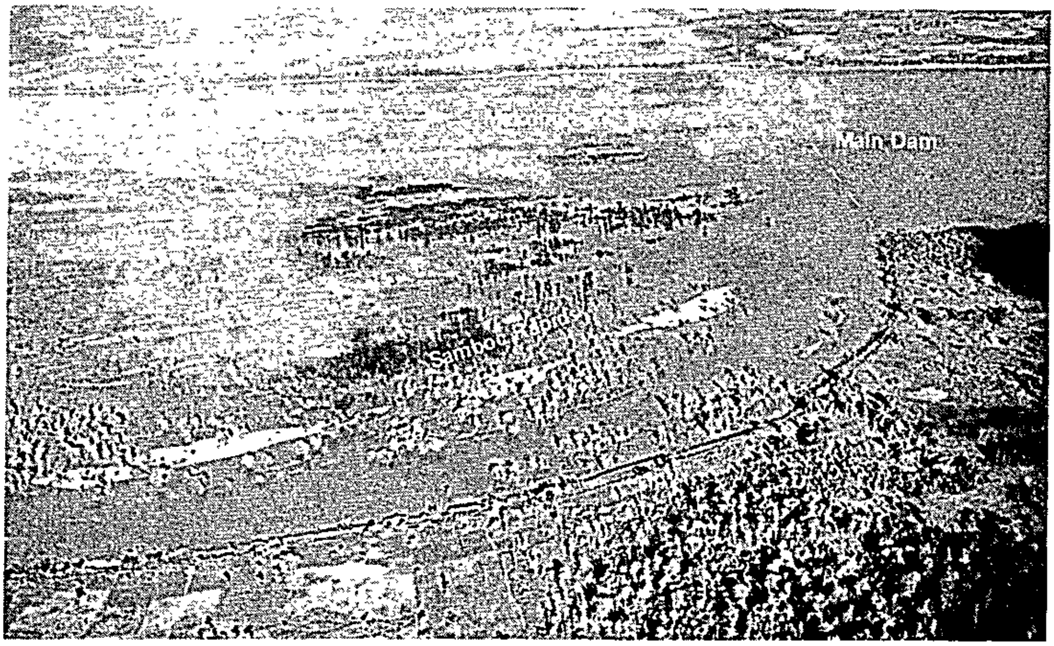


Photo. B-6 Sambor Dam Site (December 1964)

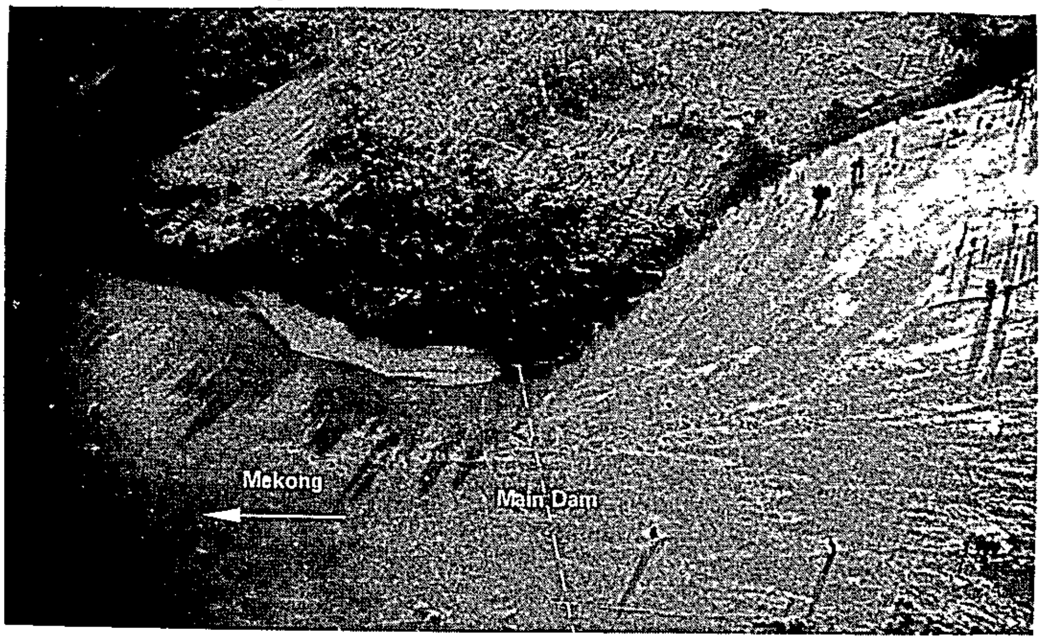


Photo. B-7 Right Bank of Sambor Dam Site (December 1964)

Photo. B-8 Samboc Rapids (December 1964)

Photo. B-9 Mekong between Sambor and Stung Treng

Photo. B-10 Mekong between Sambor and Stung Treng

Photo. B-11 Confluence of Mekong and Se San at Stung Treng

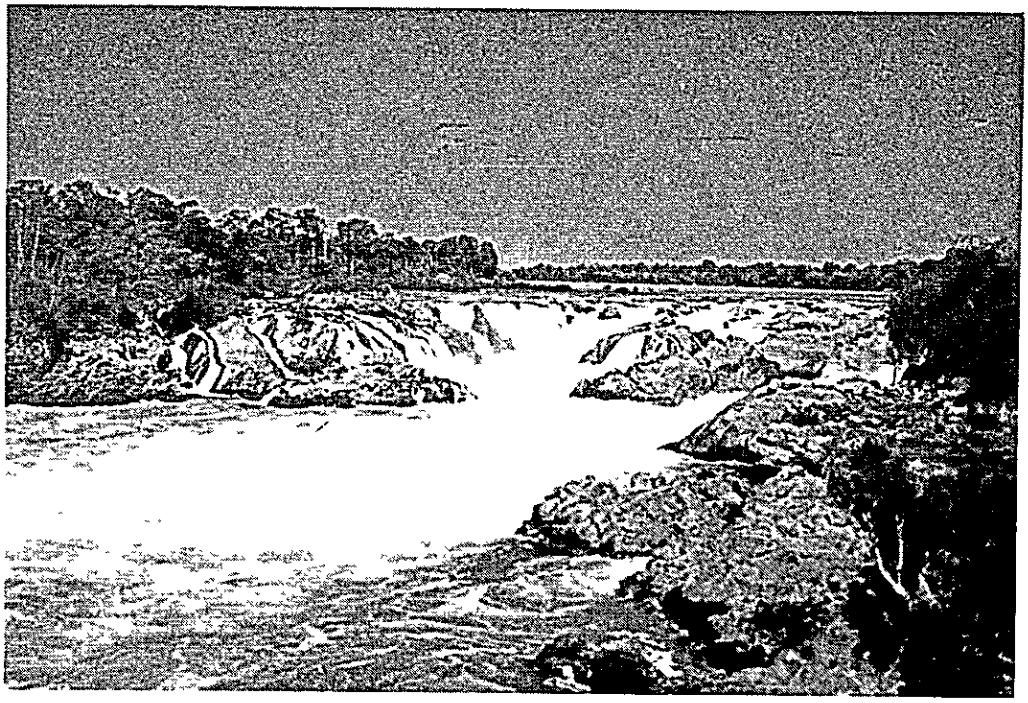


Photo. B-12 Part of the Kohn Falls (December 1964)

Dam and Hydroelectric Power

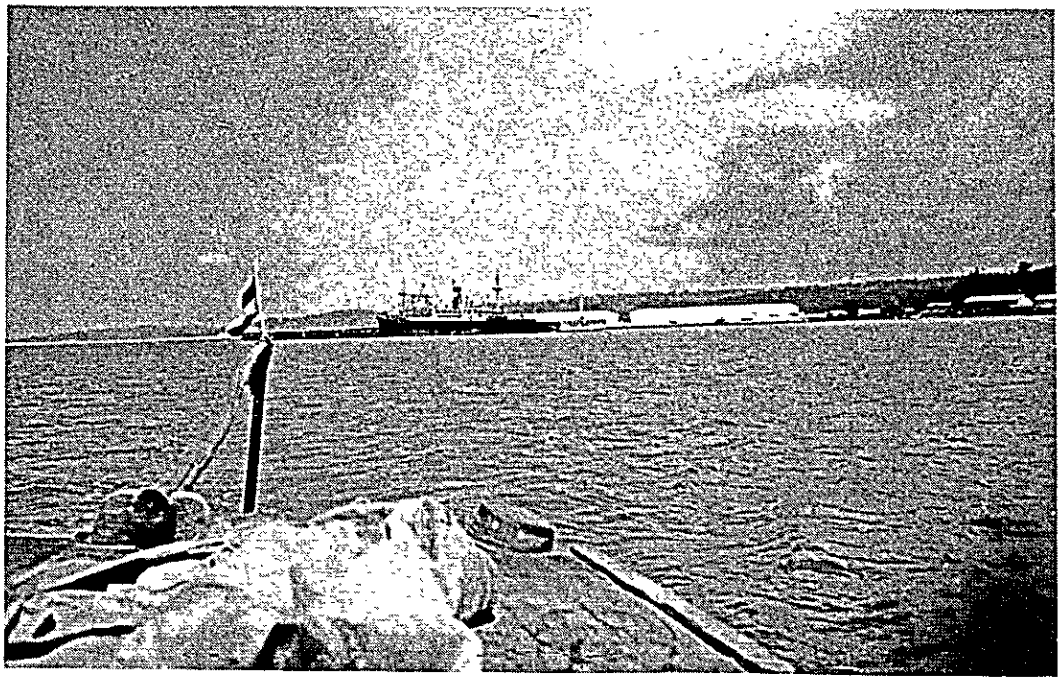


Photo. D-1 Port of Sihanouk Ville

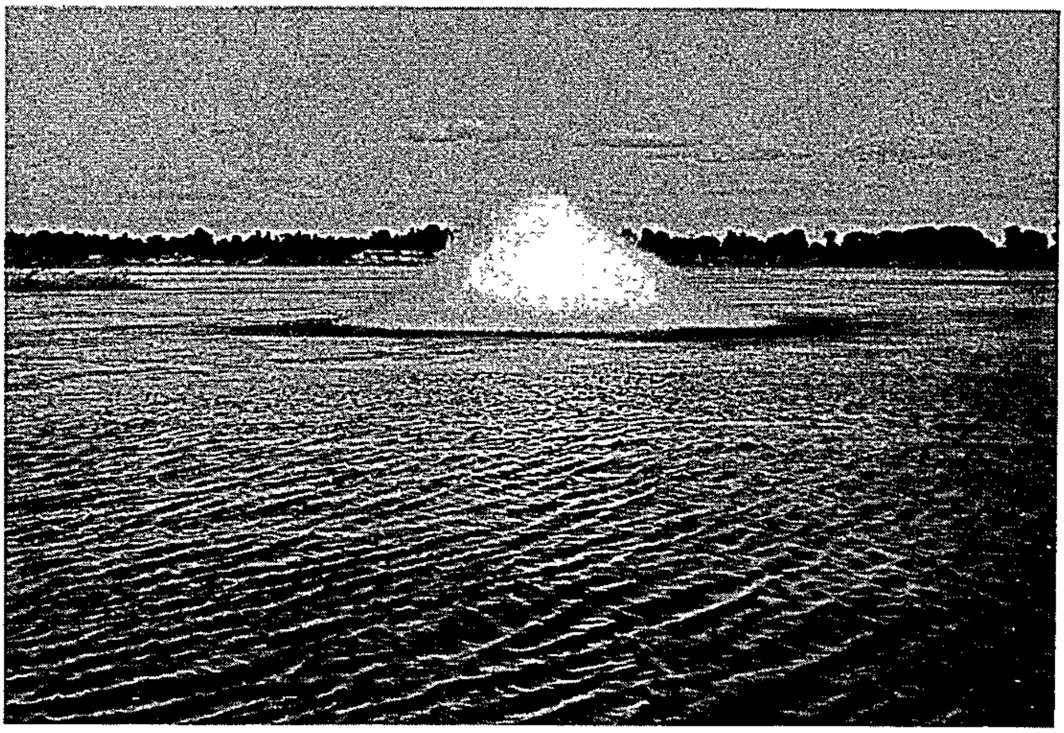


Photo. D-2 Sambor Dam Site, Seismic Survey

Photo. D-3 Sambor Dam Site (Downstream View) (March 1962)

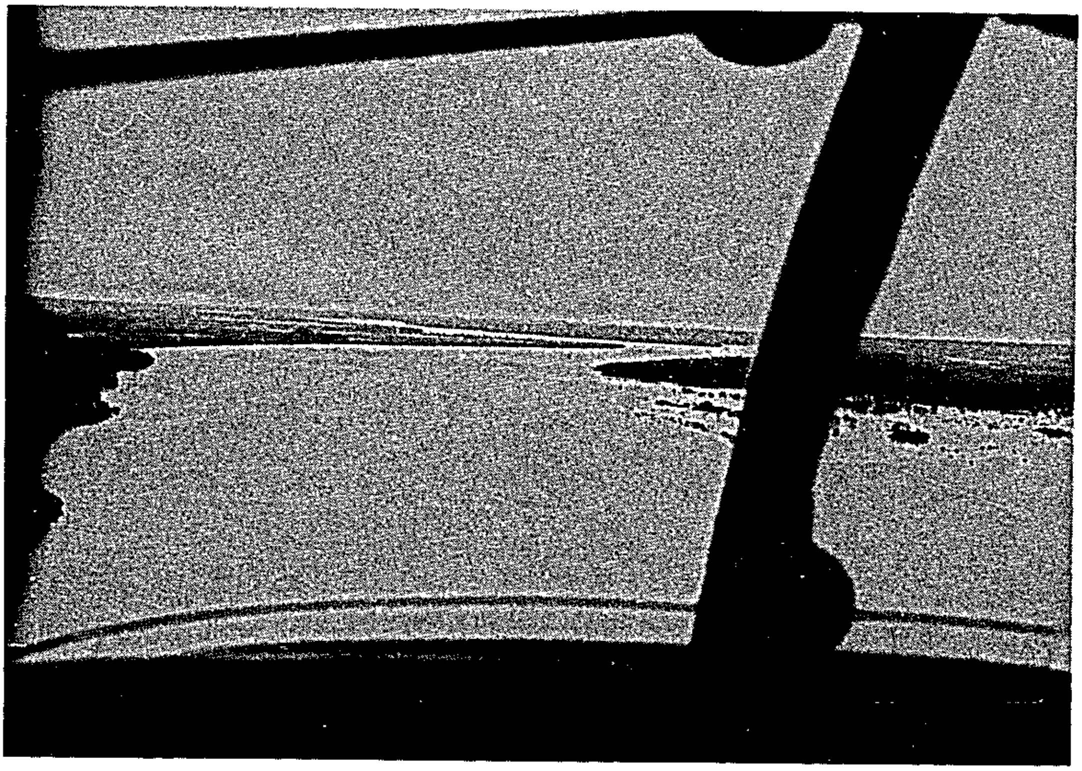


Photo. D-4 Sambor Dam Site (Downstream View) (September 1962)

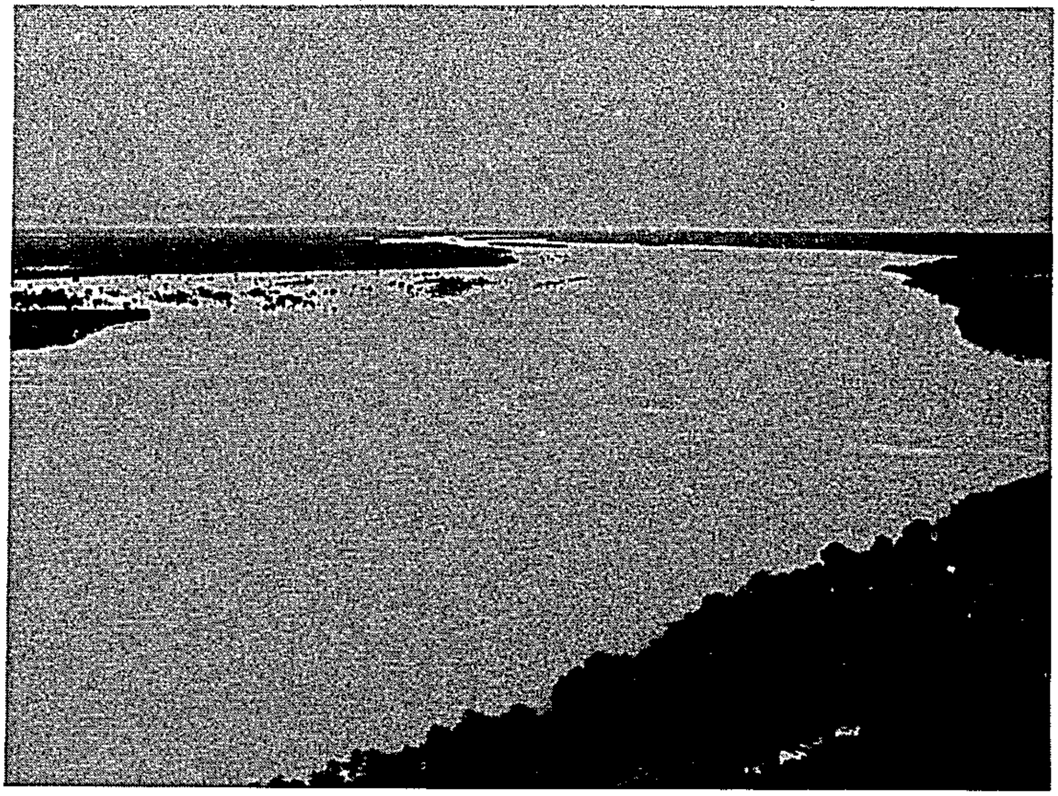


Photo. D-5 Sambor Dam Site (Upstream View) (September 1962)

Photo. D-6 Right Bank of Sambor Dam Site (March 1962)

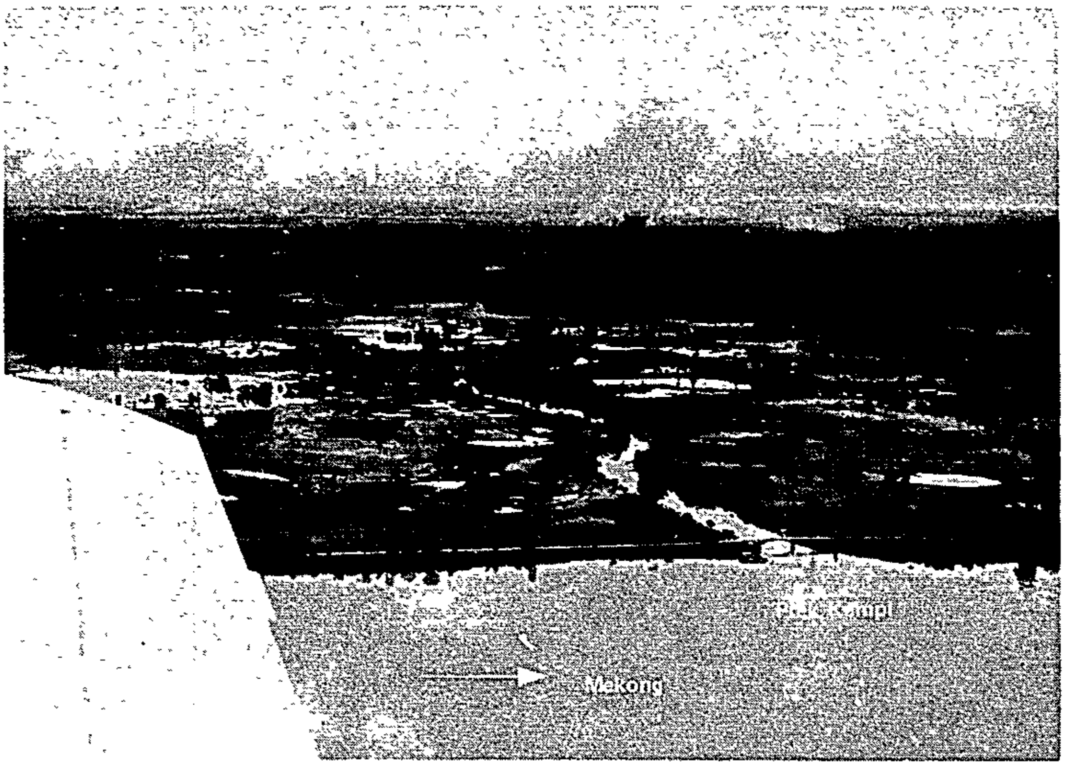


Photo. D-7 Prek Kampi at Left Bank

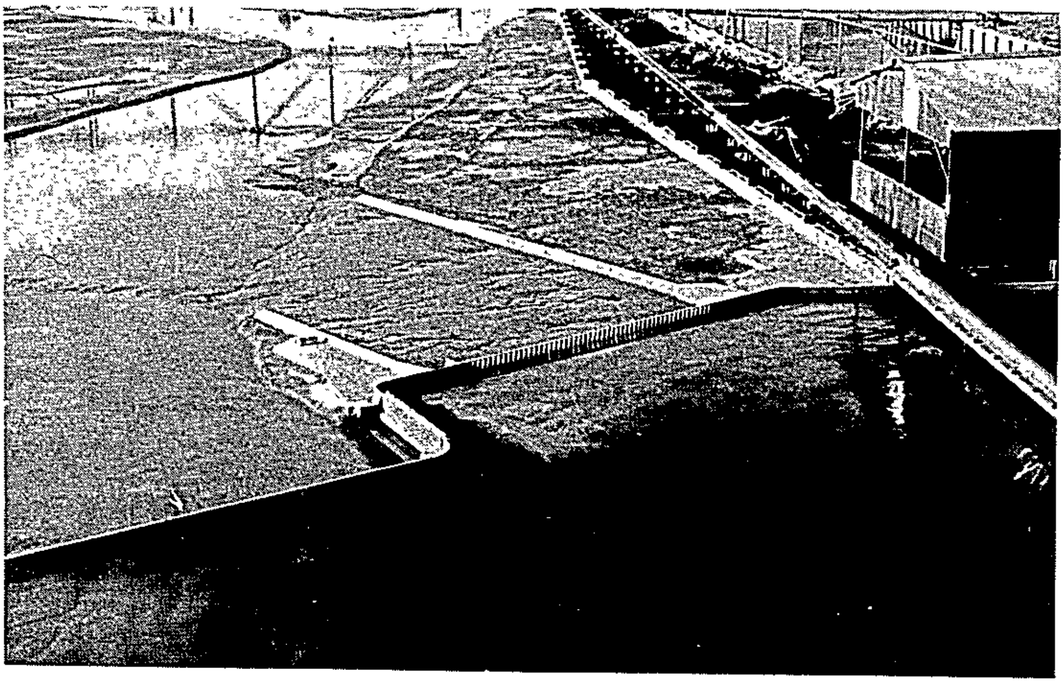


Photo. D-8 Model of the Sambor Dam showing Flood Discharge from Spillway (Downstream View) Q=10,000 cu.ms

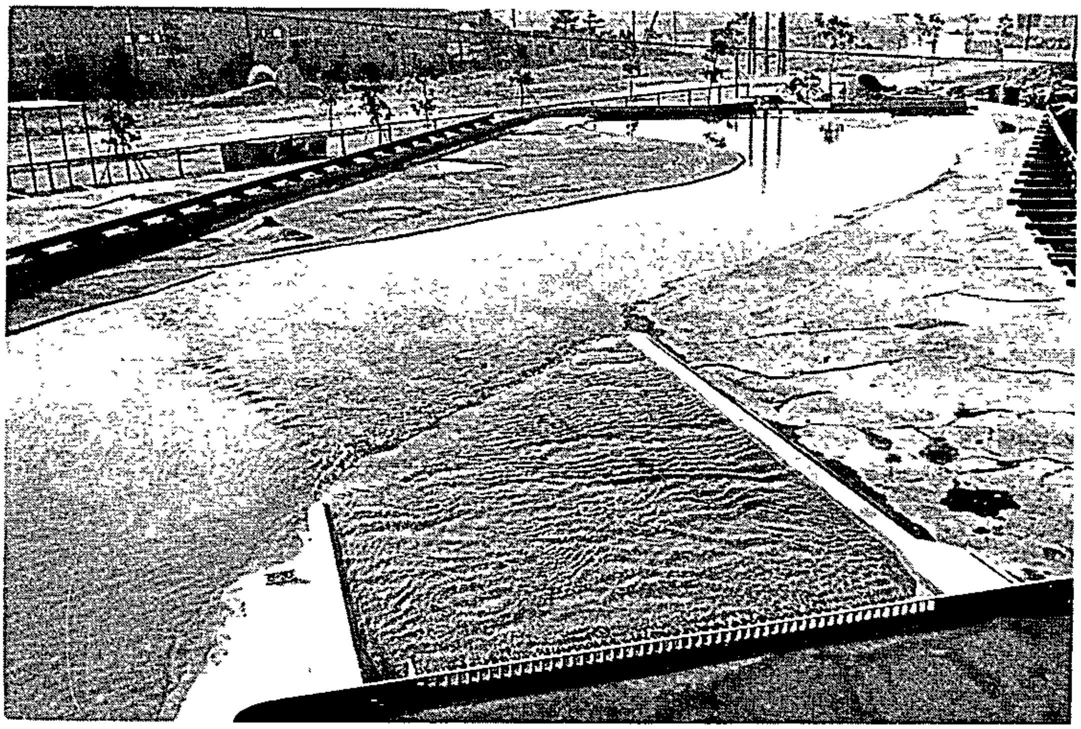


Photo. D-9 Model of the Sambor Dam showing Flood Discharge from Spillway
(Downstream View) Q=30,000 cu.ms

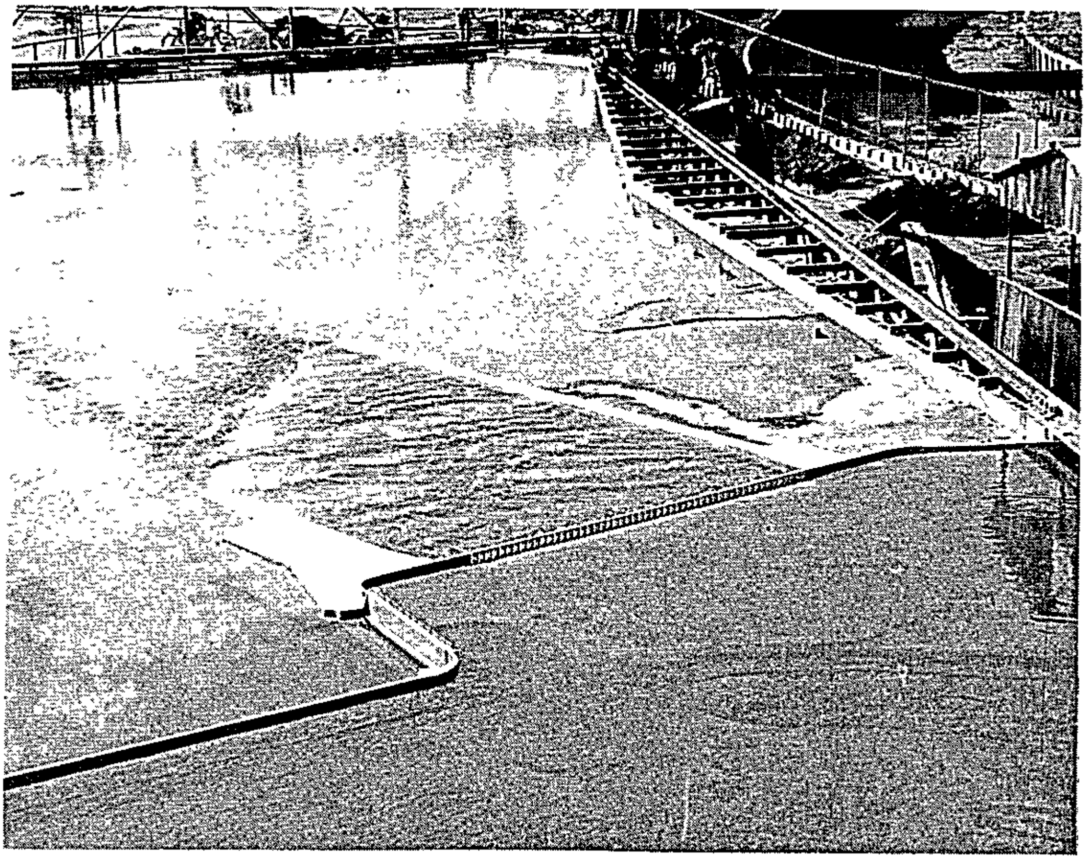


Photo. D-10 Model of the Sambor Dam showing Flood Discharge from Spillway
(Downstream View) Q=70,000 cu.ms

MAIN FEATURES OF THE PROJECT

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

A. Power and Dam Sector

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

Concrete	Refer Spillway and Power Plant

7. Spillway

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

8. Power Plant

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

9. Power Generation and Consumption Pattern

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

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

Type I
1) General Demand
2) Power-oriented Industries including Aluminum Refining

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

Type III
General Demand

10. Power Generation Facilities

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

11. Transformer

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

12. Transmission Line

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

13. Substation

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

14. Telecommunication Equipment

Powerline Carrier Telephone and VHF Radio Telephone

15. Construction Cost (excluding interest during construction)

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

in which

Foreign Currency	$236.6 million
Domestic Currency	$81.5 million

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

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

17. Economic Evaluation and Financial Analysis

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

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

CHAPTER A. CONCLUSIONS AND RECOMMENDATIONS

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A-1 Conclusions

The engineers of the Electric Power Development Co., Ltd. (hereinafter called EPDC) have studied existing information related to the Sambor Project prepared with the cooperation of the four riparian countries of the Mekong River, the member nations of the United Nations, Economic Commission for Asia and the Far East (hereinafter called ECAFE) and the Committee for the Coordination of Investigations of the Lower Mekong Basin (hereinafter called Mekong Committee), and as members of the Japanese Government Sambor Survey Team (hereinafter called Sambor Team), have taken part in several field investigations and collected much information and furthermore have discussed the project on several occasions with the Mekong Committee and officials concerned of the Government of Cambodia.

Based on the above, a study was made of the dam, power generation, transmission, transformation, and power market aspect of the Sambor Project.

(1) In the Lower Mekong Basin of Cambodia and Vietnam, due to the shortage of power supply capacity and the relatively high cost of electricity, there exists a considerable amount of unserved potential demand. Therefore, if low-cost and abundant power can be supplied, an immediate growth in load can be expected from the demand which until then had been restricted and from the rapid acceleration in industrialization.

Further, in this area, coupled with the consideration of the availability of raw materials, market for goods, site conditions of factories, labor force, etc., there is the possibility for development of power-oriented industries, chief among which would be aluminum refining industries.

(2) The installed power capacity of the Sambor Project, in order to rapidly consume the electricity available after completion of construction, was determined based on the condition that firm power will be consumed by general demand and aluminum refining industries, and secondary power by industries, (calcium carbide, caustic soda, vinyl chloride, ferro-silicon and silicon carbide), and further, with the consideration to prevent dry season runoff of mean hydro spilling of years: (consumption pattern referred to as Type I).

As the result, it was found that the optimum scale of development would be a reservoir with an effective storage capacity of 2,050 million cu.m and a power station with an installed capacity of 875 MW.

(3) Construction of the structures of the Sambor Project is technically feasible and there are no particular problems with respect to materials, foundation of structures and care of river.

The cost of the work is estimated to be 318 million Dollars of which 237 million Dollars will be required in foreign currency and 81 million Dollars in domestic currency. The construction period required will be eight years for the first stage consisting of the construction of the dam and power station with an initial installed capacity of 625 MW, and three years for the second stage in shich the power plant capacity will be increased by 250 MW.

(4) The electric energy available with this scale of development will be 4,100 million kWh of firm energy and 2,900 million kWh of secondary energy or a total of 7,000 million kWh annually under mean hydraulic condition. The internal rate of return is 4.4%.

Studies were also made of the case in which there would be no aluminum refining plant but firm energy is to be consumed by general demand and secondary energy by industries (caustic soda, vinyl chloride and calcium carbide), and the case in which only firm power would be consumed by general demand. Consumption pattern of the former is referred to as Type II, and that of the latter Type III. The internal rate of return is 5.3% in both cases.

For any of the above cases, if funds bearing interest slightly low than prevailing international money costs can be secured, the project would be feasible economically.

From the standpoint of expediting the economic development of Cambodia and Vietnam and of minimizing the fluctuation of water level in the downstream as much as possible, it will be most desirable to adopt a scheme of development which includes power-oriented industries with emphasis on aluminum refining.

The Sambor Project is situated at a favorable location for the development of the Lower Mekong Basin. Moreover, the scale of development is of a suitable magnitude and besides supplying a large quantity of electricity, the project will facilitate navigation between Sambor and Stung Treng and supply irrigation water to downstream cultivated land, and thereby enhance the economic and social development of the countries in the basin. Therefore, this project is considered as one which is worthy of early implementation. When the upstream Nam Ngum and Pa Mong Projects are constructed, the Sambor Project, as compared with an isolated development, will produce more power and energy at low-cost, and besides it will be possible to implement large-scale agricultural development in the Mekong Delta area by pumping up irrigation water, improve inland navigation through increase in dry season runoff and lessen saline damage in the delta area. It is believed that great economic development of the Lower Mekong Basin can be anticipated.

A-2 Recommendations

Based on the above conclusions, the following recommendations are made:

(1) Should it be possible to raise funds at interest rates relatively lower than the prevailing cost on international money market and to attract new large-scale industries including aluminum refining, the Sambor Project besides meeting the general demand for power and producing other beneficial effects will open the way for a vast development of Cambodia and Vietnam, and therefore, the early implementation of the project is desirable, even as an isolated project.

(2) In this report, the various studies made have been based on the assumption that the electricity produced by the project would be consumed from 1978, the tenth year after presentation of this report, and in order to meet this schedule, it will be necessary to proceed with the raising of funds and other preparations with a target of starting construction in 1970.

(3) For the early implementation of this project, the introduction of power-oriented industries is considered to be a vital condition, and therefore, detailed investigations and studies of this field must be urgently conducted.

(4) The Pa Mong Project will greatly influence the downstream area. Therefore, as soon as the plan of the Pa Mong Project becomes more definite, the power generation plan of Sambor is to be re-examined in relation to the Pa Mong Project.

Furthermore, the agricultural development of the delta area will be of a magnitude equal to that of the Pa Mong Project and will have an important bearing on the power consumption program of the Sambor Project. Therefore, investigation and research in this connection will also be necessary.

CHAPTER B. NECESSITY OF DEVELOPMENT AND PROBLEMS INVOLVED

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In the Lower Mekong Basin where Cambodia is the central region, if the present population growth continues, the population will double by 20 to 25 years and it is estimated that demand for power will grow 5 to 7 times that of the present leve. Assuming that economical stability is maintained, the gross national product increases at a medium rate, and the standard of living of the people and the national revenue and expenditure are improved, the industrial production of this region must grow by 6% to 7% 1/ annually.

The per capita energy consumption of this region is low compared with other countries with about the same national income, but demand is increasing at a generally high rate and moreover, it is anticipated the future growth rate will be even higher. At present, considerable demand is latent due to shortage in supply capacity and the relatively high cost of electricity compared with international standards. Therefore, it is anticipated that an immediate increase in load will be seen should abundant power be supplied at cost compatible with international standards and obsolete plants are put out of service. If low-cost electric power can be supplied from efficient hydroelectric plants and market for power is developed, the growth rate is expected to far exceed the present trend.

Tapping of latent demand is being planned in each riparian country by the respective governments. In this respect, the development of a multipurpose project on the mainstream of the Lower Mekong will have great significance.

Essentially, the main purpose of development of the Lower Mekong Basin is to construct several dams on the Mekong River to increase the dry season flow of the river in order to facilitate navigation from the estuary of the river to the upstream area, control floods in the Lower Mekong Basin and the delta area, carry out large-scale agricultural development in the region, and effectively utilize the power produced to meet general demand and modernize industry. Many challenging problems are involved considering the huge economic and social effects, the colossal fund requirements, and the fact that total agreement and cooperation of the four riparian nations are required in proceeding with the program; but the plentiful water resources of the Mekong River with which the peoples of the four nations have been blessed should be developed in the most effective manner through cooperation of the four nations and the other ECAFE nations for the betterment and improvement of the livelihood and welfare of the population of this area. In considering the mainstream program of the Lower Mekong Basin from this standpoint, the plans become limited to the Sambor Project and the Stung Treng Project. The Stung Treng Project has great potential and the social and economic effects including flood control in the Mekong Delta are extremely promising, but there are difficulties due to the fact that the fund requirement is approximately twice that of the Sambor Project while many other problems remain to be solved.

The reservoir to be created by the Sambor Project will have a small storage capacity, and, therefore, as an isolated project, effective flood control and large-scale agricultural development in the Lower Mekong Basin and the delta area cannot be expected. However, there are advantages such as the following:

The location is approximately in the center of Cambodia and conditions permit relatively easy development; the area covered by the reservoir is limited to within Cambodia; the loss of farmland through water storage is less than in the case of the Stung Treng Project; the construction cost is approximately one half of Stung Treng; and even if developed as an isolated project, there are social and economic benefits that can be anticipated by Cambodia and Vietnam through development of large power consuming industries and servicing of general demands with the great amount of power produced, improvement of inland navigation up to Stung Treng and construction of demonstration farms by small-scale irrigation in the area downstream of the dam.

Furthermore, in consideration of the intangible benefits the project will create the development of regional economy, it is evident that it will stimulate great development in associated areas. As evidenced in the amazing tempo of development brought about in the areas served by the Nam Pung and Nam Pong Projects built on tributaries of the Mekong River in Thailand, the benefits of constructing a hydroelectric power plant is not limited to the production of electric energy, but improves area development and modernization of industry.

Source: 1/ Gilbert F. White, Economic and Social Aspects of Lower Mekong Development, January, 1962.

However, in order to realize such benefits, many difficulties remain to be solved. In other words, an enormous amount of power and energy for the economic development of the area will be made available from the Mekong River, and for the effective consumption of this power and energy, it is necessary to prepare an appropriate economic plan, form a comprehensive economic system through cooperation of the riparian nations, and a coordinated operation in order to achieve maximum results. Furthermore, besides various effective individual policies, a coordinated program of education, agricultural guidance, transportation, credit extension, market development and other policies must be established. Without the formulation of these policies and the close cooperation of the four riparian countries, it will be difficult to expect full benefits from development of the Sambor Project.

CHAPTER C. LOAD FORECAST AND POWER CONSUMPTION PROGRAM

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C-1 Load Forecast

C-1-1 Present and Estimated Future Trend of General Demand

(1) General Demand

General demand as used here is defined to domestic and light industry demand which are at present restricted due to shortage of supply capacity and comparatively high electricity rates, and the future demand which is assumed to gradually increase corresponding with population growth, improvement of living standard of the people and industrial growth, and are separate from the demand of power-oriented industries especially assumed for the Sambor Project, and described later in this chapter.

In calculating the general demand expected to be supplied by the Sambor Project, much basic information such as past records of demand, industrial development plans, power distribution network expansion plans, number of customers and energy consumption by energy bracket, population growth, gross national product, etc. are necessary.

Especially, in order to specifically define that part of the total demand to be supplied by the Sambor Project, a certain amount of detail is necessary regarding power development programs including transmission line and substation plans and statistical data on power supply. However, adequate information in this respect and data on private generation which is estimated to account for approximately 25% to 30% (in 1963) of total demand were extremely limited.

Due to the above circumstances, a certain degree of bold estimation was unavoidable in the calculation of the demand to be supplied by Sambor Project.

However, since the purpose of load forecast is to investigate the physical feasibility and economy of the Sambor Project, the estimation described hereunder are adequate for the purpose and in fact, as far as economic evaluation is concerned, it is on the conservative side.

(2) Present State of Electric Power Industry in Cambodia and Vietnam

A survey had already been made by the Overseas Electric Power Industry Survey Institute, Inc. under contract with the Government of Japan. A report called *Survey of the Electric Power Industry in Cambodia and Vietnam, 1965* was prepared by the institute and the study in this chapter is based on the report.

(a) Cambodia

There are three organizations supplying electricity in Cambodia. Electricité du Cambodge, Franco Khmere d'Electricité de Battambang (private corporation) and Public Works Ministry (government). Electricité du Cambodge supplies power to an area centered around Phnom Penh-Kandal District which accounts for approximately 90% of the demand supplied by the electric power enterprises throughout the country. The Public Works Ministry supplies small provincial municipalities, but this activity will probably be absorbed by Electricité du Cambodge in the future. Franco Khmere d'Electricité de Battambang is the sole private utility in the country and supplies power to Battambang.

On one hand, because of the historical circumstances of the power industry and the shortage in supply capacities and transmission and distribution network, there are numerous independent private generating plants, the installed capacity being estimated to have been approximately 20 MW at the end of 1963. In the past several years, various relatively large-scale factories have been built with the majority depending on their own power generation.

The above generating facilities are all thermal, and except for a 3,000 kW steam power plant and a 20,290 kW diesel plant, there are approximately 30 small independent diesel plants with an average capacity of 1,000 kW.

As the economy of Cambodia is growing and changing, there will be created a demand for large quantity of electric energy. In looking at the demand structure from the present state of the electric power industry, the ratio between domestic and industrial demands is 75:25, the percentage of the latter being extremely small. This trend has changed very little during the past seven years. In order to enlarge the scale of total demand and change the demand structure, it is desirable to carry out development of power resources including the Sambor Project and expand the transmission and distribution networks including those of private power facilities.

Some of the pertinent data are given in Tables C-1 to C-5 below.

Table C-1 Organization of Electric Power Industry in Cambodia (1963)

Name		Installed capacity (kW)	Annual Energy production (10^6 kWh)	Growth Rate (%)	Distribution Area
Electric Power Industry	EDC 1/	27,301	83.198	14.3	All area except Battambang
	CIE 2/	1,100	2.250	6.5	Battambang
	Others	2,472	1.316	5.3	Local
Private Power Plants		24,308	22.200	-	Phnom Penh
Total		55,181 3/	108.964 3/	13.8	

Source: Survey of the Electric Power Industry in Cambodia and Vietnam, Dec. 1965, OTCA, JAPAN.

Note: 1/ EDC: Electricité du Cambodge

2/ CIE (or CFKE): Franco Khmere D'Electricité de Battambang

3/ Installed capacity is 37,000 kW in 1963, 45,000 kW in 1965, and Annual Energy Production is 87,000 kWh in 1963, 85,000 kWh in 1965. According to *Statistical Bulletin*, Dec. 1967 of the Mekong Committee.

Table C-2 Demand Distribution by Area in Cambodia (1963)

Area	Operating agency	Installed capacity (MW)	Installed capacity (%)	Consumption (10^6kWh)	Consumption (%)
Phnom Penh - Kandal	EDC	23.3	76.5	57.3	84.2
Phnom Penh - Kandal	Private Power Plants	19.0		16.9	
Sihanouk Ville	Province	0.6	1.1	0.8	0.9
Battambang	CIE	1.1	2.0	1.5	1.7
Monopolies	EDC	4.0	10.7	5.5	7.5
Monopolies	Village	1.9		1.1	
Private Power Plants except Phnom Penh - Kandal	Private Power Plants	5.3	9.7	5.0	5.7
Total		55.2	100.0	88.1 1/	100.0

Note:

1/ Consumption of electricity is 66 million kWh in 1963 and 63 million kWh in 1965 according to Statistical Bulletin, Dec. 1967 of the Mekong Committee.

Table C-3 Energy Distribution by Uses in Cambodia (1963)

Owners and Uses		Consumption (10^6 kWh)	Percentage (%)	Growth Rate 1/ (%)
Electric Power Industry	Lighting and Domestic	37.2	43.2	15.0
	Street Lighting	2.5	2.9	16.0
	Government Agencies	17.0	19.7	15.6
	Motive Power	7.6	8.8	12.7
Private Power Plants		21.9	25.4	-
Total		86.2	100.0	14.5

Note:

1) 1/ : Growth rate is 8-year average for 1956–63.

2) Discrepancy of 1.9 million kWh between total by region of 88.1 million kWh in Table C-2 and total by use of 86.2 million kWh in Table C-3 is due to uncertain distribution in Sihanouk Ville and part of Monopolies.

Table C-4 Annual Load Factor and Capacity Factor in Cambodia (1963)

Area	Installed Capacity (MW)	Maximum Output (MW)	Annual Energy Production (10^6 kWh)	Load Factor (%)	Utility Factor (%)
Phnom Penh-Kandal (EDC)	23.3	16.8	75.8	51.5	37.2
Battambang (CIE)	1.1	0.6	2.3	42.1	23.8
Monopolies (EDC)	4.0	2.6	7.4	32.4	21.1
Monopolies (Village operated)	1.9	-	1.3	-	7.0
Sihanouk Ville (Province)	0.6	-	-	-	-
Private Power Plants	24.3	-	22.2	-	10.4

Table C-5 Fuel Cost of Thermal Power Plant in Cambodia (Feb. 1964)

Fuel	Unit Price (Riel/kWh)
Diesel oil	0.578
Heavy oil	0.977

(b) Vietnam

In Vietnam as of 1963, there were five private power companies and Electricité du Vietnam, which owns Da Nhim Hydro (160 MW). The above two groups equally account for approximately 90% of the total capacity, although the private companies are scheduled to be gradually absorbed by Electricité du Vietnam in the future. Besides the above, there are small, scattered power plants in the countryside operated by provinces or municipalities, but the total installed capacity is no more than about 10% of the national total.

There is presently a small-scale transmission system limited to the Saigon-Cholon to which the recently completed Da Nhim Power Station is connected by a 230 kV, 200 km long transmission line, and therefore, there is no integrated power system covering a wide area. At major municipalities, there are isolated power plants. The Saigon-Cholon System is presently comprised of five thermal plants (a 52,200 kW steam plant and four diesel plants totalling 87 MW) connected by a 15 kV transmission line serving six secondary substations. The Saigon-Cholon System which is connected to the Da Nhim Power Station serves 85% of the total national demand.

Energy demand in 1965 is estimated to have been 430 million kWh and the maximum peak demand 70 MW. The growth rate of electric energy in the past ten years is 9.0%.

Private power generation mainly belonging to textile industries is concentrated in the Saigon-Cholon District, and there are some rubber plantations generating power in the provinces. The total estimated capacity in 1963 was 43 MW and the energy produced was 128 million kWh.

Pertinent data are given in Tables C-6 to C-11 below.

Table C-6 Electric Power Industry and Private Power Plants in Vietnam (1965)

Name		Installed Capacity (MW)	Percentage (%)	Distribution Area
EDV	(Public corporation)	200.8 1/	56.0	Approx. 90% or more sold whole sale to CEE
CEE	(Private corporation)	88.1	24.6	Saigon-Cholon and Dalat
UNEDI	(")	2.2	0.6	Southeast Coastal Region
SCEE	(")	4.3	1.2	Mekong Delta
SIPEA	(")	11.0	3.0	Central Region
SAER	(")	5.1	1.4	Southwest Region
Village operated, others		4.2	1.2	Miscellaneous Small Villages scattered in Approx. 60 Locations
Private Power Plants		42.9	12.0	Mainly Textile Industry undefined as to Region
Total		358.6 2/	100.0	

Source: Survey of the Electric Power Industry in Cambodia and Vietnam, Dec. 1965, OTCA, JAPAN.

Note:

EDV: Electricité du Vietnam

CEE: Compagnie des Eaux et d'Electricité d'Indochine

UNEDI: Union Electucité d'Indochine

SCEE: Societé Coloniele d'Elairage et d'Energie

SIPEA: Société Industrille pour les Eaux et l'Electricité en Asia

SAER: Société Anogme d'Electrité de Rachigia

1/ 200.8 MW of EDV is comprised of
160 MW at Da Nhim Hydro (80 MW in 1961, 80 MW in 1965)
33 MW at Thu Duc Thermal (1965)
7.8 MW scattered at 9 Power Stations

2/ Installed capacity is 285,000 kW according to *Statistical Bulletin* Dec. 1967 of the Mekong Committee.

Table C-7 Demand Distribution by Area in Vietnam (1962)

Area	Installed Capacity		Annual Energy Production		Growth Rate (%)	
	MW	%	10^6 kWh	%	Installed Capacity	Energy Production
Saigon-Cholon	-	-	314.8	64.5	-	9.8
Remainder of Southern District	-	-	14.7	3.0	-	-
Private Power Plants	-	-	128.7	26.4	-	-
Subtotal	136	90.7	458.2	93.9	5.9	-
Central Lowlands	11	7.3	21.9	4.5	7.7	6.1
Central Highlands	3	2.0	7.9	1.6		
Total	150	100.0	488.0	100.0	-	-

Note:

1) Subtotal assumes all private power plants to be in Saigon area
2) Growth rate 7-year average for 1956-62
3) 160 MW, first stage of Da Nhim not included

Table C-8 Energy Distribution by Uses in Vietnam (1961)

	Purpose	Consumption		Growth Rate
		10^6 kWh	%	%
Electric Power Industry	Domestic	163.4	45.9	7.2
	Commercial	58.6	16.4	
	Industrial	36.2	10.2	12.6
	Street Lighting	8.5	2.4	-
	Others	4.3	1.2	-
Private Power Plants		85.0	23.9	-
Total		356.0 1/	100.0	9.0 2/

Note: 1/ Consumption of Electricity is 261 million kWh in 1961 and 430 million kWh in 1965 according to *Statistical Bulletin*, Dec. 1967 of the Mekong Committee.

2/ Growth rate 7-year average for 1956-62

Table C-9 Annual Load Factor and Capacity Factor in Vietnam (1963)

		Saigon-Cholon	Representative Regional Municipalities (5 Locations)
Installed capacity	(MW)	86.1	1.2
Annual energy production	(10^6 kWh)	348.5	1.4
Maximum output	(MW)	73.9	0.7
Annual load factor	(%)	58.2	22.8 (15–43)
Capacity factor	(%)	46.0	13.3

Note:

1) Excludes private power plants

2) Annual load factor of private power plants higher than above

Table C-10 Power Generation Facilities in Vietnam (1961)

Type of Plant		Installed Capacity (MW)	Number of Plants (Number)	Capacity Factor (%)
Electric Power Industries	Thermal	52.2	1	50.4
	Hydro	3.9	2	29.3
	Diesel	49.2	Approx. 50	23.6
	Subtotal	105.3	53	35.6
Private Power Plants	Unknown	33.8	Approx. 20	-
Total		139.1	Approx. 70	-

Note:

1) 33 MW Thu Duc thermal scheduled for completion in 1965 not included.

2) 160 MW of Da Nhim (first stage 80 MW in 1961 and second stage 80 MW in 1965) not included.

Table C-11 Fuel Cost of Thermal Power Plant in Vietnam (1961)

Fuel	Consumption (ton)	Calorie (kcal/kg)	Fuel Consumption Rate (kg/kWh)
Coal & Heavy Oil	166,510 1/	6,900 1/	0.77
Diesel Oil	26,936	10,200	0.26

Note: 1/ Values converted to coal equivalent.

(3) Load Forecast for Cambodia and Vietnam

National load forecasts of Cambodia and Vietnam were made by Sofrelec of France which investigated the electric power market in detail for many years and published a report 1/ in 1965. This report is very reliable and has been of great reference in preparing this report.

The actual records 2/ for the two countries are available only of the electric power industry, as the data are not available of private generation. Table C-12 gives these data which are limited to the electric power industry.

Table C-12 Records of Annual Energy Construction at Consuming End in Cambodia and Vietnam (Electric Power Utility only)

	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965
Cambodia										
Annual Energy (10^6 kWh)	25.4	29.7	33.8	41.8	46.0	52.0	58.8	65.4	63.7	62.7
Growth Rate over the previous year (%)	-	17.0	13.5	24.0	10.0	13.0	13.1	10 8	(-) 2.3	(-) 1.5
Annual Growth Rate (%)		← 14.5 (1957–1963) →								
		← 10.0 (1957–1965) →								
Vietnam										
Annual Energy (10^6 kWh)	172.5	177.4	194.1	226.9	242.2	261.3	289.4	325.5	388.6	430.0
Growth Rate over the previous year (%)	-	2.8	9.4	16.9	6.7	7.9	10.8	12.5	19.4	10.7
Annual Growth Rate (%)		← 10.8 (1957–1964) →								

Source: 1/ *Survey of Electric Power Market for Domestic, Commercial and Industrial use in the Lower Mekong Basin*, Sofrelec, August 1965.

