THE THIRD PROGRESS REPORT
ON
INVESTIGATIONS OF THE SAMBOR PROJECT

SEPTEMBER 1965

OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO

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FOREWORD

In response to the request of the Committee for Coordination of Investigations of the Lower Mekong Basin, the Government of Japan conducted Preliminary Investigations in FY 1961 with the object of formulating the development plan for the proposed Sambor Project.

The Preliminary Investigations were followed by a series of detailed investigations conducted successively during the past three years by the Overseas Technical Cooperation Agency (OTCA) which has been entrusted with their execution by the Government of Japan since its establishment in 1962.

With regard to the First and Second Phase Investigations carried out in FY 1962 and 1963 respectively, the findings and recommendations have been compiled by the OTCA into progress reports already submitted to the Committee.

The present Third Phase Investigations, entrusted to the OTCA by the Government of Japan, were carried out by a Survey Team comprising a total of 34 members with Dr. K. Aki serving as Leader. Field surveys were conducted over two periods, i.e., from September to October 1964 and from November 1964 through February 1965.

It is my pleasure to state that careful studies are being made at present on the findings and data obtained during the investigations made to date with the view to submitting to the Committee a final report on the Sambor Project.

On the occasion of presenting the "Third Progress Report on the Investigations of Sambor Project", which reflects the outcome of the joint endeavours of all concerned, I wish to express my deepest gratitude to the Committee for Coordination of Investigations of the Lower Mekong Basin, the Government and people of Cambodia, and to the cooperating countries for their kind and unlimited cooperation.

September 1965

S. Shibusawa

Shinichi Shibusawa

Director General

OVERSEAS TECHNICAL COOPERATION AGENCY

LIST OF ERRATA

Page	Line		Corrected as
1 - 4	19	a dopted	adopted
1 - 6	"	materilized	materialized
2 - 4	10	utlizing	utilizing
2 - 5	17	of each case.	of each case,
3 - 1	26	ground surface	ground surface.
3 - 3	2	dray	dry
3 - 14	table (d)	Sieam Peap	Siem Reap
3 - 15	Fig .	Sambor Powor Station	Sambor Power Station
3 - 17	5	El	El.
"	15	( )	( ).
5 - 3	8	streams	streams.
5 - 4	11	dewllings	dwellings
5 - 9	20	stretchs	stretches
5 - 10	17	Paticularly	Particularly
5 - 15 5 - 16	table 5-3 13,17 & table 5-4	Rattanakiri	Ratanakiri
5 - 21	21	levele	level
6 - 1	10	Phnom Kompong Kor	Phom Kompong Kor
6 - 7	19	approx	approx.
6 - 12	10	sibsidiary	subsidiary
"	21 & 26	Dipterpocarpaceae	Dipterocarpaceae
"	26	Dept. tuberculatus	Dipt. tuber culatus
6 - 14	16	jarzardous	hazardous
6 - 15	6 & 12	stablized	stabilized
6 - 17	11	Khum Tamau	Khum Taman
"	15	unexplaitable	unexploitable

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1. INTRODUCTION

1.1 Background of Investigations

In compliance with the request of the Committee for Coordination of Investigations of the Lower Mekong Basin (hereinafter referred to as "the Committee"), the Government of Japan conducted, over a period from 1961 to 1962, the Preliminary Investigations on the Comprehensive Sambor Development Project, outcome of which was compiled into the "Sambor Project - Report on Preliminary Investigations for Development of the Lower Mekong River Basin" submitted to the Committee in November 1962. Based on this Preliminary Report, the Overseas Technical Cooperation Agency (hereinafter referred to as "the OTCA"), an executing agency of the Government of Japan, was entrusted with the execution of the detailed surveys. The OTCA consequently carried out the First and Second Phase Investigations in FY 1962 and 1963 respectively, results of which have already been submitted to the Committee as the "Progress Report" on each of the two investigations.

For the present Third Phase Investigations (FY 1964), execution of which was commissioned to the OTCA, the Government of Japan appropriated in the budget an amount of approximately $145,000. The OTCA subsequently organized, with the cooperation of competent Government authorities and private organizations concerned, a Survey Team headed by Dr. K. Aki, and despatched it for field investigations during the wet season (September to October 1964) and the dry season (November 1964 to February 1965). Since its return to Japan, the Team has directed its efforts to the compilation and review of data and materials collected during the field investigations, and the results are hereby submitted to the Committee as the "Third Progress Report on Investigations of the Sambor Project".

1.2 Outline of Investigation Plan

The Third Phase Investigations (FY 1964) were conducted with particular reference to such aspects as transmission line, power market, inland navigation and agriculture, with the necessary cost borne partly by the Government of Japan ($145,000) and partly by the Government of Cambodia in local currency as counterpart contribution (150,000 riels equivallent to about $42,800).

Organizations participating in each aspect of investigations were as follows:

1)	Hydro Electric Power Aspect	:	Electric Power Development Co., Ltd.
2)	Transmission Line Aspect	:	Electric Power Development Co., Ltd.
3)	Power Market Aspect	:	Ministry of International Trade and Industry Science and Technology Agency Overseas Electrical Industry Survey Inst., Inc.
4)	Inland Navigation Aspect	:	Japan Ports Consultants, Ltd.
5)	Agricultural Aspect	:	Sanyu Consultants International, Ltd. Ministry of Agriculture and Forestry

Further, the core boring involved in the geological survey of Inland Navigation Aspect were performed by Hazama-Gumi, Ltd., the subcontractor, under the supervision and technical guidance of Japan Ports Consultants, Ltd. The general coordination and accounting for the Survey Team were assumed by the OTCA.

1.3 Hydro Electric Power Aspect

The present field investigations (3rd Phase, FY 1964) centered upon supplementary items, e.g., observation of the inundation of the Mekong during wet season, collection of hydrological data, investigations for compensations for properties to be submerged, and sampling of materials for the dam body.

Home office work covered the re-examination of previous plans, which includes: comparative study of the alternative dam center lines (such as Line C and Line C') proposed from the results of the past two investigations, selection of the most favourable center line, and calculation of storage capacity and back water based on the topographical map (1/20,000).

1.4 Transmission Line Aspect

The First Phase Investigations (FY 1962) covered the reconnaissance of the possible routes of transmission lines, and general review of the problems to be taken into consideration for designing.

During the present investigations, various field surveys were conducted in connection with the proposed two routes (one connecting Sambor - Phnom Penh - Sihanoukville, and the other linking Sambor and Saigon), e.g., survey of bearing strength at 44 points along these two routes, reconnaissance by automobiles, aerial survey for 7 days during wet and dry season, and collection and review of meteorological data. As part of the office work, rough designing was completed, with the cost estimation being made at present for the construction of transmission lines, substations and communication facilities

1.5 Power Market Aspect

During the First Phase Investigations, the Team conducted surveys of the power supply situations in both Cambodia and Viet-Nam, which would constitute the principal service areas of the Project: namely, the Team reviewed the various plans drawn up by the Governments of the above two countries in order to appraise future prospects of the economic and social development therein, collected relevant information and data to form the opinion of the power supply and demand situation in the two countries, and concluded, as stated in the First Progress Report, that the Sambor Project may be scheduled for operation during the years from 1980 to 1985, in which the power supply and demand would become even.

Needless to say that there would be various elements affecting the scale and structure of power demand 20 years from now. Therefore, the electric power surveys should be conducted in as intensive and extensive a manner as possible, inasmuch as the time for the start of construction of the Project and the benefits to be derived from the Project will be directly influenced by the results of such surveys.

From this point of view, it can hardly be said that the manner in which investigations were conducted in FY 1962 were adequate. Nor can it be asserted that the information and data used in the investigation covered a sufficiently wide range.

In FY 1963, therefore, efforts were directed principally to the home office work covering compilation of various data collected in FY 1962, re-examination of methods to be a dopted in estimating the long range supply-demand situation and preliminary study relative to the establishment of heavy electric power consuming industries in the regions under review.

In the present investigations, which is the last of series of three investigations, an attempt was made to supplement the previous two investigations: namely, the Team made surveys, based on the results of the two previous investigations, on the present state and future possibility of the industrial and economic development, especially of the development of manufacturing industries. Further, the Team chose a few heavy electric power consuming industries and studied the siting conditions for such industries.

1.6 Inland Navigation

The past two investigations involved the survey of the domestic transport conditions in Cambodia. With the view to supplementing this survey, the present state of inland navigation was surveyed during the present investigations. In addition, geological survey and soil tests were performed at different points of the proposed routes of navigating canals, thereby to determine the locations of navigation locks and canals. Other basic data to be used in designing structures were also collected.

The survey on the present state of inland navigation was conducted with efforts made to avoid repetition of items already dealt with. Taking into account the outcome of the past two surveys for Hydro Electric Power Aspect, the geological survey was conducted mostly by core boring and partly by hand auger boring, with stress placed on the proposed canal routes on the left bank of the Mekong. Supplementary survey on the right bank was also conducted. Number of bores and total bore length are as given below:

	No.	Bore length
Core boring	13	187 m
Hand auger boring	20	63.3 m

Specimens collected by the boring tests were put to various on-the-spot tests, and a portion of specimens was brought back to Japan for further laboratory tests.

Based on the results of the reconnaissance and geological survey and of the review of relevant data collected, a comparative study is being made at present with regard to the anticipated navigation and construction difficulties and the estimated construction cost as envisaged by a number of alternative plans drawn up for the canal route (6 routes).

Studies are also being made to arrive at a basic plan for designing, in FY 1965, the canal, navigation locks, bridges, roads and navigating routes.

1.7 Agricultural Aspect

The First Phase Investigations (FY 1962) covered a general field survey to grasp the outlook of agriculture in Cambodia and to explore problems for its development. The present investigation were conducted with particular emphasis placed on the surveys of the following items which, as clarified from the results of the past investigations, are to serve as the basic elements of the future development plan: topography, geology, land and water use, and present state of the Cambodian agriculture.

The inundation of the Mekong cannot be prevented until the regulation of the discharge of the main stream has been made possible. From the viewpoint of land use, therefore, not much benefits can be expected from the Sambor Agricultrual Development Project.

However, the irrigation during the dry season utilizing the storage water of the Sambor Dam, and the irrigation and drainage improvement in the downstream areas including the Mekong delta and the outlying area of Tonle Sap, which are to be materilized by utilizing the electric power from the Sambor Power Plant, are worthy of notice.

Changes in the present conditions of water use in the Mekong delta will, if caused by artificial means, not only create problems relating to agricultural know-how but also affect, to a great extent, the social and economic conditions under which the agricultural development in this area has been placed over a long period of time. It is to be recognized that an attempt to achieve agricultural development inevitably encounters a number of diversified and complex problems.

In view of the outcome of the present investigations as well as of the obvious difficulty of surveying all the above-mentioned areas, an area of 67,000 ha has been designated to be irrigated either by gravity flow or pumping. Since the agriculture in the designated area is still in the infantile stage of development when compared with that in other cultivated areas of Cambodia, it may be said that a new pattern of development can be materialized that cannot be put into practice in advanced areas of the country.

Major items of the present investigations are as given below:

Outlook of topographical - geological - soil conditions.

Distribution of soil groups and classification of soils into 5 groups.

Sampling and analysis of 200 soil specimens.

Installation of water-gauges at 21 points and of rain gauges at 10 points; and observation of tributaries and collection of their hydrological data.

Collection and analysis of meteorological and hydrological data.

Condition of water use.

Present state of land use, and general situation of regional agriculture (e.g., agricultural know-how within each region, cultivation method of main crops, farm management, land use systems, and assessment of agriculture in the economy of the region).