2/ *Survey of Electric Power Industry of Cambodia and Vietnam*, December 1965, OTCA, Tokyo, Japan

The annual growth rates of energy consumption for the past ten years have been 10.0% and 10.8% for Cambodia and Vietnam respectively. The annual growth rate has been extremely irregular, ranging between 2.3% to 24.0%. Especially for Cambodia, in 1964 and 1965, there were decreases which are assumed to have been caused by restriction of demand because of shortage of supply capacity. Because of these circumstances, it is not appropriate to estimate future demand by the trend method based on past records.

Therefore, values obtained by the analytical method in which the annual demand estimated according to district and usage are added and the overall method in which the total demand of the entire country is estimated based on the elastic value of power demand in relation to the gross national product were used.

Since power consumption increases with economic growth, growth in demand can be considered as a function of the economic growth rate. Estimating from past records and such factors as industrialization plan, the ratio of domestic and illumination demand in the total demand is as high as 80% to 90% in the electric power industry. Therefore, in the analytical method, importance was given to analyses of these categories and the ratio of consumers to population, consumers per bracket and energy consumption per bracket were studied.

Generally, in the analytical method, entirely new types of demand cannot be considered, but in the overall method, because of its comprehensive nature, it is possible for such new types to be included. Especially, in the overall method, since demand of high added value is treated together with other demands of low added value, it is thought that the forecasted load is the upper limit. This can be said also in light of the relation between forecasts and actual records in Japan.

Therefore, the estimates of demand adopted in this report are intermediate values between the analytical method (lower limit) and overall method (upper limit). These values are shown in Table C-13 and Fig. C-1.

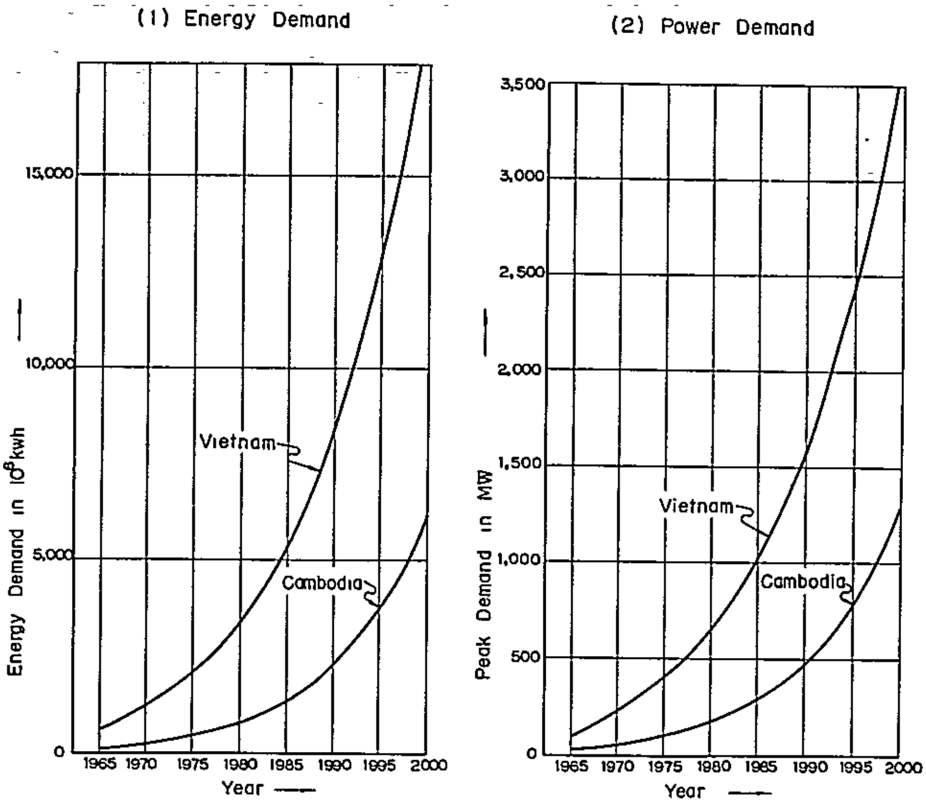
Table C-13 Nationwide Load Forecast of Cambodia and Vietnam (at Consuming End including Private Generation)

	1963	1970	1975	1980	1985	1990	1995	2000
Cambodia:								
Annual Energy(10^6 kWh)	86	260	460	800	1,360	2,290	3,780	6,150
Growth Rate (%)	-	17.1	12.1	11.7	11.2	10.9	10.4	10.3
Maximum Power (MW)	-	60	100	175	295	470	770	1,270
Vietnam:								
Annual Energy (10^6kWh)	455	1,250	2,100	3,400	5,400	8,350	12,800	19,600
Growth Rate (%)	-	15.6	10.9	10.2	9.6	9.1	8.9	8.8
Maximum Power (MW)	-	240	410	655	1,030	1,575	2,400	3,630

The growth rate in the forecast is approximately 10% to 17% from 1965 to 1985 and approximately 9% to 11% from 1985 to 2000. The values for the first period may appear large at first glance, but they are not necessarily excessive for the two countries where at present the absolute values of demand are relatively small while industrialization and improvement in the living standard are rapidly advancing.

In this forecast the growth rate is reduced as time goes by. This is because unit power consumption is lowered by the general trend of saturation in demand 1/ (the recent trend in industrialized nations as reported by the Japan Electric Power Survey Institute are indicated in Table C-14) and the fact that consumption is extended to formerly unelectrified areas through expansion of the distribution networks in the two countries, resulting in lowering of unit consumption rate. 2/

Fig. C-1 Load Forecast at Consuming End in Cambodia and Vietnam



1/ Growth trend has reached saturation point and the demand curve is beginning to show a tendency of gradual level off.

2/ Quantity of raw materials (electric energy in this case) required to produce one unit.

Table C-14 Growth Rates in Japan and U.S.A.

	Growth Rate over the Previous Year in 1966 (%)	Annual Growth Rate from 1966 to 1972 (%)
Japan	12.7	9.2 1/
U.S.A.	9.0	7.6 1/

Note: 1/ Estimated figures.

(4) Date of operation of Sambor Power Station

Usually, the date of operation of a power station is automatically decided by the state of supply and demand of electricity in the area to be surved by that station. As Sambor is a multipurpose project which, besides power generation, provides benefits to navigation, irrigation, etc., the date must be determined upon consideration of the demands of these purposes.

The development of this site will be the forerunner of development of Cambodia and Vietnam in the Lower Mekong Basin and will serve as a stimulant to further development. Generally speaking, development of new power resources is not necessarily a region where there is no critical need from the standpoint of demand, but it is conceivable that power-oriented industries can be newly attracted if abundant and low-cost energy can be supplied. From this viewpoint, the various calculations were made to start operation of Sambor Power Station in 1978 on the conception that the project should be constructed as early as technically possible.

(5) Load Forecast of Sambor Interconnected System

(a) Weight of the Sambor Interconnected System to Total Power Demand

Demand of the two countries is concentrated in the Phnom Penh-Kandal District in Cambodia and the Saigon-Cholon District in Vietnam. Considering only the demand supplied by power utility enterprises, the ratio of demand of these districts in the total demand of the two countries is approximately 90%.

The two countries have power transmission plans as shown in Table C-15 wherein local power stations and municipalities which presently have independent systems will be connected with the systems of the beforementioned two districts so that it is thought the above ratio will gradually increase in the future.

In order to supply these demands from Sambor Power Station, transmission lines will be built between Sambor-Phnom Penh-Sihanouk Ville and Sambor-Saigon. Sambor Interconnected System is to be materialized in 1978, and it will link the two countries with the above two districts as centers.

Also, private generating facilities which have independent systems seem to be gradually connected to the interconnected system with the growth in the supply capacity ot power enterprises serving the general public, in the expansion of transmission and distribution networks and the development of Sambor Project. Therefore, in calculating the percentage of demand to be supplied by the Sambor Interconnected System against total demand, private generation, which as of 1963 occupied 25% of the total, was considered to be gradually integrated with this system.

Table C-15 Power Transmission Plans in Cambodia and Vietnam

Completion date		Section	Voltage (kV)
Cambodia:	1967	Phnom Penh-Kirirom	110
	1969	Phnom Penh-Prek Thnot-Sihanouk Ville	110
	1971	Phnom Penh-Takeo-Kampot-Kamchy	110
	1973	Phnom Penh-Pursat-Battambang	110
Vietnam:	1968	Da Nhim-Phan Rang-Nha Trang	220
	1968	Saigon-Tan An-My Tho	110

Source: *Survey of Power Market of Mekong River, Sambor Project,* December 1965. OTCA, Tokyo, Japan

In consideration of the above factors, the percentage of demand to be supplied by the Sambor Interconnected System against the total demands of the two countries were calculated as shown in Table C-16.

Table C-16 Ratio of Demand in Sambor Interconnected System to Nationwide Demand in Cambodia and Vietnam

		1978	1983	1988	1993	1998
Cambodia	(%)	72.5	73.5	74.0	74.5	75.0
Vietnam	(%)	72.4	73.8	75.2	76.6	78.8

(b) Transmission and Distribution Losses of Sambor Interconnected System

Table C-17 gives the past record of the loss factor of transmission and distribution lines of the Phnom Penh-Kandal and Saigon-Cholon Districts of only power enterprises serving the general public. For Cambodia, the loss factor is 23% to 28% which is very high, but this is because consumption of power in affiliated industries is classified as loss, and although the transmission and distribution facilities are admittedly weak, the losses are thought to be several percent less. In Vietnam, the transmission and distribution network is comparatively better established so that the percentages are lower, at 17% to 21%.

Table C-17 Records of Transmission and Distribution Loss Factors

	1957	1958	1959	1960	1961	1962	1963
Phnom Penh-Kandal (%)	26.1	26.0	24.1	23.1	28.2	27.2	24.5
Saigon-Cholon (%)	21.3	20.0	21.0	21.2	17.5	17.0	16.8

Source: *Survey of Power Market of Mekong River, Sambor Project*, December 1965, OTCA, Tokyo, Japan

In both countries, the rates of transmission losses tend to decrease gradually by the year. Especially, in Vietnam, it is planned to connect an extra highvoltage transmission line from Da Nhim via Phan Rang to Nha Trang in 1968 to the existing 220 kV extra highvoltage line between Da Nhim and Saigon.

Anticipating that the transmission and distribution networks will be further expanded, it was assumed the losses would be gradually reduced to about 12% to 17%.

(c) Annual Load Factor

The annual load factor in the Phnom Penh-Kandal District was 46% to 53% during the past ten years as shown in Table C-18, but the change by year is not necessarily following a same trend. In the Saigon-Cholon District, it was 58.2% in 1963.

Table C-18 Records of Annual Load Factor of Phnom Penh-Kandal

	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965
Load Factor (%)	47.1	53.0	52.4	51.2	50.8	49.7	48.3	51.5	54.2	46.0

Source: *Survey of Power Market of Mekong River, Sambor Project*, December 1965, OTCA, Tokyo, Japan

In general, the annual load factor has a close relationship with the demand structure. That is, the load factor is high if the ratio of demand of the secondary industry and commercial use occupy a large share in the total demand. Presently, the ratio of power used for domestic and illumination purposes against total demand, not including private generation, is approximately 80% in Cambodia, and approximately 65% in Vietnam, and because of this, the annual load factor is relatively low.

However, in consideration of anticipated growth of secondary industries and interconnection with private generation which is mainly for industrial use and increases in demand for air-conditioning resulting from improvement in living standards, it is estimated the annual load factor will increase gradually year by year. On the other hand, the annual load factors of Cambodia and Vietnam can be studied from the relationships between the demand structure and the actual or estimated annual load factor of industrially advanced nations (e.g., in Japan, 68.1% in 1966 and 66.2%, six years later in 1972), and from those of the two countries.

According to the above, the annual load factors of the two countries in the Sambor Interconnected System were assumed to be 52% to 55% in Cambodia and 59% to 61% in Vietnam as shown in Table C-19.

Table C-19 Estimate of Annual Load Factor in Sambor Interconnected System

	1978	1983	1988	1993	1998
Cambodia (%)	52.4	53.3	54.0	54.6	55.0
Vietnam (%)	59.2	59.6	60.2	60.5	61.0

(d) Demand in the Sambor Interconnected System

From the abovementioned ratio of demand to be supplied by the Sambor System, the assumed loss factors and annual load factors, the maximum peak demand and annual energy demand at the generating end of the Sambor Interconnected System are calculated from the annual energy demand at the consuming end of the entire country. 1/ These are given in Table C-20.

Table C-20 Demand of Sambor Interconnected System at Generating End

		1978	1983	1988	1993	1998
Cambodia:						
Annual Energy Demand	(10^6kWh)	557	954	1,638	2,790	4,330
Max. Peak Demand	(MW)	121	204	346	582	898
Vietnam:						
Annual Energy Demand	(10^6kWh)	2,365	3,850	6,190	9,950	15,100
Max. Peak Demand	(MW)	455	738	1,174	1,875	2,820
Total:						
Annual Energy Demand	(10^6kWh)	2,922	4,804	7,828	12,740	19,430
Max. Peak Demand	(MW)	576	942	1,520	2,457	3,718
Power Growth Rate	(%)	-	10.4	10.0	9.9	8.7

In other words, total peak demand at the generating end of the two countries on the Sambor Interconnected System will be 576 MW in 1978, which is the year of start-up of Sambor Power Station, 1,520 MW 10 years later in 1988 and 3,718 MW 20 years later in 1998, making the growth rate 9.8% for the 20 years from 1978 to 1998. The annual enrgy demand at the generating end for 1978 and 1998 are 2,822 million kWh and 19,430 million kWh respectively, and the annual load factor 55.7% and 59.6%.

1/ Sambor Interconnected System (kWh)

$$= \frac{\text{Total national annual energy consumption at consuming end}}{1 - \text{Loss factor}} \times \left(\begin{array}{l}\text{Ratio of demand to be supplied by}\\ \text{Sambor Interconnected System}\end{array}\right)$$

$$\text{Sambor Interconnected System (kW)} = \frac{\text{Energy demand of Sambor Interconnected System}}{8760 \times \text{Annual load factor}}$$

The growth in peak demand at the generating end for the two countries from 1978 and thereafter are indicated in Fig. C-3. These increases in demand are to be met with the supply capacity of Sambor Power Station, which will be expanded to 875 MW, the optimum capacity, in 1988 — ten years after initial operation of the plant as described in Chapter F.

(6) Forecast of Demand to be Supplied by Sambor Project

(a) Electric Power Development Plans and Supply - Demand Balance in 1977

Both countries are poor in fuel resources but blessed with cheap hydroelectric power resources. The estimated hydroelectric potential is 3,500 MW in Cambodia, not including the Sambor Project. Of this potential, 95% is in the Mekong River. In Vietnam, the potential is 2,300 MW of which approximately 50% is in the Dong Nai River. However, the only development at present is at three sites in Vietnam (total output 164 MW), and it can be said both countries are almost totally undeveloped. The electric power development plans presently announced by the two countries are givenin Tables C-21 and C-22.

Table C-21 Hydroelectric Development Plans in Cambodia

Project	River	Installed Capacity (MW)	Annual Energy (10^6 kWh)	Year of Completion	Purpose
Kirirom-I	Kompong Som	10	50	1967	Power
Prek Thnot	Tributary of Mekong River	18	40	1969	Power Irrigation
Kirirom-II	Kompong Som	21	93	1970	Power Irrigation
Kam Chay	Prek Tuk	50	250	1971	Power
Battambang-I	Stung San Ke	20	80	1973	Power Irrigaton
Maun	Stung Daum Tri	5	30	1976	Power Irrigation
Stung Pursat	Stung Pursat	21	120	1978	Power Irrigation
Battambang-II	Stung San Ke	7	35	1980	Power Irrigation
Upper Kam Chay	Prek Tuk	45	210	1982	Power
Total		197	908		

Source: The government of Cambodia

Surplus or shortage in supply capacity is essentially determined by the characteristics of the supply capacity in relation to the pattern of annual and daily demand (variation in output due to high and low runoff, restriction on power generation due to multipurpose uses of dam, annual and daily regulating capacity of reservoir, etc.). The amount of energy available annually will vary greatly as there is pronounced fluctuation in the runoff of the rivers of the two countries due to wet and dry seasons. Although the various characteristics of the proposed hydroelectric development sites of the two countries are not clearly known, estimating these as a whole from the characteristics of the Sambor Project, the supply capacity in 1977 is calculated as shown in Tables C-23 and C-24.

Table C-22 Hydroelectric Development Plans in Vietnam

Project	River	Installed Capacity (MW)	Annual Energy (10^6 kWh)	Year of Completion	Purpose
Drayling	Srepok	12	-	1968	Power
Tri An	Do Nai	100	440	1972	Power
Da Nhim-III	Don Nai	80	-	1978	Power
Da Nhim-IV	Don Nai	80	942	1982	Power
Lagna	Don Nai	102	-	1985	Power
Da Nhim No. 2	Don Nai	80	491	-	Power
Total		454	–		

Source: The government of Vietnam

According to these tables, there will be no shortage of supply in Cambodia, but in Vietnam there will be a shortage of 170 MW in maximum output and 1,100 million kWh of energy annually. In order to relieve this shortage in power and energy output, a new thermal power plant of about 175 MW should be constructed.

(b) Proportion of Load to be Supplied by Sambor Project

As described in (a), approximately 240 MW out of the hydroelectric potential of approximately 5,800 MW of Cambodia and Vietnam will be developed by 1977, and with the existing power stations plus development of about 175 MW of thermal power, the estimated demand in 1977 will be met. Therefore, the annual increase in demand of the two countries from 1978 on would be met by other hydroelectric projects, including Sambor Project, of the two countries.

Presently, according to the electric power development plans of the two countries (Tables C-21 and C-22), projects scheduled to be developed number three in Cambodia (total output 73 MW) and three in Vietnam (total output 262 MW exclusive of projects for which the scheduled date of operation are unknown). Which project, the national projects or the Sambor Project, should be given priority in supplying power to meet the increment of demand in the Sambor Interconnected System is a matter which must be determined by the costs and importance of the various purposes of use of the projects.

However, even if those projects included in the national plans are developed, there will still be a shortage in capacity to supply the increase in demand of the Sambor Interconnected System. This relationship is indicated in Table C-25.

Table C-23 kW Balance in 1977

Unit: MW

			Cambodia	Vietnam
Maximum Supply Capacity of Existing Plants	Hydro Power		-	140
	Thermal Power		52	185
	Total	(A)	52	325
Max. Supply Capacity of Proposed Projects		(B)	106	95
Total Max. Supply Capacity (C) = (A) + (B)			158	420
Maximum Demand		(D)	150	590
Surplus or Deficit in Supply Capacity (C) - (D)			8	(-) 170

Note:

1) Maximum supply capacity of hydro is installed capacity less 15% for restriction in low water season or multipurpose operation.

2) Maximum supply capacity of thermal is installed capacity less 5% for station losses.

Table C-24 kWh Balance in 1977

Unit: 10^6 kWh

			Cambodia	Vietnam
Annual Energy Supply of Existing Plants	Hydro Power		-	900
	Thermal Power		235	515
	Total	(A)	235	1,415
Annual Supply Capability of Proposed Projects		(B)	490	450
Total Annual Supply Capability (C) = (A) + (B)			725	1,865
Annual Demand		(D)	725	3,000
Surplus or Deficit in Energy		(C) - (D)	0	(-) 1,135

Note:

1) Energy supply of hydro is energy supply potential less 10% surplus energy.

Table C-25 Demand - Supply Balance of Peak Demand for Incremental Demand of Sambor Interconnected System from 1978

Unit: MW

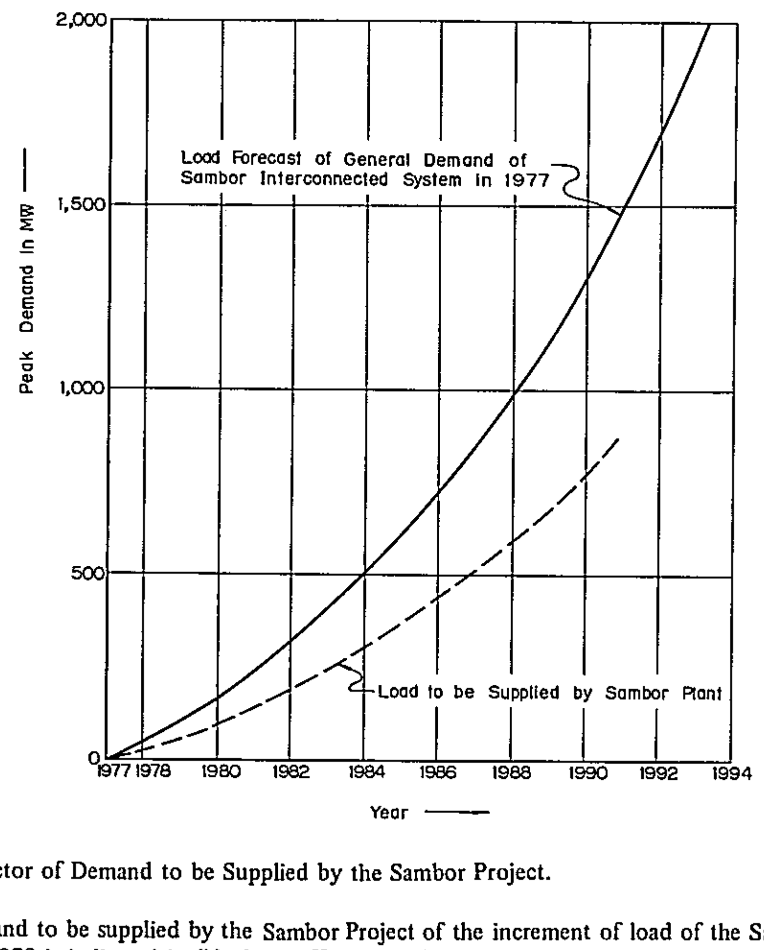
		1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Cambodia													
Power Demand Installed Capacity(A)		12	25	39	56	75	95	119	143	172	202	237	285
Stung Pursat		21	21	21	21	21	21	21	21	21	21	21	21
Battambang II		-	-	7	7	7	7	7	7	7	7	7	7
Upper Kam Chay		-	-	-	-	45	45	45	45	45	45	45	45
Subtotal	(B_1)	21	21	28	28	73	73	73	73	73	73	73	73
Surplus or Deficit in Supply Capacity	$(C_1) = (B_1) - (A_1)$	9	(-) 4	(-)11	(-)28	2	(-)22	(-)46	(-)70	(-)99	(-)129	(-)164	(-)212
Vietnam													
Power Demand Installed Capacity	(A_2)	35	75	125	180	248	318	388	465	555	650	754	853
Da Nhim III		80	80	80	80	80	80	80	80	80	80	80	80
Da Nhim IV		-	-	-	-	80	80	80	80	80	80	80	80
Lagna		-	-	-	-	-	-	-	102	102	102	102	102
Subtotal	(B_2)	80	80	80	80	160	160	160	262	262	262	262	262
Surplus or Deficit in Supply Capacity	$(C_2) = (B_2) - (A_2)$	45	5	(-)45	(-)100	(-) 88	(-)158	(-)228	(-)203	(-)293	(-)388	(-)492	(-)591
Total													
Power Demand	(ΣA)	47	100	164	236	323	413	507	608	727	852	991	1,138
Installed Capacity	(ΣB)	101	101	108	108	233	233	233	335	335	335	335	335
Surplus or Deficit in Supply Capacity	$(\Sigma C) = (\Sigma B) - (\Sigma A)$	54	1	(-)56	(-)128	(-) 90	(-)180	(-)274	(-)273	(-)392	(-)517	(-)656	(-)803
Demand-Capacity Ratio $D=(\Sigma C)/(\Sigma A) \times 100$ (%)		115	1	34	55	28	44	54	45	54	60	66	71

Without considering abnormally dry years, the annual shortage of supply capability from 1978 will be approximately 30% to 50% of the increment of demand up to 1986, the period during which projects included in the national plans of the two countries are to be developed. From 1987, since neither country has formulated plans for development of power sources, the shortage will be 60% or more. However, if it is assumed that both countries will carry out development plans in the future at the same rate as up to 1986, the shortage will be approximately 30% to 50% as before 1986.

Sambor Project would generate power to eliminate this shortage. It should be noted, however, that the shortage in supply capacity indicated in Table C-25 is based on installed capacity. In actual operation, the maximum output of a hydroelectric plant will be slightly lower than installed capacity due to the influence of wet and dry season runoff and the restrictions in operation placed on a multipurpose dam.

In consideration of the above and also using values on the safe side to prevnt shortage in supply capacity even if execution of the development plans of the two countries is delayed, the ratio of load to be borne by Sambor Power Station was determined. In this Report, the Power Consumption Program of C-2 and the economic evaluation of Chapter K were prepared on the basis that the Sambor Project would supply 60% of the increase in demand of the Sambor Interconnected System until the maximum capacity of 875 MW of the project is installed. (See Fig. C-2)

Fig. C-2 Incremental General Demand of Sambor Interconnected System and Supply Capability of Sambor Power Station (Maximum Output at Generating End)

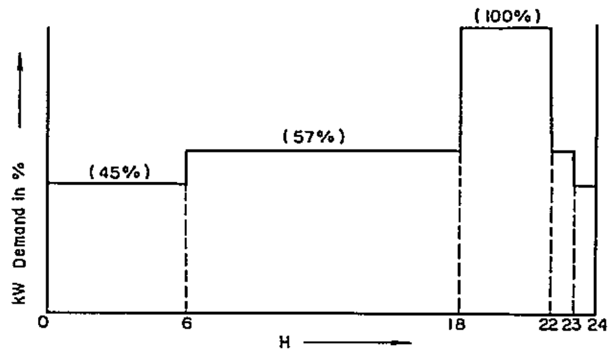


(c) Load Factor of Demand to be Supplied by the Sambor Project.

The peak demand to be supplied by the Sambor Project of the increment of load of the Sambor Interconnected System from 1978 is indicated in (b) above. However, the annual load factor and daily load factor of the demand to be supplied by the Sambor Project should not be decided only on the increment of demand but rather on total demand, and it must be determined for greatest economy in relation to the characteristics of existing and planned power projects (runoff of rivers, regulating capacity of reservoir and restrictions in operation) and the characteristics of demand.

However, since the characteristics of existing and planned power projects are unknown, the demand to be supplie by the Sambor Project was separated from demand to be supplied by other supply capacities. Judging from the daily load curve of total demand, the power generation curve for general demand was based on a daily load factor of 60%, which was assumed to be constant throughout the year, and this was applied to the Power Consumption Program of C-2 and the Economic Justification of Chapter K.

Fig. C-3 Daily Load Curve of Sambor Power Station for General Demand



C-1-2. Power-Oriented Industries

(1) Necessity and Types of Power-oriented Industries

In consideration of the characteristics of the Mekong River, it will be economical to install a fairly large capacity in the Sambor Project (See Chapter F). However, the general demands of Cambodia and Vietnam are small in comparison with the output of the Sambor Project. As a result, if the Sambor Project is to supply only the general demand, it would take many years for the general demand to reach the level of the economic output of the Sambor Project

Also, since the runoff of the Mekong River fluctuates greatly according to the year and dry or wet seasons, a great amount of surplus power would be produced if the entire output of the Sambor Project is to supply general demand only.

Therefore, in order to develop the Sambor Project at an early date to expedite regional development of the Lower Mekong Basin, it is desirable to introduce demand which will consume bulk power and also demand which will absorb surplus power, in other words, power-oriented industries should be established.

Power-oriented industry is an industry with high unit power requirement per unit of production, low productivity in terms of added value of energy 1/ and high percentage of electricity cost in the cost of production. Electrolytic process industries such as ammonium sulphate, caustic soda, aluminum refining, etc., and electric furnace industries such as carbide, electric pig iron, electric furnace steel ingot, ferro-alloy, etc. are representative of this type of industry.

If a power-oriented industry is to be introduced in the Lower Mekong Basin, the type to be selected and the feasibility of establishing a factory will naturally depend on the cost of electricity to be supplied by the Sabmor Project as well as the availability of raw materials in the area, the size of the demand for the product, the feasibility of importing raw materials, the marketing future of the product, the environmental conditions of the factory, the labor force available, etc.

1/ Added value produced by per unit of energy (added value productivity of energy)

Although there are many kinds of power-oriented industries, the one with high unit power requirement to consume the firm output of the Sambor Project and with a bright future of increased demand of its product on the international market is aluminum refining, followed by caustic soda industry. Also, as industries, which would effectively absorb the secondary energy and moreover use limestone and silica as raw materials which are abundant in the area, the carbide, ferro-silicon and silicon carbide industries are suitable. As a secondary processing industry to utilize chlorine produced simultaneously with carbide and caustic soda, it would be possible to establish a vinyl chloride industry. Pertinent information on the consumption of one of those major products is as follow:

Non-communist world consumption of aluminum is shown in Table C-26.1/ It will be noted that the world consumption in 1964 was 5.9 million tons. Estimated future demands are given in Table C-27 1/

Table C-26 Approximate Non-Communist World Total Aluminum Consumption by Region, 1948 and 1964

Region	1948 Total 1/ (10^3 metric tons)	1948 Percent of Total	1964 Total 1/ (10^3 metric tons)	1964 Percent of Total
World	1,510.8	100.0	5,933.2	100.0
Americas	997.4	66.0	3,307.4	55.7
Europe	490.6	32.5	2,052.0	34.6
Asia	16.5	0.9	464.8	7.8
Africa	1.0	0.1	26.0	0.4
Oceania	5.3	0.4	83.0	1.4

Note:

1/ : Includes consumption of crude aluminum plus local secondary production.

Source: Sterling Brubaker, *Trends in the World Aluminum Industry*, p. 24

Table C-27 Future Demand for Aluminum in Non-Communist World

Basis of Estimate	1965	1970	1975	1980 1/
Trend 1950-59 (thousand metric tons)	6,300	9,300	13,300	19,630
Annual Growth (per cent)	8.1	8 1	8.1	
Per Capita Trend 1950-59 (thousand metric tons)	6,170	9,190	13,750	20,485
Annual Growth (6.1% per capita per cent)	8.3	8.3	8.3	
GNP Correlation 1950-59: Trend (thousand metric tons)	5,800	7,900	11,100	15,500
Annual Growth (per cent)	7.2	6.8	6.9	
High (thousand metric tons)	6,000	8,300	11,900	17,005
Annual Growth (per cent)	7.7	7.4	7.4	
Low (thousand metric tons)	5,600	7,300	9,700	12,980
Annual Growth (per cent)	6.5	6.0	6 0	

Note:

1/ : Extended by author based on percent change 1970-75.

Source: Sterling Brubaker, *Trends in the World Aluminum Industry*, p 55.

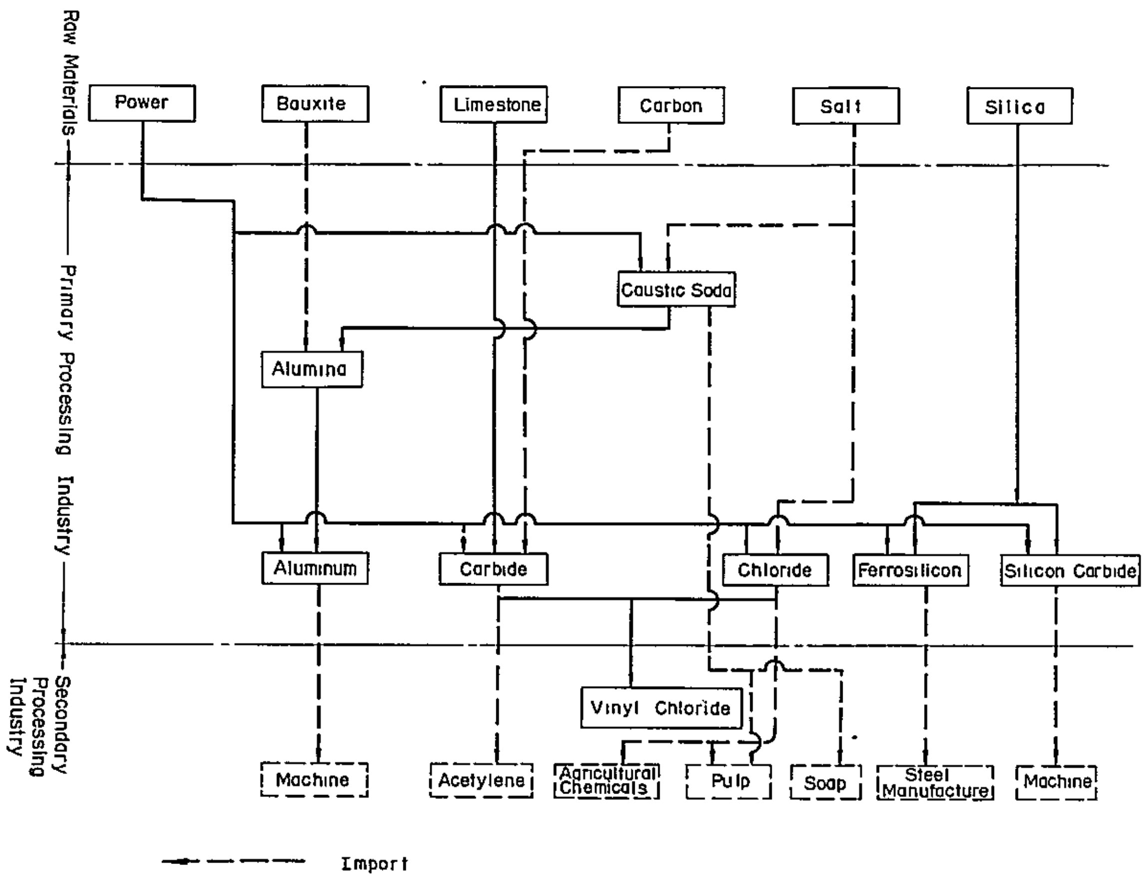
Since the worldwide demand for vinyl chloride as both expendable and productive goods is growing remarkably, it is thought that there will also be fairly large demand for vinyl chloride in the Lower Mekong Basin.

The vinyl chloride production of the world is shown in Table C-28. This is an industry which is predicted to continue to show a high growth rate. The production level of a nation is often measured in per capita terms, which at the same time is effective as a measure for estimating demand. A rough estimate of the demand for vinyl chloride in the Lower Mekong Basin will be made by this method in order to determine the scale of the vinyl chloride industry to be established under the Sambor Project.

The total vinyl chloride production and production per capita of the various countries of the world are indicated in Table C-28. According to this table, the per capita production in developed nations of Europe and America, etc. is 4 kg to 7 kg while in developing nations it is 1 kg or less in many cases. It will be noted in the table that the value grows larger with increased economic development.

The caustic soda production and the per capita production of various countries of the world as of 1965 are indicated in Table C-28. It is seen that production in advanced countries is 15 kg to 30 kg per capita and in Japan it is 13 kg.

Fig. C-4 shows the relationship between raw materials and products in the various industries.



(2) General Conditions of Industrialization in the Area Concerned 1/

Cambodia and Vietnam have only recently begun to earnestly move towards industrialization. Compared with the conditions for industrialization of developing countries in Southeast Asia and the world, Cambodia and Vietnam seem to be poor in mineral resources which can be used as raw material or fuel, and therefore, they are thought to be considerably handicapped.

1/ *Survey of Power Market of Mekong River, Sambor Project,* December 1965, OTCA, Tokyo, Japan

Table C-28 Caustic Soda and Vinyl Chloride Production of Various Countries in the World

(in 1965)

Country	Population (1,000)	Caustic Soda Production (10^3 ton)	Caustic Soda kg per capita	Vinyl Chloride Production (10^3 ton)	Vinyl Chloride kg per capita
Argentina	22,352	81	3.6	('64) 15	0.7
Australia	11,360	71	6.3	24	2.1
Brazil	82,222	69	0.8	39	0.5
Bulgaria	8,200	32	3.9	('64) 12	1.5
Canada	19,604	583	29.7	25.4	1.3
Colombia	18,068	36	2.0	-	-
Czechoslovakia	14,159	158	11.2	('64) 40	2.8
Finland	4,612	116	25.2	-	-
France	48,922	671	13.7	215	4.4
Germany (East)	16,000	364	22.7	('63) 99	6.2
Germany (West)	56,839	1,178	20.7	370	6.5
Hungary	10,148	49	4.8	16	1.6
India	483,000	215	0.4	10	0.02
Italy	51,576	704	13.6	328	6.4
Japan	97,960	1,305	13.3	('66) 534	5.5
Mexico	42,689	102	2.4	18	0.4
Norway	3,723	68	18.3	27	7.3
Philippines	32,345	15	0.5	-	-
Portugal	9,199	215	23.4	-	-
Rumania	19,027	233	12.2	50	2.6
Spain	31,604	173	5.5	42	1.3
Sweden	7,734	('64) 233	30.1	33	4.3
U.S.S.R.	230,600	1,199	5.2	('64) 130	0.6
U.S.A.	194,572	6,099	31.3	835	4.3
Yugoslavia	19,508	88	4.5	('64) 7.5	0.4

Source: UN, Statistical Year Book (1966)
Data compiled by the Japanese Poly-vinyl Chloride Association

Many people have pointed out the following as factors hindering the rapid industrialization of Cambodia and Vietnam:

1) lack of capital

2) lack of experience in management, technology and labor in industry

3) shortage of fuel and power

4) inadequate transportation facilities

5) lack of mineral resources for industrial raw materials and fuel

6) small domestic market

Of the above, the greatest disadvantage is 5), the lack of mineral resources and the other factors are more or less the same for most developing nations.

There is a possibility that these detrimental factors will be greatly changed during the next ten years. As already stated, if the development programs of the two countries progress smoothly, 3), the shortage of fuel and power, will be eliminated at least for industries set up mainly for the domestic market. At that time of the Sambor Project is realized, it would offer great opportunity to establish power-oriented industries.

However, unless there is new discovery of minerals which would be suitable for raw materials and fuel, it will be impossible to stand in a favorable position resources-wise over other areas. Nevertheless, the hydroelectric resources of Sambor are definitely an asset for industrialization.

The detrimental factors above other than 3) and5) are all socio-economic. However, the domestic market and the fields of transportation and communication are greatly influenced by natural conditions.

First, in the domestic market, both countries have economic structures based on agriculture with most of the population engaged in agricultural production. The small size of the domestic market in both countries at the present is essentially the result of the small purchasing power of the agricultural population. Therefore, as planned by the governments of both countries, the fundamental approach would be to industrialize in gradual steps while improving agricultural productivity. In general, natural conditions which determine agricultural production such as land, water and climate are not very much different from other Southeast Asian countries, except that the agricultural products are almost all rice and rubber at present. Although rice and rubber are the main agricultural products at present, other secondary agricultural products (such as animal feed, various local products, farm products for industrial use), whose relative importance in the economy of the nation is still low at present, are increasing. Their importance in the domestic and export markets and their growth in the future is greatly anticipated.

Both Cambodia and Vietnam have plans of becoming self-sufficient in chemical fertilizer as an important impetus to industrialization. This is the general approach taken in the countries of Southeast Asia.

The domestic demand for chemical fertilizer will be stimulated and, although gradually, there will be a steady increase in demand. In this connection, it will be necessary to make concerted efforts to reform land holdings, marketing structures and markets for agricultural porducts.

Next, regarding transportation and communication, there seem to be no special disadvantageous features in the Mekong River and the plain area of its basin compared with other areas. With the exception of districts separated by the surrounding mountains, there are good possibilities of forming a well-coordinated economic zone.

From the aspect of flood and drainage control, however, a disadvantageous condition exists for reinforcing the road network in the plain area of Cambodia. Overland transportation between Cambodia and Thailand can be achieved extremely readily. There is slight inconvenience topographically in overland transportation to Laos and North Vietnam, but to Laos, surveys are progressing for inland navigation on the Mekong River. For transportation overseas, both Cambodia and Vietnam have seaports besides river ports on the Mekong River. These ports are not very large, but it is feasible to expand them without difficulty.

In short, the natural conditions in regard to transportation and communications are generally favorable although perhaps not excellent in comparison with those of other areas. If these were to be developed in advance of industrialization, the problem would be mainly reflecting on financing the cost.

As described above, the only natural condition disadvantageous to industrialization seems to be the lack of mineral resources. The other conditions, except for the special problems arising from an unfortunate situation in Vietnam, are all socio-economic factors such as capital, technology and the social system. These factors are seen in newly developing countries in general. Although it is necessary to make comparisons of these factors with other areas, it may be said very broadly that there are no special differences.

The first asset for industrialization which may be cited is a natural one, the abundance of water. However, negative effects from floods must be considered and a development program which will make available abundant good quality water at cost lower than in other areas must be established.

It seems that economically the development potential of this area was in the past underevaluated. The only natural resources of note were considered to be water and land, and these were not especially superior than other areas. On the other hand it was generally thought the socio-economic condition common to newly developing nations was hindering development.

Certainly, as far as natural resources are concerned, such evaluations are justified. However, when future development is considered, social and cultural resources have important meanings, and development potential should be re-evaluated accordingly. The following three points should be noted.

1) The expanse of the possible development area

2) Geographical location

3) Initiative of the people

In connection with the first item, if the Lower Mekong Basin is thought of as one economic zone, the population and national land area, especially the size of the plain area, can be thought to be suitable for the initial stage of industrialization from the standpoint of the size of the domestic market and the efficiency of administrating the regional development.

The second item, geographical location, is extremely important in connection with foreign trade. This area is advantageously located in relation to the countries to which agricultural and industrial products are to be exported and those from which various raw materials will be purchased. In the future, even if mineral resources are not newly discovered, this advantageous geographical location will greatly compensate for any factors hindering industrialization.

The third point, initiative of the people is very pronounced in respect to industrialization of the area. Because the two countries have undergone long battles for independence since World War II, it may be said the trying experiences have strengthened national ambitions. It is obvious that regaining peace and stabilizing social condition are paramount preconditions for industrialization. At such a time misfortune should be turned to advantage, and actually, movements in this direction seems to be seen in educational and development policies. Although social and technical cpabilities cannot be compared with those of other areas, so far as the initiative of the people is concerned, there are the above objective foundation and the climate is not severe as to discourage the initiative of the people.

The following conclusions are drawn. The various conditions which hamper industrialization in this area are basically the lack of capital and technology, as well as the unbalanced social structure. Although the area is somewhat inferior in respect to natural resources, the expanse of the area and geographical location are advantageous. The initiative of the people is not lacking,and it is possible to improve established social systems. Therefore, it is thought that capital and technical cooperation with developed nations will be effective in bringing about industrialization of these countries with a result at least the equal of other newly developing nations.

(3) Conditions of Location by Category [1/]

(a) Power-Oriented Industries

Source. 1/ *Survey of Power Market of Mekong River, Sambor Project*, December 1965, OTCA, Tokyo, Japan

Aluminum, caustic soda and carbide manufacturing are basic types of industries which consuming bulk power, while ferro-silicon, carborundum and electric furnace steel manufacturing are types which absorb surplus power.

The conditions for establishment of these industries are governed in principle by electric power and the sources of raw material and fuel. Since the area must depend on imports of the major portion of raw materials and fuel, and in view of the large quantities to be transported and the low capacity to bear transportation costs, it is thought fundamental to establish the industries on the sea coast and supply electric power by transmission lines.

Aluminum: If production is considered to be 125,000 tons per year as described later in C-2., bauxite will have to be imported unless new domestic sources are discovered in the future. The quantity would be approximately 500,000 tons annually or an average of about 40,000 tons monthly. Heavy oil, carbon materials for anodes, and other materials must also be imported. As for the 125,000 tons of product, it should be considered the greater part will be exported for the time being. Therefore, it will be necessary for the aluminum industry to be established adjacent to a port which can accommodate vessels of at least the 10,000 ton class. Furthermore, water and land conditions will be important factors.

Caustic-Soda: If the production is estimated as 130,000 tons per year as described later in C-2., approximately 190,000 tons of salt and 50,000 tons of coal will be required annually. The salt sources are on the sea coast of both Cambodia and Vietnam, and it is thought advantageous to use small coastal shipping for transportation for both countries. Coal is produced in Vietnam, but there is already a plan in progress to establish an electrochemical industrial complex in the coal production district. Also, there is a plan for an electrochemical industrial complex to be established in the Cam Ranh Bay area and since this will be carried out first, it will not be possible to rely on Nong Son coal for the Sambor Project. Therefore, coal or oil would have to be imported. Although, there probably will be no export of the caustic soda produced, it will be most appropriate to establish the industry in a district where a port is available.

Calcium Carbide: As described later in C-2 , if the production is to be 242,000 tons per year, approximately 440,000 tons of limestone, which is the main raw material, will be available within the area. Approximately 160,000 tons of coke and 16,000 tons of anthracite coal will be required annually, and since it must be considered difficult to obtain this within the area, these would have to be imported. In this case, ships of the 5,000 ton to 6,000 ton class will be necessary.

In principle, the product would not be exported. If this industry were to be established independently, it would be of advantage to locate it at the source of the limestone, but overland transportation to the ports of the before-mentioned scale will be necessary. If the industry is to be established grouped with other industries, it might be more appropriate to locate it in an area with port facilities, depending on the conditions. In any event, the relation with ports and harbors will be an important factor to be considered.

As caustic soda is used in the calcining of alumina and the chlorine by-product combined with carbide becomes a raw material for vinyl chloride, it would be of advantage to locate the above-mentioned three industries in the same district if integrated aluminum production is considered.

The three other industries (vinyl chloride, ferro-silicon, and silicon-carbide) are types that absorb surplus electric power and normally are located in the same district as the basic industries. The main raw materials of ferro-silicon and silicon carbide are available within the area, but most of the product would be exported. As for steel manufacturing, at the present stage when it is not known whether the iron ore of Cambodia can be considered the raw material will be imported. Therefore, these industries should be located in the proximity of ports and harbors.

From the standpoint of raw materials and fuel, market for the products, transportation, mutual relationship among the products of the various industries and utilization of electric power, it would be desirable to locate the above power-oriented industries on the sea coast in the form of one industrial complex. However, depending on the conditions of siting of factories, it will be necessary to consider the various forms of industrial complex most suited to those conditions.

(b) Secondary Industries

Directly related to the siting of power-oriented industries, there are a number of resulting industries, but in this case factors other than electric power become of importance.

Aluminum processing, machinery, bicycles and automobile industries should be located near consumption areas. So far as machinery and automobiles are concerned, the scope would probably be limited to manufacture of some parts, assembly and repair. As urban population and industry increase, there will arise the need to improve the quantity and quality of the labor force.

In the case of the cement industry, it should be located as near as possible to both the sources of limestone and coal and the consumption areas. The limestone deposits of both countries are distributed somewhat distant from central cities, but with progress in the development of agriculture and highways, the consumption areas would extend to the provinces so that the location of the factory near the limestone source will become advantageous. Fuel for calcining cement must be imported in the case of Cambodia, but in Vietnam, Nong Son coal can be used although the conditions are not good in respect of geography and quality of coal.

In the pulp and paper industry, conditions for collection of logs and availability of water are decisively important. Experience in the bamboo pulp industry in Cambodia has revealed that the collection of bamboo involves unreasonably great volumes compared to wood and is therefore uneconomical. Although both countries abound in forest resources, as far as pulp wood is concerned, there is only a little to be expected from the pine forests in Vietnam, while in Cambodia there seems to be little hope of producing wood pulp. Furthermore, even if the primitive water utilization methods of the inhabitants of this area are modernized in the future, industrial waste which will cause water pollution will be a special problem of sanitation so that the location of this industry in inland districts will have to be given careful thought.

The mixed fertilizer industry with calcium nitrate as the main component could be located at the center of the consumption area. However, it is difficult to use calcium nitrate, and transportation costs of nitrogen material will be comparatively higher than those of ammonium sulphate and urea. Also, because of the farmers' primitive method of utilizing water, there will be the danger of water pollution, so that further study of whether this industry will be economical should be conducted.

Vinyl chloride production should in principle be located in concert with the carbide and caustic soda industries due to reasons of transportation of raw materials. Acetylene and derivatives are also in the same position. Industries which process these intermediate products are generally more advantageously located in the consumption areas.

Detergents and agricultural chemicals are normally produced in consumption areas, but in this case, it may be acceptable to locate them in the same district as the carbide and caustic soda industries.

In short, industries to be located together with power-oriented industries are vinyl chloride, acetylene and derivatives, while cement, paper and pulp should be located at the source or collection point of raw materials. Aluminum processing, machinery, bicycles and automobiles should be located in consumption areas. Detergents and agricultural chemicals, in consideration of transportation of raw materials, should rather be located in the port districts like the power-oriented industries.

(4) Siting of Power-oriented Industries [1/]

As described in the preceding section, it is necessary to locate all power-oriented industries in the port district. Ports which can be cited as locations for industries which will consume the electricityof Sambor Project are Phnom Penh and Sihanouk Ville in Cambodia and Saigon in Vietnam. Conditions, requiring special consideration based on the information contained in a report prepared by the Japanese Survey Team "Kingdom of Cambodia – New Phnom Penh Port Pre-Investment Basic Survey" on the two-port locations in Cambodia, and for the port of Saigon the information made availably by the Saigon Port and Harbor Bureau, are described hereinunder.

(a) Port of Phnom Penh

Geographical Location: The river port at Phnom Penh, the capital of Cambodia, is located approximately 330 km from the mouth of the Mekong River. The river is joined at this point by the Tonle Sap River, and the downstream part branches into the Mekong River mainstream and the Bassac River. Port facilities and the city area of Phnom Penh are on the west bank of the Tonle Sap.

Source: 1/ *Survey of Power Market of Mekong River, Sambor Project*, December 1965, OTCA, Tokyo, Japan

A new port is planned at a point 2 km upstream of the confluence of the mainstream of the Mekong River and the Tonle Sap River on the right bank of the Mekong River.

Climate:

(Temperature)

	April	January
Maximum	35.6°C	29.1°C
Minimum	24.8°C	18.5°C
Mean	30.2°C	23.5°C

(Humidity)

Average 60%-80%

(Wind Velocity, Wind Direction)

West-southwest in the rainy season and north-northeast in the dry season. The wind velocity is seldom greater than 6 m/sec.

(Rainfall)

1,500 mm/yr. in an average year

Depth of Water: Presently, due to limitations caused by sand bars at the mouth of the Mekong River, only fully loaded freighters under the 2,000 ton class can enter the port. With improvements at the river mouth, vessels with a 6.1 m draft (4,000 ton class) will be able to enter the port. In the plan for the new port, the water channel will be dredged to permit navigation of 4,000 ton vessels with berth lengths designed for 3,000 ton class, and in the future vessels up to 4,000 tons can be accommodated.

There is a problem with sand deposits at the entrance to the Port of Phnom Penh, and dredging is performed at two locations each year.

Port and Harbor Facilities:

(Mooring Facilities)

Reinforced concrete pier with two berths for 2,000 ton class vessels, four floating piers, two petroleum landing piers, one railroad connection pier, 24 floating piers for inland navigation and one pier for shipping livestock.

(Cargo Handling Facilities)

17 buildings with 8,576 sq.m, floor space for cargo storage. Truck cranes, fork lifts available for cargo handling.

Land and Water Situation:

At present, since the port facilities are in close proximity to the city area, there is no room for expansion and a new industrial port will have to be planned. Surveys are already under way.

The flat area of the hinterland is extremely expansive and is sufficient in area, but a considerable amount of land reclamation and improvement will be required for protection against floods.

Land prices in the city area of Phnom Penh are already showing a rising trend, and in the case of factory sites, the prices seem to be approaching those of newly developed areas in Japan. With progress in urbanization, it is thought the influence of rising land prices will affect areas scheduled for factory construction.

Although sufficient quantities of water can be readily taken from the river, the quality of the water is not known and must await the results of future investigations.

Other Regional Conditions:
The city of Phnom Penh has a population of about 500,000 which is reoughly 10% of the entire nation. Industry and commerce, as already states, is overwhelmingly advanced compared to the rest of the country. The city is an important center of transportation and is connected to foreign countries as well as all parts of the country by roads, railways and rivers and streams. Most of the cargo handled at the port of Sihanouk Ville passes through Phnom Penh. As it is the center of government, economy and culture, future growth can be anticipated.

(b) Port of Sihanouk Ville

Geographical Location: Located approximately 180 km directly southwest of Phnom Penh, Sihanouk Ville faces the Gulf of Thailand and is they only seaport of the country. Internationally, the location is not much different from the port of Saigon to be described later.

Climate:

(Wind Direction, Wind Velocity)

Approximately 30 times during the monsoon season from the end of May to October, there is southwest or northeast wind usually of a velocity of 10 m to 15 m lasting about 2 hours. However, it is said this has no effect on cargo handling although certain problems are arisen, which will be described later.

Both temperature and humidity are higher than at Phnom Penh and there is more rainfall.

Depth of Water:
The entrance channel extending south-southwest along the mooring pier seems to be 80 m wide with a depth of 8.40 m. The maximum permissible draft is considered to be 7.6 m. Vessels with greater draft is said to wait until high tide to enter the port.

High and low tides come twice a day. The average high tide level is +1.40 m, but at times reaches +1.70 m.

The sea bed of the port area is mostly sand with sandstone strata at places.

Port and Harbor Facilities:

(Mooring Pier)

There are two berths for 15,000 ton class vessels and two berths for 10,000 ton class vessels. Construction started in 1956 as the first stage project and was completed in 1959.

According to expansion plans, parts with depths of about 5 m were to be deepened to 10 m and berths were to be completed in 1967.

(Sheds)

There is one reinforced concrete shed, 4,620 sq.m., in floor space. A small amount of cargo handling equipment are available.

Land and Water Situation:
Thre is extremely little information in this respect, but as the New Phnom Penhm Port Survey Team has pointed out, it is true that there is a lack of flat land or water in the back of the port. However, there is a reclamation Kompong Som Bay side of the port which is thought to be practicable.

The industries which are conceivable would be required to be located extremely close to the port, but in this case they would be limited by land and water. Therefore, besides Sihanouk Ville, two alternative sites comparatively nearby were selected on a map and estimates mainly of water were made.

Sihanouk Ville: Under the present circumstances, the plain area is so small that only a part of the suggested industries can be located here. However, if reclamation of 10 million sq.m is carried out, the land area will become adequate for the time being. As for water, it is conceivable to take in water from the Prek Tuk Sap River approximately 20 km east of this district and build a storage dam behind Sihanouk Ville and pump water into the reservoir, but this would be an expensive water supply.

As an added note, it is thought there are limitations both quantitatively and qualitatively in the use of underground water.

Ph Ong District: At the point where the road between Sihanouk Ville and Phnom Penh branches off towards Ream, there is a plain with an area of 2,000 ha. If this district could be utilized, water can be taken in at the same site as mentioned before. In this case, also, since a reservoir would be necessary, the same problems exist as for Phnom Penh. However, the improvement and utilization of the port of Ream and reclamation works in the future are technically promising and further surveys of this district are anticipated.

Kampot: The distance from Sihanouk Ville is approximately 100 km, and the population is 30,000 to 40,000. The productivity of the farms in the surrounding area is comparatively high. It is possible to reclaim salt beds to create necessary land for industrial use. It is estimated that at least 10 cu.ms of firm flow can be secured from the Kam Chay Development Project on the Prek Tuk River. If industrial water supply can be included in the municipal water supply and irrigation water supply features of the project, water for industrial use can be obtained at a considerably lower cost than at the first two districts.

Other Conditions of the Area: The city area of Sihanouk Ville has only been built in recent years, and although foreign trade is lately being handled through this port, in commerce and industry it is extremely under-developed and concentration of population is very low. In order to cover this disadvantage and to develop the city as an industrial port, a railway to Phnom Penh is being planned. In this respect, so long as trade will be with Asiatic countries even after completion of the railway, Phnom Penh Port would still be at an advantage over Sihanouk Ville in regard to the transportation cost.

Also, from the point of view of availability of sheds and warehouses, the fact that there is no breakwater, and this district is in a heavy rainfall zone, which would greatly affect the cargo handling capacity of the port that might be big disadvantages. Furthermore, the land and water conditions can also be cited as basic problems. In spite of these unfavorable conditions, since Sihanouk Ville is a seaport, it can be considered better than Phnom Penh as an industrial port.

(c) Port of Saigon

Geographical Location: The port is in the capital of Vietnam and is called Port Saigon-Cholon. It is located on the right bank of the Saigon River, a tributary of the Dong Nai River, and is approximately 72 km upstream from the mouth of the river.

Internationally, the port is in an intermediate location between Europe and West Asia, China and Japan. The distances to major ports are approximately as listed below.

Hong Kong	934	nautical	miles
Manila	906	"	"
Tokyo	2,449	"	"
Singapore	650	"	"
Marseilles	7,210	"	"

Internally, the port is at the center of roads, railways and river navigation of Vietnam and is the door step to a high agricultural productivity area of the country.

The port is connected to Phnom Penh in Cambodia by a highway approximately 240 km long and beyond that to Thailand by way of Battambang.

Climate: Although Saigon is at roughly the same latitude as Sihanouk Ville, temperature, humidity and rainfall are more like Phnom Penh.

Depth of Water: The first channel from the ocean which is called Soi Rap, limits entrance to vessels of less than 6.5 m draft. The second channel, called the Saigon River, is approximately 16 km shorter than the former and permits entrance of ships up to drafts of 9.3 m and lengths of 210 m.

A pilots' office is located at Cap Saint Jacques where anchorage is protected by breakwater and vessels can drop anchor freely.

The tide at Cap Saint Jacques fluctuates between 3.6 m to 4 m, which is the same at Saigon.

Navigation obstacle or the East Bend of the river resticts the length of vessels to not more than 222 m, while there is a limestone bed at a depth of 6.20 m so that high tide must be awaited for passage.

The Saigon River is naturally maintained by tides.

Regarding the harbor itself, maintenance work which had been performed before the World War II has been almost entirely discontinued since 1941, and the deposit of sediment has begun to impede navigation.

In 1955, dredging was performed with the purpose of securing depths of 1.5 m to 3.5 m widths of 20 m to 80 m in the canal in the Cholon District and depths of 9 m at buoys and piers at Port Saigon.

As will be described later, if Saigon is to develop as an industrial port in the future, port facilities will have to be newly built downstream of the present port. From the standpoint of water depth there will be no trouble for vessels of over the 10,000 ton class to navigate the river.

Port and Harbor Facilities:

(Mooring Facilities)

Port Saigon is comprised of three parts, the respective facilities being as listed below.

Saigon Seaport: Mooring Piers. Two berths for vessels larger than the 10,000 ton class, more than seven other berths including piers for exclusive use of shipping and cement companies. 15 mooring buoys.

Nhabe Seaport: This port is located 16 km downstream of Saigon and handles inflammable or explosive cargo exclusively. There are five berths for tankers and three mooring buoys.

Saigon-Cholon River Port: 25.6 km of canals, total length of piers 5 km, numerous other small public and private mooring piers.

(Sheds)

A total of 37 sheds having 73,600 sq.m of floor space in the seaport section and numerous private sheds and warehouses in the river port section.

(Cargo Handling Equipment and Others)

Cargo handling equipment consisting of floating cranes, electric cranes, tractors, wagons, etc. Numerous other facilities consisting of railway side track, illumination boats, tugboats, launches, fresh water supply barges, etc.

(Fuel Tank)

62,000 cu.m petroleum tank at Port Nhabe.

(Ship Repair Yard)

Besides a repair yard with a 150 m x 21 m dock owned by a company with French capital, small-scale private docks owned bya number of other companies.

(Water Supply and Other Facilities)

Tank barges and fresh water supply facilities at piers, coal sheds, food supply facilities, etc.

(Expansion Plans)

Before the World War II, the port was mainly used for export, and loading was performed with vessels moored to buoys, but it would seem imports would prevail and cargo be handled at piers in future. Due to this situation, the present facilities are inadequate and congestion is unavoidable. Therefore, piers 138 m and 80 m long are to be built shortly. On a long-term basis, the port and harbor area will be expanded at Nhabe and on the left bank. It is believed the expansion as an industrial port will be in this area.

Land and Water Situation: At Saigon, as at Phnom Penh, new expansion will be required for an industrial port, but there are no special problems regarding the conditions of land and water. However, it should be noted that there might be a trend here also of rising land prices and that information on geology is inadequate.

Water would be drawn from the Dong Nai River. According to investigations made by the U.S.A. there appears to be no problem in regard to the quantity and quality of water. The distance from the intake site now under construction and the industrial port is about 25 km, and upon completion of the water conveyance facilities, there should be no problem of supply of industrial water.

Other Regional Conditions: The Saigon-Cholon District might have a population exceeding 1,600,000 and be a great center of government, economy and culture. The productivity of the farming villages in the surrounding area and population density is high. Roads and railways are developed with Saigon as the center, and in the interior, there are highways connecting to major Cambodian cities of Kompong Cham and Kratie as well as Phnom Penh.

(5) Types of Industrial Complexes 1/

Cambodia and Vietnam each has one sea port suitable for siting of power-oriented industries to consume power produced at the Sambor Project.

In the preceding section, the elimination of the river port of Phnom Penh was based on the fact that it is unsuitable as a port from the viewpoint of navigable vessel size for the aluminum and carbide industries which are among the power-oriented industries considered, while other types of industries should in principle be located in the same district with one of the two basic industries mentioned above. The method of arriving at the above premise, or in other words the method of combining power-oriented industries, should once more be examined. Because, if an industrial complex consisting only of industries which can be located at a river port handling small vessels were to be practicable, Phnom Penh should naturally be given consideration.

Also, at the time the Sambor Project is completed, the two countries concerned might not necessarily desire to introduce all of the industries suggested in this report. The reason is that both countries are pushing ahead industrialization plans based on electric power development, and there are a considerable number of industries in these plans which are identical to those considered in this report. Furthermore, as will be described later, whether one of the countries will monopolize all of these industries, or whether a friendly division is made would be an international problem of great importance.

For the above reasons, on the premise that there are two suitable locatation, i.e., Sihanouk Ville and Saigon, the industrial complex to be established will be considered.

With one suitable location in each country for the industries suggested, the types of industrial complexes conceivable according to the combination of industries are as listed below.

i. All Industries in One District

As stated above, this type is the most desirable as an industrial complex. With participation of a number of related industries, the close relationship in materials and power will make possible owering of overall costs. One transmission line system will suffice. However, in this case, either Sihanouk Ville or Saigon would be monopolizing all of the industries.

Source 1/ *Survey of Power Market of Mekong River, Sambor Project*, December 1965, OTCA, Tokyo, Japan

ii. (District A) Aluminum; (District B) Calcium Carbide, Caustic Soda, Ferro-silicon, Silicon Carbide

This would be the idea of locating aluminum alone at either one of the districts as the amount of caustic soda to be transported from District B to District A is not very great. If it is considered the aluminum industry will seek markets for its products overseas, then regardless of the domestic market, there is a possibility to locate this industry independently. The calcium carbide and caustic soda industries of District B will not be practicable unless the domestic market is developed to some degree. The related industries would be concentrated in District B.

iii. (District A) Aluminum, Ferro-silicon, Silicon Carbide; (District B) Calcium Carbide, Caustic Soda, Vinyl Chloride

The predominant industry of District A will still be aluminum. In this case, since little caustic soda is used for calcining alumina, the existing production capacity would be adequate.

There is no need to repeat that the ferro-silicon and silicon carbide industries are included to consume surplus power and will be of small scale. The carbide industry of District B would mainly be for production of vinyl chloride, besides calcium nitrate and acetylene derivatives.

iv. (District A) Aluminum, Caustic Soda, Ferro-silicon, Silicon Carbide; (District B) Calcium Carbide, Caustic Soda, Vinyl Chloride, Ferro-silicon, Silicon Carbide

The caustic soda of District A would be for the calcining of alumina so that small-scale production would be adequate. Other than the fact that surplus power consuming industries are provided in both districts, the industrial complex is similar to those of Type ii mentioned above.

v. (District A) Aluminum, Calcium Carbide, Caustic Soda, consuming Vinyl Chloride; (District B) Ferro-silicon, Silicon Carbide

The idea would be to concentrate firm power industries with aluminum and carbide as the main industries in District A and to locate surplus power consuming industries in District B.

In this case, the industries of District B would generally need less transportation. With some leniency in vessel sizes, this would be the only type of industrial complex which could be located at Phnom Penh. If the Sambor power resources were to be consumed in Cambodia alone, there would arise the possibility of establishing an industrial complex spread out over a wide area between Sihanouk Ville and Phnom Penh. However, in this case also, there would be disadvantages in transportation costs and power transmission costs in comparison with an industrial complex of Type i at Sihanouk Ville or its vicinity.

It should be noted that in Type i and Type v, load will be concentrated in either District A or District B, causing a basic change in power transmission plans as compared with Types ii to iv.

As the form of an industrial complex, Type i is the desirable. If this cannot be realized due to various circumstances, either Type ii or Type iii should be adopted.

From the ten different combinations of the five types which are conceivable as possibilities, eight location groupings are selected for comparison as shown in Table C-29

Table C-29 Types of Industrial Complexes and Locations

No.	Types of Industrial Complexes	Geographical Classification	Location
1	i	All Industries	Sihanouk Ville
2	i		Saigon
3	ii	A	Sihanouk Ville
	ii	B	Saigon
4	ii	A	Saigon
	ii	B	Sihanouk Ville
5	iii	A	Sihanouk Ville
	iii	B	Saigon
6	iii	A	Sihanouk Ville
	iii	B	Saigon
7	iv	A	Sihanouk Ville
	iv	B	Saigon
8	iv	A	Saigon
	iv	B	Sihanouk Ville

No. 1, No. 2 (Type i):

This is a type where all of the industries will be monopolized by either Sihanouk Ville or Saigon. However, in consideration of the location of the Sambor Project, No. 2, in which all industries would be concentrated in Saigon, is perhaps unrealistic. On the other hand, No. 1, in which Cambodia would monopolize all industries is conceivable. In this case, depending on the land and water situation at Sihanouk Ville, there is a possibility for a part or all of the industries to be located somewhat apart from the port. Especially, in the case of calcium carbide, since the main raw material which is limestone would be hauled from near the route of the railway between Sihanouk Ville and Phnom Penh, this industry could be located at the quarry to reduce transportation distance and lower costs.

No. 3, No. 4 (Type ii):

In this type, aluminum would be located by itself and the other industries will be concentrated in another district. Judging from the overall outlook of economic development of the two countries, it would be appropriate for Cambodia with the smaller domestic market to be responsible for aluminum which would mainly be exported, and for Vietnam with the larger domestic market to be responsible for the industries centered around carbide and caustic soda which would be mainly for domestic consumption. In this way, No. 3 would be feasible from the standpoint of allocation of power between the two countries and also would be desirable. Caustic soda for calcining alumina could be supplied from existing production or it could be supplied from Saigon.

No. 5, No. 6 (Type iii):

This is modification of Type ii with surplus power consuming industries located adjacent to the aluminum industry. On the premise of locating the aluminum at Sihanouk Ville, it would be more realistic to locate such industries to accompany the carbide complex at Saigon as in No. 3 (Type ii).

No. 7, No. 8 (Type iv):

The only difference in this case is that the electric furnace industries, which are surplus power consuming industries are separated and allocated between the two districts. Therefore, the conception is the same as in the case of Type ii. In this case, it would be appropriate to adopt No. 7 in which the aluminum industry is located in Cambodia. When this type is compared with Type ii, from the viewpoint of marine transportation for the surplus power consuming industries, it is seen that Type ii is better since these industries would be concentrated in one district. However, if emphasis is laid on allocation of power between the two countries, No. 7 offers fewer difficulties.

Another (Type v):

This type would concentrate the power-oriented industries in either District A or B, and it closely resembles the type i in which one country would monopolize the consumption of power. In this case, since Sambor is located within Cambodia, it would scarcely seem possible to consume the major part of the output in Saigon with only surplus power consuming industries located at Sihanouk Ville.

On the other hand, this type with the main consumption in Cambodia would have high probability of realization along with No. 1 (Type i) in which Cambodia would consume the power by itself.

C-2 Power Consumption Program

C-2-1 Premise

(1) Type of Plan – Type I, II and III

As already stated in the preceding section, the power demand of the Sambor Project would be divided into general demand which in the future is expected to show rapid growth and demand from suitable power-oriented industries.

The power produced at the Sambor Project at the time of completion of the seven units of 125 MW will be a maximum of 875 MW, and the 33-year average annual energy production will be 7,000 million kWh. Of the numerous conceivable combinations of allocating this energy to the various demands, three basic consumption patterns were studied.

[Type I] General demand and all of the power-oriented industries stated in the preceding section.

[Type II] General demand and, of the power-oriented industries, only the group (caustic soda, veinyl chloride and calcium carbide) which is thought will mainly be for consumption within the area.

[Type III] General demand only.

The output of the Sambor Project is 875 MW and 7,000 million kWh, but the firm output is 473 MW. Therefore, there will naturally be a certain limitation on the combination of general demand and magnitude of the power-oriented industries in each of the above types. On one hand, there are also limitations from the aspects of demand for industrial products and the scale of the economy. Next, the combinations and scales of demand, and the principles for allocation of power in each type will be described below. Economic evaluation of the power consumption plan according to type will be given in Chapter K.

(2) Type I

(a) Demand Considered and Principles of Power Allocation

The output of the Sambor Project, as described in detail in Chapter F, will fluctuate considerably according to the annual and seasonal variation of runoff. Against the installed capacity of 875 MW, the average output in the driest season will be 473 MW based on the runoff data of the past 33 years. In view of this situation load variation corresponding to the fluctuation of output must be considered.

Firm demand may be classified as below in accordance with their characteristics.

Firm Demand 1/:

General demand (the service level would fluctuate corresponding to the stage of development of the economic society, but this may reasonably be considered as being firm in comparison with power-oriented industries).

Integrated aluminum refining (it possesses technically the strongest firm nature of all power-oriented industries)

Periodical Firm Demand [2]:

- Caustic soda
- Vinyl chloride

Electric furnace industries (though it may be desirable to be supplied with firm power, it may be operated at a considerably low plant factor depending on power cost):

- Calcium carbide
- Ferro-silicon
- Silicon carbide

The allocation of the supply capacity would follow in the above order, and especially in the case of general demand and integrated aluminum refining industry, plans must be drawn up to avoid interruption of supply at least based on the 33-year runoff data. On one hand, calcium carbide and other electric furnace industries would generally be supplied with periodical firm power. However, for all industries, daily load regulation will not be performed.

Hereinafter the 33 hydraulic years will be classified as follows:

In the 33 years –

2 years (1938, 1939):	Wet years	(Group A)
15 years (1936, 1940-51, 1962, 1965):	Normal years	(Group B)
16 years (1933-35, 1937, 1952-61, 1963-64)·	Dry years	(Group C)

The overall average for the 33 years will be called "33-year average" or "average year"

(b) Magnitude of Each Demand

Because of the inherent nature of each demand, if it is required to allocate the power according to the principles described in the preceding paragraph, it would be reasonable to divide the supply capacity of the Sambor Project into firm power and secondary power in determining the scale of each demand.

First, it is more natural to allocate firm output of 473 MW to general demand and integrated aluminum refining because of the reasons given above. There are other demands which relatively require firm power, but since the requirement of aluminum for firm power is far greater, it is considered that aluminum should, along with general demand, consume the firm power of 473 MW.

The points to be considered in allocating the firm power of 473 MW to these two demands are described as follows:

As stated in C-1-1 "Present and Estimated Future Trend of General Demand," it is estimated that from 1978, the required capacity to supply the increment of general demand on the Sambor System in Vietnam and Cambodia, will be as indicated below. (Values at generating end)

1978	47 MW	247 million kWh
1980	164 MW	828 million kWh
1985	608 MW	3,068 million kWh
1990	1,289 MW	6,513 million kWh

1/ Demand with a strong characteristics requiring firm power

2/ Demand of a firm nature during a certain period, for instance, during the wet season.

The Sambor Project will supply 60% of the increment of general demand. (Values at generating end)

1978	28 MW	147 million kWh
1980	98 MW	516 million kWh
1985	365 MW	1,918 million kWh
1990	769 MW	4,042 million kWh

Therefore, if a large part of the firm power is allocated to general demand, it would mean that there will be a considerable time lag before the full output of 875 MW of the Sambor Project will be consumed, and this would be contrary to one of the aims of Type I to bring about early completion of the project from both aspects of supply and demand of power.

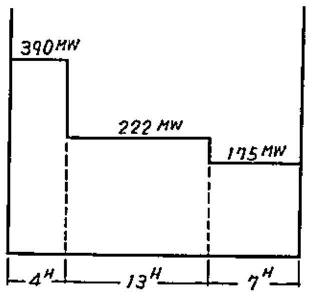
However, the larger the general demand, the higher would be the overall economic benefits of the Sambor Project. The reason for this is that the benefits created by the project would be greater if the power were allocated to general demand rather than to aluminum refining (See Chapter K-2)

Aluminum refining should, first of all, be on a unit scale which is economically suitable from an international standpoint. In other words, scales of 10,000 tons annually or 1,000,000 tons annually are unthinkable. The concept of an economic scale is based at the same time on the premise that the increase in capacity to supply aluminum ingot is roughly appropirate in relation to the scale of the market for ingot.

On onehand, as will be described later, in the operation of Sambor Project, there will be a limitation on the range of fluctuation of water level in the downstream, and there will have to be a constant discharge above a certain value. In other words, if the general demand is made too large, the kW ratio between peak and midnight off-peak is about 100:45 so that the difference in discharge between peak and midnight off-peak will become excessively great, and will excess the permissible range of fluctuation in the downstream water level. Considering the above points, the allocation of the firm power at the generating end should be as follow:

General demand	390 MW	Load factor 60%
Aluminum	250 MW	Load factor 96%

Further, the daily load curve of the 390 MW general demand is assumed as shown below.



The 250 MW for aluminum refining, assuming an overall loss of 4%, would require a 240 MW installation at the consuming end. Operating at an annual plant factor of 96%, 2,016 million kWh of energy would be consumed. With a unit power requirement of 16,100 kWh per ton, the annual production of aluminum ingot is estimated as 125,000 tons. Internationally, compared with the plans of Bellcon Aluminum of the U.S.A.1/ and a project in New Zealand 2/ and elsewhere, the proposed plant will not be too large in the light of recent economic trend.

Source: 1/ Joint venture of Showa Denko and Yawata Esconsteel of Japan and Taxas Aluminum Company of U.S.A. Annual production 118,000 tons Scheduled to begin operation in 1969.

2/ A program by Comalco Company to built a 120,000 tons aluminum refinery with alumina supplied from Queensland:

The difference of 235 MW, after deducting the 390 MW for general demand and 250 MW for aluminum refining, is allocated to the other power-oriented industries in order to fully consume the 875 MW maximum output of the Sambor Project. For this purpose, as described previously, a power consumption plan centered around vinyl chloride, ferro-silicon and silicon carbide will be established. It is not known what the demand for vinyl chloride will be in the Lower Mekong Basin around and after 1980, but for the present time, 125,000 tons will be assumed as the magnitude of the vinyl chloride production with power supplied by the Sambor Project. Assuming a 2% annual population growth rate in the four riparian countries of the Lower Mekong Basin, the total population would reach approximately 100 million in 1978 so that the scale of production would be in the range of 1 kg per capita. (See Table C-28)

At a unit power requirement of 1,000 kWh per ton for integrated vinyl chloride production, the electric energy required to produce 125,000 ton per year will be 125 million kWh. For this purpose an installation of 15 MW at a load factor of 93% will be assumed.

Although the ethylene system has recently become prominent in vinyl chloride production, in the case of the Sambor Project, it is needless to say the calcium carbide system will be adopted because of the aspects of raw materials previously described. In this system, calcium carbide and chlorine are necessary as the main raw materials.

Although the requirements depend on the method of manufacture, process, quality of raw materials, etc., approximately 1.5 tons of calcium carbide and 0.7 tons of chlorine are necessary in producing 1 ton of vinyl chloride. Taking into consideration of the load factors of the plants for the above products, influence of high and low runoff, and supply of electricity to other consumers, etc., an installation of 99 MW for calcium carbide production and 58 MW for chlorine and caustic soda production by the electrolysis process of salt water has been assumed.

Together with chlorine, approximately 130,000 tons of caustic soda would be produced annually. Of this amount 7,000 tons would be used in the calcining of alumina, but the greater part would be supplied to users outside of the complex. It will be examined to see the economic significance of a production scale of 100,000 tons of caustic soda annually in the Lower Mekong Basin. Assuming that the population of the Lower Mekong Basin will be approximately 100 million around 1978 as stated before, 100,000 tons annually would be 1 kg per capita at that time or roughly 10% of the per capita production of Japan in 1965 (See Table C-28). Whether this level would be excessively high or not is open to argument, but since the matter is related to the production level of chlorine as raw material for vinyl chloride, the magnitude of the caustic soda production will for the moment be considered reasonable.

Besides the above, an installation of 27 MW each for ferro-silicon or metallic silicon and silicon carbide or carborundum will be assumed in view of the availability of raw materials and demand for the products.

Summarizing the above, the loads for general demand and the respective power-oriented industries will be tentatively as follows:

	At Generating End (MW)	At Consuming End (MW)
General demand	390	374
Aluminum refining	250	240
Caustic soda	60	58
Vinyl chloride	16	15
Calcium carbide	103	99
Ferro-silicon	28	27
Silicon carbide	28	27
Total	875	840

The magnitudes of these demands will be checked again after computing the allocation of supply capability to see the interrelation between the production of the various products. (See C-2-2 (1))

(c) Interim Stages until Completion

The general demand to be supplied by the Sambor Project after 1978 is to be 60% of the incremental demand, so that before the general demand reaches 390 MW at the generating end, all of the ultimate installed capacity of 875 MW will not necessarily be required. Therefore, the addition of capacity can be started from 1978 in step with the growth in general demand and the ultimate output of 875 MW can be completed at the time the general demand reaches 390 MW at the generating end. However, for the 485 MW to be set aside for power-oriented industries, it will be assumed that demands will be created for the entire amount in 1978.

Schedule of installation based on the above premise would be as given below.

Year of installation	Capacity
1978	125 MW x 5 units
1981	125 MW x 1 unit(additional)
1984	125 MW x 1 unit(additional)
Total	125 MW x 7 units

The variation over the years of installed capacity and demand is indicated in the upper part of Fig. C-5.

(3) Type II

In Type I, it was considered that the 473 MW firm output of the Sambor Project would be consumed by general demand and integrated aluminum refining, but in Type II the firm power would basically be set aside for general demand and the secondary 1/ would be consumed by the power-oriented industries.

If the firm power of 473 MW for the general demand is regulated to generate a large peak demand, it would be possible to obtain about 800 MW, but in consideration of the rise in trailrace water level during flood discharge in wet years and the limitations on fluctuation of downstream water level caused by differences in discharge during peak and midnight off-peak hours, the maximum power for general demand would be limited to 760 MW. (See chapter F-1.)

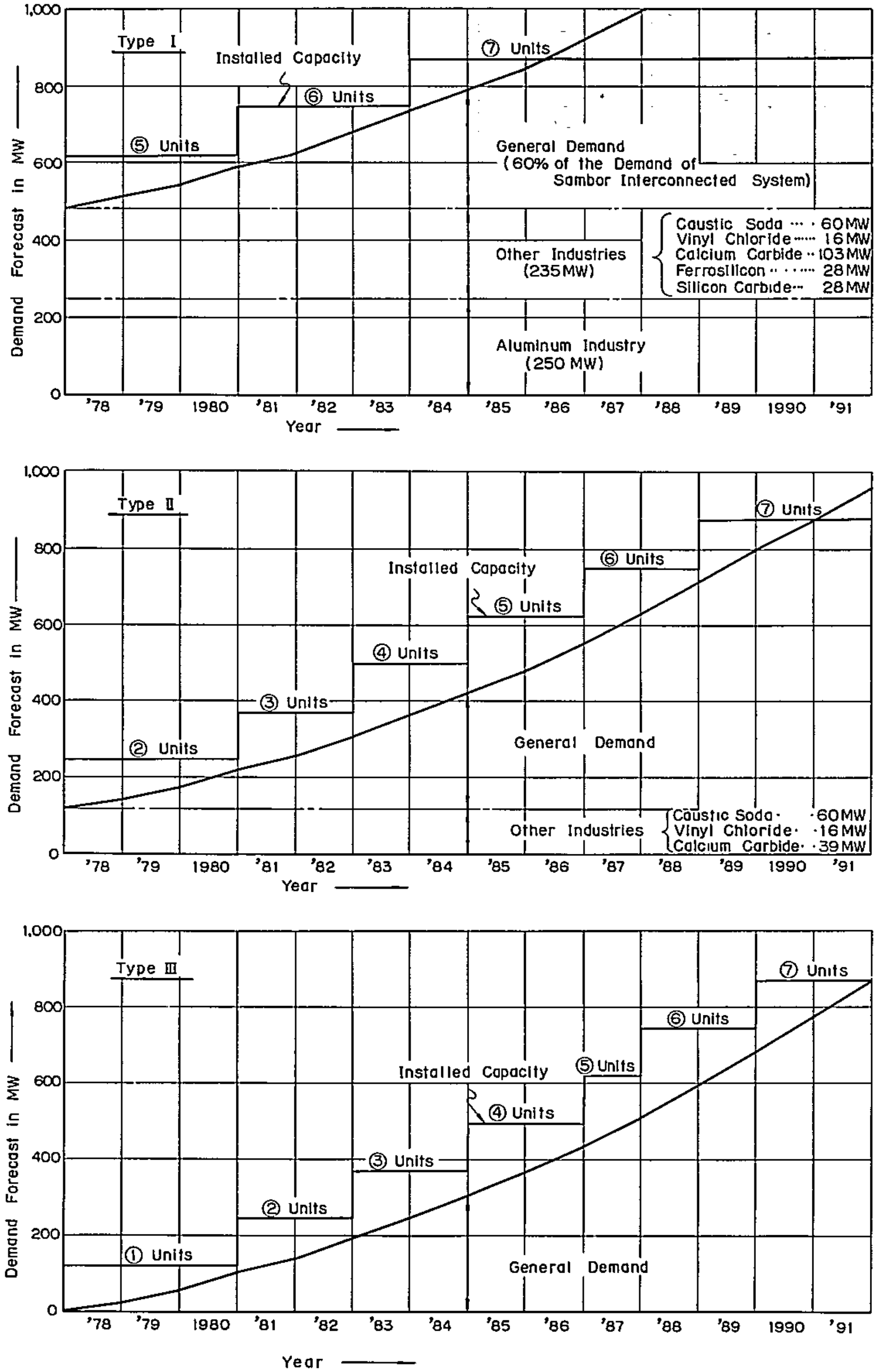
If general demand is 760 MW, then 115 MW could be supplied to power-oriented industries. Based on this allocation of power for power-oriented industries, for vinyl chloride which is promising for consumption within the area has been assumed on the same scale as that in Type I, and the remainder divided between calcium carbide, chlorine and caustic soda which are raw materials for the former product.

Summarizing the above, the type and scale of demand at the time of completion of 875 MW will be as follows:

	At Generating .End (MW)	At Consuming End (MW)
General demand	760	730
Caustic soda	60	58
Vinyl chloride	16	15
Calcium carbide	39	37
Total	875	840

1/ All hydroelectric energy other than primary energy

Fig. C-5 Demand Forecast at Generating End and Capacity Installation Schedule



In the interim period until completion to the ultimate stage, the generating capacity will be based on 115 MW for power-oriented industries from the start of operation in 1978 with gradual increases by steps in accordance with the growth of general demand. This is illustrated in the middle part of Fig. C-5.

(4) Type III

As seen in Fig. C-5, the power-oriented industries, especially in Type I, would consume 95% of the total power demand (kW) of the Sambor Project, in 1978 and 55% upon completion to the ultimate installed output of 875 MW. In consideration of the fact that the power-oriented industries hold the controlling percentage of the demand of the Sambor Project, it is essential to study the scheme of development of the project for the case the implementation of the power-oriented industries is assumed to be impossible.

Aside from the power consumption plans described heretofore, Type III depending only on general demand was examined.

In this case, the installation schedule will be in the form of development in stages corresponding to the growth in general demand as shown in the bottom section of Fig. C-5. With the start-up of the first unit of 125 MW in 1978, if 60% of the growth in general demand in the Sambor Interconnected System is to be accommodated by the Sambor Project, it will be in 1981 that the second unit will become necessary. If the units are added in accordance with the growth of demand in 1990, the final seventh unit completing the 875 MW installation will be attained,and in 1991 the demand will reach the maximum capacity of the project.

However, in this case, to supplement the drop in output during dry and flood seasons, an auxiliary thermal station having an installation of two 75 MW units will be required.

C-2-2 Power Consumption Plan

(1) Type I

(a) 33 Years Average Power Allocation

In accordance with the principles described in the preceding section, the electric energy allocation by type of demand, in 1978 when 625 MW will go into operation and from 1986 when the full installed capacity of 875 MW will be in demand, is shown in Table C-30 (1) (2). This is based on the 33 years average runoff data.

The electric energy at the generating end which can be supplied in 1978, the year of start-up, is 5,377 million kWh. Deducting from this quantity 24% of surplus energy amounting to 1,311 million kWh and loss of 4% between the generating end and consuming end, 3,904 million kWh may be allocated to general demand and power-oriented industries as shown in the table.

Since the Sambor power station is to supply power to fulfill 60% of the indrement of energy demand in its system in 1978 (See C-1-1 (6)), allocation to general demand will be limited to 141 million kWh or only 3.5% of the total energy demand, and the remaining 96.5% will be consumed by power-oriented industries. Of this, the allocation to integrated aluminum refining is a little more than 50% or 2,016 million kWh, and the allocation to the other power-oriented industries is a little more than 40% or 1,747 million kWh.

The fairly high surplus of 24% is due to the fact that against a continuous slow increase in general demand (See Fig. C-5), the installed capacity is increased in steps of 125 MW, and also that the load factor of general demand is 60% and adequate demand regulation to supplement this is not sufficiently accounted for.

At the beginning of 1978, there will be ample supply capacity regardless of wet or dry season, and the output will not be influenced by seasonal fluctuation in runoff.

The energy supply capacity at the generating end will be 7,000 million kWh from 1986 when the ultimate installed capacity 875 MW completed in 1984 will be in full demand.

Deducting the 15% surplus energy of 1,031 million kWh, 85% or 5,969 million kWh would be transmitted to the demand areas, and deducting an overall loss of 4%, 5,731 million kWh will be the electric energy reaching the demand areas.

The allocation to power-oriented industries, as shown in the Table C-30 (1) will be constant from 1978. The allocation to general demand will increase annually, starting with 4% of the total demand or 141 million kWh in 1978 and reaching 34% or 1,968 million kWh in 1986. At this point the allocation will be approximately one third each for general demand, integrated aluminum refining and the other power-oriented industries.

The difference in output between dry and wet season will be absorbed by the industries designed for secondary power, especially electric furnace industries such as ferro-silicon and silicon carbide manufacturing. This is illustrated in the upper section of Fig. C-6 (1).

The figure gives a comparison of the daily load duration curves for flood season (September), high-water season (July) and dry season (April) in a normal water year from 1986.

In the flood season, as previously stated, the supply capability drops to 854 MW because of the rise of water level in tailrace. Corresponding to this capacity loss, the load of silicon carbon will drop to 7 MW by 21 MW.

In the high-water season, it will be possible to supply the full capacity of 875 MW, and both general demand and power-oriented industries will be able to operate at full load.

In the dry season, due to the decrease in runoff, the available energy will drop to an average output of 617 MW. Although the critical maximum output will be 875 MW, supply of power to ferro-silicon and silicon carbide will be completely stopped, and calcium carbide will operate partially at 57 MW. For this reason, the available power by time will be 773 MW at peak hours, 605 MW at off-peak hours and 558 MW in the midnight hours.

The above is an indication of the difference between seasonal high and low water in the normal water year. The upper part of Fig. C-6 (2) gives the situation in the case of the dry year.

(b) Influence of Fluctuation in Annual Discharge 1/

Table C-30 (2) shows a comparison of available energy and allocation of energy by type of demand, between wet and dry year after 1986 and an average hydrological year.

The available energy in the wet year is larger by 450 million kWh than in the normal year while it is smaller by 290 million kWh in the dry year. Therefore, with that of the normal year considered as 100, the supply capacity varies between 106 and 96.

After deducting surplus energy and overall loss, the energy available at the demand end will be 5,933 million kWh in wet years, 5,731 million kWh in normal years and 5,545 million kWh in dry years. As stated in the preceding section, a constant kW and kWh will be guaranteed to general demand and integrated aluminum refining regardless of the influence of the variation in annual discharge, and the fluctuation in energy output will be absorbed by the power-oriented industries excluding aluminum. Therefore, the energy available at the generating end to these other industries will vary between 1,949 million kWh in wet years and 1,561 million kWh in dry years, which shows a fluctuation of a little more than (±)10% for 1,747 million kWh in the average year.

In looking at the fluctuation in available energy broken down by industries, shown on the top part of Table C-30 (2), it is the electric furnace industries which are affected relatively greatly, especially ferro-silicon and silicon carbide which show fluctuations of about (±)20%.

1/ Effect of fluctuation in annual discharge on the available power output of the Sambor Project. (This section deals with a comparative study of annual discharge under four typical types; wet year, normal year, and dry year)

Table C-30 Utilization of Power (Type I) (1) 33-Year Average

		1978	from 1986
Number of Unit	(Unit)	5	7
Installed Capacity	(MW)	625	875
Available Energy	(10^6kWh)	5,377	7,000
Surplus Energy	(10^6kWh)	1,311	1,031
Surplus Ratio	(%)	24.4	14.7

	1978 Generating End Power (MW)	1978 Generating End Energy (10^6kWh)	1978 Consuming End Power (MW)	1978 Consuming End Energy (10^6kWh)	1978 Load Factor (%)	from 1986 Generating End Power (MW)	from 1986 Generating End Energy (10^6kWh)	from 1986 Consuming End Power (MW)	from 1986 Consuming End Energy (10^6kWh)	from 1986 Load Factor (%)
General Demand	28	147	27	141	60	390	2,050	374	1,968	60
Aluminum	250	2,100	240	2,016	96	250	2,100	240	2,016	96
Other Industries	235	1,819	226	1,747	88	235	1,819	226	1,747	88
Caustic Soda	60	504	58	484	96	60	504	58	484	96
Vinyl Chloride	16	130	15	125	93	16	130	15	125	93
Calcium Carbide	103	793	99	761	88	103	793	99	761	88
Ferro-Silicon	28	211	27	203	86	28	211	27	203	86
Silicon Carbide	28	181	27	174	74	28	181	27	174	74
Total	513	4,066	493	3,904	90	875	5,969	840	5,731	78

Note. Energy losses between generating and consuming ends are estimated at 4%.

Table C-30 Utilization of Power (Type I) (2) Wet and Dry Years

(from 1986)

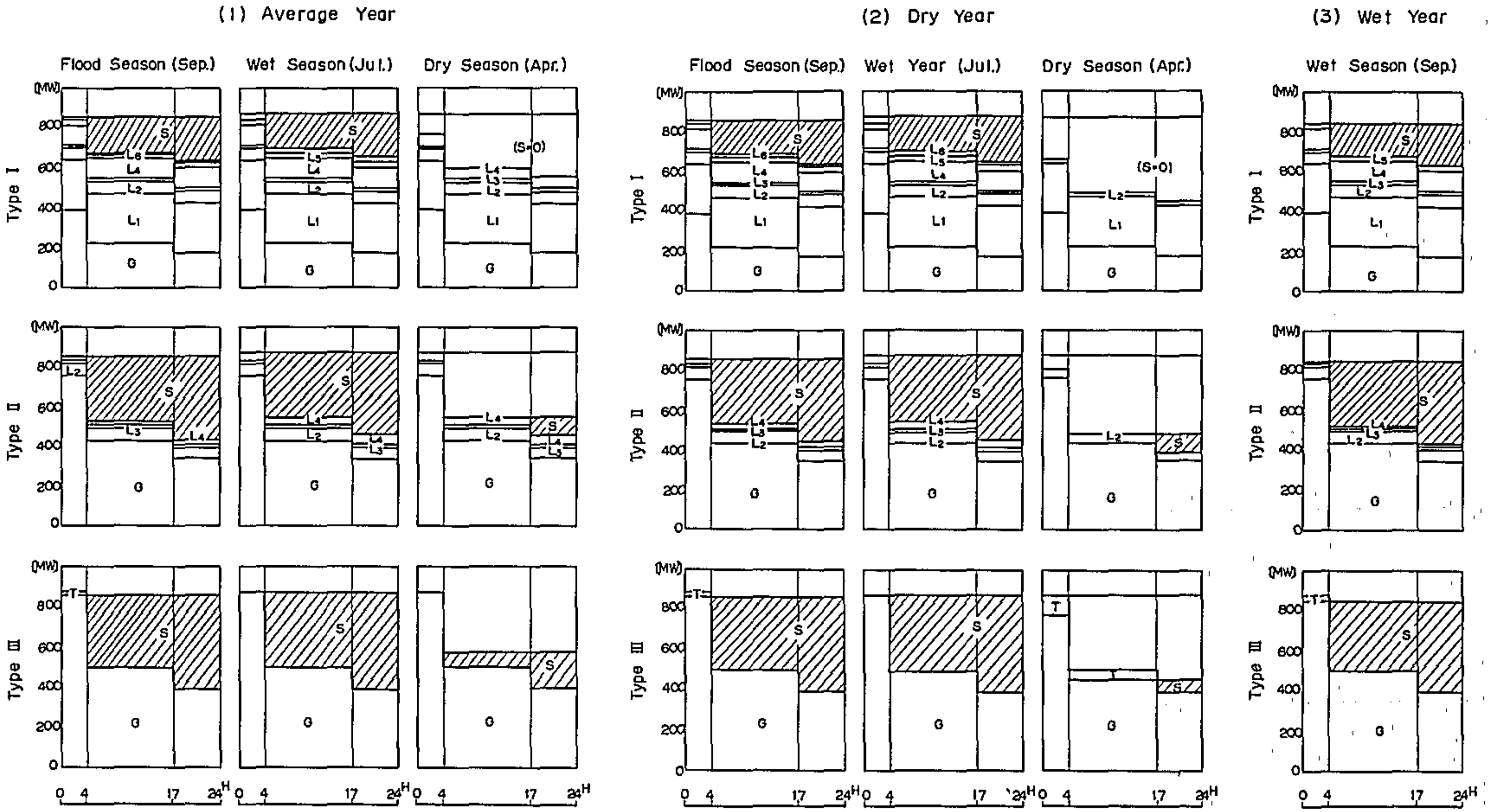
		33 Years	Wet Year	Dry Year
Number of Unit	(Unit)	7	7	7
Installed Capacity	(MW)	875	875	875
Available Energy	(10^6kWh)	7,000	7,450	6,710
Surplus Energy	(10^6kWh)	1,031	1,270	934
Surplus Ratio	(%)	14.7	17.0	13.9
Demand				
Generating End	(10^6kWh)	5,969	6,180	5,776
Consuming End	(10^6kWh)	5,731	5,933	5,545
Demand (10^6kWh)				
General		1,968	1,968	1,968
Aluminum		2,016	2,016	2,016
Other Industries		1,747	1,949	1,561
Caustic Soda		484	505	453
Vinyl Chloride		125	134	112
Calcium Carbide		761	868	678
Ferro-silicon		191	235	178
Silicon Carbide		174	207	140

Note:

Wet Year : 1938, 1939

Dry Year : 1933-35, 1937, 1952-61, 1963, 1964

Fig. C-6 Utilization of Power after Completion of the Project (875 MW)



LEGEND

G General Demand

L1 : Aluminum

L2 : Caustic Soda

L3 : Vinyl Chloride

L4 : Calcium Carbide

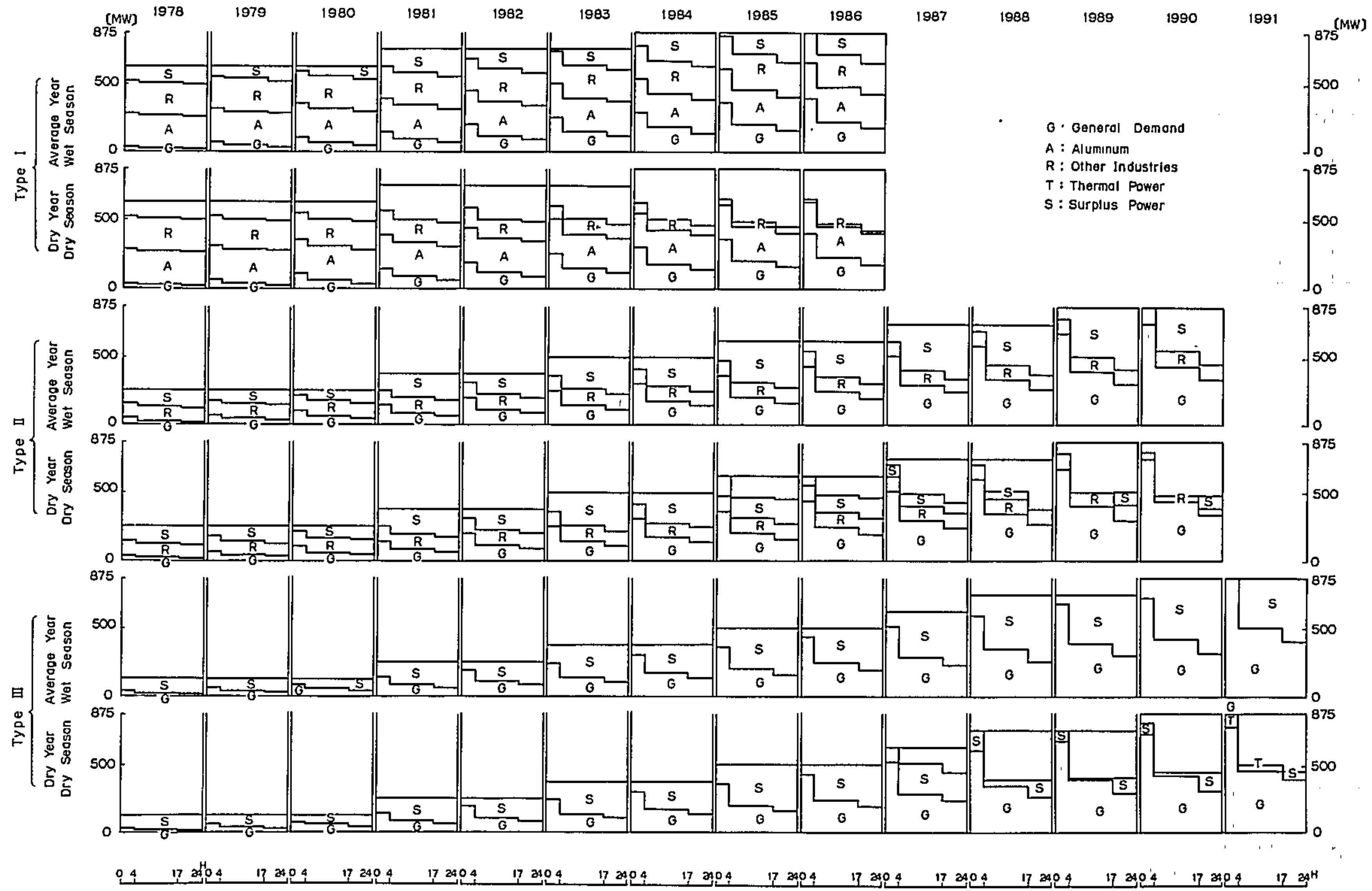
L5 : Ferro-silicon

L6 : Silicon Carbide

S : Surplus Power

T : Thermal Power

Fig. C-7 Trend in Daily Load Duration Curve



A direct indication of the seasonal effect of annual discharge is shown on Fig. C-6 (3). In other words, the influence of the phenomena of abundant water appears most distinctly in September which is the flood season of the wet year. The drop in output due to the rise in water level of tailrace is 28 MW, and the critical maximum output drops to 847 MW. As the result, the silicon carbide industry is to be stopped completely. Also, a similar influence is seen in August (See Fig. C-7).

(c) Production of Power-oriented Industries

Based on the power consumption plans indicated in the preceding section, an estimate of the 33 years average production of the various industries is given in Table C-31 (1).

The unit power requirements are assumed as follows:

	Unit Power Requirement (kWh/ton)
Integrated aluminum refining	16,100
Caustic soda	3,700
Vinyl chloride	1,000
Calcium carbide	3,150
Ferro-silicon	10,000
Silicon carbide	10,000

The unit power requirement for aluminum, which is planned to use the greater part of the energy for industrial production, is a matter which will require special attention. The 16,100 kWh per ton requirement for aluminum is assumed to be lower than the average for Japan, but according to published latest technology there seems to be a unit power requirement even smaller. Although the latest technology will not be taken into consideration, reasonable values which are neither too drastic nor too conservative are adopted.

As a result of adjustments made among the various industries, what may be called "net" production can be tabulated as follows:

	Production 1,000 ton/yr.
Aluminum Ingot	125
Vinyl Chloride	125
Caustic Soda	123
Calcium Carbide	52
Ferro-silicon	20
Silion Carbide	17

The net production in the case of calcium carbide, for example, consuming 761 million kWh of energy and operating at an annual plant factor of 88% against a 99 MW installation would be 242,000 tons. Of this amount, 190,000 tons would be used as raw material for production of vinyl chloride so that the net production which can be supplied to other uses would be 52,000 tons.

Likewise, 90,000 tons of the 110,000 tons of chlorine would be used as raw material for vinyl chloride so that the "net" production would be 20,000 tons.

The amount of caustic soda used in the calcining of alumina will differ according to the quality of alumina, but for the moment it will be considered as 7,000 tons.

Industrial production in wet years and dry years is shown on Tables C-31 (2) and C-32 in the same way.

Table C-31 Production of Power-oriented Industries (Type I) (1) 33-Year Average

		Aluminum	Caustic Soda		Vinyl Chloride	Calcium Carbide	Ferro-Silicon	Silicon Carbide	Total
			Caustic Soda	Chloride					
Pland Capacity	(MW)	240	58		15	99	27	27	466
Utility Factor	(%)	96	96		93	88	86	74	
Consumptive Energy	(10^6kWh)	2,016	484		125	761	203	174	3,763
kWh per Unit Production	(kWh/ton)	16,100	3,700		1,000	3,150	10,000	10,000	
Production	(ton)	125,000	130,000	110,000	125,000	242,000	20,300	17,400	
Raw Materials for Producing Vinyl Chloride (125,000 tons per year)	(ton)	-	-	90,000	(125,000)	190 000	-	-	
Raw Materials for Producing Aluminum (125,000 tons per year)	(ton)	(125,000)	7,000	-	-	-	-	-	
Supply to Other Factories	(ton)	125,000	123,000	20,000	125,000	52,000	20,300	17,400	

Table C-31 Production of Power-oriented Industries (Type I) (2) Wet and Dry Years

		Aluminum	Caustic Soda		Vinyl Chloride	Calcium Carbide	Ferro-Silicon	Silicon Carbide	Total
			Caustic Soda	Chloride					
Plant Capacity	(10^6kWh)	240	58		15	99	27	27	466
Wet Year									
Energy Consumption	(10^6kWh)	2,016	505		134	868	235	207	3,965
kWh per Unit Production	(kWh/ton)	16,100	3,700		1,000	3,150	10,000	10,000	
Production	(ton)	125,000	136,000	116,000	134,000	276,000	23,500	20,700	
Raw Materials for Producing Vinyl Chloride (134,000 tons per Year)	(ton)	-	-	96,000	(134,000)	200,000	-	-	
Raw Materials for Producing Aluminum (125,000 tons per Year)	(ton)	(125,000)	7,000	-	-	-	-	-	
Supply to Other Factories	(ton)	125,000	129,000	20,000	134,000	76,000	23,500	20,700	
Dry Year									
Energy consumption	(10^6kWh)	2,016	453		112	678	178	140	3,577
kWh per Unit Production	(kWh/ton)	16,100	3,700		1,000	3,150	10,000	10,000	
Production	(ton)	125,000	122,000	104,000	112,000	215,000	17,800	14,000	
Raw Materials for Producing Vinyl Chloride (112,000 tons per Year)	(ton)	-	-	81,000	(112,000)	168,000	-	-	
Raw Materials for Producing Aluminum (125,000 tons per Year)	(ton)	(125,000)	7,000	-	-	-	-	-	
Supply to Other Factories	(ton)	125,000	115,000	23,000	112,000	47,000	17,800	14,000	

(2) Type II

The balance of supply and demand in 1978, the first year of operation, and from 1990 and after when the demand will have reached 875 MW are shown on Table C-33. In 1978, when 250 MW is put into operation, the energy supply capacity as seen in the table is 2,190 million kWh, and from the standpoint of available water the installed capacity can be 100% utilized during the year. However, the demand is 115 MW for power-oriented industries and 28 MW for the increment of general demand in 1978, or a total of 143 MW. Moreover, as the load factors of the two demands are 92% and 60% respectively, the total energy demand will be only 1,077 million kWh or 1,034 million kWh at the demand end. Therefore, the 1,113 million kWh difference between the 2,190 million kWh available energy and total energy demand will become surplus energy. The ratio of this surplus to available energy is 51%. In this case, a part of the surplus energy could be used by raising the load factor of the power-oriented industries, but the quantity of the surplus energy which could be absorbed would be very small and will have very little influence on the internal rate of return of the project. Thus the surplus energy will be spilled. In view of this situation, on the basis of the 33-year average runoff, allocation of energy to industries will be fixed at a constant level during the period from 1978 and after, while generating units are added corresponding to the growth of general demand.