Export and import of agricultural products, and present state of domestic markets.

Results of the above investigations were reviewed, which led to the preparation of a rough plan for agricultural development. This plan, however, is subject to changes according to the results of the next field investigations and to the data that may be collected in the future.

The map of the Sambor Irrigation Project Area available at present is not sufficient to serve as the basis for the future planning.

The Team therefore requested the Committee, prior to the commencement of investigations, to prepare a more detailed and complete map of the designated irrigation area.

1.8 Formation of Survey Team

The formation of the Survey Team was as follows:

Name	Assignment	Occupation	Duration
Koichi Aki	Leader	Dr. of engineering, Professor of Kanto Gakuin University, Former Director, Water Resources development Div., ECAFE	Nov 8 - 10, '64 Nov 20 - Dec 1,'64 Jan 4 - 20, '65
(General Affairs Group)			
Takeyuki Inada	General affairs	Director, Development Survey Div., OTCA	Jan 4 - 24, '65
Takayuki Arikawa	Electrical economy	Staff, Development Survey Div., OTCA	Nov 8 - Dec 7,'64
Yoshikazu Shiraishi	Fisheries	Chief, Nikko Branch, Fresh Water Fisheries Resources Laboratory, Fisheries Agency, Ministry of Agriculture and Forestry	Jan 10 - Feb 18, '65
Kensaku Takeda	Agriculture	Irrigation engineer, Agricultural land bureau, Ministry of Agriculture and Forestry	Nov 10 - Dec 4, '64
Keisuke Hisatake	Civil engineering	Staff, Technical Advisory Office, OTCA	Sep 6 - Oct 14, '64
Hiroshi Kimura	Liaison & accounting (dry season)	Staff, Development Survey Div., OTCA	Nov 7,'64 - Mar 8, '65
Masao Kuwabara	Liaison & accounting (wet season)	Staff, Development Survey Div., OTCA	Sep 6 - Oct 14,'64

Name	Assignment	Occupation	Duration
(Hydro Power Group)			
Hideo Matsuo	Civil engineering	Ass't Chief, Design Office, Electric Power Development Co., Ltd.	Jan 17 - 31, '65
Toichiro Sakaguchi	Electricity	Ass't Chief, Generation Sec., Electric Power Development Co., Ltd.	Jan 17 - 31, '65
Bunya Kanahara	Civil engineering	Staff, Design Office, Electric Power Development Co., Ltd.	Sep 13 - 26, '64
Tadashi Tamura	Civil engineering	Staff, Design Office, Electric Power Development Co., Ltd.	Sep 13 - 26, '64
(Transmission Line Group)			
Seiichi Teranishi	Transmission	Electrical engineer, Foreign Activities Dept., Electric Power Development Co., Ltd.	Sep 6 - Oct 10, '64
Kiyoshi Shimada	Steel tower	Ass't Chief, Transmission & Transformation Sec., Electric Power Development Co., Ltd.	Jan 17 - Feb 10, '65
Kensuke Yokoyama	Steel tower	Staff, Transmission & Transformation Sec., Electric Power Development Co., Ltd.	Sep 6 - Oct 10, '64 Jan 17 - Feb 10, '65
(Power Market Group)			
Tamotsu Saito	Power market	Chief Researcher, Research & Statistics Dept., Overseas Electrical Industry Survey Inst., Inc.	Sep 6 - Oct 5,'64 Nov 8, '64 - Jan 6, '65
Tamotsu Nakaoka	Power market	Director, Arakawa Hydro Electric Power Co., Ltd.	Nov 8, '64 - Dec 1, '64

Name	Assignment	Occupation	Duration
Tokugoro Miyashita	Power market	Research Officer, Resources Bureau, Science & Technology Agency	Sep 6 - Oct 5, '64 Nov 8, '64 - Jan 6, '65
Hidekazu Onishi	Power market	Secretary Technician, Public Utilities Research Sec., Public Utilities Research Bureau, Ministry of International Trade & Industry	Sep 6 - Oct 5, '64 Nov 8, '64 - Jan 6, '65
Shoichi Konan	Power market	Researcher, Research & Statistics Dept., Overseas Electrical Industry Survey Inst., Inc.	Nov 8, '64 - Jan 6, '65
Yoshiro Ishihara	Power market	Researcher, Research & Statistics Dept., Overseas Electrical Industry Survey Inst., Inc.	Sep 6 - Oct 6, '64
Hideo Takase	Power market	Staff, Development Cooperation Dept., Overseas Electrical Industry Survey Inst., Inc.	Nov 8, 1964 - Jan 6, '65
(Inland Navigation Group)			
Tadao Haruta	Inland navigation	Chief, Engineering Sec., Japan Ports Consultants, Ltd.	Dec 20, '64 - Jan 19, '65
Kazuhei Mineo	Hydrography & Geology	Ass't Chief, Engineering Sec., Japan Ports Consultants, Ltd.	Jan 17 - Feb 9,'65
(Agricultural Group)			
Shingo Ito	Farm management	Professor of Tokyo University of Agriculture	Nov 8, '64 - Feb 20, '65

Name	Assignment	Occupation	Duration
Masamoto Yasuo	Soil classification & Fertility	Staff, Technical Advisory Office, OTCA	Nov 8, '64 - Feb 20, '65
Tetsuo Kato	Irrigation	Chief engineer, Sanyu Consultants International, Ltd.	Nov 8, '64- Feb 20, '65
Yasuo Miyazaki	Soil classification & Fertility	Technical Officer of Agriculture, Resources Sec., Planning Div., Agricultural Land Bureau, Ministry of Agriculture and Forestry	Nov 8, '64- Feb 20, '65
Takashi Kawai	Irrigation	Engineer, Sanyu Consultants International, Ltd.	Nov 8, '64- Feb 20, '65
(Boring Group)			
Kaneo Matsuyoshi	Geology	Soil engineer, Hazama-Gumi, Ltd.	Dec 13, '64- Feb 18, '65
Yasuyuki Sasaki	Boring	Technician, Hazama-Gumi, Ltd.	Dec 3, '64- Feb 18, '65
Goro Kimata	Soil Analysis	Civil engineer, Hazama-Gumi, Ltd.	Dec 3, '64 Feb 18, '65
(Non-regular member)			
Hirofumi Shinozuka	Liaison	Non-regular staff of OTCA. Chief Representative of Nichimen Co., Ltd. Saigon Office	Joined the Team in the Project Area

2. HYDRO-ELECTRIC POWER

2.1 Field Investigations

2.1.1 Water Level and Discharge

Data on discharge, amount of silt carried by the river, precipitation, evaporation, etc. covering the period upto 1961 are obtainable from the hydrologic report compiled by Harza Engineering Co. of U.S.A.. As for the period after 1962, the Hydrologic Year Book published by the Committee serves to provide these data.

To supplement the water level and discharge observations performed at Kratie, the water level observation at 3 different points between Kratie and Samboc Rapids has been continuously conducted since September 1962. Fig. 2-1, prepared by plotting the water level at Sambor site and the discharge obtained from the rating curve at Kratie Gauging Station, shows the rating curve at Sambor site and may be considered to simultaneously indicate the tail water level for the proposed power plant.

2.1.2 Observation of Precipitation, Evaporation, Temperature and Humidity

At the request of the Team, the provincial office in Kratie of the Ministry of Public Works has undertaken to observe the precipitation and evaporation within its premises. The observation of temperature and humidity was performed daily at fixed time (9:00 a.m.) at Hotel Kam Hoa.

2.1.3 Investigations for compensation

As for the compensation for properties expected to be submerged in the reservoir area delineated on the basis of its back water calculation, the Team handed over to the Governor of Kratie Province a map of the reservoir area (1/20,000) and requested that investigations be made relative to such compensation and that appropriate measures be taken.

2.1.4 Material Test

To secure earth materials for the main dam, investigations were conducted over the ridges on Line 1 , and tests are being conducted in Japan on specimens collected during the field investigations.

In the proposed quarry area LQ-4 on Line 3 , investigations on the overburden were performed by excavating test pits.

The previous test revealed that the concrete aggregate of comparatively good quality can be obtained from the sand-bars downstream of Kratie. During the investigations of this time, therefore, specimens were collected by test pit excavations and brought back to Japan for laboratory tests to clarify the distribution of sand-bars up- and downstream of the above-mentioned sand-bars.

2.2 Home Office Works

2.2.1 Calculations and Analyses relating to Reservoir

a) Calculation of storage capacity

The calculation of the storage capacity utilizing the aerial map (1/20,000) resulted in 1,157.5 km^2 of reservoir area and $9,903 \times 10^6$ m^3 of total storage capacity at El. 40.00 m of the reservoir water level.

These figures indicate a decrease by 32% of the reservoir area when compared with the previously assumed $1,700 \times 10^6$ m^3 and a decrease by 35% of the available storage capacity ($1,100 \times 10^6$ m^3 at El. 40.00 m of maximum water level and 1 m of draw down) when compared with the previously assumed $1,700 \times 10^6$ m^3 (Ref. Fig. 2-2).

b) Calculation of reservoir back water

A topographic map (1/20,000) of the reservoir was utilized in back water calculation to delineate the area subject to back water influence.

In case of a flood with the discharge of 70,000 m^3/sec or 81,000 m^3/sec, the back water is expected, with the water level at Sambor dam site being maintained at El. 40.00 m, to reach as far as 65 km upstream of the dam site, but not further.

The discharge corresponding to the present water level of El. 40.00 m at Stung Treng is 6,340 m^3/sec, which makes it foreseeable that the backwater effect of discharge larger than this will not reach at Stung Treng even after the completion of the dam.

c) Correction of rating curve and Analysis of flood discharge

Additional data were utilized to correct the rating curve and the flood discharge at the dam site (Ref. Fig. 2-1).

Data used for correcting the rating curve covered the period from September 1962 to January 1965; and for the analysis of flood discharge, data for 26 years recorded during the period from 1933 to 1964 were made use of.

Further, the probable flood discharge tabulated below were obtained by stochastics on probable frequency of flood.

Probable frequency Once in	Flood discharge (m^3/sec)
100 years	73,000
200 "	76,000
500 "	79,000
1,000 "	81,000
10,000 "	88,000

d) Discharge during dry season

Five-day maximum discharge during dry season was picked up from the discharge record for 24 years registered during the period from 1933 to 1964, and the calculations of discharge against each 10, 5 and 2 years excess probability were made. Fig. 2-4, to be used for closing the main stream, was subsequently prepared by plotting values obtained by such calculations as well as the maximum and minimum values recorded in the past.

e) Estimated sand sediment

Sand sediment was estimated based on the data contained in the report of Harza Co. as well as in the Hydrologic Year Book published by the Committee.

Measurement of sand sediment has been performed at Stung Treng and Pakse, but hardly at Kratie. The estimation was therefore made utlizing the measurement record at Stung Treng.

As shown in Fig. 2-3, the amount of suspended silt against discharge is greater at Pakse by about 40% than at Stung Treng.

From the values given in Fig. 2-3, the estimated annual sediment discharges were obtained and broken down by month as shown in Table 2-1.

2.2.2 Selection of Dam Center Line

Based on the results of investigations conducted during FY 1962 and 1963, a comparative review was made on the two alternative plans, i.e., Line C Plan and Line C' Plan.

Since the electric energy expected to be generated by these two plans is considered to be the same, selection of the dam center line is dependent upon the construction cost.