Full utilization of the 875 MW capacity will be from 1990. In this case, the available energy will be the same, i.e., 7,000 million kWh as indicated in the preceding section and of this amount 2,075 million kWh corresponding to 30% of the available energy will be surplus energy. The energy demand after deducting transmission and other losses will be 4,728 million kWh.

The allocation to general demand will be 730 MW and 3,835 million kWh at the demand end, while the allocation to power-oriented industries will not be changed from the time of initial operation in 1978 as shown on the table C-33.

The seasonal difference in output between high and low runoff will be regulated mainly by calcium carbide production. This situation is illustrated in the middle part of Fig. C-6 (1).

The variation in allocation of energy due to fluctuation in annual runoff is shown in the middle section of Figs. C-6 (1), (2), (3), and the 33 years average production of power-oriented industries is shown in Table C-34. The variation in industrial production is given in Table C-35.

The variation over the years in daily load duration curves for Type II is indicated in the middle part of Fig. C-7.

Table C-32 33-Year Average, Wet and Dry Year Production, and Energy Consumption according to Industry (Type I)

	1978	from 1986		
	33-Year Average	33-Year Average	Wet Year	Dry Year
Production (1,000 tons)				
Aluminum	125	125	125	125
Caustic Soda	130	130	136	122
Vinyl Chloride	125	125	134	112
Calcium Carbide	242	242	276	218
Ferro-silicon	19	19	24	18
Silicon Carbide	17	17	21	14
Consumptive Energy (10^6 kWh)				
General Demand	141	1,968	1,968	1,968
Aluminum	2,016	2,016	2,016	2,016
Other Industries	1,747	1,747	1,949	1,561
Caustic Soda	484	484	505	453
Vinyl Chloride	125	125	134	112
Calcium Carbide	761	761	868	678
Ferro-silicon	191	191	235	178
Silicon Carbide	174	174	207	140
Total	3,094	5,731	5,933	5,545

Table C-33 Utilization of Power (Type II, 33-Year Average)

		1978	from 1990
Number of Unit	(Unit)	2	7
Installed Capacity	(MW)	250	875
Available Energy	(10^6kWh)	2,190	7,000
Surplus Energy	(10^6kWh)	1,113	2,075
Surplus Ratio	(%)	50.8	29.6

	1978 Generating End Power (kW)	1978 Generating End Energy (10^6kWh)	1978 Consuming End Power (kW)	1978 Consuming End Energy (10^6kWh)	1978 Consuming End Load Factor (%)	from 1990 Generating End Power (kW)	from 1990 Generating End Energy (10^6kWh)	from 1990 Consuming End Power (kW)	from 1990 Consuming End Energy (10^6kWh)	from 1990 Consuming End Load Factor (%)
General Demand	28	147	27	141	60	760	3,995	730	3,835	60
Power-Oriented Industries	115	930	110	893	92	115	930	110	893	92
Caustic Soda	60	504	58	484	96	60	504	58	484	96
Vinyl Chloride	16	130	15	125	93	16	130	15	125	93
Calcium Carbide	39	296	37	284	87	39	296	37	284	87
Total	143	1,077	137	1,034	86	875	4,925	840	4,728	64

Note: Energy losses between generating and consuming ends are estimated at 4%.

Table C-34 Production of Power-Oriented Industries (Type II, 33-Year Average)

		Caustic Soda: Caustic Soda	Caustic Soda: Chloride	Vinyl Chloride	Calcium Carbide
Plant Capacity	(MW)	58		15	37
Utility Factor	(%)	96		93	87
Energy Consumption	(10^6kWh)	484		125	284
kWh per Unit Production	(kWh/ton)	3,700		1,000	3,154
Production	(ton)	130,000	110,000	125,000	90,150
Raw Materials for Producing Vinyl Chloride (125,000 tons per Year)	(ton)	-	90,000	(125,000)	190,000
Supply to Other Factories	(ton)	130,000	20,000	125,000	(-) 100,000

Table C-35 Production of Power-Oriented Industries and Energy Consumption (Type II, 33-Year Average)

	1978	from 1990		
	33-Year Average	33-Year Average	Wet Year	Dry Year
Production (10^3 ton)				
Caustic Soda	130	130	136	122
Vinyl Chloride	125	125	135	112
Calcium Carbide	90	90	95	81
Energy Consumption (10^6kWh)				
General Demand	141	3,835	3,835	3,835
Power-Oriented Industries:	893	893	940	820
Caustic Soda	484	484	505	453
Vinyl Chloride	125	125	135	112
Calcium Carbide	284	284	300	255
Total	1,034	3,728	4,775	4,655

Table C-36 Utilization of Power (Type III, 33-Year Average)

		1978	from 1991
Number of Unit	(Unit)	1	7
Installed Capacity	(MW)	125	875
Available Energy	(10^6kWh)	1,093	7,000
Surplus Energy	(10^6kWh)	946	2,400
Surplus Ratio	(%)	86.4	34.3
Demand Energy			
Generating End	(10^6kWh)	147	4,600
Consuming End	(10^6kWh)	141	4,415
Demand Power			
Generating End	(10^6kWh)	28	875
Consuming End	(10^6kWh)	27	840

Note: Energy losses between generating and consuming ends are estimated at 4%.

Table C-37 Monthly Demand and Supply Balance of the Driest and Wet Year (Type III, from 1991)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Driest Year (10^6kWh)													
Available Hydro Energy	651	345	373	348	599	630	651	650	629	651	630	651	6,808
Salable Hydro Energy	391	331	360	338	391	378	391	391	378	391	378	391	4,509
Surplus Hydro Energy	260	14	13	10	208	252	260	259	251	260	252	260	2,299
Supplemental Energy by Thermal Plant	-	22	31	40	-	-	-	-	-	-	-	-	93
Supply Energy	391	353	391	378	391	378	391	391	378	391	378	391	4,602
General Demand	391	353	391	378	391	378	391	391	378	391	378	391	4,602
Wet Year (10^6kWh)													
Available Hydro Energy	651	573	550	562	651	630	651	643	610	651	630	646	7,448
Salable Hydro Energy	391	353	391	378	391	378	391	390	375	391	378	391	4,598
Surplus Hydro Energy	260	220	159	184	260	252	260	253	235	260	252	255	2,850
Supplemental Energy by Thermal Plant	-	-	-	-	-	-	-	1	3	-	-	-	4
Supply Energy	391	353	391	378	391	378	391	391	378	391	378	391	4,602
General Demand	391	353	391	378	391	378	391	391	378	391	378	391	4,602
Driest Year (10^3kWh)													
Hydro Supply Capability	875	791	771	738	875	875	875	875	875	875	875	875	
Thermal Supply Capability	-	84	104	137	-	-	-	-	-	-	-	-	
Total	875	875	875	875	875	875	875	875	875	875	875	875	
General Demand	875	875	875	875	875	875	875	875	875	875	875	875	
Wet Year (10^3kWh)													
Hydro Supply Capability	875	875	875	875	875	875	875	864	847	875	875	875	
Thermal Supply Capability	-	-	-	-	-	-	-	11	28	-	-	-	
Total	875	875	875	875	875	875	875	875	875	875	875	875	
General Demand	875	875	875	875	875	875	875	875	875	875	875	875	

(3) Type III

The balance of supply and demand in 1978, the initial year of operation, and from 1991 and after when the demand will reach 875 MW, are given in Table C-36. In 1978, when one 125 MW unit will go into operation, the available energy will be 1,093 million kWh as shown in the Table, and from the standpoint of available water it will be possible to utilize 100% of the capacity during the year. However, since the demand will be only the increment in the one year of 1978, it will be 28 MW and 141 million kWh at the generating end. As the result, 86% or 946 million kWh of the total available energy will be surplus energy. As would be the case in the preceding section, a considerable portion of this surplus energy would in actual practice be used effectively by taking place of the other power sources in the Sambor System, but since at the moment it is not known what the composition of the power system will be at that time, the energy will all be listed as surplus.

It will be from 1991 and after that the 875 MW will be utilized fully, and the available energy will be 7,000 million kWh as in the preceding section. Of this amount, 2,400 million kWh corresponding to 34% will be surplus energy. The general demand, after deduction of losses, at the demand end will be 4,415 million kWh.

It has already been stated that output will drop in the flood season due to rise in the water level of tailrace. Also, in the dry season, because of the decrease of runoff, there will be a shortage in the energy supply capability. In the power consumption plan including the uses by power-oriented industries, both power and energy might be regulated mainly by the load of electric furnace industries, but since this is impossible in this case, it will be necessary to provide a standby thermal power plant in the Sambor System.

The installed capacity required for the standby thermal power plant in terms of output of a hydroelectric plant at the generating end will depend on the drop in output during the flood discharge season and the limitation to fluctuation in the downstream water level. In general, in the case of thermal power plant, the station load factor is higher than for hydropower, while the transmission distances to demand areas are shorter with less losses. In consideration of the above, the installed capacity of the standby thermal power plant will be 150 MW.

The daily load curves for the normal water years, dry years and wet years from 1991 are given in the lower part of Fig. C-6 (1), (2), (3).

In the normal year, the thermal power plant would be operated for only about four hours during the peak load hours when the output drops during the flood season. The annual energy production of the standby plant for the year would be 26 million kWh and the plant utilization factor will be 2%.

In the dryyear, the thermal plant would be operated to supplement output in the dry season, except for midnight load hours, besides being operated during the flood season as in the case of the normal year.

The monthly kW and kWh balances during the driest year and wet years, when operation of ther thermal power plant is seen in the most distinct manner, are given in Table C-37.

CHAPTER D. HYDROLOGY AND METEOROLOGY

CHAPTER D. HYDROLOGY AND METEOROLOGY

D-1 General

The Mekong River is the largest river in Southeast Asia originating from the Tibetan Plateau and flowing south through the six countries of China, Burma, Laos, Thailand, Cambodia and Vietnam, and empties into the South China Sea at the southern tip of the Indochina Peninsula. The length of the river is approximately 4,200 km and the catchment area is approximately 800,000 sq.km.

The total catchment area of the Mekong River above Kratie Gauging Station located 15 km downstream of the Sambor Dam Site is 646,000 sq.km. The catchment area divided into the countries it drains is 165,000 sq.km in China, 19,000 sq.km in Burma, 207,000 sq.km in Laos, 187,000 sq.km in Thailand, 30,000 sq.km in Vietnam and 38,000 sq.km in Cambodia. Tonle Sap flows southwest from a large natural lake called Grand Lac located approximately in the center of Cambodia and joins the Mekong River at Phnom Penh approximately 200 km downstream of Kratie. In the wet season the water from the Mekong flows up the Tonle Sap and water is stored in Grand Lac. In the dry season, this water flows down the Tonle Sap and discharges into the Mekong River.

As shown in Key and Location Map, the gradient of the Mekong River from the estuary to Kratie is extremely gentle and at present ocean-going vessels of 4.5 m draft and 2,000 tons are able to sail up to Phnom Penh throughout the year, while coastal vessels of 200 ton class can navigate as far as Kratie. However, from Kratie to the Sambor Dam Site, the river bed gradient becomes gradually steep and the Sambor Rapids are formed at the dam site which bar navigation of ships to the upstream.

The runoff of the Mekong River is governed by the rainfall in the heavy rainfall zone expanding from the eastern part of the Tibetan Plateau to the downstream Indochina Peninsula. The discharge of the Mekong River begins to increase from June and in August–September the runoff is the largest during the year. From October the runoff gradually decreases with the lowest discharge coming in February–April. In the rainy season, because of intensive rainfall, the topsoil of land is eroded so that the river water contain large amount of fine suspended mud.

Through the efforts of ECAFE and the riparian countries of the Mekong Committee, much information has been collected on hydrology and meteorology. The main data have been rearranged by the Harza Engineering Co. and the Mekong Committee. (See Table D-1 and Chapter I)

D-2 Meteorology

According to the meteorological classification of W. Köppen, the greater part of the Upper Mekong area is subtropical monsoon zone while the Lower Mekong area is tropical monsoon zone.

In general, during the period when the southwest monsoon winds are prevalent it is the rainy season, while when northeast monsoon winds are blowing it is the dry season.

The eastern part of Tibet, which is the fountainhead of the Mekong and also the Yangtze, Salween and Irrawaddy Rivers, is the warmest (mean temprature in January 0°C, in July 12°C to 17°C) and rainiest region of Tibet.

Because of wind direction and the tall mountains which provide barriers for the wind, there are interspersed rainy and dry regions The annual rainfall is 300 mm to 1,500 mm with the greater part of the rainfall seen in the summer. In this region, because of sluggish tropical fronts, the rainfall around May is rainy season type of Japan while around September it is a long-persisting type.

In the downstream area in the Indochina Peninsula, the climate is generally high-temperature, high-humidity zone, and due to the monsoon and the terrain which obstructs the monsoon winds, the year is clearly divided into the rainy season from May to October and the dry season from November to April.

In other words, the rainfall distribution is such that there is copious rain on the southwestern slopes of the Annang Mountain Range which is directly on the windward of the southwestern monsoon while there is comparatively little on the leeward side.

The feature of the rainfall of this area is that the air masses bringing rain are of high temperature and high humidity and being physically unstable and under the influence of the terrain, intertropical convergence zones, and tropical cyclones the rain is apt to be of an intense type. In the equatorial region although the rainfall is not as intense, thunderstorms are frequent.

The peak floods in the Lower Mekong Basin that come in August–September are thought to be mainly due to the above rainfall phenomena of this region.[1/]

The meteorological information in the Appendix (Vol. VII) does not include data on the upstream area. Details of the downstream area which are essential for the project planning are given below.

D-2-1 Precipitation

Observations of rainfall were started by Harza Engineering Co. at Kratie in 1960 and Stung Treng in 1961, and Traveaux Publics of the Government of Cambodia has continued the observations.

In addition, the Mekong River Survey Team of the Government of Japan carried out supplementary rainfall observation by installing an automatic recorder in the premises of Traveaux Publics in Kratie City.

From these data on rainfall at Kratie and Stung Treng, information relevant to planning of the Sambor Project was excerpted and is shown in Fig. D-1 and Tables A-1 and A-2 in Vol. VII.

According to the rainfall recorded at Kratie and Stung Treng, the annual rainfall at these two places are 1,200 mm and 1,600 mm respectively, both being concentrated in the period from May to November.

D-2-2 Temperature and Humidity

The information on monthly temperature and humidity obtained from the Government of Cambodia is given in Tables A-4 and A-5 in Vol. VII, showing the monthly maximum, minimum and mean temperature for 11 years and humidity for 18 years. The variation of mean temperature during the year is expressed graphically in Fig D-2.

Besides the above, the Japanese Government Team conducted observations of temperature and humidity in 1963 and 1964.

The temperatures and humidities at 9 a.m. during 1963 and 1964 at Kratie are given in Table A-3 in Vol. VII.

The variation in temperature shows the maximum to be in April with the minimum in November–January and the difference being 4°C to 6°C in mean temperature.

D-2-3 Water Temperature

The water temperatures at Kratie and Stung Treng were recorded by Harza Engineering Co. at the time of runoff gauging and are given in the hydrologic data of 1960 and 1961. Tables A-11 and A-12 in Vol. VII, indicate the water temperature at Kratie and Stung Treng in 1960 and 1961.

As in the case of atmospheric temperatures, water temperatures do not vary greatly throughout the year, being approximately between 25°C and 30°C, roughly proportionate to atmospheric temperatures.

Source: 1/ *Climates of the World, Vol. I, The Climate of Asia*, Supervised by Hisanao Hatakeyama, 1964, Kokinshoin, Japan

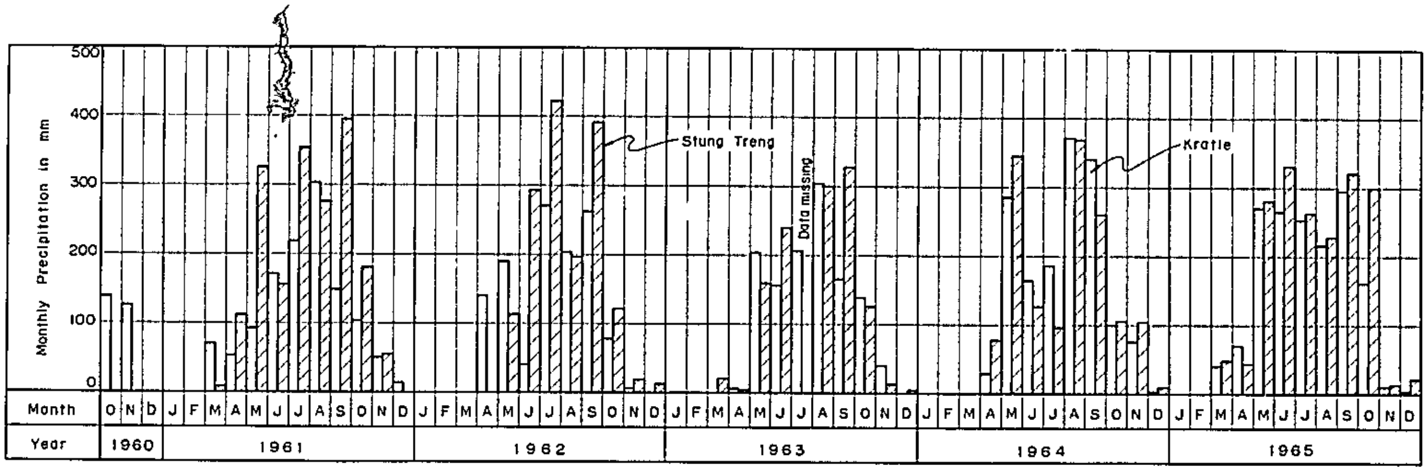
Table D-1 Hydrometeorological Data

No.1/	Data	Location	Period	Source
A-1	Precipitation	Kratie	Sept. 1960–Dec. 1965	H.E.C., M.C.
A-2	Precipitation	Stung Treng	Jan. 1961–Dec. 1965	H.E.C., M.C.
A-3	Temperature	Kratie	Nov. 1963–Jul. 1964	H.E.C., M.C.
A-4	Temperature Humidity	Stung Treng Kratie	Unknown "	Meteorological Bureau, Cambodia
A-5	Humidity	Kratie	Nov. 1963–Dec. 1964	E.P.D.C.
A-6	Evaporation	Kratie	Oct. 1962–Jul. 1964	E.P.D.C.
A-7	Evaporation	Stung Treng	Nov. 1960–Dec. 1965	H.E.C., M.C.
A-8	Discharge	Kratie	Jan. 1933–Dec. 1965	M.C.
A-9	Hydrograph	Kratie	Jan. 1960–Dec. 1965	M.C.
A-10	Suspension Concentration	Kratie Stung Treng, etc.	1960–1965	H.E.C., M.C.
A-11	Water Temperature	Kratie	Jan. 1960–Dec. 1961	H.E.C., M.C.
A-12	Water Temperature	Stung Treng	Feb. 1960–Dec. 1961	H.E.C., M.C.
A-13	Wind Movement	Stung Treng	Jan. 1961–Dec. 1965	H.E.C., M.C.
A-14	Wind Direction	Stung Treng Phom Penh	Unknown	Climate in Asia, Japan
A-15	Max. Wind Speed	Vietnam	1930–1962	Meteorological Bureau, Vietnam
A-16	Max. Wind Speed	Cambodia	1959–1963	Meteorological Burea, Cambodia
A-17	Thunderstorm	Vietnam	1959–1962	Meteorological Bureau, Vietnam
A-18	Thunderstorm	Cambodia	1959–1963	Meteorological Bureau, Cambodia
A-19	Nam Ngum, Res. Operation	Laos	Oct. 1925–Sept. 1966	Nippon Koei Co., Ltd., Japan
A-20	Pa Mong (EL 230) Res. Operation	Laos	Jan. 1953–Dec. 1966	Pa Mong Team, U.S.B.R.
A-21	Pa Mong (EL 240) Res. Operation	Laos	Jan. 1953–Dec. 1966	Pa Mong Team, U.S.B.R.
A-22	Pa Mong (EL 250) Res. Operation	Laos	Jan. 1953–Dec. 1966	Pa Mong Team, U.S.B.R.

Note: H.E.C. : Harza Engineering Co., U.S.A. Res. : Reservoir
M.C. : Mekong Committee
E.P.D.C. : Electric Power Development Co., Japan

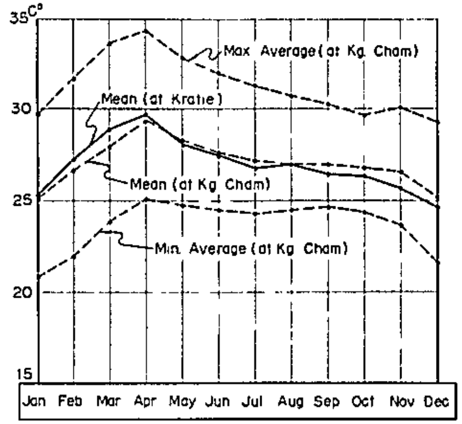
1/ Number of Tables in Vol. VII.

Fig. D-1 Monthly Precipitation at Kratie and Stung Treng in Cambodia



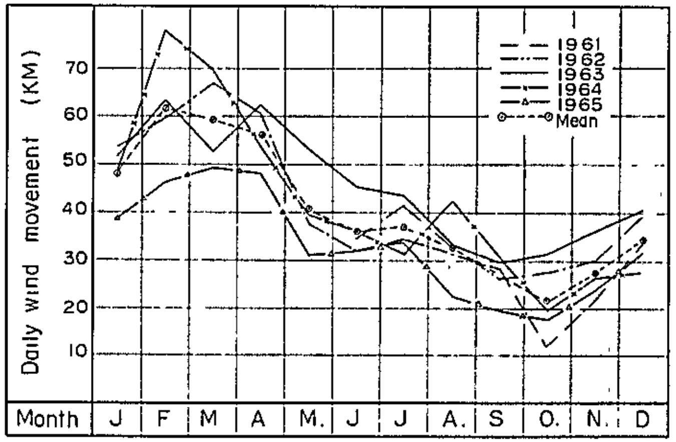
Source Hydrological Data Mekong River Basin Cambodia 1960, 1961 Harza Eng
Lower Mekong Hydrologic Year Book 1962~1965

Fig. D-2 Seasonal Variations of Temperature



NOTE Kratie, 11 Years Average
Kg Cham, 4-5 Years Average (Jan 1960~Aug 1964)

Fig. D-3 Daily Wind Movement at Stung Treng



D-2-4 Wind

From the Hydrologic Yearbooks published by the Mekong Committee, records of the daily wind movements at Stung Treng during the period from 1961 to 1965 are given in Table A-13 in Vol. VII.

Fig. D-3 indicates the daily wind movement throughout the year for each year showing high winds in the dry season and gradual decreases in the rainy season.

As for wind direction at Stung Treng-Phnom Penh, excerpts have been taken from the *Climate of Asia* and are given in Table A-14 in Vol. VII.

Maximum wind velocities at various locations in Vietnam and Cambodia are indicated in Tables A-15 and A-16 in Vol. VII.

During typhoons and thunderstorms, there are occasions when maximum wind velocities of 25 m/sec to 40 m/sec are experienced.

D-2-5 Thunderstorm

Thunderstorms have been observed by the meteorological bureaus of Vietnam and Cambodia. Tables A-17 and A-18 in Vol. VII indicate the number of occurrence of thunderstorms at various location in the two countries. According to the records, the annual average is 90 at Saigon and 140 to 180 at Phnom Penh which are extremely high frequencies.

D-3 Evaporation from Reservoir Surface

Records relevant to evaporation that are available are the data collected by Harza Engineering Co. at Stung Treng from 1960 and by the Sambor Team at Kratie from September 1962. (See Tables A-6 and A-7 in Vol. VII)

The values which were obtained by Class A evaporation pans are about 2,000 mm annually in both Kratie and Stung Treng.

The evaporation loss from the surface of the reservoir was estimated as the evapotranspiration loss from native vegetation before construction of the reservoir will be replaced by evaporation from the water surface after construction.

Since there were no actual records available on evapotranspiration loss it was calculated by the Blaney-Criddle Method [1/] using an empirical coefficient of 0.65.

Precipitation, 100% in the dry season of November to April and 75% in the rainy season of May to October, was assumed to be the source of water for evapotranspiration.

The evaporation loss of the Sambor reservoir was assumed to be the average of the monthly recorded values of Kratie and Stung Treng, and the loss was obtained by multiplying an area factor (reservoir surface evaporation/pan evaporation) of 0.7. The monthly average reservoir surface evaporation loss is shown in Table D-2.

The net evaporation-precipitation correction factors are shown in Table D-3.

1/ Blaney-Criddle Method

$$U = K\Sigma t \cdot P$$

where,
- U : Evapotranspiration in inches
- t : Mean monthly temperature
- P : Monthly percentage of daytime hours of the year
- K : Empirical coefficient (0.65)

Table D-2 Pan Evaporation and Surface Evaporation

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Monthly Average Evaporation (mm)	191	213	230	232	197	154	135	116	115	145	145	163
Monthly Average Surface Evaporation with Area-Factor (mm)	134	149	161	162	138	108	95	81	81	102	102	114

Table D-3 Net Evaporation – Precipitation Correction Factors

Month	(1) Precipitation (mm)	(2) Temperature (°C)	(3) Consumptive 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.

Table D-4 (1) Discharge Data at Kratie (1933-65)

Unit: cu ms

Month / Year	Jan	Feb.	Mar	Apr	May	Jun.	Jul.	Aug	Sep.	Oct	Nov	Dec.	Annual Runoff (10^6 cu m)	Annual Average
1933	2,600	1,800	1,300	1,290	1,620	5,630	19,430	34,290	30,430	20,320	12,190	4,910	358,958	11,318
34	2,930	2,210	1,790	1,470	2,620	5,000	22,430	39,950	44,550	30,210	12,070	5,950	452,451	14,265
35	3,460	2,300	1,810	1,590	2,990	10,490	26,320	32,780	33,910	30,740	21,150	7,880	463,478	14,618
36	3,860	2,740	2,210	2,080	2,970	9,470	25,750	34,830	38,880	15,190	6,040	3,800	390,554	12,318
37	2,800	2,030	1,780	1,540	4,060	12,590	31,580	49,500	55,660	24,620	11,090	6,460	538,081	16,977
38	4,440	3,420	2,770	3,160	4,230	16,850	29,080	33,420	35,460	35,990	13,990	8,440	505,341	15,938
39	4,580	3,110	2,560	2,610	4,540	15,950	26,620	45,730	47,430	33,270	12,680	6,860	543,932	17,162
40	4,020	2,980	2,350	2,180	3,150	12,520	34,750	49,930	60,260	20,830	8,230	5,120	544,895	17,193
1941	3,710	2,990	2,470	2,240	3,540	13,990	27,120	44,600	39,250	31,070	17,220	7,620	517,454	16,318
42	4,180	3,050	2,270	2,280	4,090	11,670	29,180	42,170	39,820	22,020	13,400	5,860	475,455	14,999
43	3,810	2,670	2,400	2,790	3,360	14,850	24,580	35,510	44,550	26,190	12,460	5,280	470,804	14,871
44	3,820	3,020	2,320	2,070	3,460	8,150	21,520	39,150	29,070	25,070	14,150	7,300	420,989	13,258
45	4,200	3,030	2,470	2,200	4,760	17,270	28,070	30,770	43,850	19,330	10,450	6,100	454,857	14,375
46	4,010	2,680	2,090	1,890	4,550	15,390	23,400	35,990	46,530	25,900	12,290	6,160	477,190	15,073
47	3,900	3,000	2,130	2,260	6,420	11,620	32,850	37,910	45,860	23,090	10,500	5,420	488,528	15,413
48	3,670	2,700	2,090	2,180	4,520	12,820	24,490	36,870	49,620	27,220	13,110	6,810	491,248	15,508
49	4,020	2,990	2,300	2,080	3,770	4,690	13,670	34,420	43,100	30,640	16,710	8,380	440,163	13,898
50	4,700	3,040	2,190	1,920	2,890	11,360	25,250	36,000	38,350	32,200	17,940	7,800	485,066	15,303
1951	4,040	3,100	2,080	2,030	3,700	14,480	22,810	36,400	34,440	23,720	12,460	6,210	436,912	13,789
52	3,070	1,960	1,760	1,720	3,200	7,210	18,810	44,450	46,700	30,810	12,260	4,260	465,596	14,684
53	2,080	1,920	1,630	1,620	5,110	14,630	20,350	33,100	33,690	20,770	10,490	5,070	395,666	12,504
54	2,850	1,890	1,510	1,700	3,170	9,080	11,300	22,580	37,160	23,560	10,570	4,770	343,016	10,845
55	3,120	2,240	1,870	2,060	2,560	7,960	20,290	25,380	30,230	17,090	11,430	7,690	348,325	10,993
56	3,960	2,510	1,930	1,990	5,550	11,980	20,990	39,340	41,350	18,430	8,940	3,740	424,483	13,393
57	3,430	2,540	1,970	2,000	2,650	10,000	22,680	24,730	34,840	27,680	10,220	5,090	390,388	12,319
58	3,350	2,510	1,920	1,730	2,160	9,390	20,810	25,080	42,720	19,780	8,730	3,750	374,078	11,828
59	2,180	1,950	1,730	1,650	2,210	6,360	11,920	26,130	37,300	24,030	10,040	4,160	342,843	10,805
60	2,880	2,300	1,830	1,360	1,800	6,320	13,550	39,540	36,120	28,390	11,380	5,830	400,017	12,608
1961	3,280	2,390	2,000	1,970	3,940	16,180	28,200	40,040	49,790	39,370	13,270	6,450	546,481	17,240
62	4,170	3,140	2,500	2,170	3,690	14,610	25,230	37,660	36,410	24,660	11,310	5,240	451,043	14,236
63	3,180	2,370	2,030	1,760	1,850	9,760	21,990	41,600	36,660	21,750	13,660	6,720	431,472	13,611
64	3,690	2,520	1,970	1,850	4,230	9,380	19,330	27,360	37,900	31,850	15,690	7,410	430,982	13,598
65	4,000	2,890	2,240	1,980	2,620	17,900	26,700	28,600	32,500	16,200	12,500	6,040	407,000	12,848
Average	3,580	2,610	2,070	1,980	3,520	11,380	23,370	35,930	40,450	25,250	12,380	6,020	445,720	14,065

Note: Prepared by the Mekong Secretariat in Apr. 1967.

Table D-4 (2) Discharge Data at Kratie (1924-65)

(1924-65)

Unit. cu ms

Month / Year	Jan.	Feb	Mar.	Apr.	May	Jun.	Jul	Aug	Sep	Oct.	Nov	Dec	Annual Runoff (10^6 cu 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	12,459	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	12,219	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	41,717	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

Note: Prepared by the Mekong Secretariat, Sep 18, 1968.

D-4 Runoff Record

The runoff at Kratie Gauging Station which is the nearest to the Sambor Dam Site is given in the report of the Harza Engineering Co. for the period from 1933 to 1961 and in the report of the Mekong Committee for the period from 1962 to 1965. In these reports, the runoff records of 1954 and the period from 1952 to 1958 are missing.

The Kratie runoff records made available by the Mekong Committee in April 1967 were intended to be a revision to the reports of the Harza Engineering Co., and the Mekong Committee supplemented most of the missing records, but the data for the following period were still unavailable:

1952	November, December
1953	January, February, March, April
1954	Entire year

In the study of the Sambor Project, runoff for the above mentioned year were estimated by correlating the specific runoff at Kratie and Pakse. (Table A-8 in Vol. VII)

Table D-4 (1) shows the monthly average discharge, annual discharge, and maximum and minimum discharges for the 33 years from 1933 through 1965 which were used for the study of the Sambor Project.

Note: In September 1968, runoff data at Kratie (monthly average runoff) as indicated in Table D-4 (2) were furnished in addition to Nam Ngum and Pa Mong discharges for the preparation of Report Vol. II (Sambor with Nam Ngum and Pa Mong) by the Secretariat of the Mekong Committee. This covered the period from 1924 to 1965. The new runoff data included missing parts in the data produced by the Secretariat in April 1967, and also revisions were made to the 1933 data and other year.

However, new runoff data were not taken into consideration in the isolated case on account of shortage of time to complete the Report except the record of 1933 and the flood discharge in 1940. It was the reason that there would be not much difference in the calculation of hydro-electric power.

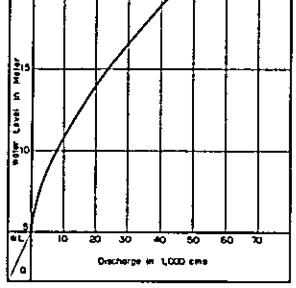
As the record of 1933 had been materially modified, the reservoir operation plan was re-examined on the basis of the revised data. Also, regarding recorded flood discharge, the 73,600 cu.ms in the year 1940 was changed to 64,000 cu.ms as a result of discussions with the Mekong Secretariat in July 1968. Therefore, the design flood discharge was also restudied.

D-5 Water Level and Discharge Rating Curve at Sambor Dam Site

At Kratie there is the bubble gauge station established by Harza Engineering Co. which is now administered by Travaux Publics and daily periodic observations of water level are made. Gauging of runoff is also performed periodically and the rating curve at the site has been established.

At Sambor Dam Site, a staff gauge was installed by the Sambor Team in 1962 and since then observations of water level have been performed twice monthly. By this means it is possible to measure the water level elevation at the dam site simultaneous to the observations at the bubble gauge station at Kratie, and on the basis of the water level and discharge rating curve at Kratie, the rating curve for the Sambor Dam Site (Fig. D-4) was prepared.

Fig. D-4 Discharge Rating Curve at Sambor Dam Site



D-6 Design Flood Discharge

The 33-year daily runoff data at the Kratie gauging station, which includes recorded runoff of the recent several years have been prepared by the Mekong Committee. As Sambor dam will be a combination of rock-fill and earth-fill dam, the design flood discharge must be based on the probable maximum flood. If the information on various meteorological conditions which correlate to the flood can be obtained, it should be possible to assume the probable maximum flood based on all of the elements contributing to occurrence of flood reaching the most critical condition simultaneously. However, for the present study of the design flood discharge, this detailed information could not be obtained and therefore, the study was made only by statistical methods based on daily runoff data for the 33 years between 1933 and 1965 prepared by the Mekong Committee.

The annual maximum discharge in the order of magnitude obtained from the runoff records at Kratie from 1933 through 1965 are tabularized in Table D-5.

From the above, the 10,000 year flood will be as follows:

83,000 cu.ms	by log-normal distribution method
105,000 cu.ms	by Gumbel method 1/
81,000 cu.ms	by Hazen-Foster method (Type 3)

Table D-5 Annual Maximum Discharge

(Unit: cu.ms)

Statistical Order	Date of Occurrence	Annual Max. Discharge	Statistical Order	Date of Occurrence	Annual Max. Discharge
1	Sep. 3, 1939	66,700	18	Sep. 16, 1946	52,400
2	Sep. 12, 1937	64,300	19	Sep. 11, 1951	51,000
3	Sep 2, 1940	64,000	20	Aug. 14, 1963	50,800
4	Aug 27, 1961	62,400	21	Aug. 9, 1962	50,100
5	Aug. 18, 1941	60,300	22	Sep. 12, 1956	49,200
6	Sep. 13, 1958	58,600	23	Sep. 5, 1947	48,900
7	Sep. 7, 1948	57,100	24	Aug. 24, 1953	48,900
8	Sep 27, 1964	56,000	25	Sep. 21, 1945	48,500
9	Sep. 8, 1936	55,200	26	Sep. 25, 1949	48,100
10	Oct. 2, 1938	54,100	27	Aug. 20, 1944	47,600
11	Sep. 25, 1943	54,000	28	Sep. 7, 1957	46,400
12	Aug. 7, 1933	53,900	29	Sep. 3, 1954	45,500
13	Aug 27, 1960	53,200	30	Aug. 3, 1935	44,200
14	Aug. 6, 1942	53,100	31	Sep. 2, 1959	42,300
15	Sep. 8, 1952	53,000	32	Sep. 12, 1965	39,800
16	Sep. 22, 1934	52,900	33	Sep. 19, 1955	34,000
17	Sep. 14, 1950	52,900			

Note: The value of 73,600 cu.ms for 1940 was changed to 64,000 cu ms by the Mekong Committee in July 1968 and this study was made on the revised figure.

Source: 1/ GUMBEL, E.J., *Flood Estimated by Probability Method, Eng. News-Record*, Vol. 134, pp. 83-837, 1945.

Computation by the enveloped curve [1] flood technique for South-East Asia rivers will give a peak flood of 8,800 cu.ms based on drainage area of 646,000 sq.km and assumed coefficient of 110. As a result, the design flood discharge was determined at 90,000 cu.ms.

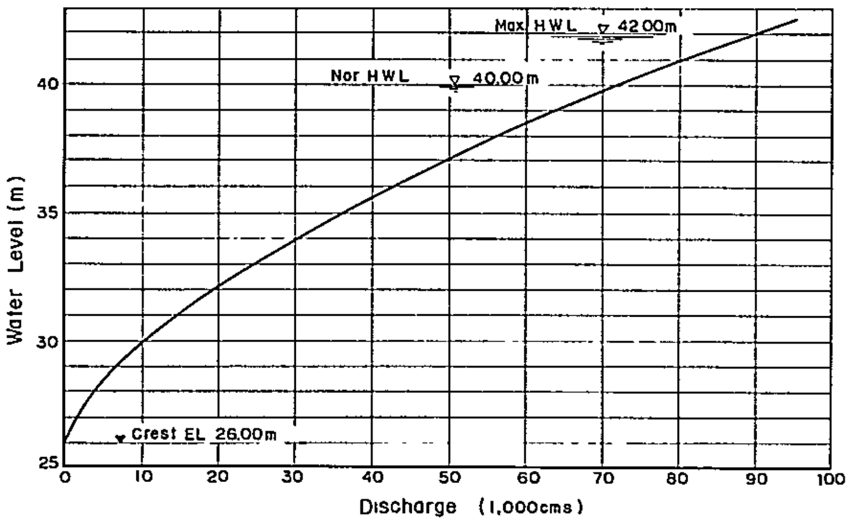
If the spillway were to be an overflow type, it would require a tremendous length and therefore as stated in H-1-1, 53 gates each of 15 m span and 14 m height will be installed.

As the spillway capacity at normal high water surface level of 40 m is approximately 70,000 cu.ms (Probability 1/100), floods of a magnitude which occur annually can be controlled by operation of gates while maintaining this water level of EL 40 m. (See F-2)

The design flood discharge of 90,000 cu.ms can be released by opening gates fully at an overflow water level of 42 m. The capacity of the spillway has been studied not only based on hydraulic calculations but also by hydraulic mode tests. These studies are given in Fig. D-5 and Chapter D in Vol. VII.

The probable maximum daily discharge at Kratie by 5-day periods for the 33 years between 1933 and 1965 obtained by the Gumbel Method were computed for studies of the construction schedule. The results are given in Fig. D-6.

Fig. D-5 Rating Curve of Spillway



D-7 Sediment Transportation and Deposition in Reservoir

Sand carried down rivers and streams may be broadly divided into the following classifications.

(1) Tractive sand directly subject to action of flowing water to slide, roll or bounce down the river bed.

(2) Suspended sand carried in a suspended condition in the cross section of the water channel due to diffusion phenomenon of water.

(3) Wash load comprised of particles finer than river bed materials.

For the Mekong River, a survey on suspended load was conducted by Harza Engineering Co. in 1960 and 1961 and subsequent to this the four riparian countries have continued with the investigations. The results of surveys of suspended load conducted at various locations along the Mekong Mainstream by Harza Engineering Co. and the four riparian countries are given in Table A-10 in Vol. VII.

Source. 1/ *Hydrology of the Mekong River Basin and Water Studies of the Mekong Irrigation Project, Thailand* by Hydrology Section, Survey Division, Royal Thai Irrigation Department.

According to these investigations, the suspension concentration (weight) fluctuates according to the river runoff. As there is little measurement data on suspended load at Kratie which can be applied to the Sambor Dam Site, the relation between runoff (Q cu.ms and suspension concentration (C weight in ton) at Stung Treng and Phnom Penh were plotted on Fig. D-7. That is, the following formula were employed:

Stung Treng: $C_s = 3.47 \times 10^{-10}\ Q_s^{2.344}$

Phnom Penh: $C_p = 3.43 \times 10^{-10}\ Q_p^{2.313}$

As the Sambor Dam Site is geographically located near Stung Treng, the formula applied to the latter, which is on the critical side, was adopted.

The monthly sediment corresponding to the 33 years average runoff at Kratie using the above relationship is shown in Table D-6 and the annual volume of sediment transported is 147 million tons. If about 15% of the sediment 1/ is estimated as bed load, the annual volume of sediment transported to the Sambor Dam Site would be 169 million tons (specific gravity of 1.3) or approximately 200 cu.m per sq.km.

As the storage capacity of Sambor reservoir is extremely small in proportion to the runoff of the Mekong River, almost all of the flow will be discharged without being deposited. Therefore, it is thought that sediment deposition within the reservoir will be relatively small.

If the trap efficiency of the reservoir is assumed to be 50%, the deposition of sediment in the Sambor reservoir would amount to 65 million cu.m annually.

Based on the above study, the revised area-capacity curves for the Sambor reservoir, after 50 years, obtained by using the area-increment method 2/ will be as shown in Fig. D-8.

It will be seen in the figure that reduction in effective capacity of Sambor reservoir due to sediment deposition is extremely small and the influence to power generation can be considered negligible.

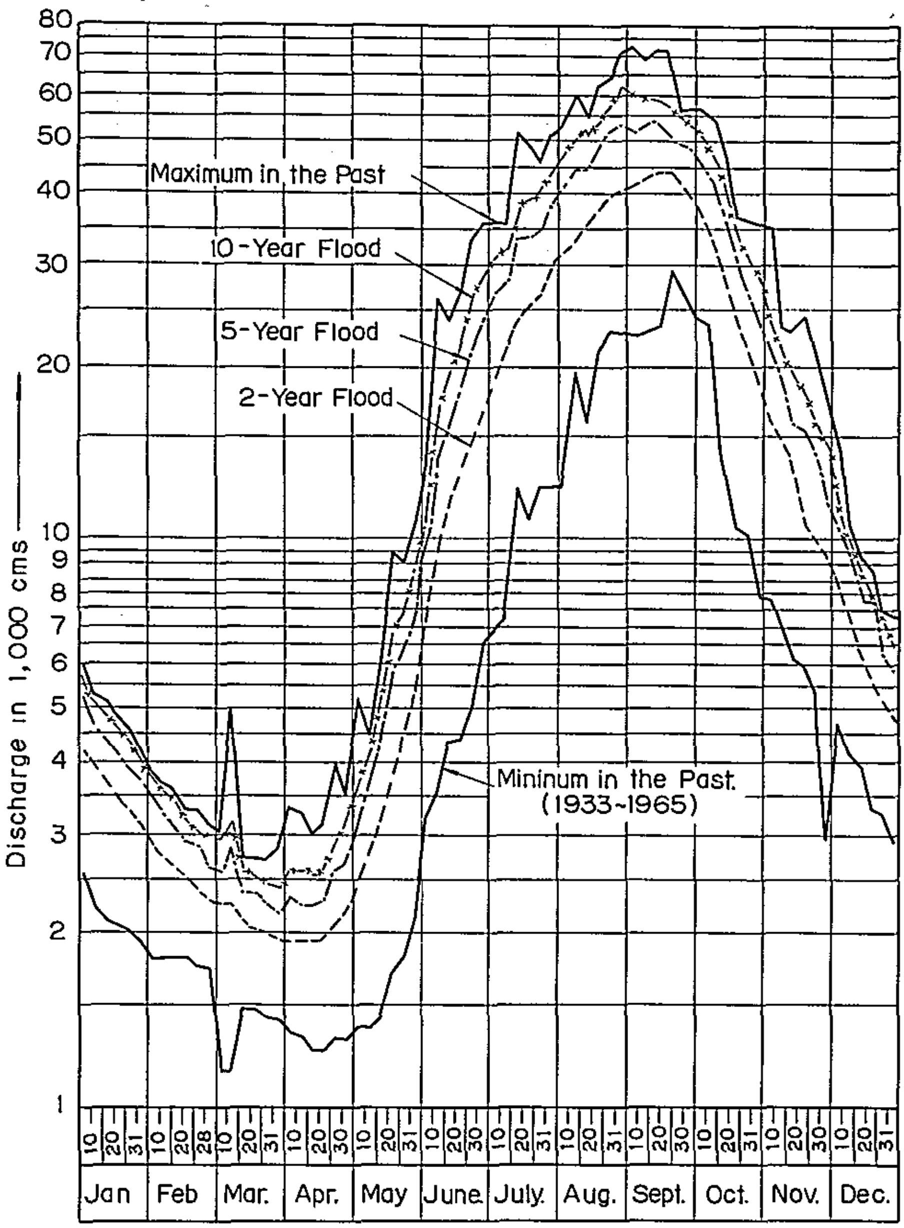
Table D-6 Monthly Sediment

Month		Unit	Jan	Feb	Mar	Apr	May	Jun.	Jul.	Aug	Sep	Oct	Nov	Dec.	Total
Monthly Average Discharge	(Q)	cu.ms	3,640	2,640	2,100	2,020	3,560	11,510	23,430	35,920	40,430	25,580	12,440	6,100	
log Q			3.56110	3.42160	3.32222	3.30535	3.55145	4.06108	4.36977	4.55534	4 60670	4.40790	4 09482	3 78533	
2.344 log Q			8.34722	8.02023	7 78728	7 74774	8.32460	9.51917	10.24274	10 67772	10 79810	10.33212	9.59826	8.87281	
$Q^{2.344}$		10^6 cu.ms	222 4	104 8	61.3	55 9	211 2	3,305 0	17,488.0	47,612.0	62,820.0	21,484 0	3,965.2	746 1	
Amount of Monthly Sediment	(C)	ton/sec	0 077	0.036	0.021	0.019	0.073	1 147	6.068	16,521	21,799	7,455	1,376	0.259	
		10^6 ton	0.2	0 1	0 1	0 1	0.2	3 1	16.3	44 2	58.4	20.0	3 7	0 7	147 1

Source: 1/ *Pa Mong Project, Phase I Report*, Mar. 1966, Vol 5, App. V.

2/ Distribution of Sediment in Large Reservoirs USBR Hydraulic Engineers, Commissioners Office.

Fig. D-6 Probable Flood at Kratie



Note: The calculations were based on runoff data of Kratie provided by the Mekong Secretariat in Apr. 1967.

The recorded maximum flood of 73,600 cu.ms in 1940 is not revised since the modified daily discharge is not available.

Fig. D-7 Relation of Suspension Concentration and Discharge at Phnom Penh and Stung Treng

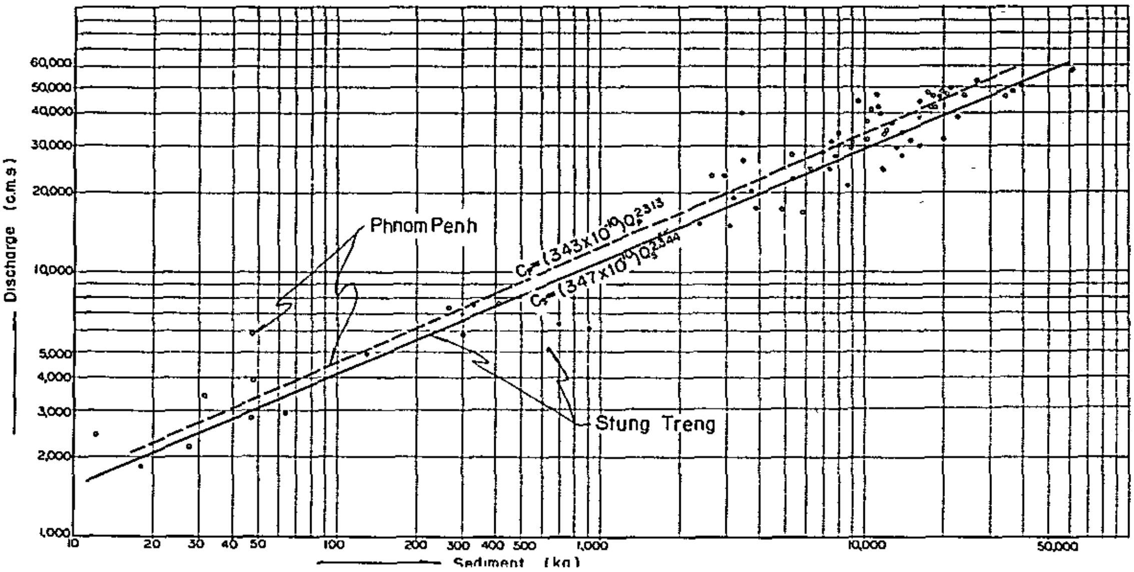
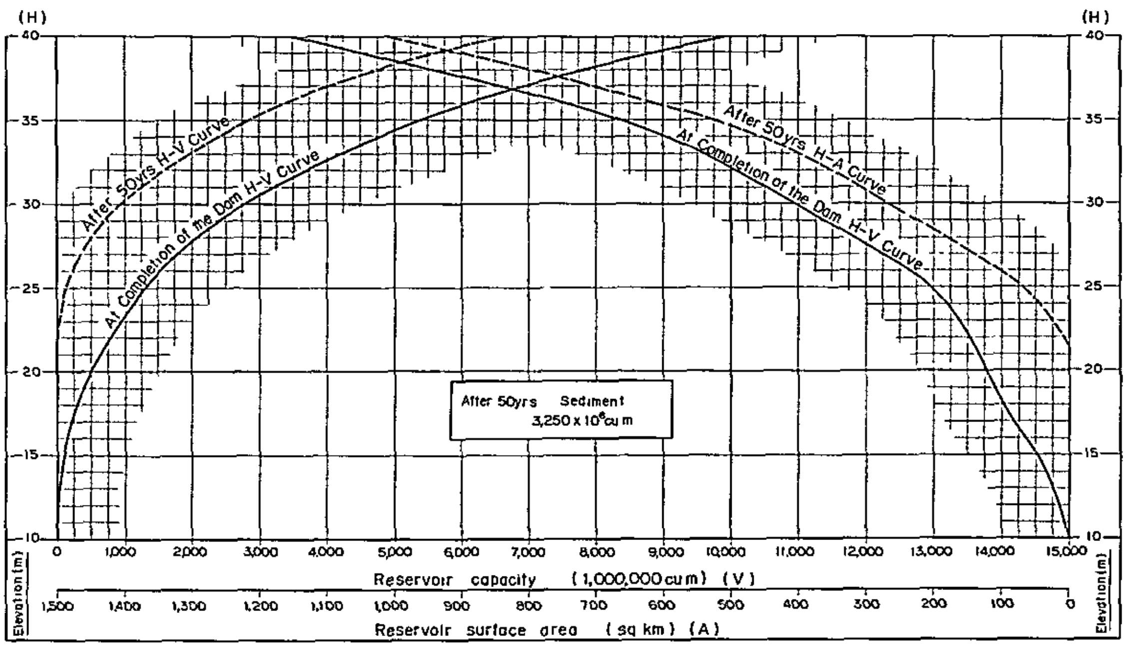


Fig. D-8 Revised Area - Capacity Curve of Sambor Reservoir (without Pa Mong)



CHAPTER E. TOPOGRAPHY AND GEOLOGY

CHAPTER E. TOPOGRAPHY AND GEOLOGY

E-1 Basic Information

Great efforts were exerted by the Government of Cambodia, the member nations of ECAFE and the Mekong Committee in connection with the investigations of topography and geology of the Sambor Project. Especially, the topographical map of the project area based on the Hunting Map Survey prepared with the cooperation of the Government of Canada and other topographical maps were of great help in the project planning. Also, the report on geological investigations 1/ by the Snowy Mountain Authority prepared with the cooperation Government of Australia should be evaluated highly.

The Japanese Government Survey Team carried out various investigations in the field to supplement these existing basic data.