To make a comparative study of the costs to be incurred by the construction of the two plans, results of soil tests performed for the earth-fill dam on Line 1 and Line 4 during the 2nd Phase Investigations were utilized in determining the dam section for each different quality of soils.

Further, rough designs were prepared for the power plant on Line C and Line C'.

Comparisons and studies mentioned above led to the conclusion that Line C' Plan would, in some measure, cost less than Line C Plan.

2.2.3 Temporary Diversion Channel

The capacity of the temporary diversion channel at the time of closing the main stream was studied on the assumption that the intake for the supplementary generators be utilized for this purpose.

2.2.4 Power Generating Facilities

The annual mean head has so far been utilized in computing the power generation and its output. In the case of Sambor Project, however, the efficiency drop of the water turbine during wet season can be minimized and a higher firm capacity maintained if the rated head for designing the turbine is close to that of the head during the flood season. Studies were therefore made with the rated head set at 20 m, 25 m, 27.5 m and 30 m.

The computation of power generation was conducted for a number of different cases in order to make economic assessement of each case. i.e., the case where the unit of generators is changed (5 - 6 - 7 - 8 generators), where the operation of 1 - 2 generators is suspended throughout the year excepting the flood season, and where the operation depth is changed (1 - 2 - 3 m).

Table 2-1 Sediment Discharge (No. 1) (Unit 10^3 ton)

year / month	1933	1934	1935	1936	1937	1938	1939
1	209	264	369	458	241	608	650
2	90	135	147	216	110	325	268
3	52	99	101	150	98	236	202
4	50	65	76	128	71	298	203
5	81	211	276	271	509	550	638
6	947	748	3,290	2,690	4,740	8,460	8,030
7	11,600	15,490	21,320	20,400	30,800	26,100	21,800
8	36,300	49,200	32,150	37,400	75,500	34,400	72,800
9	27,590	59,300	34,300	45,200	92,500	37,500	84,800
10	12,700	28,100	29,020	7,110	18,700	39,900	33,600
11	4,440	4,360	13,300	1,090	3,660	5,850	4,810
12	745	1,090	1,910	446	1,290	2,190	1,450
Total	94,804	159,062	136,259	115,559	228,219	156,417	229,251

year / month	1940	1941	1942	1943	1944	1946	1947
1	499	422	539	446	448	494	467
2	256	24	259	199	263	200	250
3	170	18	158	177	166	134	140
4	143	150	155	232	128	106	143
5	305	387	513	347	369	639	1,270
6	4,660	5,850	4,070	6,610	1,980	7,070	4,020
7	37,300	22,600	26,200	18,600	14,200	16,900	33,300
8	76,800	61,300	54,400	38,900	47,200	39,900	44,300
9	108,200	45,900	47,300	59,300	25,100	64,500	62,300
10	13,300	29,900	14,900	21,100	19,400	20,650	16,400
11	2,020	8,830	5,350	4,650	6,000	4,510	3,290
12	807	1,780	1,060	865	1,650	1,120	917
Total	244,460	177,555	154,904	151,426	116,904	156,223	166,797

Note: Sediment discharge = Silt content (P.P.m) corresponding to monthly mean discharge × Monthly total discharge

(No. 2) (Unit 10^3 ton)

year / month	1948	1949	1950	1951	1952	1953	1959
1	415	500	682	502	290	123	193
2	210	249	256	267	111	100	129
3	134	162	148	133	96	69	97
4	142	129	110	123	88	76	63
5	630	439	258	422	317	649	141
6	4,900	659	3,860	6,250	1,560	6,390	640
7	18,000	5,790	19,700	16,000	10,900	12,700	4,290
8	41,900	36,500	39,900	40,800	60,700	33,800	20,500
9	73,300	55,400	43,900	35,350	65,000	33,900	42,200
10	22,800	28,900	31,900	17,300	29,200	13,300	17,900
11	5,120	8,320	9,570	4,650	4,440	3,290	3,140
12	1,430	2,170	1,870	1,190	542	804	576
Total	168,981	139,218	152,154	122,987	173,247	105,201	89,869

year / month	1960	1961	1962	1963			
1	255	332	534	312			
2	152	169	277	156			
3	103	123	193	115			
4	55	116	140	92			
5	100	465	420	105			
6	1,180	7,820	6,370	2,840			
7	5,640	24,400	19,650	14,850			
8	48,300	49,200	42,600	52,400			
9	38,900	73,900	39,350	40,100			
10	24,800	47,600	18,670	14,800			
11	3,870	5,270	3,840	5,570			
12	1,046	1,280	847	1,410	Average		
Total	124,401	210,675	132,891	132,750	153,608		