E-2 Description of Project Area

The project area is located in the southeastern part of the Indo-China central lowlands and the southern part of the Northeastern Cambodian Plain. Although there is a small protruding hill called Phnom Samboc (EL 97 m), the area as a whole is extremely level having a profile which could be said to "have valleys but no mountains," the average elevation being 40 m.

The bed rock of the project area is composed of a part of the strata called the Indochinian Formation which is the major component of the Indochinian Land Block. The Indochinian Formation may be broadly divided into a practically horizontal upper formation, a undulating middle formation in the orogenic period and a lower formation not yet in the folded Noric period spread around the Indochinian Formation.

The geologic age of the rock forming the project area and the surrounding regions appear to belong mainly to the Indochinian Formation prior to the Middle Triassic period according to the studies of Saurin 2/, 3/ and Fromaget. 3/ 4/ This formation is composed of shale siltstone, sandstone and complex of these rocks which are generally calcareous and in rare cases are accompanied by thin strata of limestone or conglomerates.

The strata are considerably folded with the axis prominently NNE-SSW although there is some local variation.

As for instrusive rocks, besides diorite in some places, dikes of porphyrite can be seen. In addition, intrusions of neutral or basic rocks have been reported. 3/

These bed rocks are covered with alluvium or residual soil. In the river section fine sand is mainly deposited while on the low lands along both banks of the Mekong River, silty soil of medium plasticity and clayey soil are predominate and in this area rice is cultivated in the rainy season. The mountain slopes on both banks of the river are covered thinly with weathered residual soil subject to slight lateritization and the area is either clear forest or jungle.

Source: 1/ *Progress Report on Geological Investigations, Sambor Dam Sites, Cambodia, 1960, 1961,* Snowy Mountains Hydro-Electric Authority.

2/ *Etudés Géologiques sur l'Indochine Sud-Est. E. SAURIN, Bulletine du Service Géologique du l'Indochine,* Vol. 22 Fascicule 1, 1935, Hanoi.

3/ *Carte Géologique de l'Indochine á l'échelle du 1/2,000,000* Revue et Complétée par J. FROMAGET et E. SAURIN, 1952.

4/ L'Indochine Francaise sa Structure Géologique, ses Roches, ses minesec Iurirs Relations Possibles avec la Tectonique. J. FROMAGET, *Bulletine du Service Géologique du l'Indochine,* Vol. 26 Fascicule 2, 1941, Hanoi.

E-3 Reservoir Bed

E-3-1 Topography (See Fig. E-1)

The Mekong River is joined by three tributaries, the Se Khong, Se San and Srepok Rivers, which flow in from the left bank at Stung Treng at the backwater of Sambor reservoir, and flows almost directly south for approximately 100 km at an extremely gentle gradient to the Samboc Rapids which is the site of the proposed dam. The undulations of the both banks are extremely gentle and for approximately 80 km downstream from Stung Treng the river becomes wider at places with numerous large sand bars in the channel, chief among which is Khan de Kg. Chan. From Sambor Village approximately 20 km upstream of the dam site, the width of the river narrows to 2.5 km. The river width at the dam axis is approximately 2 km and in the river channel immediately upstream of the dam, islets are scattered to form the Samboc Rapids.

Most of the tributaries flowing into the reservoir are on the left bank of the Mekong River, the major ones being the Se Khong, Se San and Srepok which join the Mekong at the backwater. Smaller tributaries are the O Kach Preul, O Tatoeung, Prek Kakot and Prek Kampi. Each of these tributaries form inundated plains corresponding to its scale near the confluence with the Mekong.

E-3-2 Geology 1/ (See Fig. B-1 in Vol. VII)

The reservoir area is composed of the Indochinian Formation which consists mainly of shale, siltstone, sandstone and complex of these rocks, with interbeds of conglomerate and thin layers of limestone. Although these strata are cut by faults, the distribution is along a geologic structure closely parallel to the Mekong River channel. Regarding igneous rock, other than dikes of porphyrite, there are only some neutral or basic rock intrusions reported on the opposite bank of Sambor Village and near the backwater. The basal rock is covered by fine-particled alluvial deposit and weathered residual soil.

Except for parts close to the surface, the alluvial deposit and the weathered residual soil are generally adequately compacted and is tight with the bed rock, and as the bed rock itself is of comparatively low permeability, it is thought leakage of stored water will be negligible.

Faults are relatively undeveloped, the sheared zones being adequately sealed by fault breccia, clay and silty material. Due to secondary geological phenomena such as mylonitization and filling by veinlets of calcite, many of the faults are healed and actually can be considered to be watertight.

In the reservoir area, there are no deposits of soluble minerals or rocks, nor can any permeable igneous rocks be seen.

E-4 Topography Around Hydraulic Structures

The Mekong River from the vicinity of the confluence of Prek Kakot to the vicinity of the confluence of Prek Kampi, a distance of approximately 4 km is called the Samboc Rapids. The river gradient in this section is approximately 1.2 m/km forming a rapid steam.

The width of the river is approximately 2.5 km near the upstream end of the rapids, but gradually widens and at the middle portion it is close to 4 km. From the midstream portion to the downstream portion the river gradually narrows to approximately 2 km near the downstream end of the rapids. The dam will cross the river at a point slightly above the downstream end of the rapids. Downstream of the dam axis, the width of the river again widens.

In the dry season, the Samboc Rapids shows numerous islets and reefs covered with fine sand, silt and growth of grass and shrubs with the mainstream being divided into a great number of narrow streams flowing among these islets and reefs. Some of these channels can be easily forced in the dry season, but as shown in Figs. E-4 and 5, there are places where troughs of more than 100 m widths with bottoms below sea level are found.

Source: 1/ *Carte Géologique de l'Indochine à l'échelle du 1/200,000,* Revue et Complétée par. J. FROMAGET et E. SAURIN, 1952.

Both banks of the mainstream come down close to the water in the form of steep slopes of silty soil. The top of the banks are about 14 m above low water level, and as shown in Fig. E-4, the height decreases slightly as the distances from the banks increase. The flood plains which spread out along the mainstream on both banks are covered thickly with tall grass while low areas are swamps filled with water even in the dry season.

Still farther from the river where the elevation begins to exceed approximately 20 m, a transition is seen to hilly area covered with short grass, bamboo and shrubs. As shown in Figs. E-1, 2 and 3, the hilly zone gain elevation at an extremely gentle gradient and at approximately 10 km from the river, the elevations is 50 m. The left abutment of the dam will rest on the hill forming the divide the Prek Kakot and Prek Kampi and the right abutment on the hill forming the watershed between the Prek Krieng and Prek Krasang.

These tributaries have extremely gentle gradients and the runoff in the dry seasons are extremely small.

Of the tributaries, the one joining the Mekong River near the site of hydraulic structures is the Prek Kampi entering from the left bank just downstream of the dam axis. The Prek Kampi meanders south-southwest to west and cuts the left bank in a box-like cross section.

One of the outstanding features topographically is the former river channel on the right bank. The old river channel, as shown in Fig. B-1 in Vol. VII, has its upstream end at the protruding section of the Samboc Rapids upstream of the dam axis and winding gradually to the west again joints the mainstream near Trong Island on the opposite bank of Kratie. This former river channel forms a band approximately 3 km wide with the upstream portion being a jungle area and the downstream portion being marshy land.

The old river bed is filled with alluvial deposit and is lower than EL (-) 10 m at places near the dam axis.

E-5 Geology of Foundations of Hydraulic Structures

E-5-1 Outline of Investigations

Through the geological surveys conducted by the Australian Team, 1/, 2/ basic items regarding geology such as stratigraphy and geological structure have been made clear. For the purpose of this report, the results of the said surveys were used as a basis and some supplemental investigations were carried out.

The supplemental investigations made by the Japanese Government Survey Team, besides surface reconnaissance, included geological observations by core boring, auger boring and test pits, permeability tests by injection and pumping utilizing boring holes and test pits, as well as seismic prospecting of the river portion where bed rock could not be directly observed, the flood plains on both banks and the old river channel on the right bank with deep alluvial deposit.

The total amount of geological investigations carried out at the site is shown in Table E-1 while the locations of the investigations near hydraulic structures covered in this report are indicated in Figs. E-1 and 6.

Table E-1 Geological Investigation Works

	Core Boring		Auger Boring		Test Pit		Seismic Survey	
	Hole	Length (m)	Hole	Length (m)	Hole	Length (m)	Measure Line	Length (m)
EPDC	78	1,483	55	159	287	772	23	28,390
Australian Team	17	943	Holes, Pits 269, Total Length 768					
Total	95	2,426	Holes, Pits 611, Total Length 1,699				23	28,390

Source: 1/ *Progress Report on Geological Investigations, Sambor Dam Sites, Cambodia, 1960, 1961*, Snowy Mountains Hydro-Electric Authority.

2/ *Geological Investigations, Sambor Dam Site, Cambodia* Vol. 1-4, 1960–1962.

Beginning with the dam, suitable foundations were found for the hydraulic structures in accordance with the type of each structure. The bed rock is hard and there are no special problems in regard to foundation for structures and leakage from the reservoir, and the geological conditions may be said to be satisfactory in general.

E-5-2 Dam

The location of the dam axis is as shown in Fig. E-1. The important geological phenomena of the dam foundation observed from the geological investigations are given below:

(1) In the river channel towards the right bank, there is an eroded trough formed by scouring of the bed rock by flowing water. The elevation of the bottom of this trough is as low as approximately EL (-) 12 m. Besides this, there are several similar troughs on a smaller scale along the dam axis about 800 m from the left bank towards highland.

(2) Along the dam axis on both banks which will be the foundation for the earth dam, bed rock can be uncovered by excavating a small amount of topsoil.

(3) The right bank of the dam axis crosses an old river channel approximately 2 km wide (See Fig. B-1, in Vol. VII). According to results of field permeability tests of the deposits in the former river channel and the upper part of the bed rock underneath, comparatively little permeability was indicated. Therefore, if suitable treatment is applied, there should be no proglem in respect of the foundation for the dam.

Rock-Fill Dam in River Portion (See Figs. E-4 and 5):
In the river section to be the foundation for the rock-fill dam, fresh rock is exposed over a wide area and the river deposits is generally thin. The rocks comprising the foundation are sandstone, shale and siltstone and alternations of these rocks. The bed rock is extremely fresh and hard, the area of loosening of rock being limited to the very top surface portion. The results of seismic prospecting almost all show velocities of 3.8 km/sec–4.2 km/sec to 5.5 km/sec–6.0 km/sec, and this also indicates the good quality of the bed rock in the river section.

It is assumed that the velocities of 3.8 km/sec–4.2 km/sec indicate a statum of an exfoliative nature while 5.5 km/sec–6.0 km/sec indicate a stratum which is close to being massive.

Most of the faults and sheared zones have limited areas of influence and the sheared material in most cases are either mylonite which is fault breccia tightly compacted with clay and silt or filled by a network of veinlets of calcite, or headed by intrusions of dike rocks along the faults. As the result of permeability tests, the bed rock including faults and sheared zones are thought to be generally watertight.

Some of the eroded troughs are filled with river deposits. The trough of the greatest magnitude is located on the right bank of the river section.

This trough was measured with sounding devices which gave a W-shape with a protruding section in the middle dividing the trough into two roughly symmetrical parts as shown in Figs. E-4 and 5. The deepest part of the trough is approximately EL.(-)12 m and the width including the protrusion in the middle is as much as 150 m. The seismic prospecting was made of this trough. From the results of seismic prospecting and measurements with an echo sounding device it was estimated that the slope closest to the right bank is covered uniformly with a river deposit most likely consisting of fine sand, but bed rock is exposed at the bottom where there are no river deposits.

Right Bank Earth-Fill Dam (See Figs. E-3 and 4):
Part of the foundation crosses the old river channel (See Fig. B-1 in Vol. VII)

This portion corresponds to the approximately 2.5 km stretch from the vicinity of the west end of the spillway towards the wing of the dam. The part at the former river channel has denser vegetation than the other parts and is a jungle. The deposits in the old river channel are mostly reddish brown fine and medium-grained sand and clay with the material becoming coarser with increasing depth, with some parts having coarse-grained sand and scattered well-rounded pebbles of about 1 cm diameter. The pebbles are almost entirely quartz pebbles.

The deposit is as deep as 30 m in the middle area of the old river channel, but the deposit is densely consolidated and tightly adhered to the bed rock underneath with the weathered surface being no more than 2 m to 3 m according to test borings. Deeper than this, it is thought fresh silstone, shale and sandstone and alternations of these rocks dominate as in the case at the upstream end of the old channel.

As the result of permeability tests, it was found that the deposits in the old channel, the bed rock underneath and the boundary between the two are relatively watertight.

As shown in Figs. E-3 and 4, the part west of the old river channel to the wing of the dam is covered with a sandy topsoil underneath which is weathered residual soil.

The residual soil is generally 1 m to 4 m deep with slight lateritization and with about 50 m of concentration of laterite nodules which are generally constant for the whole area. Since the mother rock of the weathered residual soil is calcareous, the interstices of the soil particles are at times filled with a calcareous material, so that the soil is generally dense and when dry becomes harder. Under the surface residual soil is weathered bed rock, but the depth to fresh rock differs in places and even where weathering is not prominent it is more than 4 m. Permeability tests of weathered residual soil were carried out utilizing test pits and the results showed high watertightness.

Left Bank Earth-Fill Dam (See Fig. E-2 and 4):
The low elevation area near the Mekong River is a flood plain and in places is marshy even in the dry season. The flood plain at the dam axis occupies the area from the river bank of E 26. This area is covered with clay of high plasticity and silty soil of medium plasticity. The surface layer is dark gray humus 10 cm to several meters deep. The geology between the eastern edge of the flood plain to the dam wing is roughly the same as the part west of the western edge of the old river channel on the right bank, but the depth of the weathered residual soil is generally less than on the right bank.

Approximately 8 km east of the confluence of the Prek Kakot, conglomerate is predominant on the highland at X 1,400 km and Y 620 km. The conglomerate is in the form of a sandy matrix filled by well-rounded pebbles of siliceous rock, limestone, shale and rhyolite and is very hard.

This conglomerate is distributed from around E 45 to E 47 and the vicinity is covered with pebbles separated from the matrix by weathering. According to investigations by test pits the pebbles under the surface is filled tightly with sandy clay and a high degree of watertightness is estimated.

E-5-3 Spillway (See Figs. E-6 and 8)

The foundation of the overflow spillway consists of alternation of sandstone and predominantly shale. East of the spillway, there is a marshy area.

The surface deposits consisting of fine sand, silt and clay are extremely thin at the marshy area but around the middle of the spillway axis it is about 6 m deep and near the western end of the spillway it is approximately 10 m. Therefore, the bed rock rises slightly at the middle with gentle undulations at EL 15 m to 20 m, gradually falling from near the western end of the spillway to the former river channel.

The depth of the weathered bed rock is approximately 5 m from the eastern end of the spillway to the middle and shows a trend to decrease the nearer it becomes to the western end. The bed rock is extremely weathered 1 m to 3 m from the surface and in the execution of the construction, it will be necessary to excavate the weathered rock.

The surface deposits along the center line of the spillway are thin except for the area corresponding to the eastern edge of the old river channel, which is the section from N 1,392 m of the center line to X 1,391.4 km coordinate, where it is about 2 m to 3 m and the elevation of the bed rock is about 20 m. From X 1,391.4 km of the center line and towards the outlet, the depth of the surface deposit gradually increases until it is 20 m near the outlet and the elevation of the bed rock is lower than 5 m.

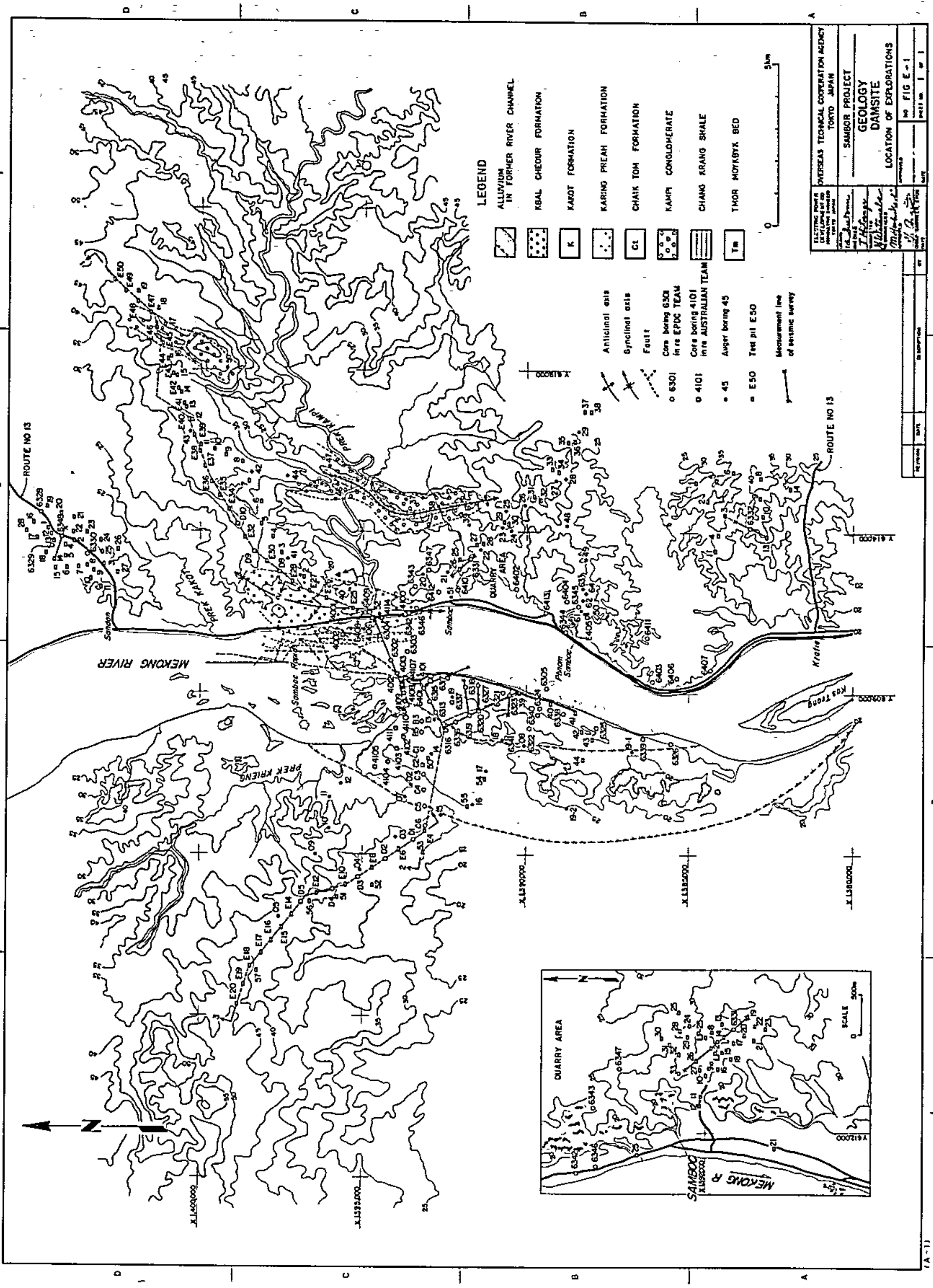
The geology of the entire area of the spillway discharge channel is similar to that at the training levees. The depth of the surface deposits, except for the former river channel and the especially thick portion near the Mekong River is approximately 4 m. Under the surface deposit are alternation of sandstone and shale. According to investigations by borings and test pits, approximately 60% is sandstone and approximately 40% shale showing sandstone to be slightly predominant. In general, this bed rock has been subjected to strong folding so that exfoliation is greatly developed and the depth of the weathered zone is usually greater than 4 m.

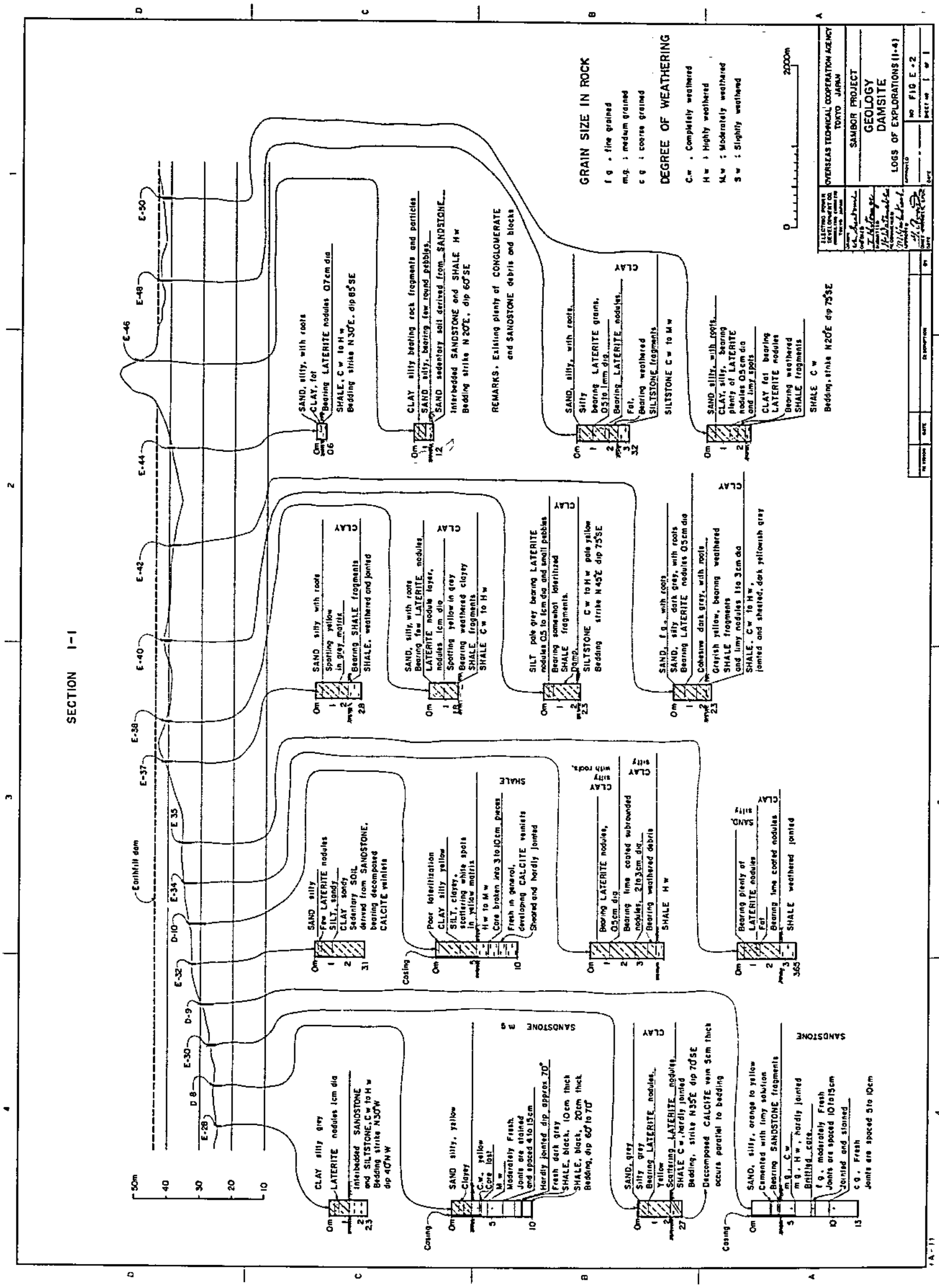
E-5-4 Powerhouse and Intake (See Figs. E-6 and 7)

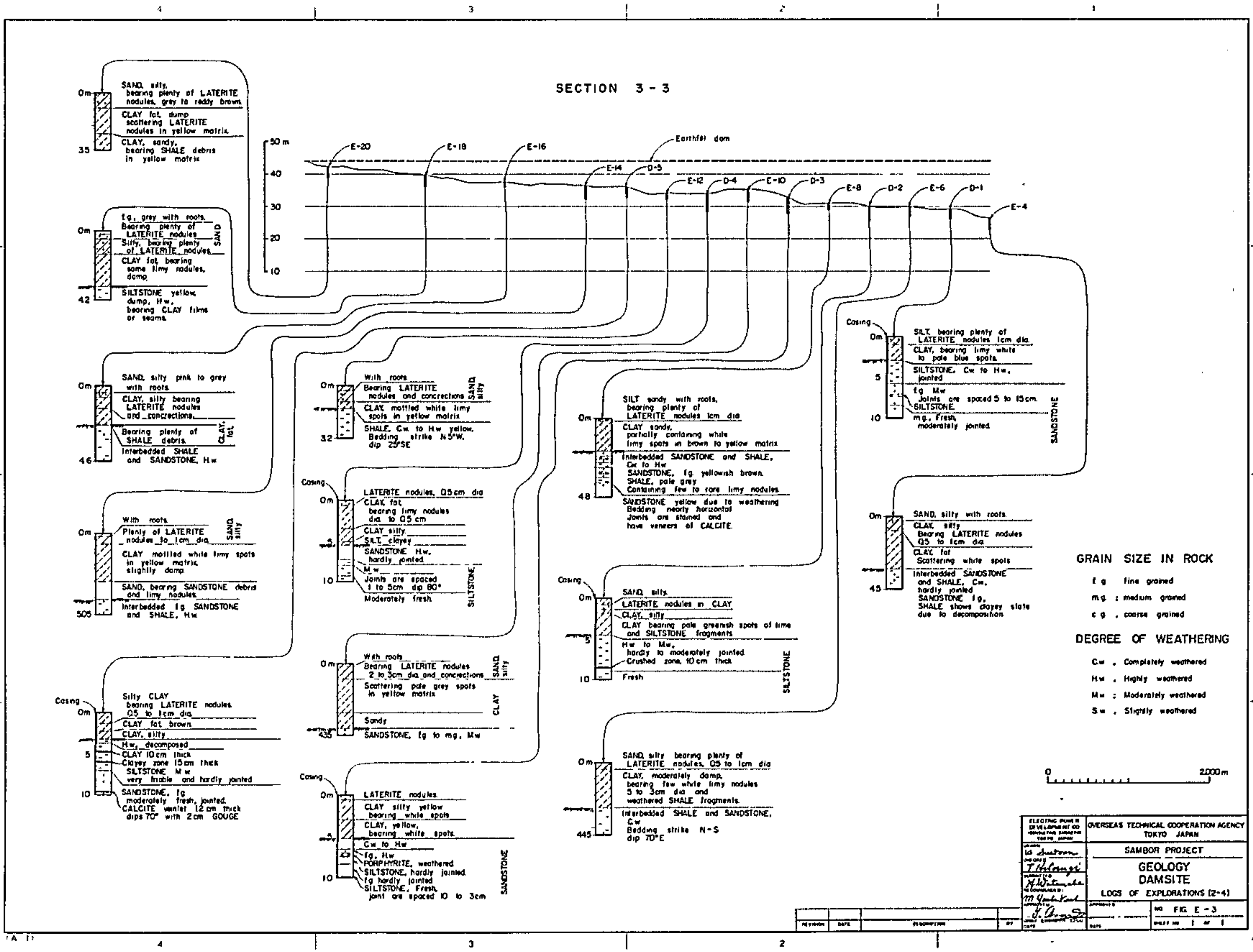
The tableland near the powerhouse is covered with surface deposits consisting of fine sand, silt and clay, with outcrops of bed rock only being found in small areas at the valley wall and part of the river bed.

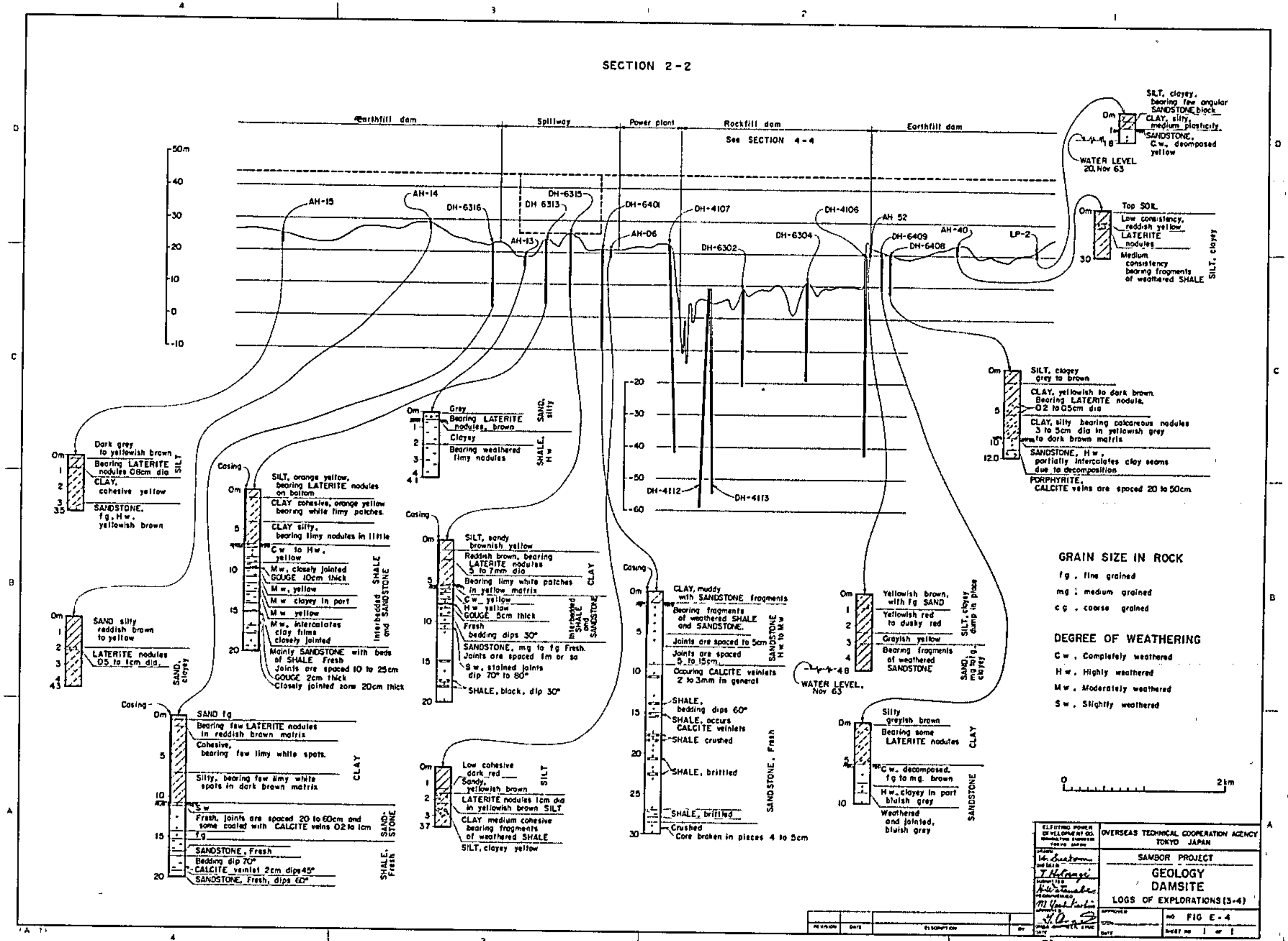
As shown in Fig. E-7, the depth of the surface deposit at the tableland is approximately 10 m at site boring A-0, but excepting this area, it is generally 4 m to 6 m. The bed rock of the tableland forms a flat plane of about EL 15m and although there are localized variations it drops towards the Mekong River at a gradient of 1/20 and eventually continues on to the troughs in the river bed section.

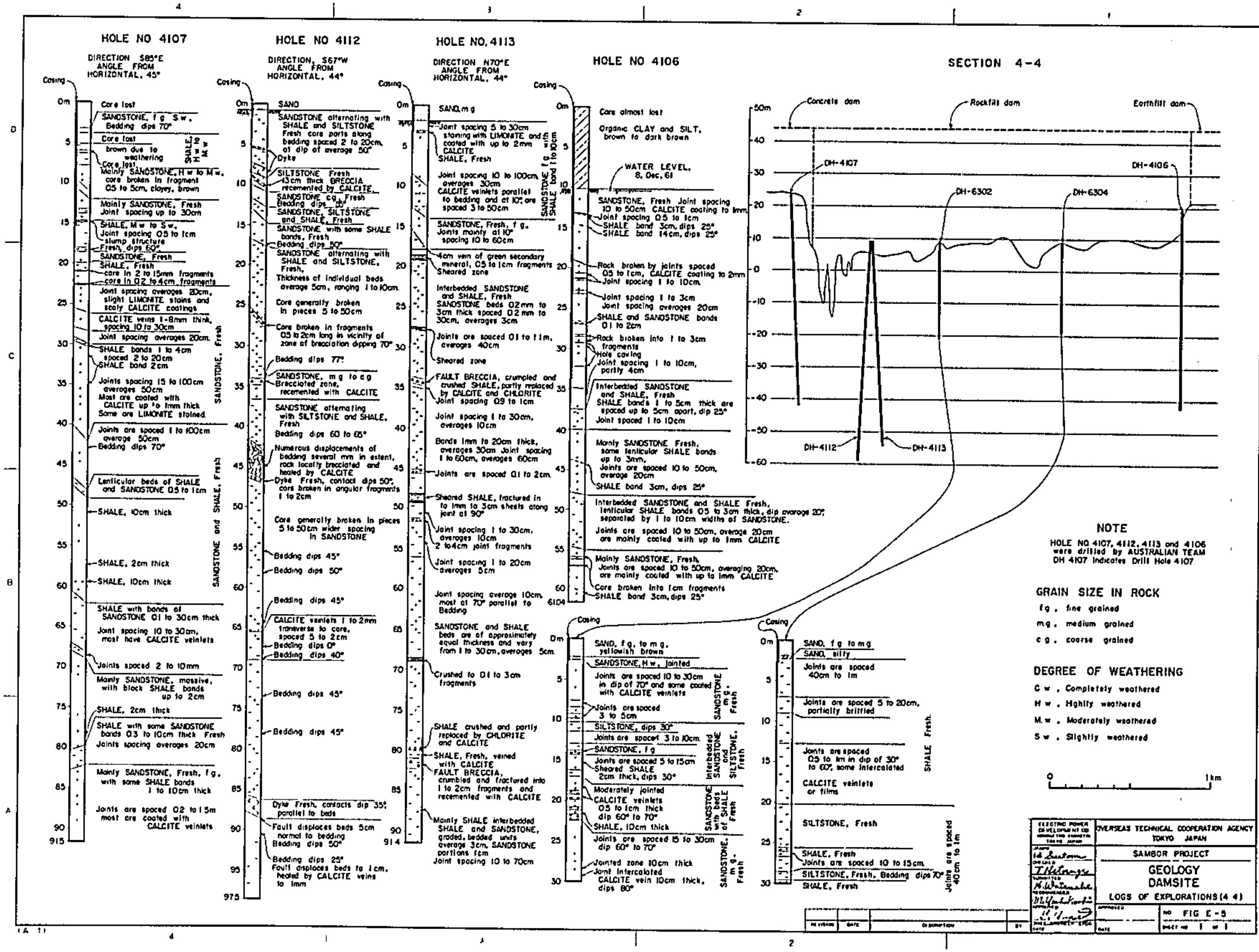
The foundation of the powerhouse, as shown in Fig. E-7, is composed of sandstone and shale, and alternation of these rocks and the dip of the strata are steep. At parts, exfoliation is developed by severe folding and the strata are in a fissile condition. The surface of the bed rock is in most cases weathered to a depth of 2 m to 3 m and joints, stained rusty color, have developed. Bed rock where weathering is especially marked has thin layers and films of clay in the joints and the color of the rock has changed from dark gray to yellow. Excepting the weathered parts, the fresh rock is hard and is suitable as a foundation for the powerhouse.

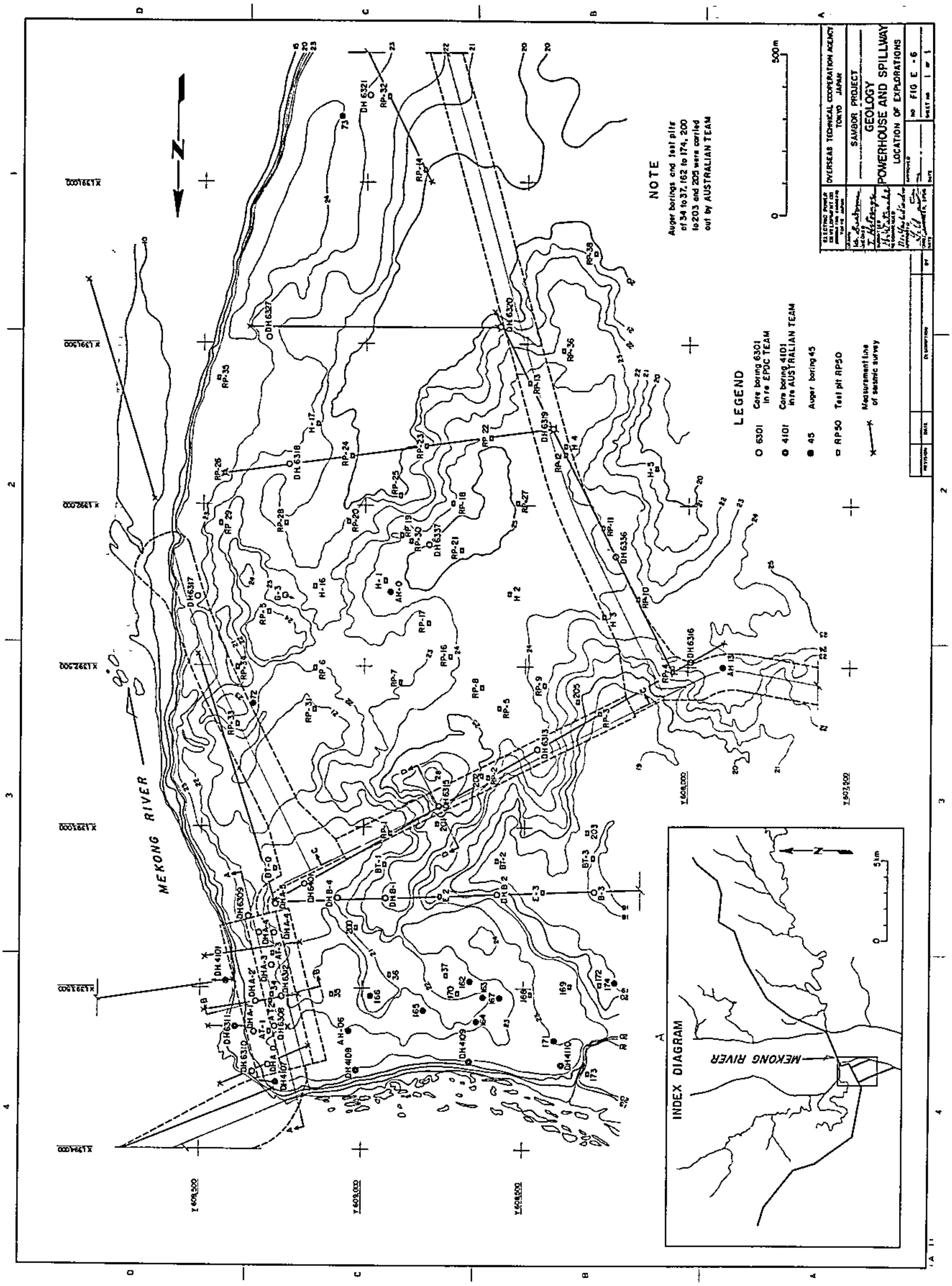

LEGEND
ALLUVIUM IN FORMER RIVER CHANNEL
KBAL CHEOUR FORMATION
K
KAKOT FORMATION
KARING PREAH FORMATION
Ct
CHAIK TOM FORMATION
KAMPI CONGLOMERATE
CHANG KRANG SHALE
Tm
THOR MOYKBYK BED
Anticlinal axis
Synclinal axis
Fault
o 6301 Core boring 6301 in re EPDC TEAM
o 4101 Core boring 4101 in re AUSTRALIAN TEAM
• 45 Auger boring 45
▫ E50 Test pit E50
Measurement line of seismic survey
0
5km
OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO JAPAN
SAMBOR PROJECT
GEOLOGY
DAMSITE
LOCATION OF EXPLORATIONS
FIG E-1
MEKONG RIVER
ROUTE NO 13
PREK KAKOT
PREK KAMPI
PREK KRIENG
Sambor Rapids
Sambor
QUARRY AREA
Phnom Sambor
Kratie
Koh Trong
QUARRY AREA
SCALE
500m
MEKONG R
SAMBOR

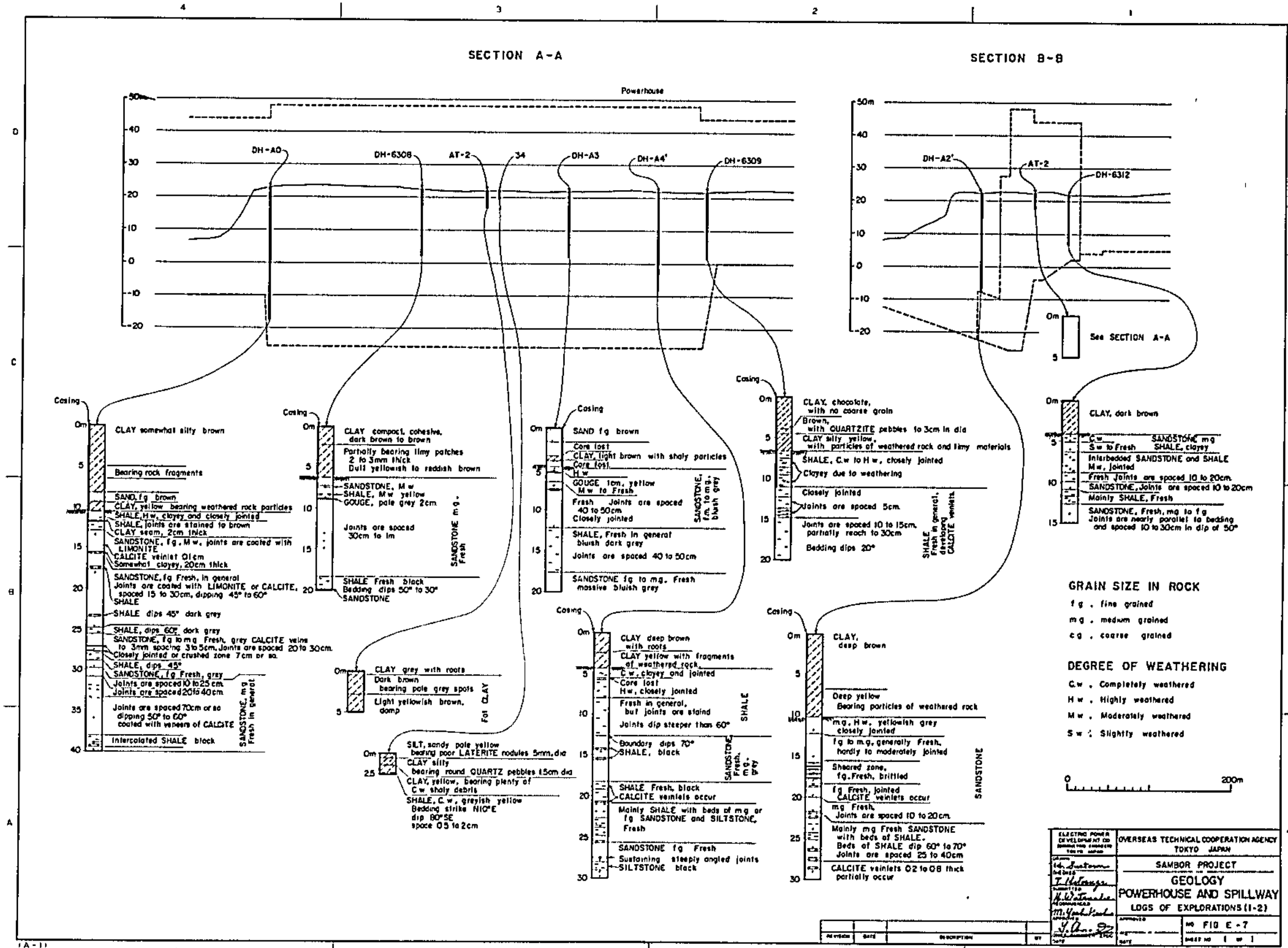

SECTION I-I
Earthfill dam
E-28
D 8
E-30
D-9
E-32
D-10
E-34
E 35
E-37
E-38
E-40
E-42
E-44
E-46
E-48
E-50
GRAIN SIZE IN ROCK
f g . fine grained
m.g. : medium grained
c g : coarse grained
DEGREE OF WEATHERING
C w . Completely weathered
H w : Highly weathered
M w : Moderately weathered
S w : Slightly weathered
REMARKS. Existing plenty of CONGLOMERATE and SANDSTONE debris and blocks
OVERSEAS TECHNICAL COOPERATION AGENCY TOKYO JAPAN
SAMBOR PROJECT
GEOLOGY
DAMSITE
LOGS OF EXPLORATIONS (I-I)
NO FIG E-2

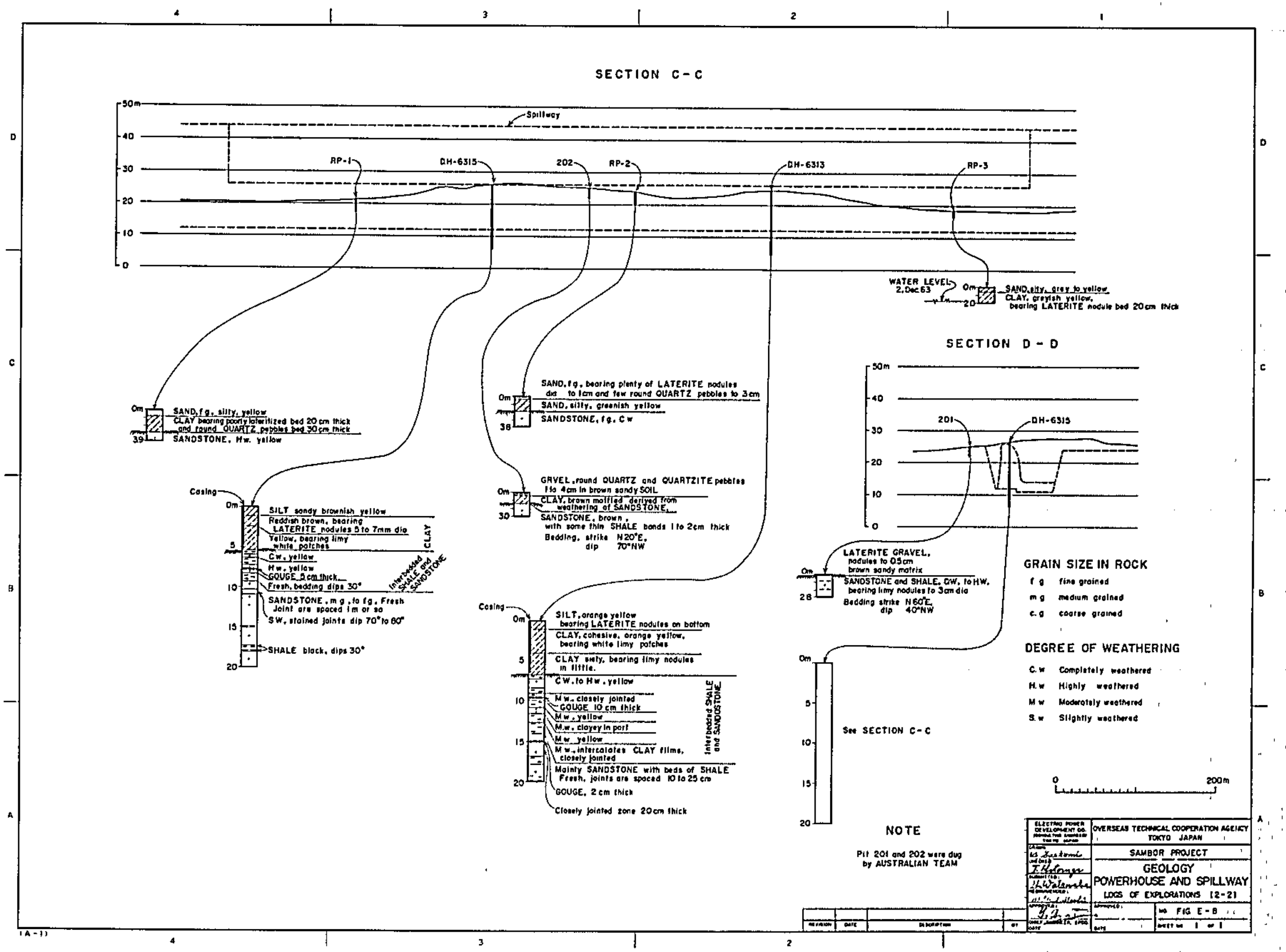

SECTION 3 - 3
Earthfill dam
E-20
E-18
E-16
E-14
D-5
E-12
D-4
E-10
D-3
E-8
D-2
E-6
D-1
E-4
50 m
40
30
20
10
SAND, silty, bearing plenty of LATERITE nodules, grey to reddy brown
CLAY fat, dump scattering LATERITE nodules in yellow matrix
CLAY, sandy, bearing SHALE debris in yellow matrix
f.g. grey with roots. Bearing plenty of LATERITE nodules
Silty, bearing plenty of LATERITE nodules
SAND
CLAY fat, bearing some limy nodules, damp
SILTSTONE yellow, dump, Hw, bearing CLAY films or seams
SAND, silty pink to grey with roots
CLAY, silty bearing LATERITE nodules and concretions
Bearing plenty of SHALE debris
CLAY, fat
Interbedded SHALE and SANDSTONE, Hw
With roots
Plenty of LATERITE nodules to 1cm dia
SAND silty
CLAY mottled white limy spots in yellow matrix, slightly damp
SAND, bearing SANDSTONE debris and limy nodules
Interbedded f.g. SANDSTONE and SHALE, Hw
Silty CLAY bearing LATERITE nodules 0.5 to 1cm dia
CLAY fat brown
CLAY, silty
Hw, decomposed
CLAY 10 cm thick
Clayey zone 15 cm thick
SILTSTONE Mw very friable and hardly jointed
SANDSTONE, f.g. moderately fresh, jointed
CALCITE veinlet 1.2 cm thick dips 70° with 2 cm GOUGE
With roots
Bearing LATERITE nodules and concretions
CLAY mottled white limy spots in yellow matrix
SHALE, Cw to Hw yellow. Bedding strike N 5°W, dip 25°SE
LATERITE nodules, 0.5 cm dia
CLAY, fat bearing limy nodules dia. to 0.5 cm
CLAY silty
SILT clayey
SANDSTONE Hw, hardly jointed
Mw
Joints are spaced 1 to 5cm dip 80°
Moderately fresh
SILTSTONE
With roots
Bearing LATERITE nodules 2 to 3cm dia and concretions
Scattering pale grey spots in yellow matrix
Sandy
CLAY
SANDSTONE, f.g. to m.g., Mw
LATERITE nodules
CLAY silty yellow bearing white spots
CLAY, yellow, bearing white spots
Cw to Hw
f.g., Hw
PORPHYRITE, weathered
SILTSTONE, hardly jointed
f.g. hardly jointed
SILTSTONE, Fresh, joint are spaced 10 to 3cm
SANDSTONE
SILT sandy with roots, bearing plenty of LATERITE nodules 1cm dia
CLAY sandy, partially containing white limy spots in brown to yellow matrix
Interbedded SANDSTONE and SHALE, Cw to Hw
SANDSTONE, f.g. yellowish brown
SHALE, pale grey
Containing few to rare limy nodules
SANDSTONE yellow due to weathering
Bedding nearly horizontal
Joints are stained and have veneers of CALCITE
SAND, silty
LATERITE nodules in CLAY
CLAY, silty
CLAY bearing pale greenish spots of lime and SILTSTONE fragments
Hw to Mw, hardly to moderately jointed
Crushed zone, 10 cm thick
Fresh
SILTSTONE
SAND, silty bearing plenty of LATERITE nodules, 0.5 to 1cm dia
CLAY, moderately damp, bearing few white limy nodules 5 to 3cm dia and weathered SHALE fragments
Interbedded SHALE and SANDSTONE, Cw
Bedding strike N-S dip 70°E
SILT, bearing plenty of LATERITE nodules 1cm dia
CLAY, bearing limy white to pale blue spots
SILTSTONE, Cw to Hw, jointed
f.g. Mw
Joints are spaced 5 to 15cm
SILTSTONE
m.g., Fresh, moderately jointed
SANDSTONE
SAND, silty with roots
CLAY, silty
Bearing LATERITE nodules 0.5 to 1cm dia
CLAY, fat
Scattering white spots
Interbedded SANDSTONE and SHALE, Cw, hardly jointed
SANDSTONE f.g.
SHALE shows clayey slate due to decomposition
Casing
0m
5
10
35
42
46
505
32
435
48
445
45
GRAIN SIZE IN ROCK
f.g. fine grained
m.g. : medium grained
c.g. , coarse grained
DEGREE OF WEATHERING
Cw , Completely weathered
Hw , Highly weathered
Mw : Moderately weathered
Sw , Slightly weathered
0
2,000m
OVERSEAS TECHNICAL COOPERATION AGENCY TOKYO JAPAN
SAMBOR PROJECT
GEOLOGY
DAMSITE
LOGS OF EXPLORATIONS (2-4)
FIG. E-3


SECTION 2-2
Earthfill dam
Spillway
Power plant
Rockfill dam
See SECTION 4-4
Earthfill dam
AH-15
AH-14
DH-6316
DH 6313
DH-6315
AH-13
DH-6401
AH-06
DH-4107
DH-6302
DH-6304
DH-4106
AH 52
DH-6409
DH-6408
AH-40
LP-2
DH-4112
DH-4113
WATER LEVEL 20, Nov 63
WATER LEVEL, Nov 63
Casing
SILT, clayey, bearing few angular SANDSTONE block
CLAY, silty, medium plasticity
SANDSTONE, C.w., decomposed yellow
Top SOIL
Low consistency, reddish yellow LATERITE nodules
Medium consistency bearing fragments of weathered SHALE
SILT, clayey
SILT, clayey grey to brown
CLAY, yellowish to dark brown. Bearing LATERITE nodule, 0.2 to 0.5cm dia
CLAY, silty bearing calcareous nodules 3 to 5cm dia in yellowish grey to dark brown matrix
SANDSTONE, H.w., partially intercalates clay seams due to decomposition
PORPHYRITE, CALCITE veins are spaced 20 to 50cm
Dark grey to yellowish brown
Bearing LATERITE nodules 0.8cm dia
CLAY, cohesive yellow
SILT
SANDSTONE, fg, H.w., yellowish brown
SAND silty reddish brown to yellow
LATERITE nodules 0.5 to 1cm dia.
SAND, clayey
Grey
Bearing LATERITE nodules, brown
Clayey
Bearing weathered limy nodules
SAND, silty
SHALE, H.w
SILT, orange yellow, bearing LATERITE nodules on bottom
CLAY cohesive, orange yellow bearing white limy patches.
CLAY silty, bearing limy nodules in little
C.w to H.w, yellow
M.w, closely jointed GOUGE 10cm thick
M.w, yellow
M.w clayey in part
M.w yellow
M.w, intercalates clay films closely jointed
Mainly SANDSTONE with beds of SHALE Fresh
Joints are spaced 10 to 25cm
GOUGE 2cm thick
Closely jointed zone 20cm thick
Interbedded SHALE and SANDSTONE
SILT, sandy brownish yellow
Reddish brown, bearing LATERITE nodules 5 to 7mm dia
Bearing limy white patches in yellow matrix
C.w yellow
H.w yellow
GOUGE 5cm thick
Fresh bedding dips 30°
SANDSTONE, mg to fg Fresh. Joints are spaced 1m or so
S.w, stained joints dip 70° to 80°
SHALE, black, dip 30°
CLAY
Interbedded SHALE and SANDSTONE
SAND fg
Bearing few LATERITE nodules in reddish brown matrix
Cohesive, bearing few limy white spots.
Silty, bearing few limy white spots in dark brown matrix
S.w
Fresh, joints are spaced 20 to 60cm and some coated with CALCITE veins 0.2 to 1cm
fg
SANDSTONE, Fresh
Bedding dip 70°
CALCITE veinlet 2cm dips 45°
SANDSTONE, Fresh, dips 60°
SAND-STONE
SHALE, Fresh
Low cohesive dark red
Sandy, yellowish brown
LATERITE nodules 1cm dia in yellowish brown SILT
CLAY medium cohesive bearing fragments of weathered SHALE
SILT, clayey yellow
CLAY, muddy with SANDSTONE fragments
Bearing fragments of weathered SHALE and SANDSTONE.
Joints are spaced to 5cm
Joints are spaced 5 to 15cm
Occuring CALCITE veinlets 2 to 3mm in general
SHALE, bedding dips 60°
SHALE, occurs CALCITE veinlets
SHALE crushed
SHALE, brittled
SHALE, brittled
Crushed
Core broken in pieces 4 to 5cm
SANDSTONE H.w. to M.w
SANDSTONE, Fresh
Yellowish brown, with fg SAND
Yellowish red to dusky red
Grayish yellow
Bearing fragments of weathered SANDSTONE
SILT, clayey dump in place
SAND, mg to fg, clayey
Silty greyish brown
Bearing some LATERITE nodules
C.w., decomposed, fg to mg. brown
H.w., clayey in part bluish grey
Weathered and jointed, bluish grey
CLAY
SANDSTONE
GRAIN SIZE IN ROCK
fg, fine grained
mg : medium grained
cg, coarse grained
DEGREE OF WEATHERING
C.w, Completely weathered
H.w, Highly weathered
M.w, Moderately weathered
S.w, Slightly weathered
0
2km
ELECTRIC POWER DEVELOPMENT CO.
OVERSEAS TECHNICAL COOPERATION AGENCY TOKYO JAPAN
SAMBOR PROJECT
GEOLOGY
DAMSITE
LOGS OF EXPLORATIONS (3-4)
FIG E-4
1 of 1


HOLE NO 4107
DIRECTION S85°E ANGLE FROM HORIZONTAL, 45°
HOLE NO 4112
DIRECTION, S67°W ANGLE FROM HORIZONTAL, 44°
HOLE NO. 4113
DIRECTION N70°E ANGLE FROM HORIZONTAL, 44°
HOLE NO 4106
SECTION 4-4
Concrete dam
Rockfill dam
Earthfill dam
DH-4107
DH-6302
DH-6304
DH-4106
DH-4112
DH-4113
WATER LEVEL, 8, Dec, 61
NOTE
HOLE NO 4107, 4112, 4113 and 4106 were drilled by AUSTRALIAN TEAM
DH 4107 indicates Drill Hole 4107
GRAIN SIZE IN ROCK
f g , fine grained
m g , medium grained
c g , coarse grained
DEGREE OF WEATHERING
C w , Completely weathered
H w , Highly weathered
M w , Moderately weathered
S w , Slightly weathered
0
1km
OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO JAPAN
SAMBOR PROJECT
GEOLOGY
DAMSITE
LOGS OF EXPLORATIONS (4 4)
FIG E-5


MEKONG RIVER
N
NOTE
Auger borings and test pits of 34 to 37, 162 to 174, 200 to 203 and 205 were carried out by AUSTRALIAN TEAM
LEGEND
○ 6301 Core boring 6301 in the EPDC TEAM
● 4101 Core boring 4101 in the AUSTRALIAN TEAM
● 45 Auger boring 45
□ RP50 Test pit RP50
Measurement line of seismic survey
500m
OVERSEAS TECHNICAL COOPERATION AGENCY TOKYO JAPAN
SAMBOR PROJECT
GEOLOGY
POWERHOUSE AND SPILLWAY
LOCATION OF EXPLORATIONS
FIG E - 6
INDEX DIAGRAM
MEKONG RIVER


SECTION A-A
SECTION B-B
Powerhouse
DH-A0
DH-6308
AT-2
34
DH-A3
DH-A4'
DH-6309
DH-A2'
DH-6312
See SECTION A-A
Casing
GRAIN SIZE IN ROCK
f g , fine grained
m g , medium grained
c g , coarse grained
DEGREE OF WEATHERING
C w , Completely weathered
H w , Highly weathered
M w , Moderately weathered
S w , Slightly weathered
0
200m
ELECTRIC POWER DEVELOPMENT CO
OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO JAPAN
SAMBOR PROJECT
GEOLOGY
POWERHOUSE AND SPILLWAY
LOGS OF EXPLORATIONS (1-2)
FIG E-7
1 of 1


SECTION C-C
Spillway
RP-1
DH-6315
202
RP-2
DH-6313
RP-3
WATER LEVEL 2,Dec 63
SAND, silty, grey to yellow
CLAY, greyish yellow, bearing LATERITE nodule bed 20cm thick
SAND, f.g., silty, yellow
CLAY bearing poorly lateritized bed 20cm thick and round QUARTZ pebbles bed 30cm thick
SANDSTONE, Hw. yellow
SAND, f.g., bearing plenty of LATERITE nodules dia to 1cm and few round QUARTZ pebbles to 3cm
SAND, silty, greenish yellow
SANDSTONE, f.g. Cw
GRVEL, round QUARTZ and QUARTZITE pebbles 1 to 4cm in brown sandy SOIL
CLAY, brown mottled derived from weathering of SANDSTONE
SANDSTONE, brown, with some thin SHALE bands 1 to 2cm thick
Bedding, strike N20°E, dip 70°NW
Casing
SILT sandy brownish yellow
Reddish brown, bearing LATERITE nodules 5 to 7mm dia
Yellow, bearing limy white patches
CLAY
Cw. yellow
Hw. yellow
GOUGE 5cm thick
Fresh, bedding dips 30°
Interbedded SHALE and SANDSTONE
SANDSTONE, m.g. to f.g. Fresh Joint are spaced 1m or so
SW, stained joints dip 70° to 60°
SHALE black, dips 30°
SILT, orange yellow bearing LATERITE nodules on bottom
CLAY, cohesive, orange yellow, bearing white limy patches
CLAY silty, bearing limy nodules in little.
CW. to Hw. yellow
Mw. closely jointed
GOUGE 10cm thick
Mw. yellow
Mw. clayey in part
Mw. yellow
Mw. intercalates CLAY films, closely jointed
Mainly SANDSTONE with beds of SHALE Fresh, joints are spaced 10 to 25cm
GOUGE, 2cm thick
Closely jointed zone 20cm thick
Interbedded SHALE and SANDSTONE
SECTION D-D
201
DH-6315
LATERITE GRAVEL, nodules to 0.5cm brown sandy matrix
SANDSTONE and SHALE, CW. to HW. bearing limy nodules to 3cm dia
Bedding strike N60°E, dip 40°NW
See SECTION C-C
GRAIN SIZE IN ROCK
f.g fine grained
m.g medium grained
c.g coarse grained
DEGREE OF WEATHERING
C.w Completely weathered
H.w Highly weathered
M.w Moderately weathered
S.w Slightly weathered
0
200m
NOTE
Pit 201 and 202 were dug by AUSTRALIAN TEAM
ELECTRIC POWER DEVELOPMENT CO.
OVERSEAS TECHNICAL COOPERATION AGENCY TOKYO JAPAN
SAMBOR PROJECT
GEOLOGY
POWERHOUSE AND SPILLWAY
LOGS OF EXPLORATIONS (2-2)
FIG E-8
SHEET 1 of 1

CHAPTER F. POWER GENERATION SCHEME

CHAPTER F. POWER GENERATION SCHEME

F-1 Basic Conditions

An important point in the examination of the power generation scheme of the Sambor Project is that it will have a close relation with the magnitude, characteristics and timing of development of the various upstream projects such as Pa Mong and Stung Treng. Therefore, the power generation scheme of the Sambor Project should be formulated in connection with the development plans of the upstream projects, but since the latter are still in the stage of study by the Mekong Committee and the Pa Mong Team, Sambor is treated as an isolated project. The basic conditions for the study of the isolated development of Sambor are given below.

(1) The backwater of Sambor Dam shall not affect the discharge level of the proposed Stung Treng Power Station to be built immediately upstream in the future.

(2) Consideration shall be given to other purpose such as irrigation and navigation in determining the available depth of Sambor reservoir.

(3) As the Sambor Dam would be the most downstream of the dams on the Mekong River, the discharge to the downstream areas shall not be less than the minimum monthly average runoff of 1,350 cms recorded at Kratie during the past 33 years.

(4) In order to minimize the fluctuation in water level due to daily load fluctuations, operation shall be carried out within a range of minimum discharge of 1,350 + a cu.ms and maximum discharge of 2,250 + 2a cu.ms.

(5) By the time of completion of the Sambor project, power resources now under investigation in Cambodia and Vietnam will have been developed and transmission interconnection will have been completed between these sources and the Sambor Project.

(6) The capacity of Sambor Power Station shall be expanded in step with the future development of the upstream Mekong River Projects and the increase in power demand.

(7) Initial investment shall be made as small as possible and at the same time produce benefits which will make the project economically feasible.

F-2 Sambor Reservoir

The height of Sambor Dam must be considered in view of many factors starting with the economy of power production. The propsed Stung Treng Project to be built immediately upstream will be a large-scale project and will be a key project in the development of the mainstream of the Mekong River. Since the Sambor Project has a close relationship with the Stung Treng Project, this must be taken into consideration in determining the height of Sambor Dam.

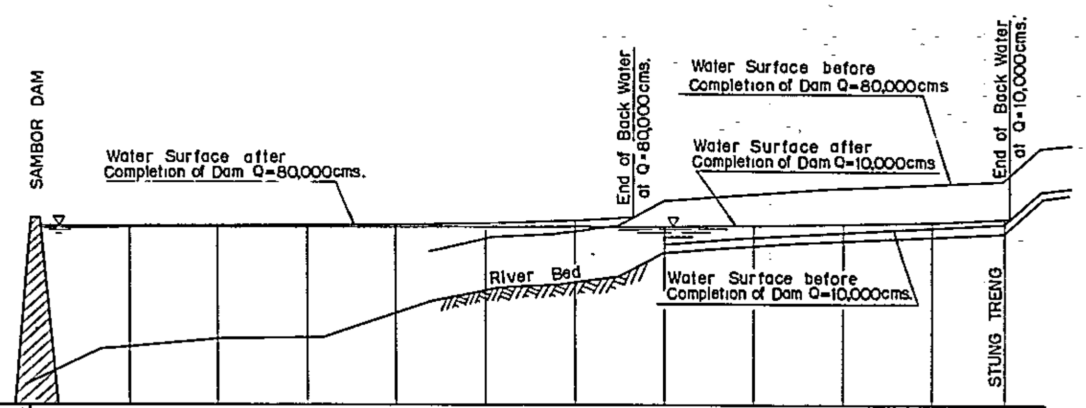
Regarding the Stung Treng Project, according to the Japanese Government Report on Reconnaissance of Major Tributaries of the Lower Mekong Area, 1/ the dam site is proposed near the junction of the Mekong River and the tributary Sekong River and the tailwater level of the power generation will be EL 40 m corresponding to mean water level (mean runoff 6,300 cu.ms) at this location. Therefore, the planned high water level of the Sambor reservoir will be fixed at EL 40 m to coincide with the planned tailwater level of the Stung Treng Project. Fig. F-1 gives the results of studies of backwater effects at a discharge of 10,000 cu.ms and 80,000 cu.ms with the normal high water level of 40 m at Sambor Dam.

The area-capacity curve of the Sambor reservoir is given in Fig F-2 showing that the total storage capacity will be approximately 10,000 million cu.m at a high water level of EL 40 m.

The annual runoff at the Sambor Dam Site is a maximum of 546,481 million cu.m (1959). This means that the percentage of the total shortage capacity to the total annual runoff is only 2% to 3%, so that the Sambor Power Station would be essentially a run-off-river type station.

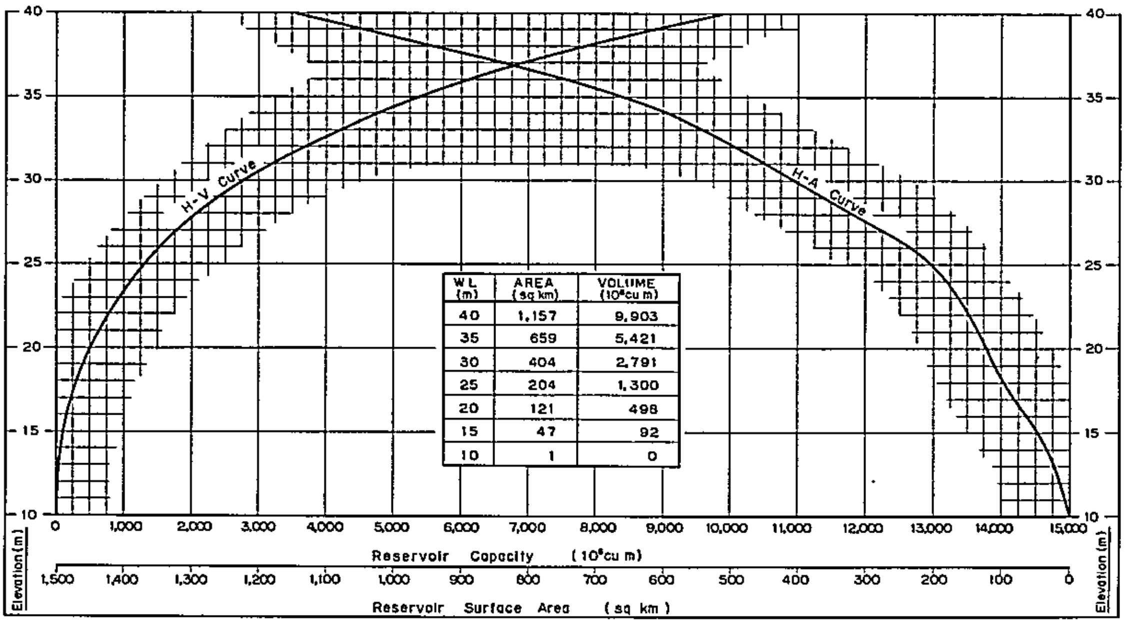
Source: 1/ *Comprehensive Report of Reconnaissance of Major Tributaries of Lower Mekong Area*, September 1962, Japanese Government Mekong River Reconnaissance Team.

Fig. F-1 Backwater Influence of Sambor Reservoir



NO	0	1	2	3	4	5	6	7	8	9	10	11
Distance (m)	0	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	8,000
Total Distance (m)	0	10,000	20,000	30,000	40,000	50,000	60,000	70,000	80,000	90,000	100,000	108,000
River Bed Elev (m)	8.0	13.0	15.0	15.0	20.8	25.8	27.5	34.5	36.0	37.0	38.0	38.5
Water Level 10,000 cms	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.1	40.4	40.8	41.2	41.8
Water Level 80,000 cms	41.0	41.1	41.1	41.2	41.4	41.8	42.7 43.3					

F-2 Area Capacity Curve of Sambor Reservoir



W.L. (m)	AREA (sq km)	VOLUME (10^6cu m)
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

F-3 Study of Reservoir Operation

When studying operation of a reservoir for power generation only, the benefits of electric power are greater as available drawdown becomes greater. In the Sambor Project, however, it is necessary to consider operation of the reservoir to satisfy other purposes such as improvement of navigation and supply of irrigation water.

If available drawdown is great, the number of places required to be improved in the navigation channel to Stung Treng will be increased while the intake water level for irrigation will be lowered to reduce the area benefiting from irrigation.

In consideration of the above factors of navigation and irrigation, the available drawdown of Sambor reservoir is determined to be 2 m.

In this case, the effective stotage capacity will be 2,050 million cu.m and the ratio to the total average annual runoff 446 billion cu.m (343 billion to 546 billion cu.m) is approximately 0.5% which means the reservoir would be able to only the discharge of several months in the dry season.

In order to utilize this effective storage capacity most efficiently and maintain in output even in the dry season, the operation rules of reservoir given below have been established.

In other words, the river runoff at the Kratie site between January and May for the 33 years is divided into three groups, and three models identified as A, B, and C are established with the lower limit of each as that group's basic runoff (See C-2-1, (2), (a), Note).

Model A represents the group of the larger dry season inflow, Model B the average and Model C the smaller.

A mass curve has been prepared for each model from which net evaporation-precipitation correction factors described in D-3 and the amount of water for irrigation uses were deducted to arrive at the mean available discharge for power generation of 2,775 cu.ms for Model A, 2,300 cu.ms for Model B, and 1,860 cu.ms for Model C.

At an effective head of 30 m in the dry season with an overall efficiency of turbines and generators of 85% and at a load factor of 100%, available power of each model in March, April and May is as follow.

Model A	710 MW
Model B	590 MW
Model C	480 MW

The operation of the reservoir, whether it will be Model A, B or C would be determined by the inflow into the reservoir in January and February of that year, and thus gives the minimum amount of available discharge for power generation in the dry season of that year. Therefore, it is possible to forecast the power and energy that can be produced.

F-4 Scale of Development

Since the discharge of the Mekong River fluctuates greatly by wet and dry season, secondary power and energy of Sambor Power Station will increase with the additional installation of capacity although the additional construction cost would be relatively small.

Therefore, if the reduction in output due to decrease of river runoff during the dry season is supplemented by thermal power, the secondary power will be made firm and even if the cost of auxiliary thermal power is considered, the overall cost against firm output will become smaller than for hydroelectric power only.

In contemplating the optimum scale of Sambor Project from the foregoing, the combination of hydro and thermal is applied while at the same time firm power from Sambor Project along, not considering auxiliary thermal power, is also applied.

Further, there will be a loss of output of the Sambor Project during the rainy season due to the rise in the tailwater level, and this point is of major importance in determining the optimum scale of the Sambor Project.

The above studies are based on the runoff data of the 33 years from 1933 through 1965. If auxiliary thermal power is used in combination with Sambor Power Station, the overall unit cost of hydro and thermal combined drops abruptly as the scale of generation is increased from 625 MW to 750 MW and from 750 MW to 875 MW. However, if the scale of generation is increased to 1,000 MW, 1,125 MW, 1,250 MW, etc., there is no corresponding decrease in the cost of energy.

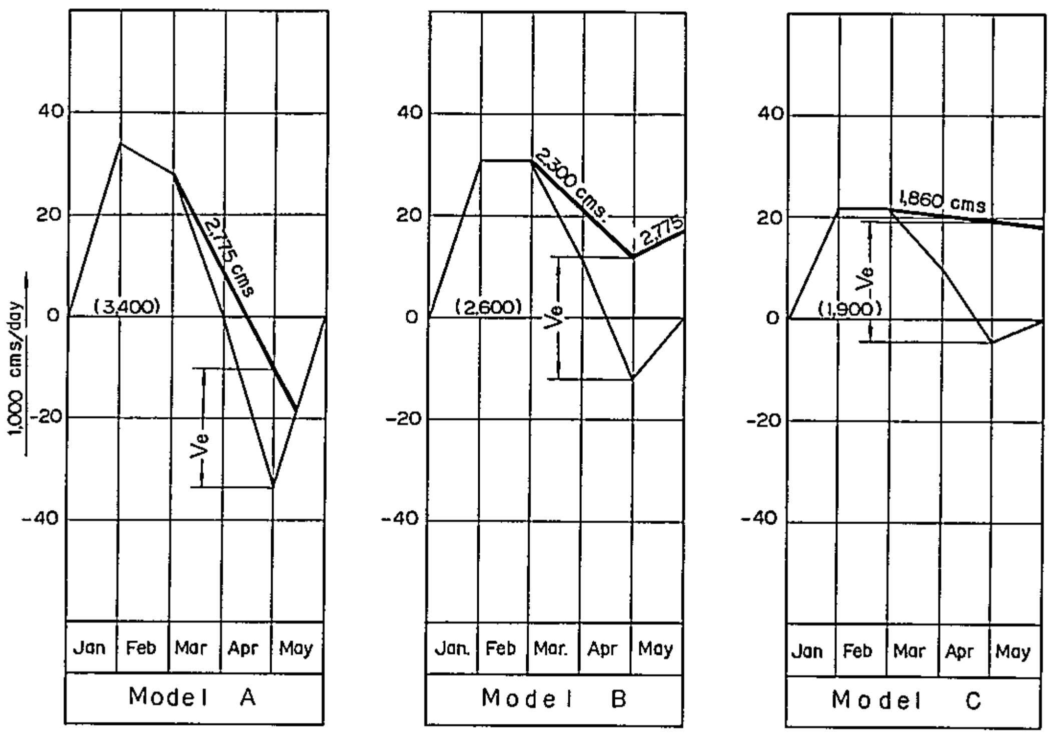
On the other hand, for hydro only, without considerating thermal power, the optimum scale becomes 900 MW. On weighing the above, the optimum scale of Sambor Power Station will be approximately 900 MW. (See Fig. F-4)

In determining the optimum unit capacity of turbines and generators for the scale of development the following factors must be considered. The cost of equipment according to number of units, the technological limits in the manufacturing of equipment, especially the turbines. Also, since the Sambor Power Station at the initial stage of operation will be the major plant in the entire electric power system of Cambodia and Vietnam, the heavy losses incurred on the entire power system through reduction in output at times of outage for repair and maintenance or in case of accidents must be taken into account in selecting the unit capacities of turbines and generators.

From the above considerations, it is determined that the unit capacity of turbines should be 128 MW, that the maximum discharge at the rated head of 19.7 m should be 775 cu.ms and that the unit capacity of generators and transformers should be 140 MVA taking into account supply of reactive power necessary for the power system. With a power factor of 90% the generator output will be 125 MW.

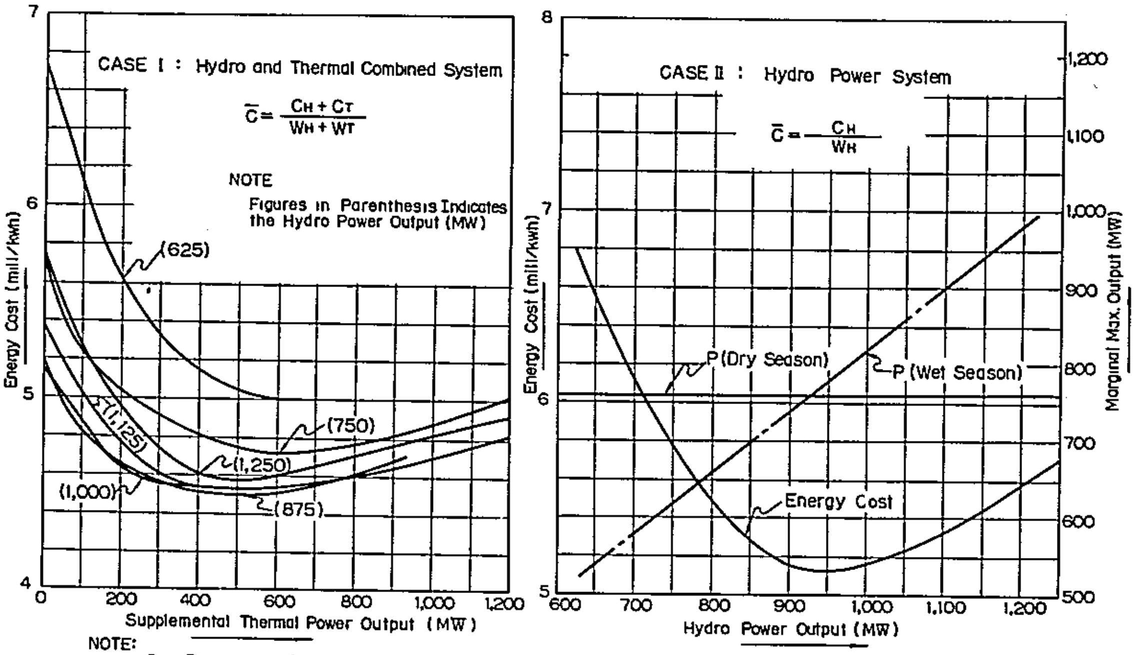
Therefore, as the optimum installed capacity is about 900 MW, the number of turbines and generators are determined to be seven units giving an installed capacity of 875 MW.

Fig. F-3 Mass Curve of Sambor Reservoir



Ve Effective Storage Capacity (cms)

F-4 Optimum Output Facility



NOTE:

C : Energy Cost (mill/kwh)
C_H Annual Cost of Sambor Power Plant (Including Transmisson and Transformation Facilities)
W_H Annual Energy of Sambor Power Plant (at Primary Substation)
C_T. Annual Cost of Thermal Power Plant for Supplemental Power
W_T Annual Energy of Thermal Power Plant for Supplemental Power

F-5 Available Power and Energy

The available power and energy are based on the reservoir operation described in F-3 dividing the dry season runoff of each year into either of Models A, B or C in accordance with the inflow into Sambor reservoir during the 33 years from 1933 through 1965. (See Table D-4 (1) and Fig. F-5)

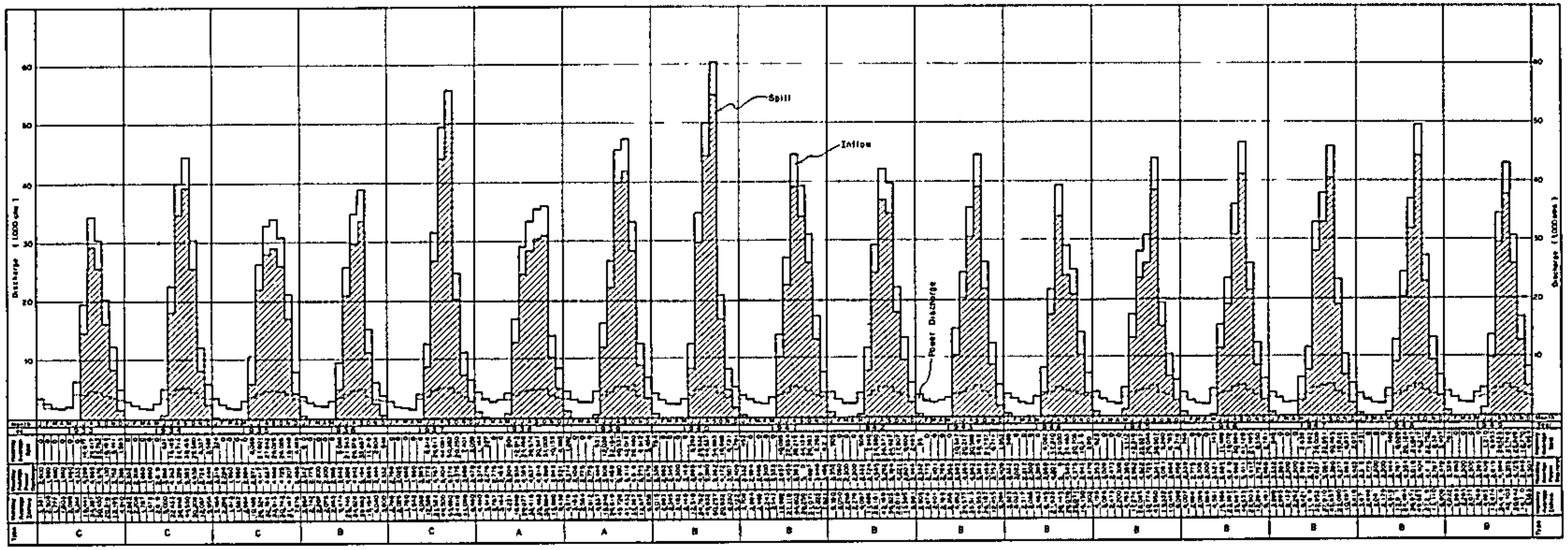
F-5-1 Effective Head

The difference in the elevation between the monthly average water surface level of reservoir and the tailwater level (water level corresponding to "power discharge + spillway discharge" shown in Fig. D-6) is 17.7 m to 33 m, with an extremely wide fluctuation range, but the effective head was determined by deducting a head loss of 1.0 m irrespective of the total head, power discharge and other factors. (See Fig. F-6 and 7)

F-5-2 Efficiency of Turbines and Generators

The overall efficiency of the turbine at an output of 128 MW and generator at an output of 140 MVA under a rated head of 19.7 m, and maximum discharge of 775 cu.ms is shown in Figs. F-8 and F-9 indicates the P-H-Q curve and P/Q curve of turbine and generator.

Fig. F-5 Inflow and Outflow (1)



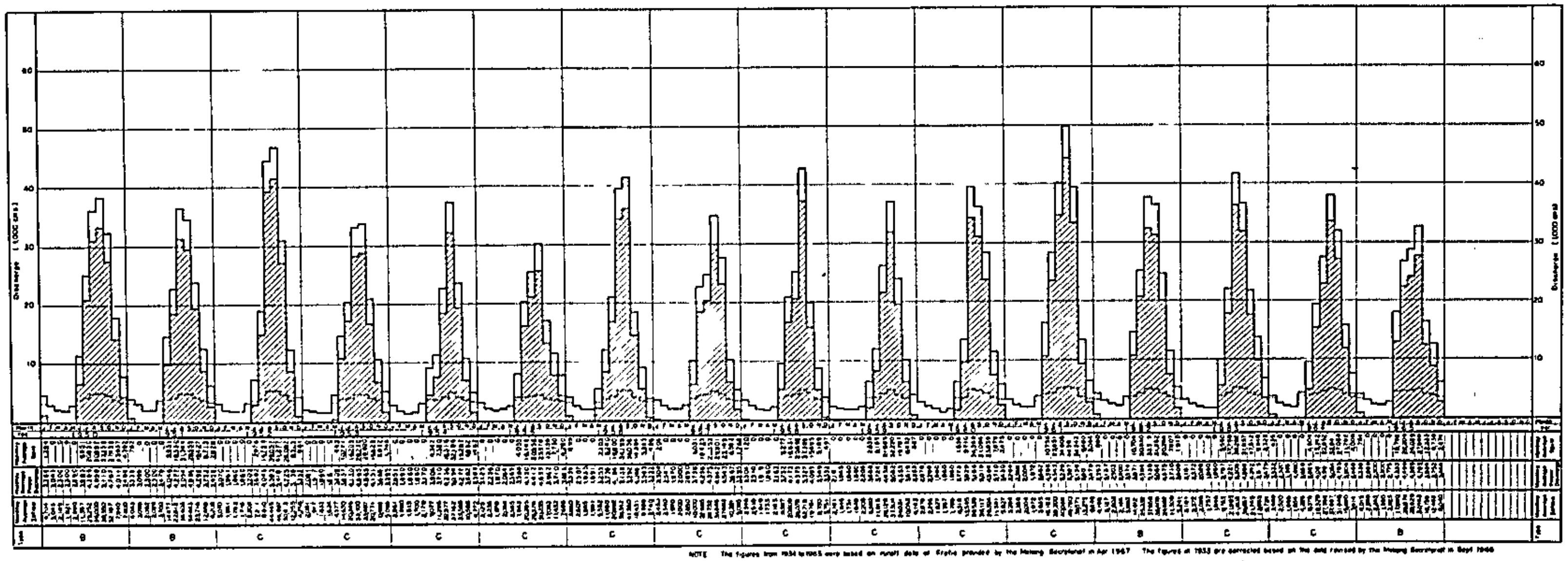
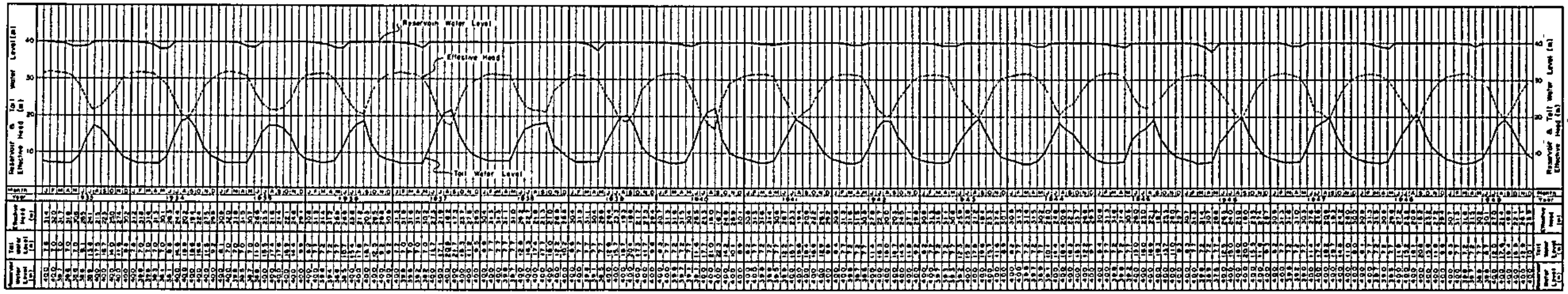
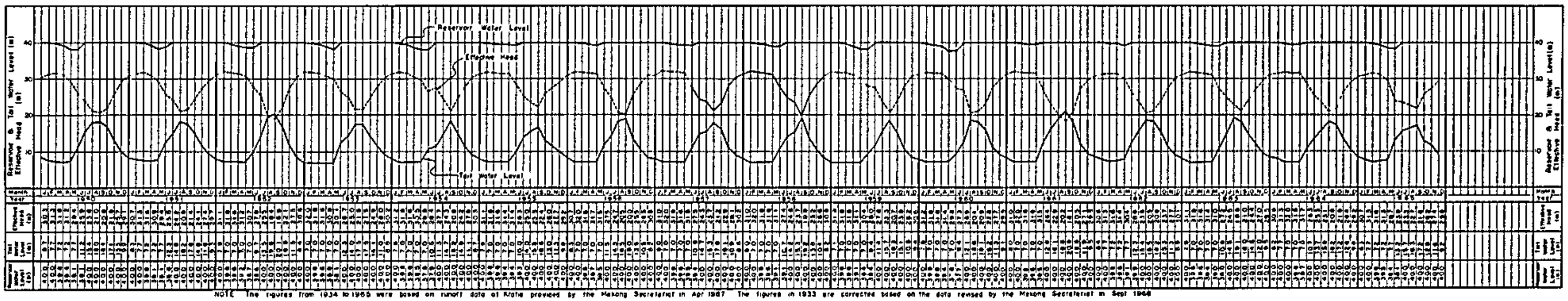


Fig. F-6 Reservoir and Tail Water Levels





NOTE The figures from 1934 to 1966 were based on runoff data of Kratie provided by the Mekong Secretariat in Apr 1967. The figures in 1933 are corrected based on the data revised by the Mekong Secretariat in Sept 1968.

Fig. F-7 Frequency of Effective Head

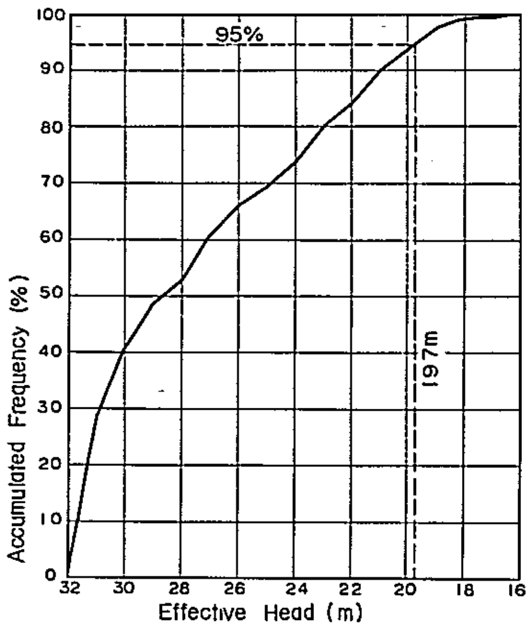


Fig. F-8 Effieicny of Turbine and Generator

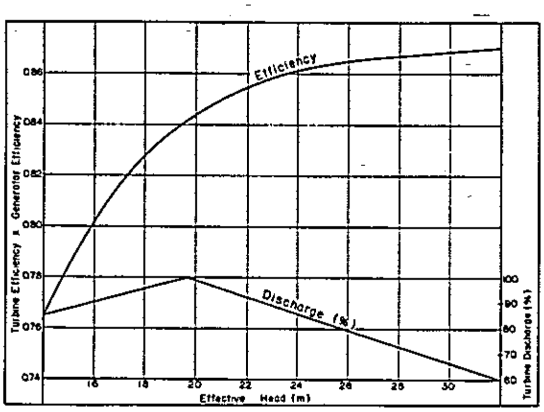
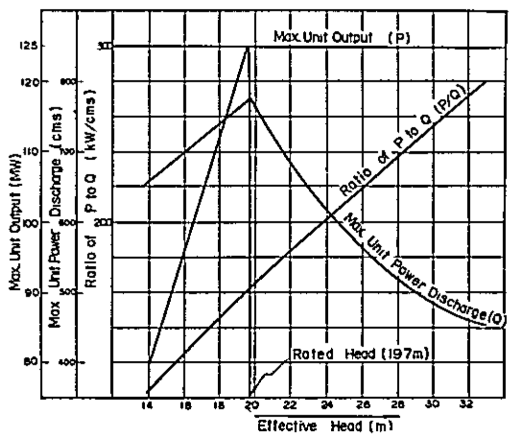


Fig. F-9 P-H-Q and P/Q Curves



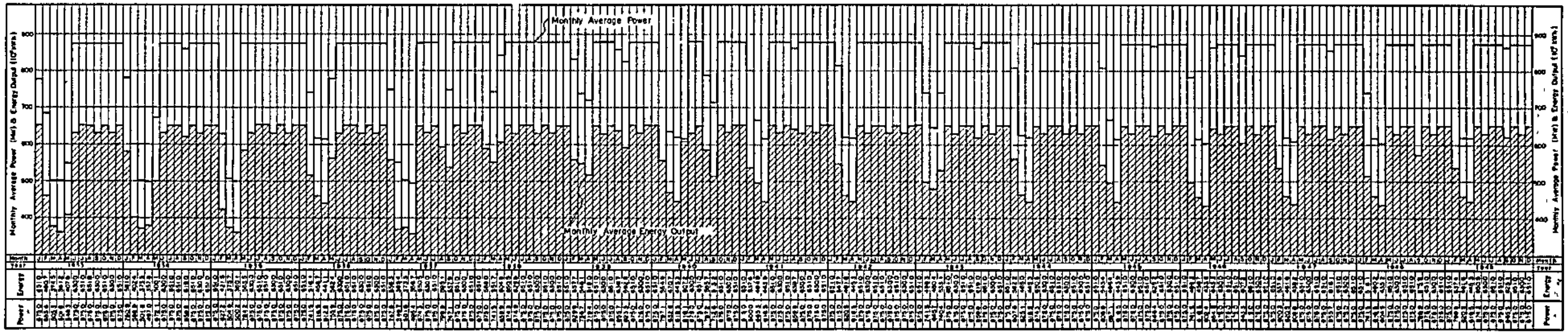
F-5-3 Available Power and Energy

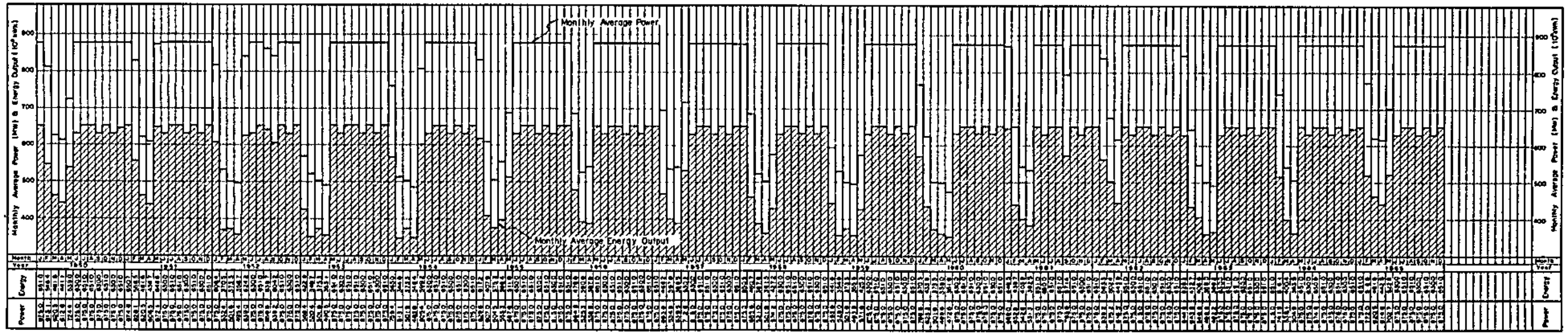
The 33-year monthly average power (kW) and the monthly average energy (kWh) production calculated for the installed capacity of 875 MW based on the reservoir operation rules described in F-3. The results are given in Fig. F-10 and Table F-1.

The firm power is 473 MW and the average annual energy production is 7,000 million kWh consisting of 4,100 million kWh of firm energy and 2,900 million kWh of secondary energy.

During the 33-year period studied, the downstream water level rises every year in the rainy season and the effective head is reduced causing a decrease in output. However, when considering the supply capability to the aluminum industry, general demands and other uses such as electrolytic industries, this degree of fluctuation in output due to dry or wet season is of a range which can readily be augmented by reserve power of the system. On the basis of the past maximum flood discharge (66,700 cu.ms), the downstream water level rises to 23.5 m and the output drops to 637 MW.

Fig. F-10 Monthly Average Power Output and Energy





NOTE The figures from 1934 to 1965 were based on runoff data of Kratie provided by the Mekong Secretariat in Apr 1967
The figures in 1933 are corrected based on the data revised by the Mekong Secretariat in Sept 1968

F-6 Variation in Water Level Upstream and Downstream of Dam

F-6-1 Variation in Water Level Upstream of Dam (Reservoir)

The variation in water level of the reservoir according to the operation rule described in F-3 is shown in Fig. F-6. According to the figure, on the basis of the 33 years data from 1933 through 1965, there are four months in which the reservoir water level is slightly below the limit of 38.0 m. These months are May 1946 at 37.5 m, May 1954 at 37.8 m, June 1954 at 37.9 m and June 1960 at 37.7 m.

However, these occurred during periods which do not require much irrigation water and thus should not adversely influence the intake of water for irrigation. Also, it is thought that the drop in the water level of this magnitude and frequency will not materially influence river navigation.

On the basis of the date received from the Mekong Secretariat in April 1967, the water level will drop 6 m in May 1933, but according to the revised data received in September 1968, the water level will be within the allowable limit.

Further, as the upstream Nam Ngum Project is under construction, it is evident that the runoff condition of the Mekong River will be improved upon its completion. The results of study on the above are given in Fig. L-3, which shows the runoff to increase approximately 164 cu.ms to 217 cu.ms in the dry season, with the water level in the dry season of a dry-year not falling below 38 m.

F-6-2 Effect on Downstream Water Level

Since Sambor reservoir will be located on the most downstream of the Mekong River, considerations are given to prevent the minimum discharge, due to the operation described in F-1, from being less than the past minimum monthly average runoff (1,350 cu.ms) and to keep the fluctuation of water level due to variation in daily load from becoming excessive.

Fig. F-11 shows the range of fluctuation in runoff downstream of Sambor if the reservoir is operated in accordance with the rules described in F-1.

If the reservoir is operated according to Type I and Type II of demand described in C-2, the fluctuation will be within the limit in almost all cases, but if Type III demand is considered, restrictions will be incurred (other power sources, i.e., auxiliary thermal power will become necessary.)

As the result of the above studies, the range of fluctuation of water level at Kratie will be within 1 m. The effect at Phom Penh on the downstream is considered negligible because of regulating effect of the river channel.

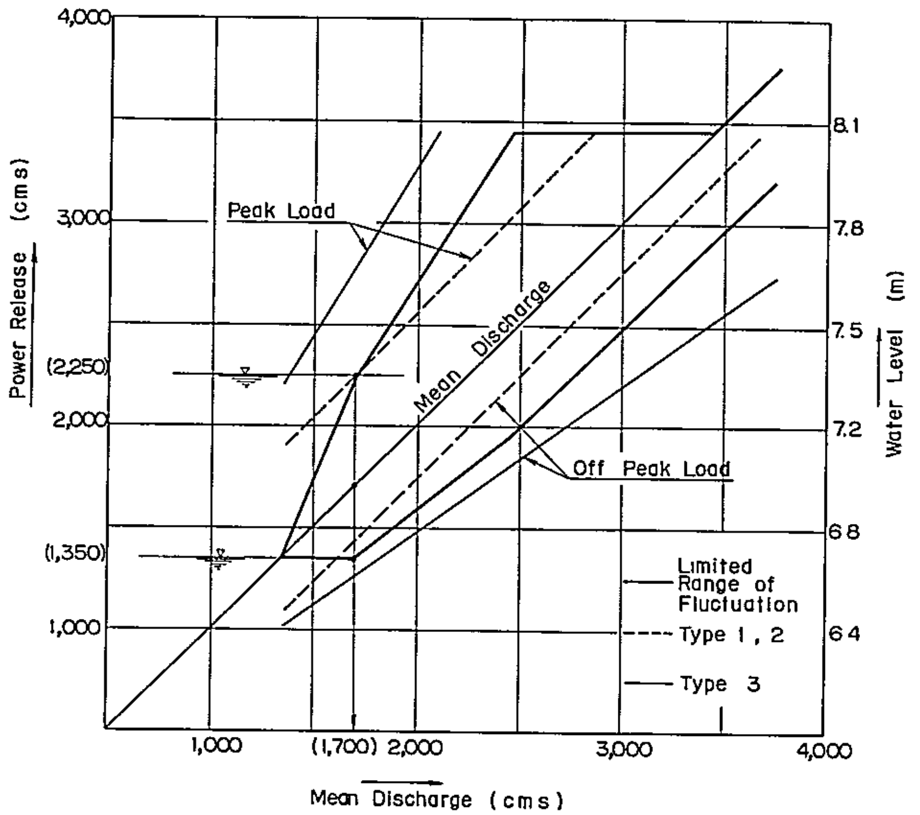
F-7 Size of Powerhouse Taking into Account Upstream Projects

The size of Sambor powerhouse was determined without taking into consideration proposed upstream projects as the details of those projects were not available. However, the reservoirs of the proposed upstream projects are of enormous capacity and if they are operated effectively upon completion, the flow condition of the Mekong River will be improved remarkably as compared with the present condition and greatly contribute not only to power and irrigation, but also to flood control in the downstream, particularly in the Mekong Delta.

Description of Upstream Projects

Project	Effective storage capacity in million cu.m
Nam Ngum (under construction)	5,000
Pak Beng	20,000
Pa Mong	75,000
Stung Treng	60,000
Total	160,000

Fig. F-11 Range of Fluctuation at Downstream of Sambor Dam



It is desirable, therefore, to consider the layout of Sambor powerhouse so that addition of capacity may be made corresponding to the progress of the upstream projects. Another study (see Vol. II) revealed that upon completion of both Nam Ngum and Pa Mong Projects, the firm discharge at the Sambor site will increase from the present 1,860 cu.ms for isolated development to about 4,400 cu.ms.

Judging from this calculation, the runoff in the dry season upon completion of the above projects is estimated to be between 7,000 cu.ms and 9,000 cu.ms. Therefore, if turbines of the capacity similar to those determined for the isolated development (775 cu.ms per unit) are to be installed, the powerhouse will require bays for 12 units. Based on the above condition, a plan has been developed to construct foundations for the future seven units simultaneously with the five 125 MW units to be installed in the first stage, and the foundations for the future units will be utilize as temporary diversion canals during construction (see Chapter I). Since it is conceivable that the Sambor Power Station will have been interconnected with other stations and the flow condition of the Mekong will have been regulated at that time, installation of generators having larger capacity (approximately 200 MW)1/ than those planned for the isolated development could be installed in the future units, and with 12 bays, the capacity of the Sambor Power Station may be enlarged to 1,800 MW to 2,400 MW.