Figure 2-1 Tail Water Level and Dischare Rating Curve

at Sambor Power Plant

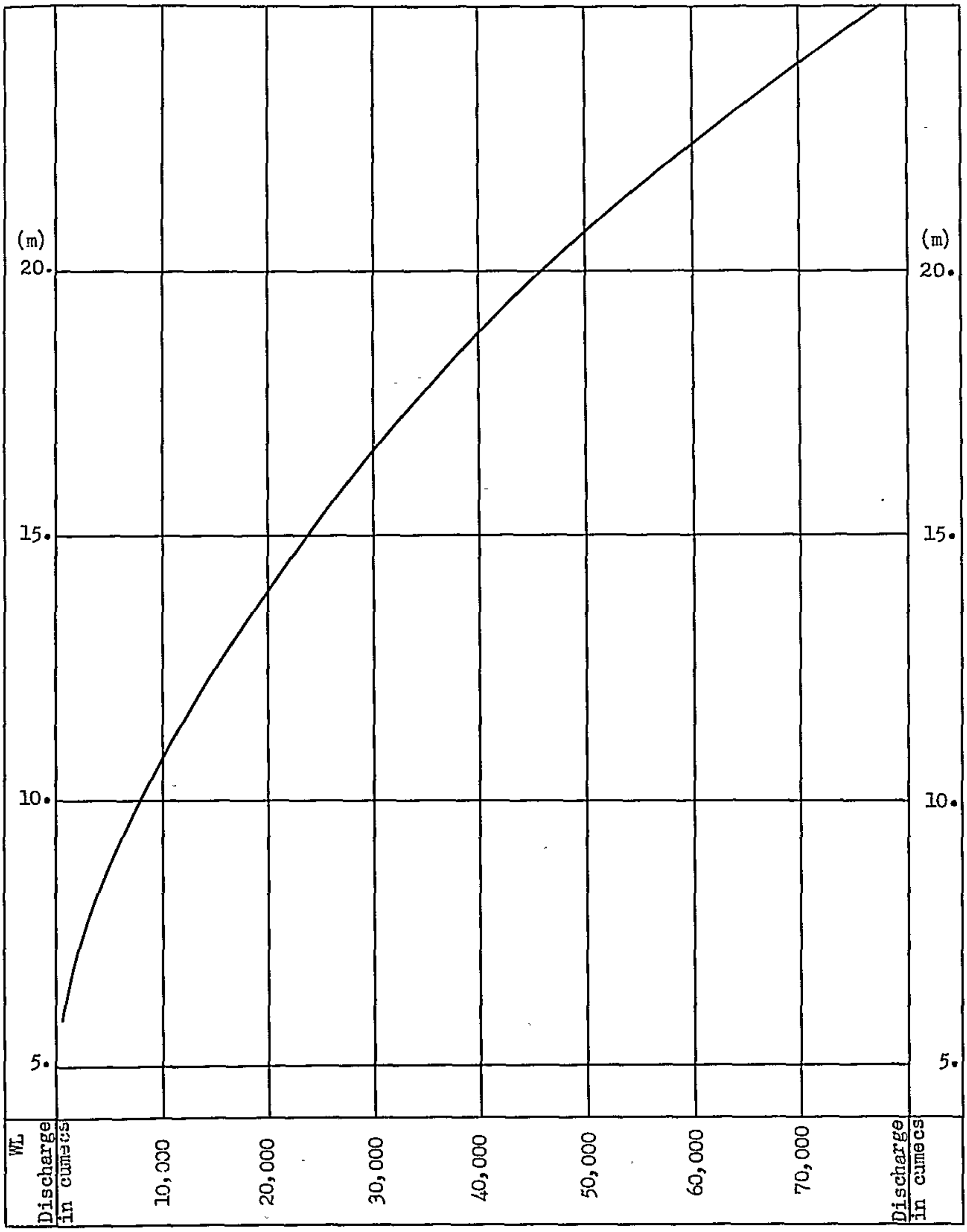


Figure 2-2 Area Capacity Curve of Proposed Sambor Reservoir

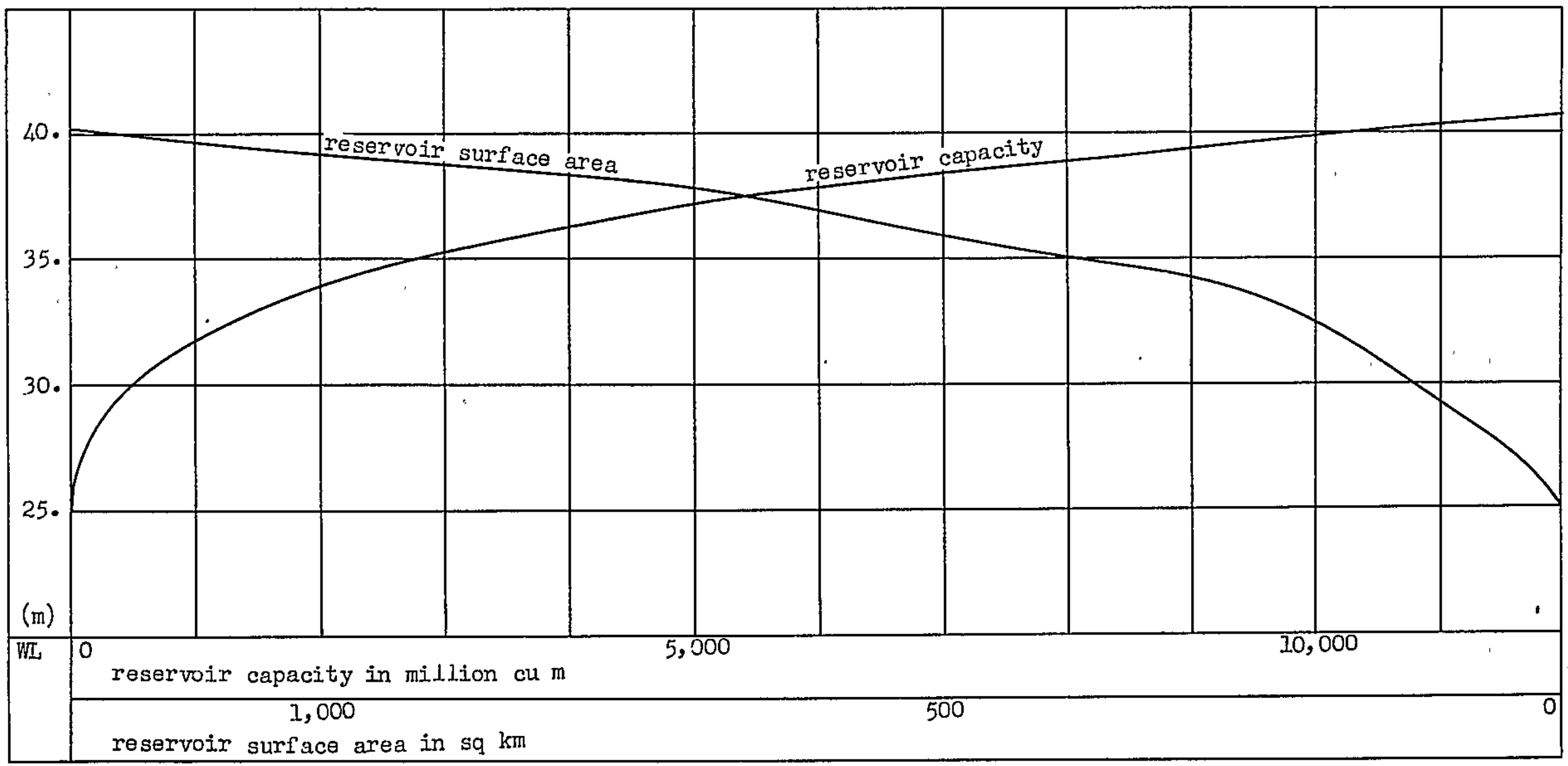


Figure 2-3 Silt Contents

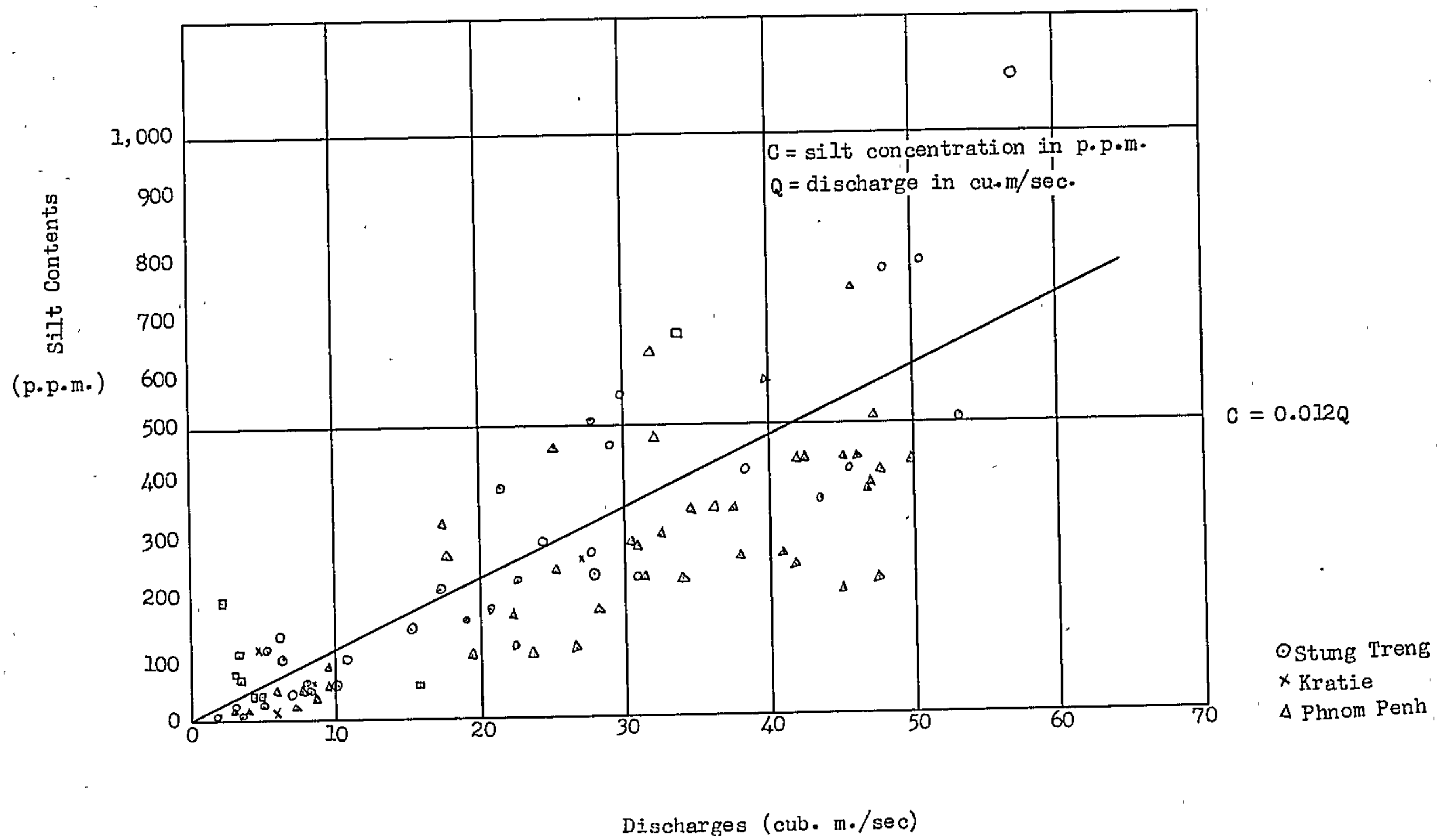
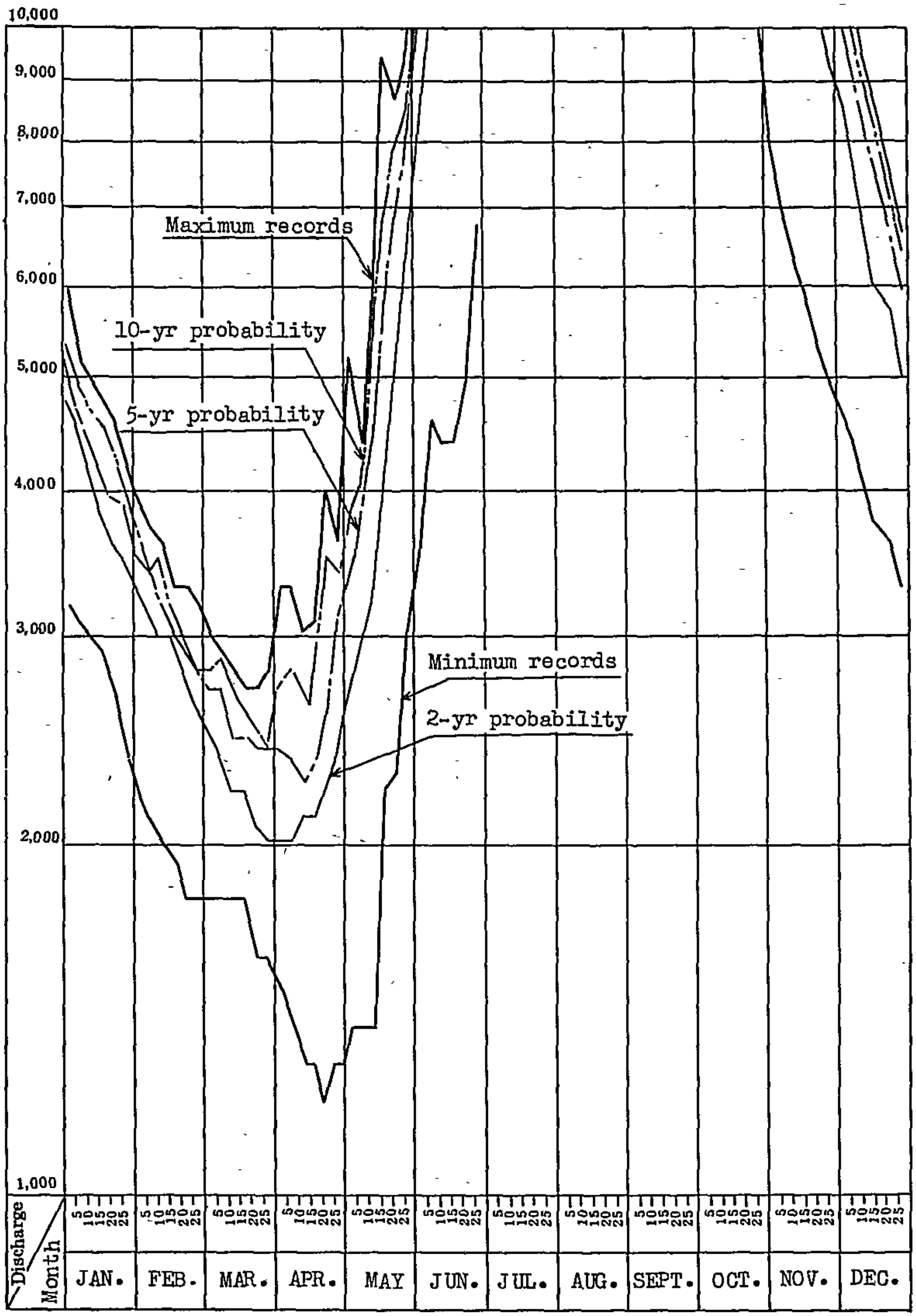


Figure 2-4 Probable Discharges
on the Mekong at Sambor Site



3. TRANSMISSION

3.1 Field Investigations

3.1.1 Reconnaissance of the possible routes of transmission line

On the basis of the reconnaissance carried out in 1962 and 1963, and under the presumption that the power output of the Sambor Power Plant is in the range of 600 - 750 MW and under the assumption that there will be a power demand of 150 MW in Phnom Penh, 150 MW in Sihanoukville, which is expected to be highly industrialized as a new port city, and 300 MW in Saigon, investigation and soil survey for the tower foundations (penetration tests) and collection of data necessary for designing have been conducted along the two routes of Sambor - Phnom Penh - Mahouly (Distance: about 350 km) and Sambor - Snoul - Saigon (Distance: about 230 km).

In view of the necessity of avoiding as much as possible the areas to be submerged in the rainy season when the Mekong overflows, aerial investigations were carried out for a total of seven days during the rainy season and the dry season.

3.1.2 Soil Survey for the Tower Foundations

Soil survey was conducted over the whole of the possible routes of the transmission line, for the reason that soil survey had much to do with the selection of the route of the transmission line, estimation of the construction cost, etc. (Viet-Nam was not included in this survey).

In the investigation of the soil, portable penetration test machine was employed to clarify the nature of the soils including the bearing strength, etc. in the layers about 10 m below the ground surface The investigation was carried out along the proposed route at selected points, i.e., 25 points for the survey in the rainy season and 19 points for the survey in the dry season.

The investigation placed emphasis on the difference in the conditions of the soils in the areas with paddy fields and low-lying lands. The investigation also concentrated on the difference in the conditions of the soils between the rainy season and the dry season and the distribution of the soils of small bearing strength. The results are shown below.

(a) Areas where the soil has enough strength

Sambor - Skoun	about 130 km
Kompong Speu - Sihanoukville	about 130 km
Sambor - Saigon	about 230 km

These areas are either hilly or mountainous and greater part of the areas are covered with dense or sparse forests. The nature of the soil is good containing soft laterite for a depth of about 1 - 2 m immediately below the ground surface and the part below is presumed to be formed of sandy soil, sandstone and others. The bearing strength is presumed to be about 60 tons/m^2 so that no special treatment or consideration will be required.

(b) Soft soil areas

Skoun - Kompong Luong - Kompong Taket	about 40 km
Phnom Penh - Kompong Speu	about 37 km

Most of these areas are with either paddy fields or highland fields with clayey soil. Portable penetration tests revealed that the bearing strength is about 20 - 30 tons/m^2 at about 3 - 4 m below the ground surface.

(c) Soft, swampy areas

Phnom Penh - Kompong Taket	about 20 km

These areas are low-lying swampy place consisting of paddy fields with water pools remaining in the dray season. The results of the penetration tests show that down to about 10 m from the ground surface, there is no layer with sufficient resisting power strength, and the bearing strength is no greater than 10 ton/m^2 so that it is considered that piling will be needed.

(d) The condition of soft soil area - its difference between the dry and rainy seasons

In the rainy season the areas described in (b) and (c) above are submerged in water and become like paddy fields or swamps, and access to these areas is impossible without the use of boat or barge. In the dry season, the surface soil is dry except for a part of the region between Phnom Penh and Kompong Taket. According to the penetration test, the soil for 2 m below the ground surface has a bearing strength of about 30 tons/m^2 and is therefore sufficiently hard to permit passage of motor car.

(e) Investigation in Viet-Nam

As regards the soil survey in Viet-Nam, observations were made in the vicinity of Saigon, but no penetration tests were actually performed. However, the surface soil was generally noticed to show little difference in nature from that in Cambodia.

(f) Penetration test

The results of penetration test are as follows.

a) Results of simple penetration tests during the rainy season along the possible route of the transmission line (Complete list of N-values obtained)

Location \ Depth (m)	1	2	3	4	5	6	7	8
1. Vicinity of Phnom Penh	5	21	27	(3.65m) 40				
2. "	30	(1.88m) 41						
3. "	26	(1.44m) 73						
4. "	36	9	14	13	(4.45m) 73			
5. "	(0.97m) 107							
6. "	28	8	9	18	23	22	28	14
7. "	29	11	12	15	10	13	10	(7.55m) 15
8. Vicinity of Kratié	4	6	6	7	13	16	16	10
9. "	32	(1.75m) 73						
10. "	(0.5m) 43							
11. "	(0.6m) 50							
12. Vicinity of Kompong Cham	(0.9m) 47							
13. "	11	26	(2.57m) 67					
14. "	46	26	(2.80m) 48					
15. Vicinity of Skoun	(0.65m) 69							

Depth (m) / Location	1	2	3	4	5	6	7	8
16. Vicinity of Skoun	9	11	12	16	25	(5.8m) 40		
17. Vicinity of Phnom Penh	7	9	26	23	(4.90m) 62			
18. "	8	195						
19. "	46	41	20	23	30	18	20	(7.65m) 17
20. "	7	8	16	13	16	20	26	(7.50m) 27
21. "	10	33	96	(3.15m) 99				
22. 30 km from Takeo	11	37	37	(3.40m) 129				
23. 50 km from Takeo	6	6	15	21	17	22	27	(7.20m) 25
24. Vicinity of Kompong Speu	5	4	4	8	5	(5.45m) 25		
25. Col de Pech Nil	6	8	9	12	38	(5.40m) 52		

b) Results of portable penetration test during the dry season along the possible route of the transmission line (Complete list of N-values obtained)

Location \ Depth (m)	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
1' Vicinity of Phnom Penh	7	17	31	38	(4.20 m) 222					
2' Vicinity of Kratie	18	9	6	14	16	31	14	44	14	(9.95 m) 243
3' "	20	(1.45 m) 550								
4' "	10	(1.05 m) 492								
5' Vicinity of Pram Peam	15	(1.55 m) 462								
6' Vicinity of Skoun	5	9	(2.30 m) 116							
7' "	12	9	24	13	47	(5.30 m) 73				
8' Vicinity of Phnom Penh	4	6	21	39	(4.90 m) 200					
9' "	60	(1.60 m) 270								
10' "	17	7	8	24	46	217				
	271	9	30	18	(4.85 m) 220					
12' "	600									
13' "	7	6	11	15	8	17	16	24	31	(9.80 m) 31
14' "	4	8	24	(3.25 m) 181						
15' Vicinity of point where route crosses the Tonle Sap	4	8	10	6	9	12	17	20	18	(9.50 m) 27

Location \ Depth (m)	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
16' Vicinity of point where route crosses the Tonle Sap	11	12	16	24	120	m (5.05) 258				
17' "	5	5	14	27	88	m (5.70) 287				
18' "	6	10	16	17	27	17	20	74	m (8.25) 157	
19' Vicinity of Phnom Penh	23	22	9	13	56	m (5.15) 170				

3.1.3 Collected Data

Data obtained in Cambodia are as follows.

(a) Thunderstorms in Viet-Nam (By courtesy of the Bureau of Meteorology, Viet-Nam)

days/month

Station / Period / Month	Qung-Tri	Hoang-Sa	Hue	Dr-Nang	Quang Ngai	Qui-Nhon	Tuy-hoa	Phan-Thiet	Saigon
	59-62	50-62	50-62	50-62	57-62	56-62	56-62	56-62	50-62
Jan.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
Feb.	0.0	0.0	0.3	0.4	0.4	0.2	0.2	0.0	0.4
Mar.	2.6	0.2	2.4	1.4	0.8	0.3	0.3	0.6	1.4
Apr.	6.9	0.9	6.9	4.5	3.8	2.7	2.7	3.0	8.2
May	15.9	1.7	14.3	11.2	11.6	7.5	5.7	9.0	17.6
Jun.	4.4	2.3	9.1	9.4	14.2	4.0	3.8	8.5	15.2
Jul.	7.2	1.0	11.1	8.0	12.5	5.2	4.0	6.0	11.4
Aug.	3.0	2.1	10.0	8.3	12.5	4.6	2.8	6.7	10.0
Sep.	3.7	3.1	7.3	7.6	11.1	8.2	4.3	7.6	10.2
Oct.	2.0	0.9	1.9	2.4	4.3	2.7	0.7	4.7	11.6
Nov.	0.5	0.0	0.1	0.2	0.2	0.4	0.2	0.1	4.6
Dec.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6

Month \ Period \ Station	Rach-Gia	Khant-Hung	An-Xuyen	Phu-Quoc	Con-Son	Plei-ku	Banme-thot	Dalat
	56-62	50-62	57-62	57-62	50-62	58-62	55-62	50-62
Jan.	0.3	0.1	0.4	0.0	0.1	0.0	0.0	0.7
Feb.	1.0	0.1	0.4	0.0	0.0	0.2	0.1	1.4
Mar.	6.8	0.6	2.8	1.6	0.1	4.1	2.5	4.8
Apr.	13.8	6.6	12.8	7.4	1.1	11.0	9.5	15.6
May	26.4	17.0	21.6	12.5	6.3	12.5	18.6	22.8
Jun.	11.4	14.7	14.8	3.7	5.9	7.1	14.0	14.0
Jul.	11.0	13.7	9.8	3.7	4.8	5.3	9.4	11.7
Aug.	8.0	8.9	8.6	3.4	3.4	3.3	7.5	10.8
Sep.	6.6	8.9	8.4	1.2	3.9	7.1	8.2	10.5
Oct.	10.6	6.0	8.8	3.8	3.6	7.6	4.7	8.8
Nov.	8.6	1.7	3.4	1.1	0.4	0.4	0.1	1.6
Dec.	0.9	0.1	1.4	0.6	0.0	0.0	0.0	0.1

(b) Thunderstorms in Cambodia (By courtesy of the Bureau of Meteorology, Cambodia)

	Phnom Penh	Siem Reap	Kampot	Stung Treng	Battam-bang	Kra-kor	Siha-nouk-ville	Kom-pong Cham	Svay-rieng
(1959)									
Jul.	6	13	4		1				
Aug.	8	1			4				
Sep.	3	2							
Oct.	4	1	5						
Nov.	11	7	5	4	8	4	7	3	6
Dec.	2	12	1			1	3		
(1960)									
Jan.									
Feb.		2	2		3		2		
Mar.	16	19	9		9		8	3	3
Apr.	15	9	17		13	3	13	5	2
May	22	13	22		16	5	10	8	
Jun.	13	11	5		5		7	1	2
Jul.	7	21	8		20		8	1	2
Aug.	6	11	3		12	1		2	
Sep.	19	15	14	1	14			3	1
Oct.	21	12	10		6	1	3	2	1
Nov.	17	15	10		4		2	1	
Dec.	4		2						
(1961)									
Jan.							1		
Feb.	5								
Mar.	13	15	2		9		3	1	1

	Phnom Penh	Siem Reap	Kampot	Stung Treng	Battam-bang	Kra-kor	Siha-nouk-ville	Kom-pong Cham	Svay-rieng
(1961)									
Apr.	17	11	2		14	2	2	6	3
May	22	15	5	12	8	1		5	5
Jun.	14	8	4	1	13		2	10	2
Jul.	9	6	2		11			2	
Aug.	17	9			6			3	
Sep.	22	13	4		9	6		5	1
Oct.	28	20	15	1	12	1	1	7	1
Nov.	24	7	17	4	21			6	
Dec.	10		5		8				
(1962)									
Jan.	1		1						
Feb.		1	1		3	1			
Mar.	8	2	2	6	13	9		6	1
Apr.	8	1	3	5	16	7		1	2
May	20	16	18	20	22	19	2	20	17
Jun.	13	2	4	19	19	16	1	18	13
Jul.	20	18	11	24	11	18		23	11
Aug.	16	10	10	11	22	18		24	13
Sep.	17	17	9	20	20	16		19	12
Oct.	26	14	18	19	21	22	3	25	18
Nov.	26	12	21	18	20	23		20	17
Dec.	3		3	3		1		2	3

	Phnom Penh	Siem Reap	Kampot	Stung Treng	Battam-bang	Kra-kor	Siha-nouk-ville	Kom-pong Cham	Svay-rieng
(1963)									
Jan.	1				1				
Feb.	2				4			1	
Mar.	11	10	1		10		1	1	3
Apr.	21	13	16		18	9	7	1	15
May	25	15	21		26	18		5	24
Jun.	18	10	12		22	14		3	14
Jul.	9	9	9		17	6		1	7
Aug.	19	18	11	7	17	21	2	1	16
Sep.	22	14	8	16	19	19		4	13
Oct.	25	15	21	18	21	9	2	14	16
Nov.	13	3	8	5	3	7		7	9
Dec.	3				1			3	1

(c) Maximum wind velocity recorded in Viet-Nam (By courtesy of the Bureau of Meteorology, Viet-Nam)

Unit: m/sec

	Saigon 50 - 62	Dalat 48 - 62	Vungtau 50 - 62	Rachgia 57 - 62	Hatien 30 - 39
Jan.	11	16	19	12	4
Feb.	10	16	19	9	4
Mar.	14	18	19	12	4
Apr.	11	16	19	9	4
May	14	13	19	12	4
Jun.	16	18	19	12	4
Jul.	18	16	16	12	4
Aug.	23	18	19	12	3
Sep.	15	15	16	12	5
Oct.	16	14	19	16	4
Nov.	13	16	19	9	5
Dec.	15	16	19	9	5

Remarks: The wind velocity may reach occasionally 25 - 40 m/sec in typhoon or thunderstorm.