1/ Turbines to be installed are to be fixed and designed on a rated head of 19.7 m and discharge of 775 cu.ms. If the effective head (ranges from 15.5 m to 32 m) exceeds the rated head, they can be operated by regulating the discharge with advisting vanes. Therefore, at a rated head of 30 m and discharge of 775 cu.m s, the maximum unit output will make 200 MW

Table F-1 Monthly Average Energy Output

(Unit: Million kWh))

MONTH / YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL TOTAL
1933	518.5 (651.0)	339.3 (460.7)	372.1 (374.5)	339.1 (361.2)	326.2 (407.9)	630.0	651.0	651.0	630.0	651.0	630.0	651.0	6,389.2 (6,749.3)
1934	581.0	402.4	373.3	357.8	500.1	630.0	651.0	651.0	619.0	651.0	630.0	651.0	6,697.6
1935	651.0	421.5	375.7	360.1	583.5	630.0	651.0	651.0	630.0	651.0	630.0	651.0	6,885.8
1936	651.0	516.1	458.7	441.1	562.4	630.0	651.0	651.0	630.0	651.0	630.0	651.0	7,123.3
1937	556.3	369.4	373.3	356.7	650.5	630.0	651.0	595.1	537.9	651.0	630.0	651.0	6,652.2
1938	651.0	588.0	551.7	604.8	650.5	629.9	651.0	651.0	630.0	651.0	630.0	651.0	7,539.9
1939	651.0	557.7	548.1	518.0	651.0	630.0	651.0	636.7	592.8	651.0	630.0	651.0	7,368.3
1940	651.0	554.8	470.7	445.3	607.2	630.0	651.0	585.7	513.2	651.0	630.0	651.0	7,040.9
1941	651.0	537.6	494.9	443.9	651.0	630.0	651.0	639.7	630.0	651.0	630.0	651.0	7,261.1
1942	651.0	547.7	461.6	445.3	651.0	630.0	651.0	651.0	630.0	651.0	630.0	651.0	7,250.6
1943	651.0	498.3	480.4	533.1	651.0	630.0	651.0	651.0	619.0	651.0	630.0	651.0	7,296.8
1944	651.0	562.2	465.0	445.3	650.5	630.0	651.0	651.0	630.0	651.0	630.0	651.0	7,268.0
1945	651.0	543.4	496.4	443.9	651.0	630.0	651.0	651.0	625.2	651.0	630.0	651.0	7,274.9
1946	651.0	498.3	458.7	433.8	643.2	630.0	651.0	651.0	607.2	651.0	630.0	651.0	7,156.2
1947	651.0	537.8	461.6	438.2	651.0	630.0	651.0	651.0	616.1	651.0	630.0	651.0	7,219.7
1948	651.0	516.1	460.2	435.2	651.0	630.0	651.0	651.0	575.9	651.0	630.0	651.0	7,153.4
1949	651.0	537.4	461.6	445.3	650.5	630.0	651.0	651.0	623.1	651.0	630.0	651.0	7,232.9
1950	651.0	546.4	461.6	441.1	539.0	630.0	651.0	651.0	630.0	651.0	630.0	651.0	7,133.1
1951	650.7	556.5	461.6	436.7	648.8	630.0	651.0	651.0	630.0	651.0	630.0	651.0	7,248.3
1952	606.4	370.5	373.3	356.7	624.2	630.0	651.0	639.7	604.2	651.0	630.0	651.0	6,788.0
1953	422.9	349.7	373.3	353.1	651.0	630.0	650.4	650.8	629.8	651.0	630.0	651.0	6,643.0
1954	565.0	344.8	373.3	348.4	599.2	630.0	651.0	630.0	651.0	651.0	630.0	651.0	6,724.7
1955	617.2	406.9	375.3	398.4	511.6	630.0	651.0	651.0	630.0	651.0	630.0	651.0	6,803.4
1956	651.0	476.6	390.8	387.9	651.0	630.0	651.0	651.0	630.0	651.0	630.0	651.0	7,051.3
1957	651.0	466.2	397.9	388.5	530.2	630.0	651.0	651.0	630.0	651.0	630.0	651.0	6,927.8
1958	650.5	460.7	387.6	361.3	427.2	630.0	651.0	651.0	630.0	651.0	630.0	651.0	6,781.3
1959	441.8	354.8	373.3	355.5	425.3	630.0	651.0	651.0	630.0	651.0	630.0	651.0	6,444.7
1960	570.3	433.8	373.3	359.0	351.6	630.0	651.0	651.0	630.0	651.0	630.0	651.0	6,582.0
1961	646.5	495.0	445.1	415.1	651.0	630.0	651.0	651.0	571.4	651.0	630.0	651.0	7,088.1
1962	651.0	563.3	502.4	443.9	651.0	630.0	651.0	651.0	630.0	651.0	630.0	651.0	7,305.6
1963	628.3	432.7	406.6	359.0	366.2	630.0	651.0	651.0	630.0	651.0	630.0	651.0	6,686.8
1964	651.0	516.1	452.8	422.2	651.0	630.0	650.9	651.0	630.0	651.0	630.0	651.0	7,187.0
1965	651.0	518.8	461.6	442.5	522.8	630.0	651.0	651.0	630.0	651.0	630.0	651.0	7,090.7
Monthly Average	620.5 (624.5)	479.4 (481.4)	435.6 (432.8)	416.9 (414.8)	581.3 (583.8)	630.0	651.0	646.2	616.2	651.0	630.0	651.0	7,009.0 (7,019.9)

Note: The figures from 1934 to 1965 were based on runoff data of Kratie compiled by the Mekong Secretariat in Apr. 1967.
The values for 1933 are corrected based on the revised data prepared by the Secretariat. (Sept. 1968)

CHAPTER G. TRANSMISSION LINE AND SUBSTATION

CHAPTER G. TRANSMISSION LINE AND SUBSTATION

G-1 Basic Conditions

There is much left to be done before a final decision can be made as to the method of allocating electricity generated at the Sambor Project between Cambodia and Vietnam, in order to be able to estimate the power current. However, the following is assumed in establishing a transmission and substation plan.

(1) Power-oriented industries (485 MW) will be founded at Sihanouk Ville.

(2) The general demands of Cambodia and Vietnam will be supplied through the substation, at Phnom Penh and Saigon with loads of 90 MW and 300 MW respectively.

The transmission plan considered in this report is limited to the transmission lines from Sambor Power Station to Phnom Penh, Sihanouk Ville and Saigon and the receiving end substation at these locations. It does not include the reinforcing of the low-tension side of these receiving substations, the exclusive transmission lines for power-oriented industries, and the expansion of distribution systems.

G-2 System Composition

G-2-1 Existing System

At the time of initial operation of Sambor Power Station, it is assumed that in Cambodia there will be a 110 kV transmission line to the capital city Phnom Penh from Kam Chai Power Station (50 MW), Prek Thnot Power Station (18 MW) and Kirirom Power Station (19 MW), comprising a primary transmission trunk line. Also, it is assumed that power from Battambang Power Station (30 MW) and others that will be developed in the future on the tributaries around Great Lake will progressively be transmitted to the provincial cities by expansion of the 110 kV system for operation in parallel with the 110 kV Phnom Penh System.

In Vietnam, it is thought the 220 kV Da Nhim System completed in 1966 will be extended to be interconnected with the Dong Nhai River Power Stations, and around Saigon there will be 110 kV and 66 kV transmission systems.

G-2-2 System Voltage and Number of Circuit

The voltage, number of circuits and conductor to be used for the Sambor transmission system must be considered. The four riparian nations of the Mekong River presently have maximum voltage of 230 kV (220 kV and 230 kV considered to belong to the same group) in Thailand and Vietnam, and 110 kV (110 kV and 115 kV considered to belong to the same group) in Laos and Cambodia. When contemplating the development of the huge undeveloped potentials of the Mekong River, whether the maximum system voltage should exceed 230 kV or be 345 kV or an even higher 400 kV, should be determined in consideration of the overall tempo of the Mekong River development and the state of the power current. However, at the stage of preparation of this report, there was a lack of informations for making an overall judgement, and it was only possible to select the voltage in relation to transmission of power produced at Sambor Power Plant. Therefore, it will be necessary to re-examine the system voltage at an appropriate future time together with the transmission plans for the other projects.

The voltage required to transmit the power assumed previously is given in Table G-1 which is obtained by the surge impedance loading method.

Table G-1 Transmission Voltage and Number of Circuit

Section	Sambor-P. Penh		P. Penh-S.Ville		Sambor-Saigon	
Length	190 km		160 km		230 km	
Power	575 MW		485 MW		300 MW	
Number of cct & Trans. Voltage	1 cct	480 kV	1 cct	441 kV	1 cct	347 kV
	2 cct	339 kV	2 cct	312 kV	2 cct	246 kV
	3 cct	279 kV	3 cct	255 kV	3 cct	200 kV

The power demand at Sihanouk Ville will be predominantly industrial while at Phnom Penh it will be general demand. At Sihanouk Ville a demand of approximately 250 MW at the aluminum plant is to be contemplated, and it will be necessary to consider the reliability of supply. At Saigon it is assumed the existing 230 kV system will have been expanded, making it not necessary to study the reliability of power supply.

Therefore, regarding the number of circuits for the transmission lines, two circuits will be suitable from Sambor to Phnom Penh, Phnom Penh to Sihanouk Ville, and one circuit from Sambor to Saigon.

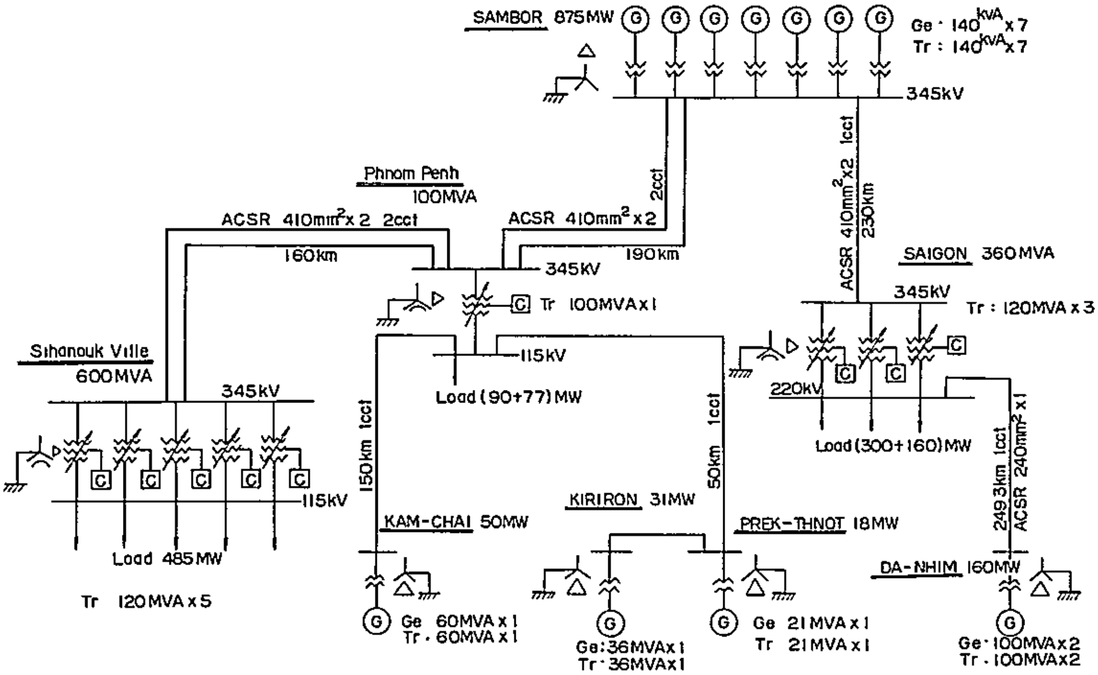
It would be appropriate to adopt an economical voltage of 345 kV in view of Table G-1 and the number of circuits required from the aspect of reliability of power supply.

As for the type of conductor, upon technical and economic studies made of three types, ACSR 330 sq.mm x 2, 410 sq.mm x 2 and 520 sq.mm x 2, the ACSR 1/ 410 sq.mm x 2 were adopted.

G-2-3 Protective Relaying of Transmission Lines

For protection of transmission lines, giving due consideration of increasing reliability, the single-phase, three-phase and multi-phase reclosing for the two circuits section between Sambor and Sihanouk Ville, and the single-phase reclosing for the one circuit section between Sambor and Saigon will be made possible by adopting phase comparison relays with directional comparison elements having pilot relays as the main protective system, and directional distance relays and power directional relays as back-up protection.

Fig. G-1 Transmission Line System Diagram



G-3 Substation

G-3-1 General Description

As previously mentioned, primary substations will be constructed in the vicinities of Phnom Penh, Sihanouk Ville and Saigon for interconnection with the respective transmission systems.

As shown in Fig. G-1, the transformers at the various substations will be 345 kV for the primary system, 110 kV (Cambodia) or 220 kV (Vietnam) for the secondary system, and since they will be direct grounding, auto-transformers are to be adopted with the total substation capacity planned for a power factor of 90%.

1/. ACSR: aluminum conductor steel reinforced

G-3-2 Equipment

The unit capacity of the connecting transformers are selected so that there would be two or three transformers in consideration of transportation and convenience of maintenance work. As the systems to be interconnected will all be effective grounded systems, the transformers will be reduced and graded insulation types.

For reasons of operation, maintenance and economy, power condensers will be used for reactive power and synchronous condenser will not be employed.

The capacity of reactive power equipment should be determined to minimize costs in consideration of voltage range of transformer LRC, allowable range of voltage change on load side, allowable range of voltage change at sending and receiving ends and power factor of load, but in this report 30% of the capacity of the respective substation is used as an approximate value.

Circuit breakers on the 345 kV side are all provided with single-phase and three-phase reclosing devices.

G-4 Telecommunication

G-4-1 Telecommunication Facility for Load Dispatching

The load dispatching center will be established in the Sambor service building. Therefore, VHF multi-channel equipment will be installed between Sambor service building and the plant in order to form circuits for exclusive telephones for load dispatching and general telephones for maintenance between the center, plant and substations. Further, all of these stations will be provided with power line carrier equipment and automatic telephone exchangers. The power line carrier equipment will also be used for protective relay devices of the power system.

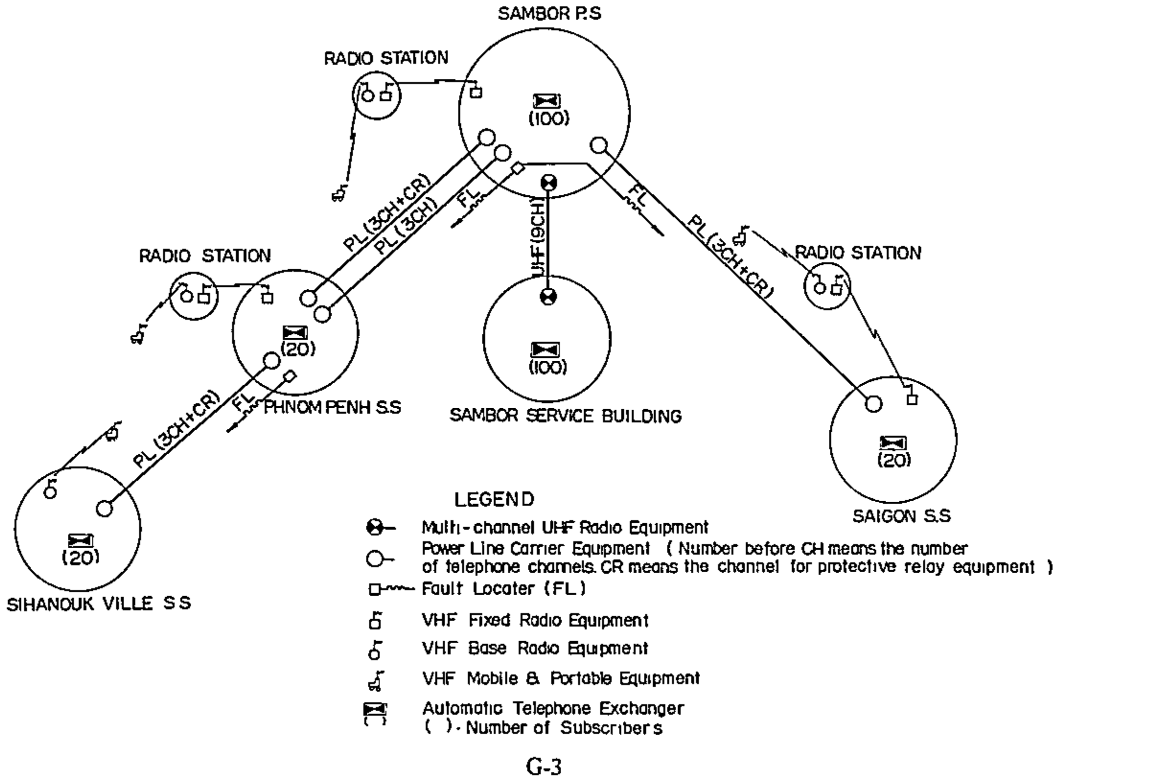
G-4-2 Telecommunication Facility for Maintenance of Transmission Line

Base and mobile radio equipment will be provided for communication, and transmission line fault locators will be provided for quick discovery of location of faults and quick restoration of service.

G-4-3 Other Facilities

For efficient load dispatching, telemetering and supervisory apparatus will be provided.

Fig. G-2 Telecommunication System Diagram



CHAPTER H. PRELIMINARY DESIGN

CHAPTER H. PRELIMINARY DESIGN

H-1 Hydraulic Structure

H-1-1 Dam and Spillway

(1) Outline: The area investigated to select the dam site is the section between the Sambor Rapids, 15 km upstream of Kratie on the Mekong River and a point 6 km below the rapids. Four dam sites are studied. For a reservoir with the high water surface level of EL.40 m, it is judged that the proposed site closest to the dam axis in the river bed mentioned in the geological report on the Sambor site prepared by the Australian Mission 1/ is most desirable.

In the preliminary design, this dam axis was adopted to prepare the general layout of the project as shown in Dwg. No. 1.

In other words, concrete structures, such as powerhouse and spillway are located on the right bank tableland, the dam in the river bed is a rock-fill structure and the wings on both sides are earth-fill dams.

As the result of studies concerning diversion and care of river during construction, scale of the dam, topography, geology, availability of construction materials and the method of obtaining them, transportation, etc., it is concluded that a fill type dam, except for the spillway, would be the most suitable. Especially, in selecting the type of dam for the river bed, the several alternative described below were studied in addition to the basic proposal.

1. An alternative in which the location of structures are not different from those in the basic proposal, but in which the diversion and care of the river during construction would be accomplished by utilizing the spillway. The sill of the spillway will be lower than that of the basic proposal, and embankment of the dam would be executed by constructing coffer dam on the upstream and downstream of the dam site.

2. An alternative in which the location of the dam would be moved approximately 2 km upstream of the site in the basic proposal. The powerhouse and spillway will be constructed near the right bank and the river bed to the left bank will be a rock-fill dam. Construction would be performed by first erecting the powerhouse and the piers of the spillway, and the upstream and downstream sections of the dam would be embanked. The core section will be constructed in the dry. Following this, the overflow portion of the spillway would be constructed by closing off several section at a time.

3. An alternative for a dam at the same location as alternative 2. which would be constructed by closing one hold of the river at a time. In other words, the powerhouse and spillway would first be constructed and then the dam would be embanked.

4. An alternative for a concrete dam in the river bed instead of a rock-fill dam. The construction would be carried out in a manner similar to that of the spillway in alternative 2.

These alternatives including the basic proposal each has its merits and demerits, and further studies will be necessary in the definite study. However, the basic proposal which would not involve enormous expenditures for temporary diversion and care of river was selected with reference to the Dalles Dam 2/ in the U.S.A. The outline of the dam and spillway is given below.

(2) Earth-Fill Dam: The tableland on both banks will be homogeneous earth-fill structures with the exception of the spillway and the section between the spillway and the powerhouse. Drainage of water will be performed by embanking pervious materials and rock will be embanked at the base of the dam. The upper section of the upstream and the downstream faces will be covered with rip-rap to withstand erosion by fluctuation of reservoir water level and wave action as well as scouring by surface flow of rain-fall.

Source: 1/ *Geological Investigation, Sambor Dam Site, Cambodia,* Vol. 1-4, 1963; Australian Survey Mission Report, Snowy Mountains Hydro-electric Authority.

2/ "Transactions of the American Society of Civil Engineering" Vol. 125, 1960 Part II, P 473.
"Rockfill Dams: Dalles Closuve Dam" By Robert J. Rope.

Table H-1 Description of Dam and Spillway

	Dam		
Type	Earth-fill, Rock-fill and Concrete Dam		
Dam Height	Max. 54 m		
Crest Length	Earthfill		26,080 m
	Rockfill		2,350 m
	Concrete	Spillway	1,471 m
		Intake	763 m
	Total		30,664 m
Crest Width	Rock and Earthfill		10 m
	Concrete		6.6 m
Volume	Embankment		25,900,000 cu.ms
	Concrete		900,000 cu.ms (Spillway only)
	Spillway		
Type	Overflow with Gate		
Design Discharge Capacity	90,000 cu.ms		(Overflow Water Level EL.42.00 m)
Dissipator	Hydraulic Jump Dissipator		(with Horizontal Apron)
Width	1,003 m		(including Piers)
Gate	Height 14.0 m x Span 15.0m		53 Gates
Road Bridge	Effective Width 6.0 m		53 Spans

The crest of the dam will have a total width of 10 m in consideration of future use for general traffic.

On the right side of the spillway, there is an area with a deep deposit which is judged to be an old river bed. The depth of the deposit is as much as 20 m. According to the results of survey made to the present, the permeability of this stratum is low and has been found to be adequate for the dam foundation so that special treatment will not be considered. However, in the detail designs, thorough investigation and study of this area will be necessary.

(3) Rock-Fill Dam: The main dam which will be 2,350 m long across the present river section will be an inclined impervious core rock-fill structure, and as described in Chapter I, this dam will be embanked in water after all of the structures including the powerhouse have been essentially completed.

The standard cross section of the dam is as shown in Dwg. No. 1. Based on the upstream and downstream water levels anticipated during construction, the portion below EL 30 m will be embanked in water while the portion above this elevation will be embanked in the dry. The slope gradient of the underwater section will be at the underwater angle of repose of the embankment materials. Furthermore, the section which will be constructed in flowing water or submerged in water and influenced by flowing water will be constructed of boulders of sufficient size and other materials to withstand the flow velocity anticipated in order to prevent the embanked materials being washed away by flowing water. As for the impervious core materials, thorough compaction of the portion embanked in the dry will be possible so that soil materials can be used, but compaction will be impossible of the section to be embanked in water. Therefore, the properties of the materials in this section should be such that when dumped in water they will settle comparatively rapidly and moreover be able to form a layer of low permeability. For this purpose, in the preliminary design, the

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	Spillway		
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Design Discharge Capacity	90,000 cu.ms		(Overflow Water Level EL.42.00 m)
Dissipator	Hydraulic Jump Dissipator		(with Horizontal Apron)
Width	1,003 m		(including Piers)
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In the actual construction of the dam in water, more detailed investigation and study of materials to be used should be carried out at the stage of the definite studies and during construction in order to adopt the most suitable cross-section and construction method in accordance with the water levels anticipated during the work.

The upper section of the upstream face of the dam will be protected with rip-rap to prevent erosion by fluctuation of water level and wave action. The total width of the dam crest will be 10 m as in the case of the earth dam.

(4) Spillway: The spillway will be constructed on the right side of the powerhouse on the right bank tableland as shown in Dwgs. No. 1 and 2. The structure constructed of concrete and equipped with gates will have a total width of 1,003 m. Training levees will be constructed on both sides of the channel to conduct the discharged water into the river channel. The capacity of the spillway will be 90,000 cu.ms.

The total number of gates to be installed in the overflow section will be 53, with each gate being a two-stage roller gate having a span of 15 m and a height of 14 m. The gates will be operated by winches mounted on an overhead platform. On the downstream side of the gates, a bridge for vehicular traffic with an effective width of 6.0 m will be constructed to connect with the road on the crest of the dams.

The overflow crest will be a parobolic configuration to prevent negative pressures at times of overflow and the dissipation of energy will be done by horizontal apron creating a natural hydraulic jump.

The foundation of the concrete section will be excavated to sound rock which will be thoroughly treated prior to placing concrete. After completion of placing of concrete, curtain grouting will be performed on the upstream side to reduce uplift pressure.

The training levees will be embanked over the entire lengths and the slopes facing the spillway will be protected by stone masonry.

The direction of the spillway, the direction of the training levees, the condition of the water flow at the end of the levees and method of protection, must be carefully studied by hydraulic model tests.

(5) Non-Overflow Section: The section between the spillway and the powerhouse will be a concrete gravity structure. The crest will have an effective width of 6 m and will connect to the roads on the earth-fill and rock-fill dams.

H-1-2 Intake

Water drawn from the intake will be conducted directly to the turbine casings, and there will be no steel penstocks. Therefore, the intake will be an integral part of the powerhouse. The twelve orifices will be made sufficiently large to reduce losses at a maximum discharge of 775 cu.ms. The intake sill will be at EL 5 m in consideration of part of the intake being used as temporary diversion channel during construction.

Twelve trashracks will be installed on the upstream face of the intake orifices, and on the immediate downstream side of the transhracks, grooves will be provided to enable insertion of gates when necessary. Roller gates capable of being lowered at full hydraulic head will be installed in view of the fact that the turbines will not be provided with main valves and the fact that it is planned to accomplish final closure of the river after the intake has served the purpose of temporary diversion channel. Hoisting of these gates will be carried out with a gantry crane traveling at EL44.0 m on the crest of the intake.

The power station will utimately have twelve units of turbines and generators. If type I of power consumption pattern is to be adopted, five units will be installed in the first stage and two in the second stage. and later five in future.

Three gates will be required to close one turbine. However, there will be no need to provide for all of the turbines. They can be used to close any of the turbines as required. Therefore, in estimating the construction costs, giving due consideration to the operation and maintenance way of the power station, 27 gates are included in the first stage construction. And 21 of them will be used for closing the intake of future units. 1/

1/ It will be used for temporary diversion of the river during construction (see Chapter I)

H-1-3 Powerhouse and Outdoor Switchyard

In consideration of fluctuation of water level of the river and to facilitate foundation excavation, the power station will be constructed on the right bank parallel with the river as shown in Dwgs. No. 1, No. 3 and No. 4. The house itself will be additionally installed in stages depending on the power consumption pattern to be adopted, although all the foundation is to be constructed at the first stage. The particulars are as given below.

Table H-2 Description of Powerhouse

Type	Indoor, Reinforced Concrete Structure	
Dimension		
Length	1st Stage	240 m (In the case of type I of power consumption pattern)
	2nd Stage	80 m (Total 320 m)
	Future	240 m (Total 560 m)
Width		45 m
Height		73 m

The powerhouse will be a reinforced concrete structure partly with structural steel and will be an integral part of the intake structure. The wall on the downstream side will be required to be watertight as the downstream water level will rise at time of flood flow.

The powerhouse will ultimately be of a size to accommodate 12 turbines and generators, but in the first stage the part of the powerhouse on the downstream side large enough to house five units and service area for operation and maintenance will be built, while in the second stage two units will be added.
be added.

Including those for future units, 12 draft tubes will be installed during construction. The draft tubes will be L-shaped and grooves for sluice gates will be constructed at the outlet portals. Three sluice gates will be required for each draft. The gates will be operated by a gantry crane traveling on the deck at EL 27 m. The ends of the draft tubes will be of such design so that water released from the turbine will be discharged into the river channel section over the entire width of the power station. For this purpose the tailrace will be excavated over the entire width of the powerhouse.

The elevation of the access road will be 27 m above mean sea level in consideration of the tailrace water level during flood flows. The floor of the erection bay will be lower than the elevation of the access road, but the overhead traveling crane will be at a relatively high location in view of the size of the turbines and generators. Also, a corner of the erection bay will be at the same level as the access road so that heavy piece of turbines, generators, etc. can be moved into the erection bay by use of the overhead crane. Therefore, no special handling facilities will be required for moving of heavy equipment.

The main transformers will be installed between the powerhouse and the intake at EL 44 m which is the same elevation of the road on the dam crest. Circuit breakers and disconnecting switches will be installed on the powerhouse deck and the auxiliary switchyard for the outgoing transmission lines will be constructed downstream of the power station between the spillway training levee and the river. The area required for the switchyard is 56 m x 76 m.

H-2 Electrical Equipment

H-2-1 Turbine and Generator

Units will be installed in stages, and the number of units corresponding to each stage will be determined depending on the power consumption pattern to be adopted.1/ The technical features of the turbines and generators to be installed at Sambor Power Station are as follows.

1/ See Fig. C-5

Table H-3 Description of Turbine and Generator

Turbine:			
Type	Vertical Kaplan		
Rated Output	128,000 kW		
Effective Head [1/]	Max. 32 m		
	Min. 15.5 m		
Discharge	Max 775 cu ms at the Rated Output		
No. of Unit	Total	12 units	
	Installed at 1st stage	5 units	(Type I pattern)
	Installed at 2nd stage	2 units	(Type I pattern)
	Installed in future	5 units	(Type I pattern)
Generator:			
Type	Three Phase, Alternating Synchronous Generator		
Capacity	140,000 kVA		
Frequency	50 c/s		
Voltage	15,400 V		
Power Factor	0.89		
No. of Unit	Total	12 units	
	Installed at 1st stage	5 units	(Type I pattern)
	Installed at 2nd stage	2 units	(Type I pattern)
	Installed in future	5 units	(Type I pattern)

As the tail water level will fluctuate greatly between wet and dry season at Sambor Power Station, the effective head will vary seasonally between a minimum of 15.5 m and a maximum of 32 m Therefore, it is necessary to use Kaplan turbines which operate at relatively high efficiency even under fluctuating heads. The maximum discharge per unit will be 775 cu ms which is of the largest class for a turbine operating at a low head. Judging from present international technological development in manufacture of turbine, it is considered technically possible to manufacture a turbine of this scale, but thorough studies will be required in its detailed design and manufacture.

The generator will be 3-phase, alternating current with a rated capacity of 140,000 kVA. Generators of this size are already being made and used in various countries, and no special problems are anticipated.

H-2-2 Main Transformer and Accessory Equipment

Units will be installed in stages, and the number of units corresponding to their stages will be determined depending on the power consumption pattern to be adopted. [2/] The technical features of main transformers are given below.

1/ This effective head, 15.5 m to 32.0 m, is the result of calculation using the daily-flow data of 33-year period from 1933. Instead, it will be 16.7 m to 32.0 m in the case of calculation using the monthly-flow data of 15-year period from 1950 which was provided by Mekong Secretariat in September 1968.

2/ See Fig C-5

Table H-4 Description of Main Transformer

Type	Outdoor, Three Phase, Forced Oil, Air-cooled		
Capacity	140,000 kVA		
Frequency	50 c/s		
Voltage	Primary	15,400 V	
	Secondary	345,000 V	
No. of Unit	Total	12 units	
	Installed at 1st stage	5 units	(Type I pattern)
	Installed at 2nd stage	2 units	(Type I pattern)
	Installed in future	5 units	(Type I pattern)

As there is no power station of large capacity near the Sambor Power Station, it will be operated independently and it is thought it will occupy a position of great importance in the power system. Therefore, in order to increase the reliability and flexibility of operation, a unit system with one transformer for each turbine-generator will be adopted and double connection system for outdoor switchyard bus lines will be provided for the same reason. Two alternatives are conceivable for the switchyard. One is to design the power plant of an outdoor or semi-outdoor structure with main transformers installed near the power plant and the switchyard located independently in the downstream clearing with main transformers and switchyard connected by high-voltage of cables, and the other to install the turbines and generators indoors with the switchyard on the powerhouse deck. Upon technical and economic studies, the latter was selected. That is, the turbines and generators will be housed indoors and the switchyard will be located on the powerhouse deck.

H-3 Transmission Line

H-3-1 Selection of Route

(1) Sambor to Phnom Penh: Between Sambor and Phnom Penh, two routes, one along the right bank and the other along the left bank of the Mekong River, can be considered. However, after aerial survey it was found that the left bank route has a larger inundated area which would make an uneconomical detour necessary. Therefore, the right bank route was selected. The route passes from Sambor to the east of Srok Rotes, enters Bas Khnor from east of Kohn Batong, and along from Beng-Nay crossing the Tonle Sap near K.P. Luong, then passing east of Oudong, it enters Phnom Penh. Special attention must be paid to the fact that since there are scattered rubber plantations from the vicinity of Kohn Batong to the vicinity of Sor Sen, these plantations should be avoided as much as possible when selecting the route. From the vicinity of Sam Koeup to Phnom Penh, there are inundated areas which, if avoided, will cause the route to be longer. Overall construction costs will be cheaper if a special design is considered for the tower foundations in passing through this area.

From Sambor to the vicinity of Kohn Batong, there is a hilly zone of 50 m to 100 m elevations which is mostly sparse forest or paddy fields. As there are comparatively great number of roads for hauling out timber in these forests, they can be used as construction roads. As for the location of Phnom Penh Substation, the western outskirt of Phnom Penh is suitable if city planning and site conditions are considered.

(2) Phnom Penh to Sihanouk Ville: The route between Phnom Penh and Sihanouk Ville passes parallel to the national highway east of Konpong Speu, crosses the Elephant Mountain Range near Pech-Nil Pass, passes east of Cham Ca Luong to Mahouly 30 km north of Sihanouk Ville. The reason Mahouly is selected as the location for the substation is in consideration of salt contamination and site conditions, and also because this location commands a vantage point in case industries develop at both Sihanouk Ville and Kampot.

Except for the virgin forest of the Elephant Mountain Range, the route is mostly flat and almost entirely paddy field.

(3) Sambor to Saigon: Because of the political situation of Vietnam, it was impossible to make a survey except for the section between Sambor and Snoul and the vicinity of Saigon. Therefore, the route of the unsurveyed section was selected from topographical maps and oral information. This route will start from Sambor Power Station, crossing the mainstream of the Mekong River either by constructing supports on the dam or by building piers in the river bed of the mainstream and erecting steel towers on the piers. Crossing the national highway near Anchanh, it will pass north of Snoul, and along the road from the west of Loc-Ninh to Saigon. Special attention should be paid to detour the rubber plantations near Loc-Ninh. But as near Bien Tay a detour will be extremely long and distant from the national highway making construction and maintenance inconvenient, it will be more economical to pass through the middle of the rubber plantation along the existing railroad.

Regarding the location of Saigon Substation, since factories are being rapidly built in the northern suburbs of Saigon, the area 5 km north of Vinh Binh is thought suitable in consideration of the proximity to this industrial area and of topography.

H-3-2 Design Considerations

(1) Tension Design: The design conditions are determined as given below based on meteorological data of the past 10 to 20 years obtained from the meteorological agencies of Cambodia and Vietnam.

Worst condition	25°C wind speed 25 m/sec
Mean temperature	30°C
Maximum temperature	45°C

The standard height of steel towers is determined assuming a maximum temperature of conductors of 60°C In this case, since the worst condition is comparatively mild, the tension of conductors is determined from every day stress. It is recommended that the conditions of every day stress be at 30°C with no wind, not more than 20% for conductors and not more than 13% for overhead ground wires.

(2) Insulation Design: The number of discs per insulator string and clearance are determined on switching surges. In other words, the magnitude of the switching surge is designed to prevent flash-over at a voltage of 2.8 times the maximum allowable voltage of the system since this system is a direct grounding type. Therefore, 19 discs of 250 mm suspension insulators (ball & socket type 35,000 lb) will be used for one string with arcing horns for corona shielding. For this insulation resistance, the minimum spacing for insulation will be 1.90 m.

(3) Lightning Protection Design: According to data obtained from the meteorologidcal agencies of Cambodia and Vietnam, the frequency of lightning recorded for the areas of the transmission line routes is 60 to 90 days per year. As it is uneconomical to increase insulation against lightning voltages, overhead ground wires will be strung to avoid direct hits on conductors as much as possible and prevent flash-over at the time of direct strike on steel towers and overhead ground wires. Therefore two overhead ground wires will be strung for a shielding angle of not more than 20°; and to prevent flash-over from the overhead ground wire between spans, the spacing with the conductor will be at least 10 m. In order to lower the electric potential of steel towers due to lightning currents, counterpoise will be provided at places where the grounding resistance of tower footings is 10 ohms or more.

(4) Corona: At a voltage of 345 kV, the maximum potential gradient of two 410 sq.mm conductors (spacing 40 cm) will be approximately 15 kV/cm.

The corona noise level at that time will be 60 db at a location 10 m immediately below the conductors in rainy weather and will interfere radio reception where the broadcasting field strength is weak.

Therefore, before making final decision on the routes of the transmission lines, it will be necessary to measure broadcasting field strengths along the proposed routes. Also, the routes should be set at a distance from populated areas as much as possible.

(5) Electromagnetic Induction: As the transmission lines will be extra high voltage of 345 kV, the method of grounding will be direct grounded system with one line-to-ground fault current being extremely large. Therefore, there is a fear that extreme electromagnetic induction in neighboring communications lines will

cause trouble. In order to economize on construction costs, it will be advantageous to select routes of transmission lines parallel to existing roads as much as possible. For the same reason, communications lines are often strung along roads and they are almost all bare aerial wires. As a measure against this, aerial ground wires with high permittivity should be used at places to provide induction shielding. The provision of lightning arrestors on the communication line is also conceivable.

(6) Salt Contamination: Measures against salt contamination are not considered in this report. However, at the stage of preparing the final designs, since the vicinity of Sihanouk Ville Substation is near the sea coast, not only the 345 kV transmission line, but the secondary transmission line to Sihanouk Ville and the substation, should be studied for salt contamination to insulators and conductors, and insulation design should be adopted accordingly.

(7) Supporting Structures (See Dwg. No. 6): Considering the structural scale of the transmission lines and the loading conditions in the field, steel towers are suitable as supporting structures. As the greater part of the transmission line routes is on flat land, more than 90% of the supports will be suspension-type straight steel towers. Consequently, as a result of studies made of the most economical structure for straight steel towers, it was decided that the guyed-suspension type shown in F-1 of Dwg. No. 6 would be the most economical for a single-circuit steel tower.

For double-circuit transmission lines, the abovementioned single-circuit guyed-suspension type for two single-circuit routes is more economical and stable than the double-circuit steel tower also shown in the same drawing. From the aspect of construction costs, there is no appreciable difference between the two types, but there will be less corona interference in a single-circuit tower than in a double-circuit tower. Also, from the standpoint of reliability, since the two single-circuit towers would be independent of each other the occurrence of simultaneous fault in two circuits will be greatly reduced. However, in the rubber plantations and certain locations, it will be more economical to adopt the double-circuit tower.

The various types of foundations of steel towers shown in Dwg. No. 6 are conceivable according to the bearing strength of the ground. The rough geological outline obtained as a result of field surveys and the foundation types suited for each type of foundation are described below.

(a) Areas of Good Foundation

Sambor-Skoun	Approx. 130 km
Kompong Speu-Sihanouk Ville	Approx. 120 km
Sambor-Saigon	Approx. 230 km

These areas are hilly or mountain districts and are mostly covered with jungle or sparse forests. The soil is good with 1 m to 3 m from the surface being soft laterite, beneath which is assumed to be sandy soil or sandstone and other soft rock. The bearing strength is thought to be approximately 60 ton per sq.m or more. For this type of soil, the conventional inverted L-type foundation, F-5, is suitable for the steel towers.

In parts of these sections there are no roads and there are mountainous areas inconvenient for transportation so that steel foundations may be considered for these places.

(b) Soft Foundation Areas

Skoun-Kompong Luong-Compong Taket	Approx. 40 km
Phnom Penh-Konpong Speu	Approx. 40 km

These areas are mostly rice paddies or fields, and the soil is cohesive earth. From the results of simple penetration tests, it is estimated that the bearing strength at approximately 3 m to 4 m from the surface is about 20 ton to 30 ton per sq.m. It is thought the inverted T-type foundation with a large base width, F-3, would be suitable, in preparing the final designs, detailed investigation of soil should be carried out to determine the type of foundation to adopt.

(c) Soft Marshy Areas

Phnom Penh-Compong Taket Approx. 20 km

This area is paddy fields or marshes where stagnant water remains in parts even in the dry season. As a result of penetration tests, there is no stratum with sufficient bearing strength within a depth of 10 m from the surface and the bearing strength is estimated to be less than about 10 ton per sq.m.

For this area it will be necessary to obtain data required for the foundation design at the stage of preparation of final designs by investigating the geology through boring and bearing strength tests. In any case, the foundations in this area will probably be self-supporting type pile foundation or a special type, F-4, with the four tower legs supported on a common concrete bed.

(d) Location for Special Design

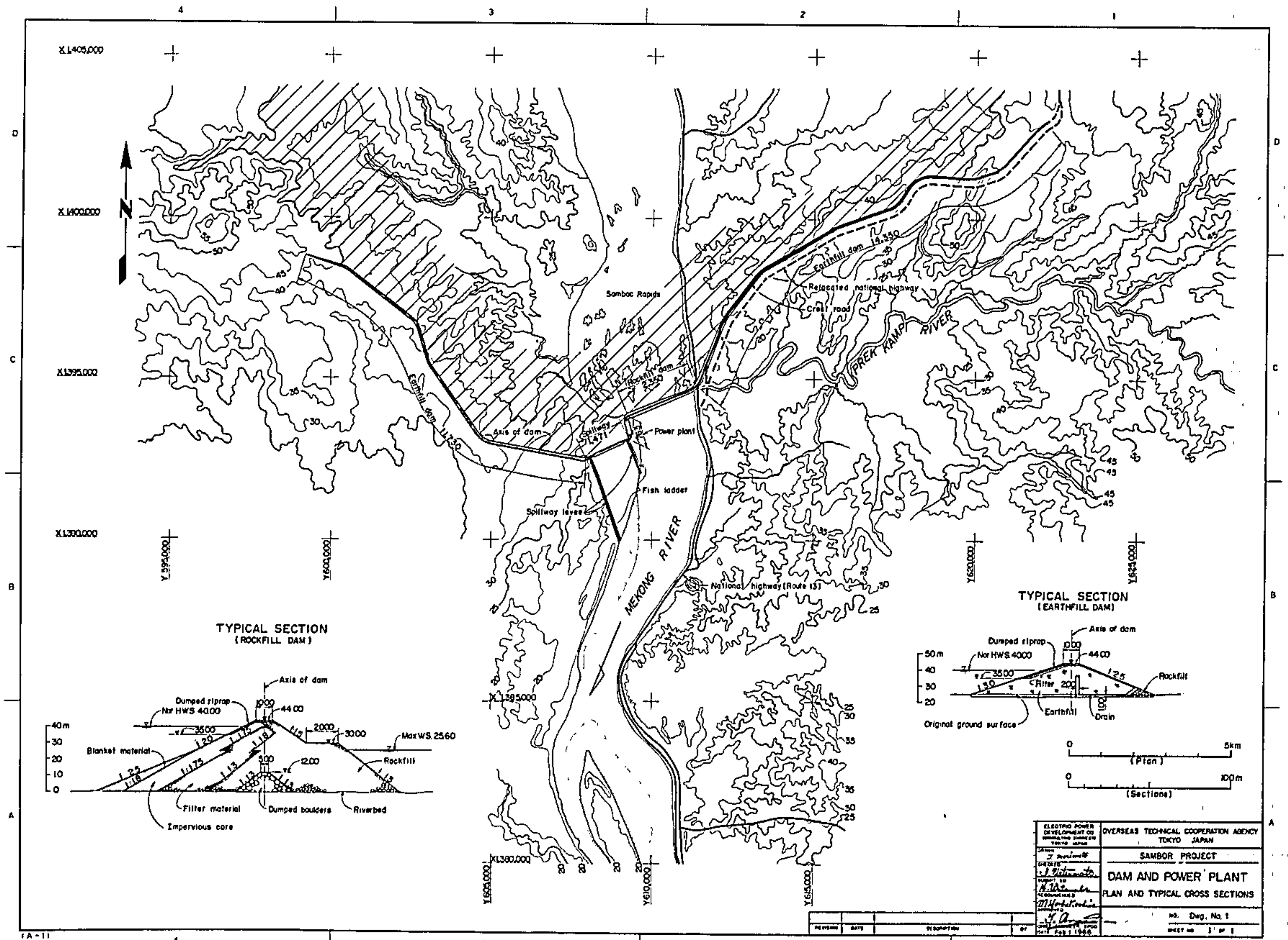
On the route between Sambor and Phnom Penh, there is a section, crossing the Tonle Sap which is approximately 1,500 m wide. Not only the conductors and insulators, but also the steel towers and foundations must be of special design. In preparing the final designs, it will be necessary to keep this point in mind.

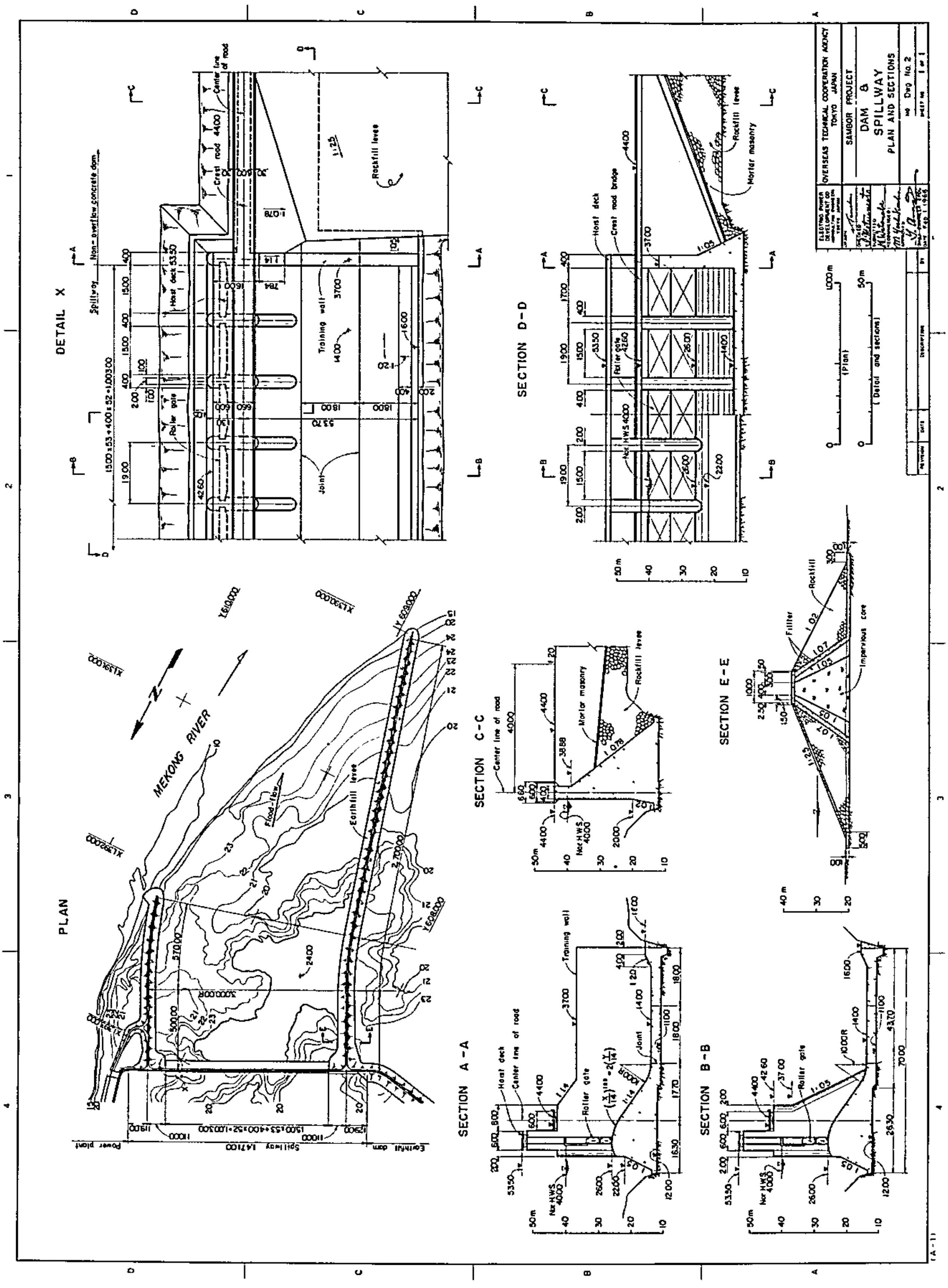
Table H-5 Description of Transmission Line

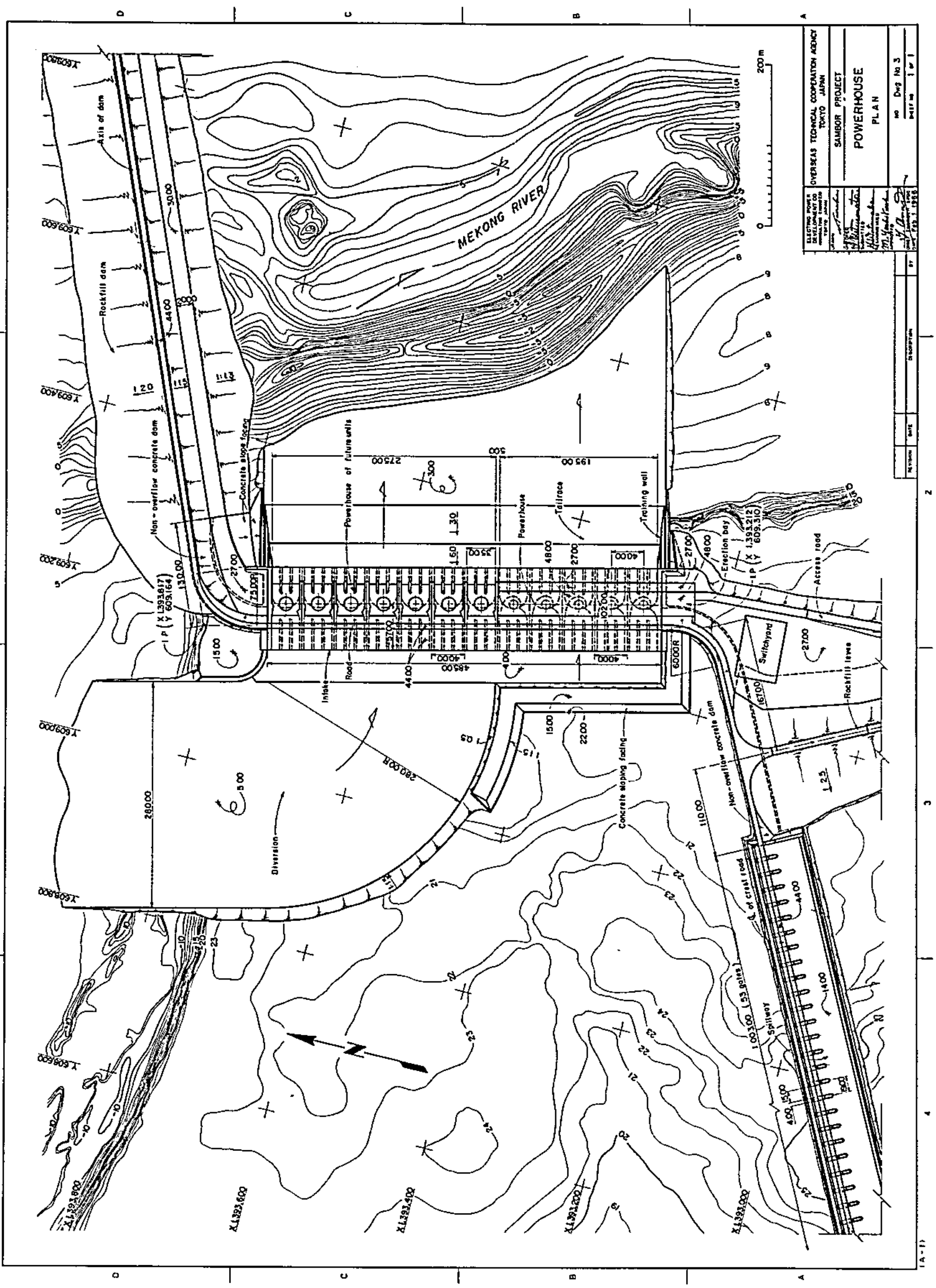
	Sambor-P. Penh	P. Penh-S. Ville	Sambor-Saigon
Length	190 km	160 km	230 km
Voltage	345 kV	345 kV	345 kV
No. of cct	1 cct x 2 route	1 cct x 2 route	1 cct
Conductor	410 sq.mm ACSR x 2 (Al 26/4.5 mm St 7/3.5 mm)	410 sq.mm ACSR x 2 (Al 26/4.5 mm St 7/3.5 mm)	410 sq.mm ACSR x 2 (Al 26/4.5 mm St 7/3.5 mm)
Ground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

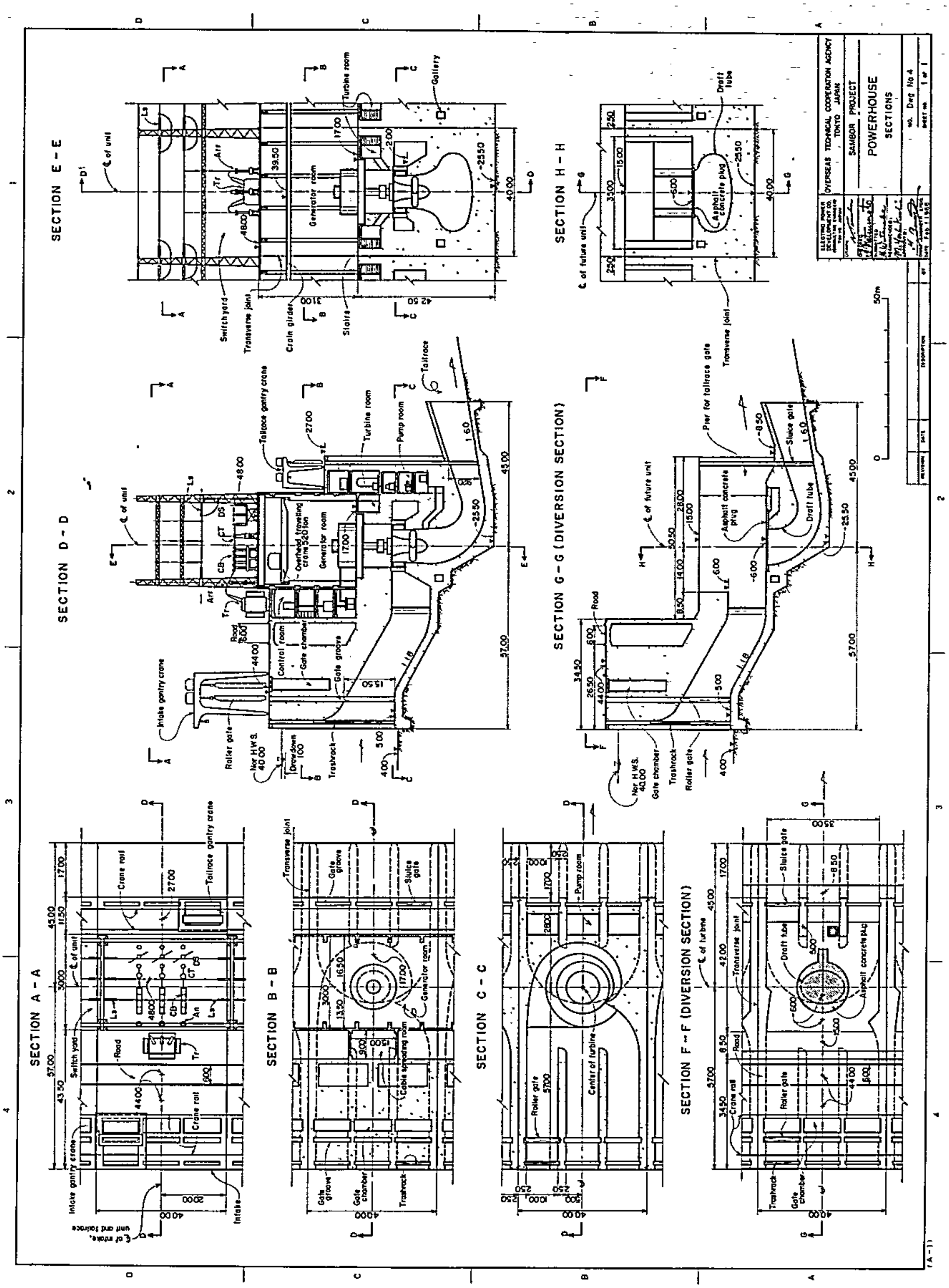
Note:

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

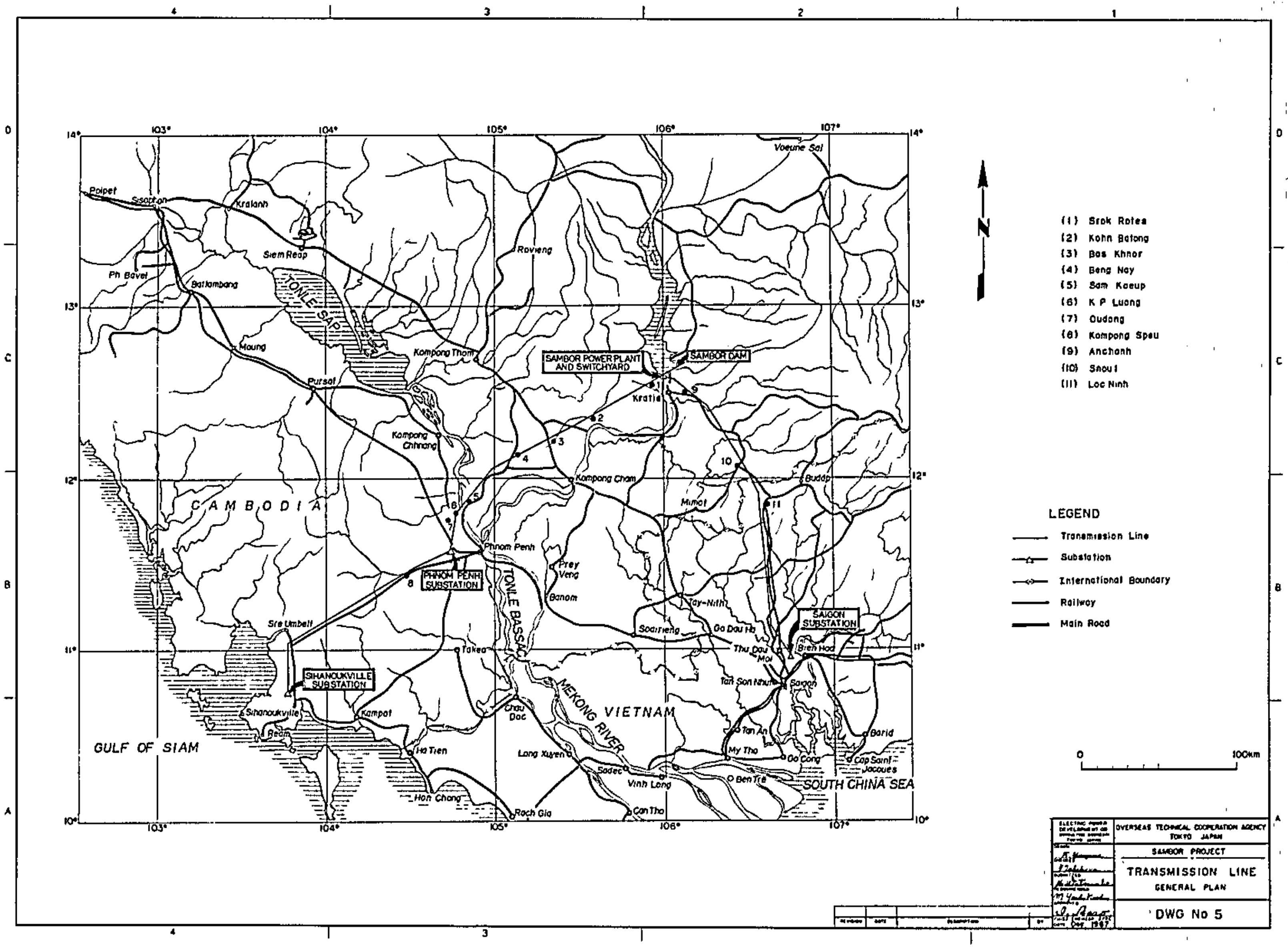

TYPICAL SECTION
(ROCKFILL DAM)
Axis of dam
Dumped riprap
Nor HWS 40.00
10.00
44.00
35.00
20.00
30.00
Max W.S. 25.60
12.00
3.00
Blanket material
Rockfill
Filter material
Dumped boulders
Riverbed
Impervious core
TYPICAL SECTION
(EARTHFILL DAM)
Axis of dam
Dumped riprap
Nor HWS 40.00
10.00
44.00
35.00
Filter
2.00
Rockfill
Earthfill
Drain
Original ground surface
(Plan)
5km
(Sections)
100m
Sambor Rapids
Earthfill dam 14,350
Relocated national highway
Crest road
PREK KAMPI RIVER
Rockfill dam
Spillway
Power plant
Axis of dam
Earthfill dam 11,730
Fish ladder
Spillway levee
MEKONG RIVER
National highway (Route 13)
OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO JAPAN
ELECTRIC POWER DEVELOPMENT CO.
SAMBOR PROJECT
DAM AND POWER PLANT
PLAN AND TYPICAL CROSS SECTIONS
Dwg. No. 1

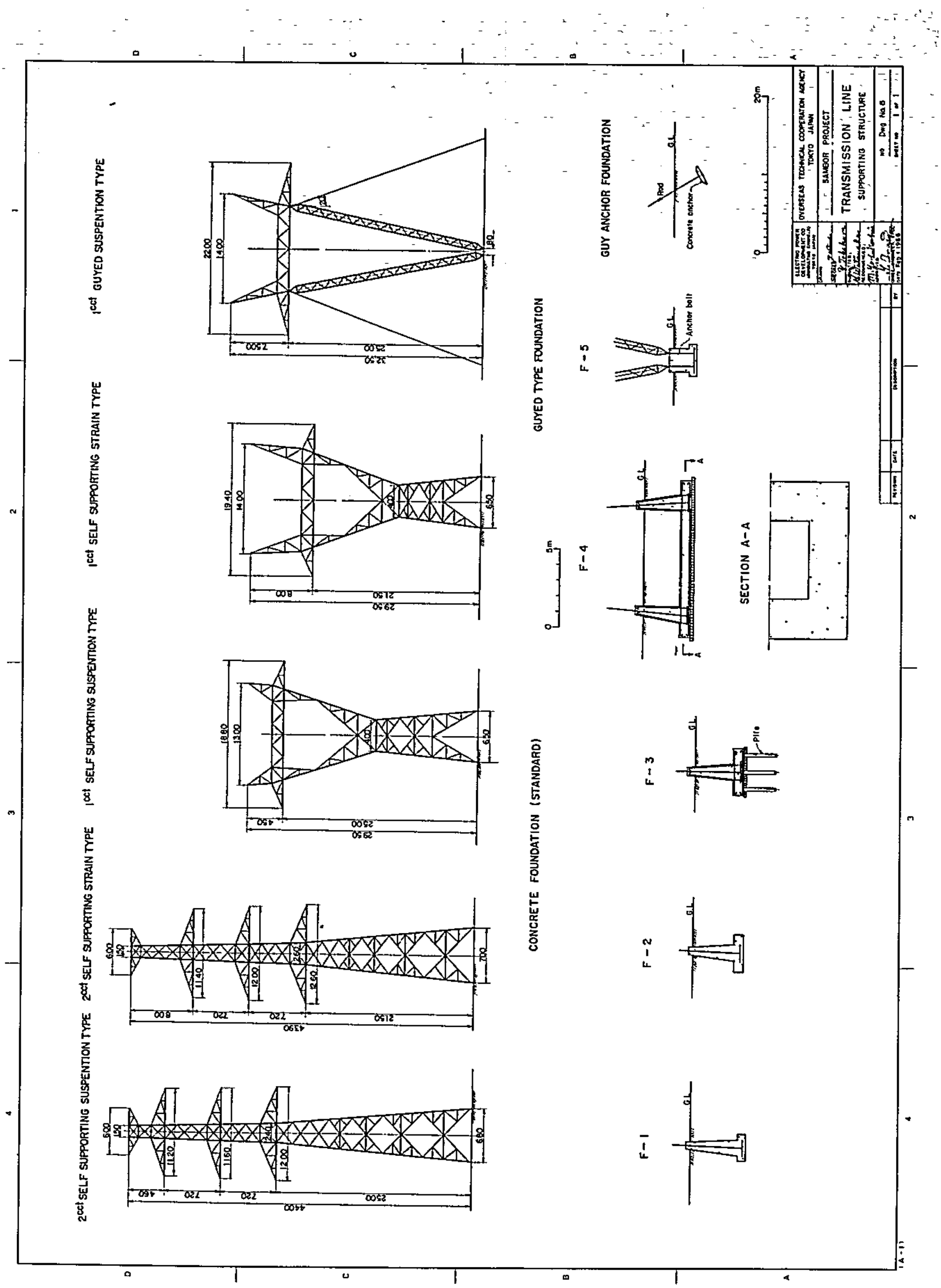

OVERSEAS TECHNICAL COOPERATION AGENCY TOKYO JAPAN
SAMBOR PROJECT
DAM & SPILLWAY
PLAN AND SECTIONS
PLAN
MEKONG RIVER
Earthfill levee
Flood-flow
DETAIL X
Spillway
Non-overflow concrete dam
Crest road
Hoist deck
Roller gate
Training wall
Rockfill levee
Joint
SECTION D-D
Hoist deck
Crest road bridge
Mortar masonry
SECTION C-C
Center line of road
Nor.H.W.S.
SECTION E-E
Filter
Rockfill
Impervious core
SECTION A-A
Hoist deck
Center line of road
Roller gate
Training wall
SECTION B-B
Roller gate
Spillway
Earthfill dam
Power plant
(Plan)
(Detail and sections)


OVERSEAS TECHNICAL COOPERATION AGENCY TOKYO JAPAN
SAMBOR PROJECT
POWERHOUSE
PLAN
MEKONG RIVER
Axis of dam
Rockfill dam
Non-overflow concrete dam
Concrete slope facing
Powerhouse
Tailrace
Training wall
Erection bay
Access road
Switchyard
Intake
Road
Diversion
Concrete sloping facing
Spillway
200 m



SECTION E - E
SECTION D - D
SECTION A - A
SECTION H - H
SECTION G - G (DIVERSION SECTION)
SECTION B - B
SECTION C - C
SECTION F - F (DIVERSION SECTION)
OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO JAPAN
SAMBOR PROJECT
POWERHOUSE
SECTIONS
Dwg. No 4
ELECTRIC POWER DEVELOPMENT CO.
Switch yard
Transverse joint
Crane girder
Stairs
Turbine room
Gallery
Generator room
Intake gantry crane
Roller gate
Trashrack
Control room
Gate chamber
Gate groove
Overhead travelling crane 320 ton
Tailrace gantry crane
Pump room
Tailrace
Draft tube
Asphalt concrete plug
Pier for tailrace gate
Sluice gate
Crane rail
Road
Center of turbine
Cable spreading room
50m


(1) Srok Rotea
(2) Kohn Batong
(3) Bas Khnor
(4) Beng Nay
(5) Sam Koeup
(6) K P Luong
(7) Oudong
(8) Kompong Speu
(9) Anchanh
(10) Snoul
(11) Loc Ninh
LEGEND
Transmission Line
Substation
International Boundary
Railway
Main Road
N
0
100km
SAMBOR POWER PLANT AND SWITCHYARD
SAMBOR DAM
PHNOM PENH SUBSTATION
SIHANOUKVILLE SUBSTATION
SAIGON SUBSTATION
TONLE SAP
TONLE BASSAC
MEKONG RIVER
CAMBODIA
VIETNAM
GULF OF SIAM
SOUTH CHINA SEA
Poipet
Sisophon
Kralanh
Siem Reap
Ph Bovel
Battambang
Moung
Pursat
Kompong Thom
Kompong Chhnang
Rovieng
Kratie
Kompong Cham
Voeune Sai
Buddp
Mimot
Phnom Penh
Prey Veng
Banam
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
Takeo
Chau Doc
Long Xuyen
Sadec
Vinh Long
Can Tho
Rach Gia
Ha Tien
Hon Chong
Kampot
Sre Umbell
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
OVERSEAS TECHNICAL COOPERATION AGENCY TOKYO JAPAN
SAMBOR PROJECT
TRANSMISSION LINE
SUPPORTING STRUCTURE
NO Dwg No.6
1 of 1

CHAPTER I. CONSTRUCTION SCHEDULE

CHAPTER I. CONSTRUCTION SCHEDULE

I-1 Construction Schedule

The construction schedule is based on Type I of power consumption pattern of the three patterns described in Chapter K-4-4 as this pattern of consumption appears to be more realistic and feasible. The construction schedule shown in Fig. I-1 is based on the volume of work, water level of the river and the construction method and construction equipment and plant to be employed which are described in the following section. According to this schedule, the period of construction including preliminary works such as construction of base camp, roads, etc. will be 8 years for the first stage and 3 years (divided into two parts) for the second stage.

The major factors governing this construction schedule are the three listed below.

(1) Construction of the rock-fill dam in the river channel.

(2) Construction of temporary diversion channel to be used during construction of the rock-fill dam, i.e., construction of intake and powerhouse foundation.

(3) Installation of turbines and generators.

The above (1) and (2) are works which will be greatly influenced by the water level of the river, and in connection with (1), it will be essential to execute the scheduled quantities of work on time to prevent overtopping of the dam during construction.

I-2 Various Problems Related to Construction

I-2-1 Transportation

From Phnom Penh to the dam site, there is at present an overland route and a navigation route which can be used year-round.

The overland route is 340 km long via National Highways Nos. 5, 6, 7 and 13. These highways are two-lane asphalt paved. The load limits of bridges are 12 tons. The time required for a truck to negotiate the distance is approximately 12 hours including a waiting period for the ferryboat at Kompong Cham.

The navigation route ascends the Mekong River a distance of 215 km to Kratie approximately 15 km downstream of the dam site. It is possible for a craft of 1.7 m draft to navigate this route even in the low water season and a one-way trip takes 12 to 18 hours by scheduled passenger ship.

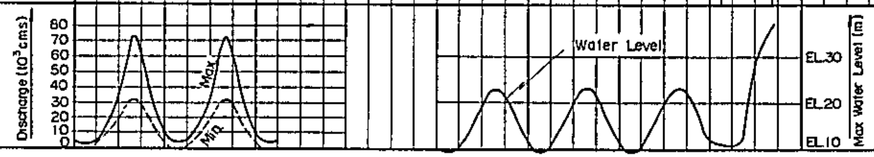
The materials required for construction of Sambor Power Plant are estimated to total upwards of 1,100,000 tons. Also, when considering the foods, daily needs and expendibles which would become necessary as a result of concentration of population accompanying construction, the total materials and goods to be transported will become an enormous amount.

Regarding the transportation route of the construction materials, eight different routes were studied taking into consideration the location of deep sea ports, inland navigation, extension or new construction of railroads, improvement or new construction of roads. As a result, it was decided that for safe, reliable and economic transportation of materials, it was most practical for heavy objects such as turbines and generators, and cement to be delivered by ocean-going vessels to Phnom Penh where they would be transferred directly to barges for further ascent of the Mekong River, while all other materials would be hauled from Phnom Penh over National Highway No. 6 and a new road 195 km long to be constructed on the right bank of the Mekong River.

At the landing point near the dam site for cement transported up the river by barges, in consideration of the draft of barges and the fluctuation in the water level of the river, inclined ramp and floating pier will be built to permit year-round landing. Heavy objects such as turbines and generators will be landed in the high water season at an exclusive landing place designed especially for this purpose.

Fig. I-1 Construction Schedule

Construction Items		Quantity	First Stage 1st Year	2nd Year	3rd Year	4th Year	5th Year	6th Year	7th Year	8th Year	Second Stage 1st Year	2nd Year	3rd Year	4th Year	Remarks
Land and Right		L.S.													
Preparatory Works	Improvement of Existing Roads	L.S								(Diversion of River)					
	Landing Facilities	L.S													
	Base Camp	L.S													
	Plant Erection	6kV, 80 km													
	Relocation of High Way	32km													
	Access Road	L.S													
Dam	Embankment for Earthfill Dam of Right Bank	L = 11,730m V = 8,160x10^{3}cum								(Start of Operation)					
	Embankment for Earthfill Dam of Left Bank	L = 14,350m V = 9,020x10^{3}cum													
	Embankment for Rockfill Dam	L = 2,350m V = 8,720x10^{6}cum													
	Boulders	160x10^{6}cu m													
	Rockfill	5,180x10^{6}cu m													
	Filter	1,820x10^{6}cu.m													
	Impervious Core,	1,560x10^{6}cu m													
Spillway	Excavation	1,380x10^{3}cu m													
	Concrete	900x10^{3}cu m													
	Gate	53 Gates													
	Embankment for Levee	3,170x10^{3}cu.m													
Power Plant	Excavation	6,900x10^{3}cu.m													
	Concrete	1st Stage 1,250x10^{3}cum 2nd Stage 81x10^{3}cum													
	Gates, etc	Draft Gate 5 Intake Gate 9					Draft Gate	Intake Gate							
	Turbine and Generator	1st Stage 5 2nd Stage 2					Installation of Draft								
Transmission Line															
Substation															



The overland route as shown in Dwg. No. 7 will be maintained by improving the existing road between Kompong Cham and the dam site.

National Highway No. 13 and bridges in the sector upstream of Kratie will be improved.

I-2-2 Construction Base Camp

At present, near the dam site, there is Kratie which is the center of culture, commerce and communication of this region. Should construction be started, the population of Kratie will be tripled at once by those connected with the construction besides their families and people employed in shops and stores, schools, hospitals, etc.

Therefore, in view of the fact that the construction period will be approximately 8 years and there will be a concentration of population, it will be necessary for a city (New Kratie) to be formed to provide an orderly base camp from the standpoint of security, sanitation and safety. After completion of Sambor, it would be advantageous to utilize this city as a center for maintenance and administration of the power station.

Considering the above, the base camp would be built by preparing land for the camp site and providing such facilities necessary for daily community life such as roads, water supply and drainage, power distribution lines, communications and recreation facilities.

It is considered that buildings directly connected with the construction works to be put up at the base camp including living quarters, offices, public buildings, etc. of the Government, Mekong Committee, consulting engineer and contractors will amount to 100,000 sq.m with the total ground area of the camp being around 700,000 sq.m to 1,000,000 sq.m.

I-2-3 Electric Power for Construction

At present, there is no power supply system in the project area which can be used for construction purposes. Therefore, it will be most advantageous to employ construction equipment and plant operated by internal combustion engines insofar as possible. However, for equipment and plant such as concrete mixing plants, aggregate plants, jib cranes, pumps, illumination, etc., which cannot use alternative motive power or which are much more economical to use electric power, it will be necessary to provide power generating facilities.

The generating capacity necessary for construction purposes was estimated to be 5,500 kW to 6,000 kW.

I-2-4 Relocation of National Highway

Presently, National Highway No. 13 passes the dam site and extends to Stung Treng, but after completion of the dam a stretch of 16 km will be submerged in the reservoir. Also, there will be interference to general traffic utilizing this road during construction.

Therefore, it will be necessary to detour and relocate this part of the road in advance of the dam construction works. After relocation, the road will extend from Prek Kampi Bridge to the downstream side of the dam, the left bank of the reservoir and join the present highway at an elevation higher than the reservoir water retention level.

This relocated section will be made wider than the present width of the national highway to make possible passage of general traffic and also traffic connected with the project construction.

I-3 Construction Method

I-3-1 Care of River

In studying the method of care of river, it was based on the premise that the recorded maximum monthly runoff would be handled safely in consideration of the importance of care-of-river in this project and the chacteristics of the river. The runoff of each month used in the study is shown in Fig. D-6.

The rating curve downstream of the dam site is given in Fig. D-4.

The method of care of river described below will make it possible for the rock-fill dam itself to serve the purpose of a coffer dam so that large-scale coffering will be unnecessary; and at the same time shorten the period of use of the temporary diversion channel.

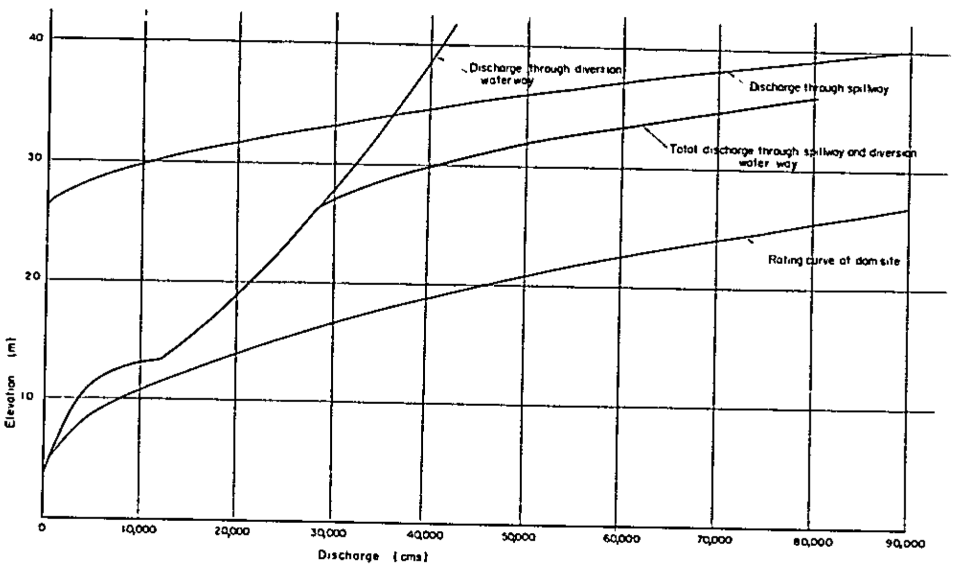
In other words, the method fundamentally is to use in the first construction stage the intake for the seven units of turbines and generators to be installed in the power station at a future date. In order to prevent a undue rise in the upstream water level due to inflow loss through the diversion channel, the forebay of the intake will be excavated to elevation 5 m over the entire width of the future seven units. The rating curve of the temporary diversion channel will then be as shown in Fig. I-2.

When the temporary diversion channel is ready for use, the river will be diverted through the channel in the low-water period and the rock-fill dam in the river channel will be constructed.

When the low-water season is over, the water level of the river will gradually rise and when it is above EL 26 m the river will flow down the spillway as well as the temporary diversion channel. Therefore, the embankment of the dam must proceed at a rate so that water will not overtop the dam. The temporary plant on the upstream side of the dam is to be removed before this time in order that the rise in water level will not hinder the construction work.

Upon completion of the rock-fill dam, the intake of the seven skeleton units utilized as temporary diversion channel will be closed with gates, and the spillway gates will be lowered to begin storage of water behind the dam.

Fig. I-2 Rating Curve During Diversion



I-3-2 Dam

Based on the results of geological surveys, materials surveys and other investigations conducted on several occasions in the field by borings and shafts, it is judged the best to execute the construction of the dam in the following manner:

(1) Construction of Earth-Fill Dam

The foundation of the earth-fill structures on the left and right banks can be prepared by stripping the overbuden with bulldozers, and the dam can be embanked with earth materials. The embankment of the dam will be carried out in the dry season, but even in the rainy season during the period that daily precipitation is not more than 1 mm and rainfall is not continuous, construction will be possible.

On the right bank, earth materials are available near the dam site, and motor scrapers of 33 cu.m capacity will be used to excavate, haul and embank the materials. On the left bank, some of the materials must be hauled a considerable distance and this transportation will be handled by combination of tractor shovels and dump trucks.

Compaction of earth materials will be performed with tire rollers under proper quality control to obtain maximum density and to prevent the development of abnormal pore water pressures.

Filter and interceptor materials in right bank dam will be excavated muck from the powerhouse or spillway. Filter materials for the left bank dam will be obtained and hauled from borrow area.

The earth-fill structures on both banks can be constructed without being affected by the water level of the river and may be completed by the flood season 8 years after start of construction.

(2) Construction of Rock-Fill Dam

As described in I-4, the impervious core material will be fine sand obtained on the right bank at a site 4 km downstream of the dam, and filter materials will be weathered conglomerate found approximately 5 km from the left bank of the dam. Rock materials will be obtained from the sandstone stratum 2 km downstream of the dam on the left bank and the excavated muck from the powerhouse and temporary diversion channel.

The locations of these borrow and quarry areas are shown in Dwg. No. 7.

The major part of the dam will be embanked in water so that quality control of embankment materials must be exercised with thorough care.

As for methods of constructing this rock-fill dam according to the care-of-river procedure described in I-3-1, there is the method of dividing the river channel into two or three parts and embanking these parts in the low-water months of February and March. Various other methods are also conceivable, but as a typical example, the following method may be suggested. (See Fig. I-3)

(a) In the first low-water season after the excavation of powerhouse foundation, the placing of concrete in the substructure and intake, and the excavation of the tailrace bay are completed, and it becomes possible to divert water through the temporary diversion channel (January and February of the seventh year). Then a coffer dam with crest elevation of 12 m will be built from the right bank extending in the direction of the middle of the river.

This coffer dam will be part of the rock-fill structure. The elevation of the crest of the coffer dam will be 12 m taking into account that the water level at the dam site will recede to EL 8 m in the low-water season and some freeboard has been included to accommodate inflow loss at the diversion channel (First Stage).

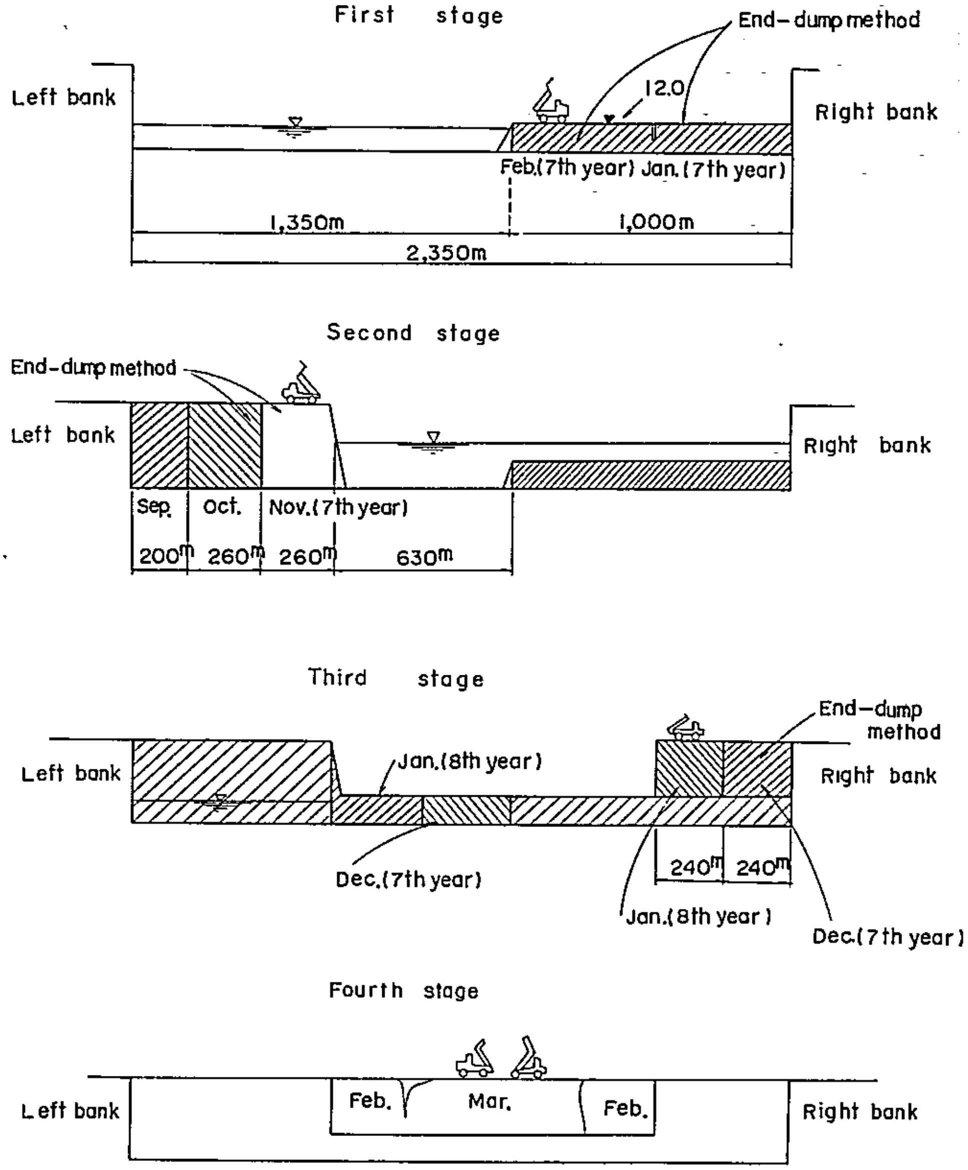
(b) From the beginning of the next low-water season (September of the seventh year), rock embankment from the left bank will be started executing towards the center of the river channel corresponding, and the embankment work will be with the gradual decrease in natural runoff. (Second Stage).

(c) In the second low-water season, the river flow will be diverted through the diversion channel and the unembanked section in the middle of the river channel. At this stage, the crest of the coffer dam constructed in the first stage will be at an elevation higher than the water level of the river, and river flow will be diverted through the diversion channel only (Third Stage).

(d) After the flow is only diverted through the diversion channel, the rock embankment will be completed along the entire width of the river channel, and the filter and impervious core will be embanked (Fourth Stage).

(Part of the filter and impervious core can be constructed before the rock embankment is completed.)

Fig. I-3 Study for Embankment of River Channel



I-3-3 Powerhouse

The powerhouse will require extensive and considerable volume of foundation for excavation and concrete work. It will take approximately three years before turbines can be installed.

Since the flood discharge level at the powerhouse will be considerably higher than the setting elevation of turbines and generators, it will be necessary to perform the excavation, concrete work and installation of various equipment and machinery in a manner to assure adequate safety against this high water level.

(1) Excavation: The excavation work can be broadly divided into three parts: excavation of powerhouse foundation, temporary diversion channel and tailrace.

First, the topsoil will be excavated by bulldozers, and hauled and disposed with tractor shovels and dump trucks. Earth and sand under the topsoil will be excavated and hauled to the spillway training levees and embanked. The amount of excavation of topsoil, earth and sand will be approximately 1.4 million cu.m. After this work is completed, the powerhouse foundation will be excavated by the bench-cut method using crawler mounted drills. The excavation of rock in this section will amount to approximately 2.1 million cu.m. Since this rock excavation will be an extremely large volume, 4.5 cu.m bucket capacity power shovels and dump trucks will be used. In this work, the natural ground on the river channel side will be used as a coffer dam and therefore will not be excavated.

The excavation of this natural ground used as coffer dam will be performed simultaneously with the excavation of the tailrace bay during the low-water season after completion of concrete works in the powerhouse and installation of draft gates. The quantities of excavation are approximately 0.6 million cu.m of earth and sand and approximately 1.0 million cu.m of rock. As the low-water season is only three months long and it will be difficult to use large-capacity shovels, and also since large-scale blasting cannot be performed, the excavation work must be performed in three low-water seasons.

The temporary diversion channel will be excavated after completing the excavation of the powerhouse foundation. The volume of excavation in the temporary diversion channel will be approximately 1.8 million cu.m.

The excavated muck as described in the respective sections, will be completely used as concrete aggregate, embankment material in the rock-fill dam, embankment of the spillway training levee and the dam on the right bank.

(2) Concrete: The volume of concrete in the powerhouse in the first stage including the wing dam will amount to 1.25 million cu.m. Concrete will be placed using trestles and a 13.5 ton (4.5 cu.m buckets) traveling jib crane. At the peak time, it is estimated the volume of concrete to be placed will be a 65,000 cu.m monthly.

(3) Installation of Gates, Turbines and Generators: Concrete in the powerhouse will be placed from the downstream side and after placing casing concrete, columns of structural steel reinforced concrete will be erected in order to use the overhead traveling crane as soon as possible. Installation of turbines will be commenced from the high-water season of the sixth year using the overhead traveling crane.

Intake gates and tailrace gates will be installed and closed by the high-water season of the sixth year so that the river water will not enter the powerhouse during flood discharge and hinder installation of turbines.

I-3-4 Spillway

Installation work of spillway gates will require a considerable period of time. As it is not desirable to prolong the peak period of construction in consideration of the relationship with the powerhouse works, the spillway construction will be started one year earlier than the powerhouse.

(1) Excavation: After stripping topsoil, excavation will be performed with power shovels and dump trucks, and excavated materials will be used for embankment of the training levees.

(2) Concrete: Concrete in the overflow weir and piers will be placed by employing a 13.5 ton jib crane, capable of lifting 4.5 cu.m buckets, which will be installed on the upstream side of the dam. Concrete for the apron and foot protection of the training levees will be placed by truck mixers.

(3) Installation of Spillway Gates: Installation of spillway gates will require one month per gate. Therefore, as soon as the pier concrete is placed and cured, the gates will be installed from both ends of the spillway. The spillway bridge will be used for transportation of impervious core materials of the dam.

(4) Embankment of Training Levees: A volume of 3.17 million cu.m of earth and sand will be necessary for embankment of the training levees. Of this amount, 2.62 million cu.m of earth, sand and rock excavated from the powerhouse and spillway sites can be utilized and the remaining 0.55 million cu.m will be taken from borrow areas.

Compaction will be accomplished by using tire rollers and bulldozers.

I-3-5 Future Extension Plan

For the seven turbines and generators scheduled to be installed in the future, concrete in the intake and the part of the powerhouse foundation below EL 4m in which draft tubes will be embedded will be placed in the first stage. Also, in order to prevent the flow of water into the powerhouse during installation of the turbines and generators, the wall on the tailrace side will be constructed and grooves will be provided so that stop-logs may be inserted.

Therefore, in the expansion works, as soon as the stop-logs are inserted in the tailrace in the low-water season, the tailrace watertight wall is constructed and the tailrace gates are closed, it will be possible to place without difficulty casing concrete, erect the columns for the traveling crane and install the turbines and generators.

The transportation of turbines and generators can also be easily achieved.

I-4 Construction Materials

I-4-1 Cement

The total quantity of cement required in the first stage is estimated to be approximately 650,000 tons, and it is estimated that a monthly maximum of about 15,000 tons and a daily maximum of about 700 tons will be required.

In Cambodia, at present, there are cement plants in operation at Charay Ting and Kampot with daily production of 200 tons. However, the production capacity is too small to meet the needs of the project and it was assumed that the entire quantity would be imported.

The cement will be delivered to the Port of Phnom Penh by ocean-going vessels of 5,000 ton class, transferred to 180 ton class barges and transported to a site on the opposite bank of Kratie where it will be stored. From the store room, the cement will be trucked to the vicinity of the batching plant.

An economic comparison of bulk and bagged cement was made, but as there was little difference in cost it was decided to adopt bagged cement which would not require mechanical facilities. Unloading of cement will be done manually.

In consideration of the hauling distance, the method of transportation and the volume of concrete work, it will be necessary to install four cement silos of 1,000 ton capacity at the site.

I-4-2 Aggregates

It is estimated that the required quantity of aggregates for concrete in the first stage will be 4.6 million tons of which 3.4 million tons will be coarse aggregate and 1.2 million tons fine aggregate.

Investigations of natural sand and gravel deposits along the Mekong River in the vicinity of the construction site revealed that good quality fine aggregate is available on the left bank of the Mekong River 17 km downstream of the dam and within the city limits of Kratie, but the deposit is not suitable for concrete aggregate as it does not contain coarse materials. The deposit is suitable for fine aggregate, but in view of the hauling distance and as it is on the left bank, it is not economical to use this material.

Geological exploration revealed that the bedrock at the powerhouse site is alternate layers of shale and sandstone showing an elastic wave velocity of 5 km per sec. The rock is assumed to be comparatively dense and the specific gravity high and it is thought the coefficient of elasticity is also high.

Also, judging by laboratory tests of samples taken near the project site (See Chapter C in Vol. VII), it is believed that material excavated from the powerhouse site can be used as concrete aggregate.

In view of the above situation, it was decided that concrete aggregate will be secured by crushing excavated material instead of using natural river deposits.

The amount of rock necessary for concrete aggregate is approximately 1/3 of the total excavated rock so that the quantity of material available will be more than sufficient.

The type, capacity and arrangement of the plant for manufacturing concrete aggregate from excavated rock will be determined after considerating the properties of the rock, the quantity of aggregate to be produced and the grading of aggregate. Therefore, in the stage of preparing the detail design of the project, it will be necessary to carry out further investigations and tests of the raw material.

I-4-3 Embankment Materials for Earth Dam

The embankment materials for the earth dam consist of soil materials, coarse materials for interceptor and filter and materials for protection of the upstream and downstream slopes.

(1) Soil Materials: As a result of field surveys, on the right bank upstream of the dam site, with the exception of the former river bed, there is uniform distribution of silty earth which is mainly weathered shale that is suitable as material for embankment of the dam. On the left bank, at the ridge parallel and near the bank of the Mekong River and at the ridge near the abutment of the dam, there is uneven distribution of silty clay which is weathered sandstone and conglomerate.

Materials available at areas other than the abovementioned places are deposited in thin layers, and above all the cohesiveness is too high to be suitable for embankment material.

Therefore, the abovementioned three locations will be used as borrow areas. The distances of haul from these locations is about 4 km at the most.

(2) Coarse Materials and Slope Protection Materials: The quality, grading, etc. of these materials will be determined in the detail design work, but quantities required will be comparatively small.

On the right bank, no borrow area will be established as it should be possible to use excavated materials from the powerhouse foundation or the tailrace.

On the left bank, as there will be no excavated material which can be diverted for this purpose, weathered conglomerate located approximately 6 km from the river bank between the dam axis and the Prek Kampi River will be used. If comparatively large pieces of rock for the upstream rip-rap cannot be obtained from this area, fresh rock under the earth material borrow area will be quarried and embanked.

I-4-4 Embankment Materials for Rock-Fill Dam in River Channel

The embankment materials for the rock-fill dam consist of boulders for coffer dam, rock for the main dam body, filter materials and impervious core materials.

(1) Boulders and Rock Materials for Dam Body: Since the boulders will be used for the coffer dam and will be embanked starting from the right bank, the large pieces excavated from the powerhouse foundation will be sorted and stored temporarily until embankment is started.

Rock materials for the dam body must be embanked in large quantities during a short period of time and it will be advantageous to haul them from both the right and left banks.

The volume of rock to be embanked is 5 million cu.m of which approximately 2 million cu.m can be obtained from the powerhouse foundation.

Therefore, the volume to be obtained from the quarry on the left bank will be approximately 3 million cu.m.

Investigations of quarry sites on the left bank were carried out in the area approximately 10 km upstream of the dam, the area 2 km downstream of the dam, the area 2 km north of Kratie Airfield and the area 10 km northeast of the airfield. The area upstream of the dam is excellent in respect to properties of rock and quantity available, but it is not suitable as the road for hauling embankment material will be submerged and the distance is great. The areas 2 km north and 10 km northeast of Kratie Airfield are too far and not within economical hauling distance.

Therefore, the desirable quarry site on the left bank is the area 1.5 km east of Samboc Village and 2 km downstream of the dam. The geology of this area is alternate layers of sandstone and shale, and it will be possible to quarry rock of the required properties for the main dam body from strata with comparatively little shale.

(2) Filter Material: The quality, grading, etc. of filter materials will be determined in the detail design work, but it is thought material from the coarse material borrow area for the earth dam on the left bank side can be used for the filter of the rock-fill dam.

(3) Impervious Core Material: For the impervious core material of the rock-fill dam, it will be necessary to carry out further detailed investigations in the field and tests of mechanical and physical properties of the materials to be used before starting the detail design work. On the basis of the present stage of investigation, it is judged that the fine sand deposited on the right bank of the present river bed 4 km downstream of the dam site will have the required imperviousness according to its gradation curve.

Also, it is assumed that materials with the necessary properties also exist on the left bank of the dam site, but in this report it was assumed that the fine sand on the right bank 4 km downstream of the dam site will be used as impervious core material.

I-4-5 Others

Steel required for construction, materials such as reinforcing steel and shaped steel and fabricated items such as gates, steel forms and outdoor steel structures, with the partial exception of wire, nails and wires are considered to be imported. Wood, whether sawed lumber or logs, will be procured locally. Kerosene, heavy oil, gasoline and lubricants although not produced indigenously, can be procured in Cambodia. Materials for blasting such as explosives, detonators and fuses will all be imported.

I-5 Temporary Construction Equipment and Plants

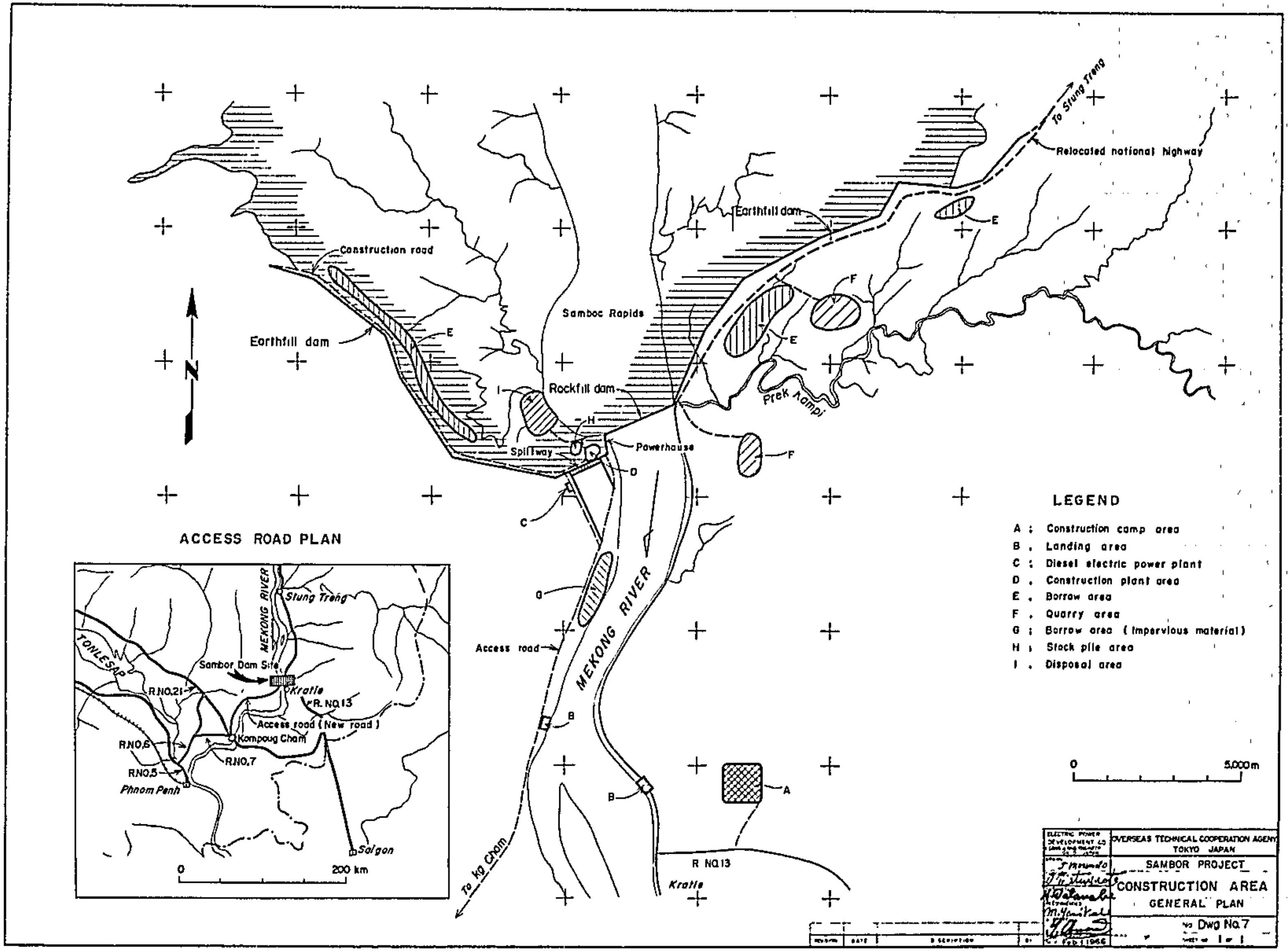
The major equipment and plants thought necessary for execution of the works based on the construction schedule and construction method described in I-1 and I-3 can be summarized as indicated in the Table I-1 below.

Table I-1 Construction Equipment

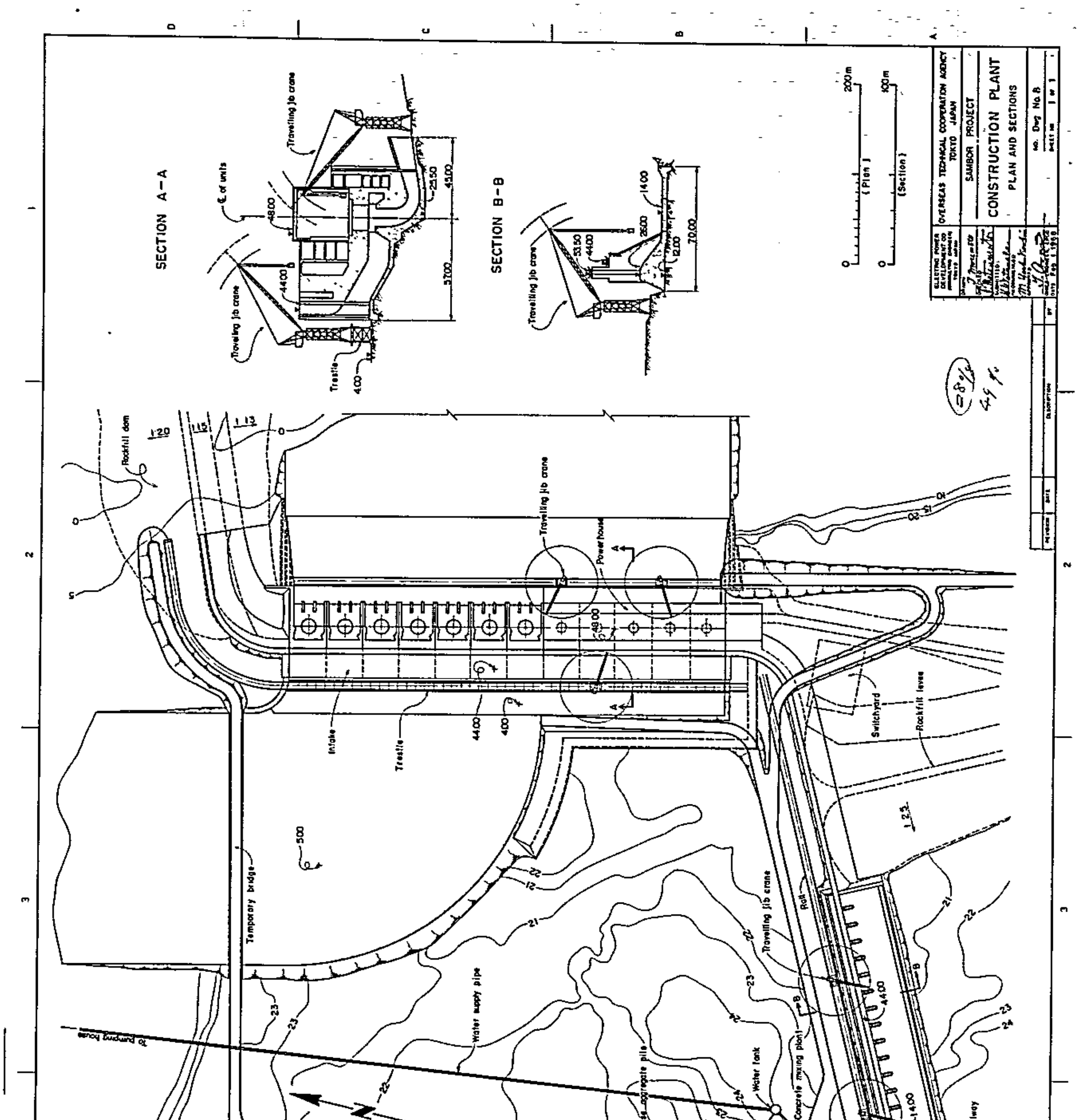
Name	Unit	Capacity	Quantity
Shovel type excavator	cu.m	3.8-1.2	7
Power shovel	cu.m	4.5-1.2	13
Dump truck	ton	35-15	90
Bulldozer	ton	45-30	40
Motor scraper	cu.m	33	4
Tamping roller	ton	40	12
Crushing plant	ton/hr	400	1
Batching plant	cu.m/hr	60	2
Jib crane	ton	13.5	4
Diesel engine generator	kVA	700-200	5,400

The selection of these equipment and plants for construction will probably be left to the free choice of the contractor in the actual execution of the works.

The layout of the construction plants in the vicinity of the dam plant as shown in Dwg. No. 8.



To Stung Treng
Relocated national highway
Earthfill dam
Construction road
Samboc Rapids
Earthfill dam
Rockfill dam
Prek Kampi
Spillway
Powerhouse
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
Feb. 1966



SECTION A – A
SECTION B – B
Travelling jib crane
Trestle
℄ of units
Intake
Powerhouse
Switchyard
Rockfill levee
Rockfill dam
Temporary bridge
Water supply pipe
To pumping house
Construction road
Primary crusher
Primary stock pile
Screening plant
Coarse aggregate pile
Water tank
Concrete mixing plant
Cement silo
Cement warehouse
Fine aggregate pile
Repair service shop
To right bank road and landing area
Spillway
Rail
To disposal area
Stock pile of excavated material for concrete aggregate
(Plan)
(Section)
200m
100m
OVERSEAS TECHNICAL COOPERATION AGENCY TOKYO JAPAN
SAMBOR PROJECT
CONSTRUCTION PLANT
PLAN AND SECTIONS

CHAPTER J. ESTIMATED CONSTRUCTION COST