(d) Maximum wind velocity recorded in Cambodia
(By courtesy of the Bureau of Meteorology, Cambodia)

Unit: m/sec

	Phnom Penh 59 - 63	Sieam Reap "	Battam-bang "	Stung Treng "	Kampot "	Siha-nouk-ville "	Kompong Cham "
Jan.	19	18	18	14	19	20	18
Feb.	18	12	18	12	17	16	18
Mar.	18	16	19	13	18	16	14
Apr.	14	12	16	13	17	16	16
May	18	17	30	10	19	18	18
Jun.	18	16	19	15	19	22	18
Jul.	31	19	18	13	17	21	16
Aug.	24	17	24	14	17	20	18
Sep.	21	12	13	19	17	18	14
Oct.	19	16	16	9	19	24	26
Nov.	17	12	23	13	19	16	16
Dec.	18	10	16	13	19	20	16

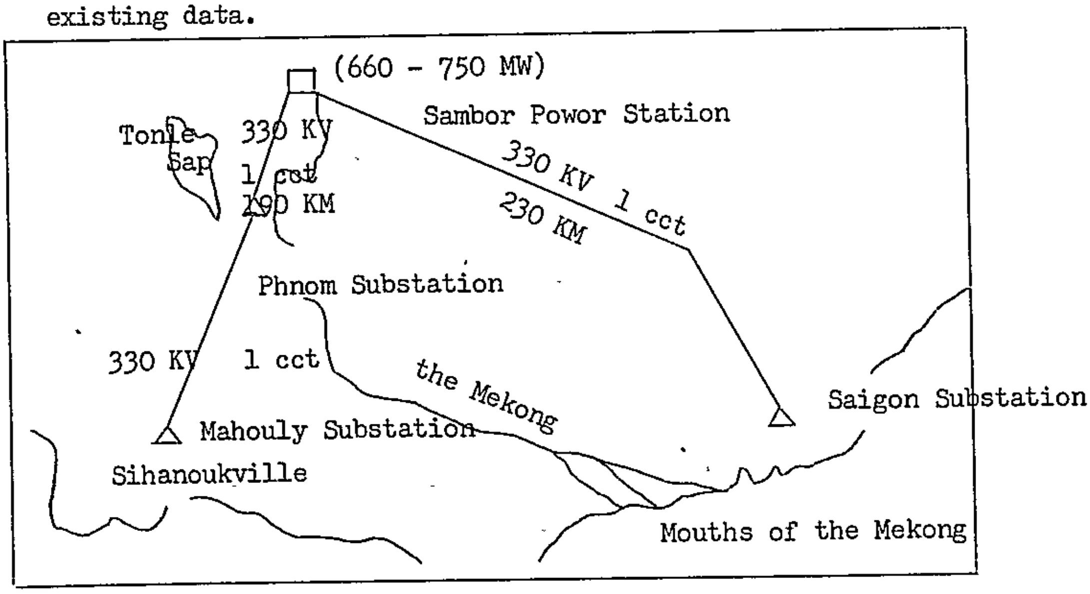
(e) Major communications system in Cambodia (By courtesy of the Central Post Office, Cambodia)

1. Phnom Penh - Kompong Speu - Sihanoukville	(1 cct line)	(With bare wire)
2. Phnom Penh - Kampot - Sihanoukville	(2 cct line)	
3. Phnom Penh - Skoun - Kratie	(4 cct line)	
4. Kompong Cham - Mimot - Kratie	(1 cct line)	(Only voice carried)
5. Skoun - Kompong Thom	(2 cct line)	
6. Kompong Thom - Siem Reap	(2 cct line)	
7. Phnom Dahm - Kompong Chnnang	(3 cct line)	
8. Kompong Chnnang - Pursat	(3 cct line)	
9. Pursat - Battambang	(3 cct line)	
10. Battambang - Sisophon	(2 cct line)	

Note: All these lines run along the roads.

3.2 Work at the Office

3.2.1 Study on the preliminary design prepared on the basis of the existing data.



No definite demand estimates being available and consequently the transmission capacity and voltage being undecided, a tentative transmission plan as shown in the above chart has been prepared.

Such being the case, this plan may happen to be modified to a large extent when the definite demand estimates becomes available.

3.2.2 Selection of the transmission routes

(a) Sambor - Phnom Penh - Mahouly

For the transmission line between Sambor and Phnom Penh, two routes were originally considered, one along the right bank of the Mekong and the other along the left bank. Upon aerial survey, however, the possible route on the left bank was found to pass through larger submersible area than would the route on the right bank. In the reconnaissance, therefore, the left bank route was omitted as it would be economically disadvantageous and the right bank route only was surveyed. For the section between Kompong Cham and Sambor, about 80 km, investigation was carried out in the dry season, as jeep was useless in the rainy season, during which parts of the road submerge in water.

As the result of the aerial survey and reconnaissance, the route was considered to pass the following points.

The route starting from Sambor passes Srok Roteh in the east, enters Bao Khnor by way of the east of Kohn Batong, and by way of Beng-Nay crosses Tonle Sap at Kompong Luong, and passing Oudong in the east enters Phnom Penh. It is to be noted in designing that there are rubber plantations along the route of this line between Kohn Batong and Sor Sen which are better be detoured.

There are submersible areas between Sam Koeup and the neighburhood of Phnom Penh, but if these points are to be detoured the distance of the transmission line would be very long. Therefore, it is better not to detour these areas but rather give special consideration in the design of the steel tower foundations.

Between Sambor and Kohn Batong there is an area of hilly land with elevations varying from El 50 to 100 m which comprises wild region of sparse forests and paddy fields. Paths for transporting lumber, which lie in comparatively large number in the forests, could be utilized for construction purposes.

As to the location of the substation in Phnom Penh, the town planning and industrial zoning for Phnom Penh were taken into account and the western suburbs of the city was selected.

The route from Phnom Penh to Sihanoukville will pass, parallel to the National Highway, the east of Kompong Speu, cross the Elephant Mountains (by Pech Nil pass), and will pass the east of Cham Ca Luong and reach Mahouly (which is located 30 km to the north of Sihanoukville) In selecting the location of the substation in Mahouly, salt pollution of the electrical insulation, industrial zoning, etc. were considered, but the main reason is that Mahouly is situated at a convenient point for both Sihanoukville and Kampot for which the industrialization is very imminent.

The route passes for most of its length plane area with paddy fields, except for the Elephant Mountains which are covered with virgin forests.

(b) Sambor - Saigon

For this route, except for the section between Sambor and Snoul and Saigon and its vicinities, no reconnaissance was carried out. The following route was designed based on the available maps and on information obtained by interviews with the natives.

Thus the route, starting from Sambor, crosses the road in the neighbourhood of Anchanh, passes the north of Snoul and the west of Loc-Ninh, and proceeds along the road until it reaches the Saigon substation.

What should be noted about this route is the fact that there is a large rubber plantation extending from Loc-Ninh to Bien Tay, and to avoid this the length of the route would have to be long so that it is considered economical to cross the rubber plantation at its central part along the railway.

As to the location of the Saigon substation, it is advisable to locate it at Vine Binh situated about 5 km north of Saigon, taking into account the fact that the industrial area is rapidly growing in the northern areas of Saigon and also the topographical conditions of that place.

3.2.3 Outline design

(a) Wind velocity

The Indo-China Peninsula is within the influence of the Asian monsoon and is subjected to the north-eastern monsoon in winter and to the south-western monsoon in summer. The typhoons which rise either in the Pacific Ocean or the South China Sea tend to take their courses in the western direction, and most of them reach the Indo-China Peninsula but hindered by the Annam Cordillera, lying in the east of the Mekong basin, their forces diminish and the wind velocity lessens to 30 - 40%. Thus, as shown in 3.1.3, the maximum wind velocity is as low as 30 m/sec at Phnom Penh and 23 m/sec at Saigon. It must be noted, however, that anemometers used in Viet-Nam are not of self-recording type and the measurements are made only at predetermined times so that the recorded maximum values are not the actual maximum values.

According to information obtained from the Vietnamese, the wind velocity rises to as high as 25 - 40 m/sec in the typhoon or thunderstorm.

(b) Measures against inductive influences on the telecommunication lines

The route of the transmission line was selected so as to pass along the road to save the construction cost. Moreover, since the transmission voltage is as high as 330 kV, the neutral point will be of direct earthing type and when one phase grounding occurs the earthing current will be several thousand amperes, so that the induced voltage of the communication line along the road will be very large. On the other hand, since almost all of the communications lines are bare wires, measures against induction should better be taken on the communication line. For instance, it would be more economical to install the lightning arresters to the communication line.

(c) Various factors for the design of the transmission line

(1) Voltage

The transmission voltage was selected on the assumption that 300 MW will be transmitted to Saigon, 300 MW to Phnom Penh.

In view of the transmission capacity, the transmittable voltage will be 230 kV with 2 cct, and 330 kV with 1 cct. The voltage level in Cambodia and Viet-Nam is at present 15 kV, and it is expected that 60 kV and 115 kV will be adopted in Cambodia and 60 kV and 230 kV in Viet-Nam.

The total power demands of both Cambodia and Viet-Nam being estimated not to exceed 1,200 MW even after completion of the Sambor Project, it is more advisable to adopt the transmission voltage of 230 kV which is already in effect in Viet-Nam rather than to start with an extra high voltage of 330 kV. However, this has the drawback of requiring the multi-circuit transmission line.

It was accordingly determined to proceed with studies for the design of transmission line under the presumption that the voltage will be 330 kV which is subject to modification according to the final power demand estimates.

(2) Design of insulators

Ball-and-socket-type suspension insulators (Size: 254 × 145 mm) will be used. In consideration of the expected switching surge by 2.8 times and of the voltage rise by 1.37 times in case of the line fault in commercial frequency, a set of 19 insulators, including 1 for stand-by use, is planned to be installed.

Measures against the salt damage will have to be taken in the vicinity of Mahouly since the district is situated near the sea.

(3) Conductor

The ACSR double conductor of 330 mm^2 will suffice for the proposed transmission line if the corona noise level of ACSR single conductor of 610 mm^2 - 250 kV adopted in Japan is taken as the standard. From the viewpoint of transmission capacity, the above conductor will make possible the transmission of 400 MW to Saigon and 450 MW to Phnom Penh.

(4) Designing against thunderstorms

As indicated in 3.1.3, thunderstorms are very frequent both in Cambodia and Viet-Nam, recording as many as about 90 days a year. It will therefore be required to provide 2 ground wires to the transmission line with a shield angle not exceeding 20° and to install the counterpoise.

(5) Design of steel tower

Basic conditions for designing the steel tower cannot be determined in detail until the final decision is reached regarding the transmission voltage, number of circuit, and the type of conductor. However, on the basis of the investigations conducted up to date, the supporting structures may safely be considered to comprise chiefly of the steel tower because of the extra high transmission voltage which will expectedly exceed 220 kV.

The structure of a steel tower is to be determined according to the basic electrical conditions, e.g., transmission voltage and capacity. In the present case, however, it will be appropriate to start with the design of the most economical structure for tangent suspension tower, inasmuch as the proposed routes run mostly through plane area and the tangent suspension tower is expected to constitute more than 90% of all the supporting structures required. In case of a single circuit of extra high voltage, therefore, the Guyed-Tower shown at the end of this chapter well deserves to be examined as a proposed structure.

In designing the steel tower, the standards of load conditions adopted in Japan may generally be applied, with the exception of the designed wind velocity of 25 - 30 m/sec. The foundation designing in the soft, swampy area in the vicinity of Phnom Penh will have to depend on the results of the penetration test, and will also require special consideration such as piling. It is to be noted that the aggregate construction cost will show a considerable fluctuation according to the span selection since most of the routes passes through plane land. It is therefore necessary that the best economical span be determined after careful studies.

(6) Outline design of transmission line

From the concept of the outline design described above, the following factors can be conceived of at present regarding the transmission line.

	Sambor - Phnom Penh - Sihanoukville	Sambor - Saigon
Distance	190 km + 150 km = 340 km	230 km
No. of circuits	1 cct	1 cct
Voltage	330 kV	330 kV
Steel tower	Horizontal arrangement	Ditto
Insulator	250 mm suspension insulator	Ditto
Conductor	330 mm^2 ACSR × 2 or 410 mm^2 ACSR × 2	Ditto
Ground wire	90 mm^2 GSC, 2 wires	Ditto

(d) Outline design of substation

As already mentioned, 1 substation with 300 MW capacity in the vicinity of Saigon, and 1 each with 150 MW capacity in the vicinity of Phnom Penh and the suburbs of Sihanoukville (Mahouly) are planned to be established.

At the Saigon substation, a main step-down transformer (Cap: 400 MVA) will be installed together with an autotransformer (Cap: 200 MVA; 330/230 kV) with the view to linking the Saigon and the existing Thu-Duc substations.

1 each of transformer to be installed at the Phnom Penh and Mahouly substations (Cap: 100 MVA and 200 MVA respectively) will be connected to the loop transmission system (Vol: 110 kV or 220 kV) which is being planned to link Phnom Penh - Prek Thnot - Kirirom -

Kam Chai - Phnom Penh.

The Mahouly substation, which has no power loads in its vicinity, will be equipped only with a transformer (Total Cap: 200 MVA) to be connected to the above transmission system, whereas the Phnom Penh substation will additionally have a step-down transformer (Cap: 200 MVA) in order to meet with the power loads in its vicinity.

(e) Outline of communication facilities

In order to ensure the despatching as well as the maintenance and operation of the Power Plant and substations, establishment of the following communication facilities is considered necessary.

(1) Communication facilities for despatching, and for the maintenance and operation of the Power Plant and substations

In order to establish the proper telephone circuit for despatching, and to secure the automatic telephone circuit for the maintenance and operation of the Power Plant and substations, the power line carrier telecommunication equipment and the automatic telephone exchanges will have to installed both at the Power Plant and substations. The power line carrier telecommunication equipment will also serve as the carrier relay equipment.

(2) Communication facilities for operation and maintenance of power line

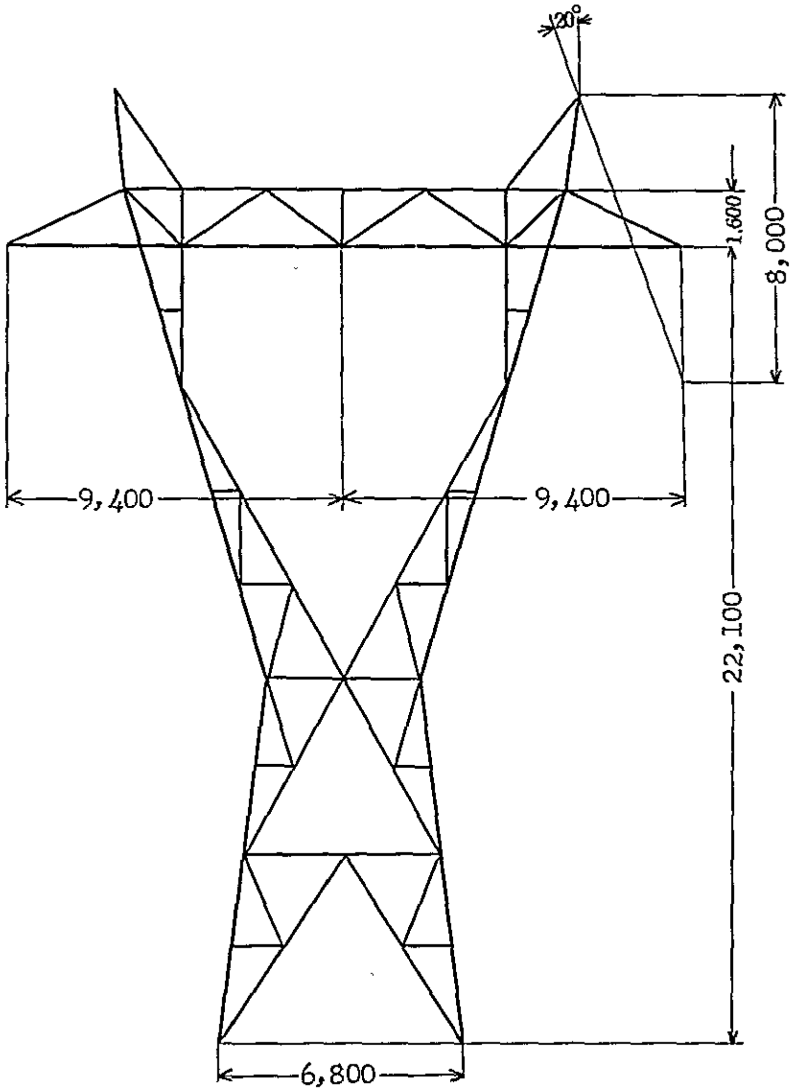
Base and mobile radio stations will have to be installed at the Power Plant and substations so that the communications for power line operation may be ensured; and the fault locator should be installed in view of the expected extra high transmission voltage and the long distance of the transmission routes.

(f) Estimate of construction cost

Studies are being made at present on the estimated construction cost for transmission line, substations and communication facilities on the basis of the results of field investigations and data collected.

Figure 3-1 Suspension Tower

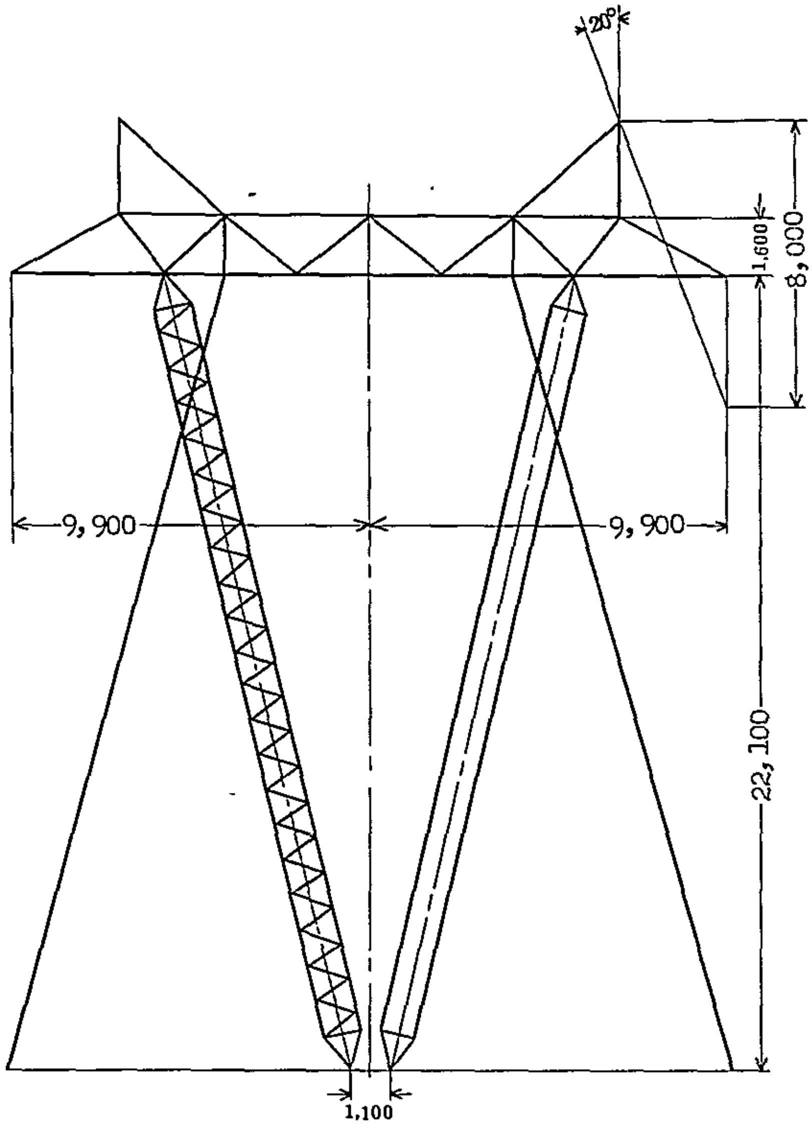
(Voltage 330 kv
Single circuit)



Scale 1:200
Unit mm

Figure 3-2 Suspension Tower

(Voltage 330 kv
Single circuit)

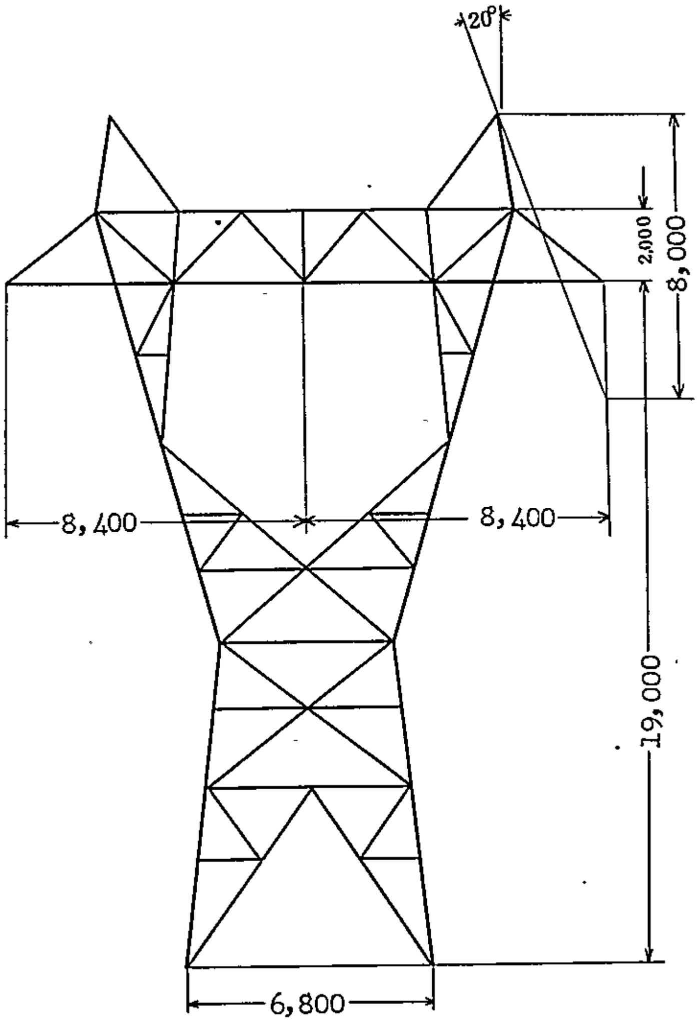


Scale 1:200

Unit mm

Figure 3-3 Strain Tower

(Voltage 330 kv
Single circuit)



Scale 1:200

Unit mm

4. ELECTRIC POWER MARKET

4.1 Survey of Present State of Electric Utility Industry and Private Power Installations

Based upon the results of field surveys conducted in both Cambodia and Viet-Nam and relevant information obtained during the First Phase Investigations as well as upon the additional data collected by the supplementary surveys carried out in FY 1964, the Team compiled basic facts and materials with regard to the present state of the electric utility industry in the two countries, to serve for estimating the future electric power supply and demand.

With regard to the private power installations, it was hardly possible to grasp their present state statistically due to the lack of data in both countries. Therefore, using fragmentary information made available by the two government authorities, and data obtained from the previous surveys conducted by private organizations, together with the information collected by the Team when the under-mentioned surveys of major plants and factories were made, the Team was able to grasp, to a substantial degree, the present state of the private power installations. This information was compiled into the above-mentioned basic facts and materials.

4.2 Surveys regarding Conditions for Economic Development

Needless to say that the trend of electric power demand is closely related to the growth of industries and economy and also to the structural transformation thereof. Therefore, when surveys are conducted of an electric power market, the actual conditions of various industries should first of all be investigated and based upon the results of such investigations, the relativity of the long range prospect of industrial and economic growth to the trend of electric power demand should be made clear.

From this point of view, the Team made surveys of the under-mentioned major industries in Cambodia and Viet-Nam out of those industries which closely affect the trend of electric power demand, and explored the operating conditions of the plant, siting conditions, and other outstanding problems including other conditions under which these major industries are placed. Results of these surveys were compiled into the basic facts and materials to be used in estimating the future power demand.

Major Industries which Underwent Investigations		
Kind of Industry	No. of Plants and Factories	
	(Cambodia)	(Viet-Nam)
Foodstuffs	4	3
Chemicals	-	4
Textile	4	12
Ceramics & Quarrying	4	-
Lumber & Wooden Articles	3	1
Metal Work	2	1
Pulp and Paper	1	1
Rubber	1	1
Electric Products	1	-
Public Utilities (Water supply)	1	-
Others	6	3
TOTAL:	27	26

However, because of restrictions placed on time and personnel, it was impracticable to conduct surveys in a wider range of industries than listed above. Therefore, the Team endeavoured to collect as much information as possible from other sources than the above-listed industries and made use of such information together with the results of the surveys to explore the present state of mining and manufacturing industries and their locational conditions, and assessed the future prospects of industrial development. Basic facts and materials covering these points were compiled later.

Alongside of this, the Team also endeavoured to collect as much information and data as possible concerning the industrial and economic activities of the two countries and attempted to grasp the present state of economy and to forecast the future possibility of development.

4.3 Survey regarding Heavy Electric Power Consuming Industries and Siting Conditions for Establishment

In view of the current scale of electric power demand in both countries, the electrical output obtainable from the Sambor Project is much too large to be absorbed solely by the growth of electric power demand that could be reasonably anticipated from the present electric power demand. Therefore, heavy electric power consuming industries should be taken into consideration as power consuming potentials at the time of completion of the Project.

The Team selected the prospective industries in Cambodia and Viet-Nam, giving due consideration to the existing natural and social conditions of these two countries which are to become the service areas of the Project and assessed the economic feasibility of these industries. Basic facts and materials covering these points were also compiled.

Further, regarding the siting for these heavy electric power consuming industries, the Team made research and studies. As a result, the Team drafted a general plan designating areas in the vicinities of Sihanoukville in Cambodia and of Saigon in Viet-Nam as proposed locations. Also, the Team studied the possibility of establishing industries utilizing electrolytic methods and electric furnaces, e.g., aluminium industry, carbide industry, chloric and caustic soda industry, together with the scale and arrangement of these industries. Basic facts and materials covering these points were also compiled.

4.4 Forecast of Long Range Electric Power Supply and Demand Situation

The forecast of the future general electric power demand in Cambodia and Viet-Nam was made on the basis of the following three premises, i.e., the long-term supply-demand balance as drawn up from the survey conducted in FY 1961, the outlook on the economic development formed as a result of the detailed survey in FY 1964, and analysis and review of various elements affecting the trend of electric power demand.

To make the above-mentioned forecast, the time series method was adopted: that is, the total electric energy requirements in the two countries were estimated from a) the requirements by the utility systems, b) the requirements by privite power installations, c) the requirements by regions and the requirements by the pattern of use. At the same time, a comparative study was made between the total requirements thus arrived at and the assumptive requirements inferred by a macroscopic method which was established in relation to economic indices.

Then, based upon the construction programme of electric power generation and transmission systems and the long-term prospect of such construction in the two countries, the Team estimated the power requirements of electric utilities to be supplied through the power systems assumed to be connected to the Sambor Power Plant when the Project is brought into operation in the years 1980 through 1985.

Further, the Team reviewed the hydro power potential in the two countries and its development possibilities together with the construction programme of hydraulic and thermal power plants and transmission lines in the two countries. Thus, the Team estimated the power supply capability of the above-mentioned systems.

Thus, the Team completed, in addition to the compilation of basic facts and materials, the long range forecast of electric power supply-demand balance in the prospective service areas of the Sambor Project.

5. INLAND NAVIGATION

5.1 Geological Investigations

5.1.1 Outline of Investigations

Investigations were conducted to study the geological features of the proposed routes of the navigating canal, chiefly through core boring tests as well as hand auger boring tests to obtain further information.

The bore length, the elevation of the surface ground, and the depth of the rock and silt layers of the various holes are given in tables 5-1 and 5-2.

Table 5-1 Core Boring Tests

No.	Bore Length	Elevation		Type of rocks
		Surface ground	Rocks	
Right bank	m	m	m	
DH 6401	30.00	+20.70	+19.35	Sandstone
Left bank				
DH 6402	10.00	+20.50	+12.50	Sandstone
DH 6403	25.00	+18.30	-4.20	"
DH 6404	5.00	+18.00	+14.50	"
DH 6405	8.00	+20.00	+15.55	"
DH 6406	24.00	+18.00	-3.60	"
DH 6407	30.00	+19.90	-8.60	Shale
DH 6408	12.00	+19.80	+10.30	Sandstone
DH 6409	10.00	+19.10	+11.80	"
DH 6410	10.00	+20.80	+14.90	Shale
DH 6411	7.00	+18.00	+15.70	Sandstone
DH 6412	6.00	+20.30	+16.40	Shale
DH 6413	20.00	+20.50	+5.35	Sandstone

Table 5-2 Auger Boring Tests

No.	Bore length	Elevation			Note
		Surface ground	Rocks	Ground water	
Right bank					
AH 6422	m 2.50	m +20.00	m +18.00		Sandstone
AH 6423	5.00	+20.00	-	m +16.00	
Left bank					
AH 6402	5.00	+19.00	-		
AH 6403	5.00	+19.00	-		
AH 6404	3.20	+19.00	+16.25	+17.30	Sandstone
AH 6404'	1.20	+19.00	-		
AH 6405	3.00	+20.00	+17.35		Sandstone
AH 6406	1.00	+24.00	+23.50		Shale
AH 6407	2.00	+19.00	+17.40		Sandstone
AH 6408	0.70	+20.00	+19.80		"
AH 6409	4.00	+19.00	-	+16.50	
AH 64010	0.80	+20.00	+19.80		Sandstone
AH 64011	0.70	+20.00	+19.50		"
AH 64012	3.00	+18.00	-	+15.20	
AH 64015	5.00	+19.00	-	+16.00	
AH 64017	5.00	+18.00	-		
AH 64018	3.00	+18.00	-		
AH 64019	5.00	+19.00	-		
AH 64020	3.50	+19.00	-	+17.50	
AH 64021	5.00	+19.00	-	+17.20	

5.1.2 Topographical Features

(a) Topography of the Right Bank

On the right bank downstream from the dam site, a road runs on the embankment of El. +22-23m along the river side. The road is neither paved nor well-maintained.

Between the dam site and a spot 20km downstream, two streams run into the river draining the water of the rear low lands, but the lack of adequate bridges obstruct the passage of motor cars across the streams

Several roads branch off in roughly perpendicular directions from the main road along the river bank to the Prek-Kah district. Lumber, charcoal and other cargo are transported by means of these roads.

Dwellings and charcoal factories are found along the road on the river bank, but compared to the left bank, the number is far smaller, decreasing as the road extends further northward.

To the rear of the dwellings, farm lands of El. +18-22m stretch out along the bank for a width of 500-1,500m, and the land is cultivated to a far larger extent than the regions on the left bank, and the agricultural products are conveyed to Kratie and Phnom Penh on the opposite bank.

To the west of the farmland lies a stretch of low marsh lands of El. +13-19m, subject to inundation during the wet season.

The former river road of El. +23-24m runs along the west side of the marsh lands thickly covered with trees and bushes at present.

(b) Topography of the Left Bank

Downstream from the dam site on the left bank, a road runs on the embankment of El. +22-24m along the river side. The road is completely paved and serves as an important route to Stung Treng.

Between the dam site and the town of Kratie, the Prek Kampi River and four other tributaries drain the rainfall of the area, but each river is equipped with adequate bridges for the convenience of traffic across the rivers. The basin of the Prek Kampi River is of a considerable area, while those of the other tributaries are relatively small.

Several roads wide enough for the passage of jeeps branch off almost perpendicularly from the main road, as well as numerous small trails for ox-cart traffic.

Dwellings are crowded along the road on the river bank with charcoal and lumber factories, but along the road for a distance of 1 km to the south of the dam site, and in locations 1 km north and 5 km south of Phnom Samboc, relatively few dewllings are to be found.

Rice fields of El. +19.5-20.0m stretch out for a narrow width of 200-400m to the rear of the dwellings. Low marsh lands of El. +16-19 m are found on the east side of the rice fields, covered with bushes and trees, and subject to inundation in the wet season.

Approximately halfway between the dam site and Kratie, lies a low mountain called Phnom Samboc, and the east foot of the mountain of El. +25-30m stretches out to the hills of El. +40m on the east side.

(c) Topography of the River

At the dam site, numerous rocks covered with trees are exposed in the river, but submerge under the water during the wet season. The water threads it way through the rocks during the dry season. Small rocks are scattered in the channel downstream from the dam site, marked with concrete signposts for the safe navigation of small boats. Stretches downstream from the vicinity of Phnom Samboc are free of rocks, but due to sand bars on the right bank, the water depth is quite shallow.

In the stretches approximately 3.5 km downstream from Phnom Samboc, the river becomes narrow and deep, with rock beds in two locations along the left bank. Near the town of Kratie lies the island of Kas Trong where the river is divided into two streams of extremely shallow depths.

5.1.3. Geological Features

From the present geological investigation and observations carried out in previous years, it has been revealed that the geological features of the right bank and the left bank of the river are of different characteristics, and the upper stretches and lower stretches of either bank also show varied features.

(a) Upper Stretch of the Right Bank

Observations at boring holes DH6316, 6336, 6319, and 6320 along the right bank of the spillway of the dam, reveal a surface layer of 2-10m consisting of clay or silty clay, under which there is a rock bed of sandstone or shale at depths of El. +13-22m. The deposit of rock beds at these depths constitute a marked characteristics of the geology of this area.

Lower downstream at boring holes DH 6321, 6323, 6324 and 6340, similar features were observed in the composition of the soil layers, with a thicker layer of clay on the surface, and the bed rocks found at depths of El. +7-14m.

(b) Lower Stretch of the Right Bank

At boring holes DH 6325, 6326 and 6339, a thick layer of sand or sandy silt is found at the surface with sandstones at depths of El. +5-15m. At DH 6338, observations reveal features common to both the upper and lower stretches, and the section across the river from Phnom Samboc may be considered as the boundary line between the upper and lower stretches of the river.

The surface layer of sand in the lower stretch is a deposit of a later period than the clay deposit in the upper stretch with a higher rate of permeability.

(c) Upper Stretch of the Left Bank

Observations at boring holes DH 6408, and 6409 at the intersection of Route G of the proposed canal and the dam, reveal that the surface layer consists of compact laterite clay, under which there is a layer of silty clay or silty sand, with a sandstone layer at depths of El. +10-11m.

Around the mouth of the Prek Kampi River, the bed rock is found at depths of El. +8.5-9.0m, while along the river banks 1 km further downstream, rocks are found at depths of El. +4.5-5.0m. However, in areas approximately 400-500m further inland, the bed rock is found at depths of El. +15-17m.

The marsh lands subject to inundation in the wet season are covered with a thin layer of organic clay on the surface. At boring holes DH 6410 and 6412 along Route G, similar features may be observed and a bed rock of shale is found at depths of El. +15-16m.

At DH 6402, and DH 6404, the bed rock is found at depths of El. +12-15m, while at DH 6413 on Route I, the depth is El. +5.5m, and El. +2.50m at DH 6344.

The laterite deposit in this region is dry with a small water ratio and is very compact. The laterite layer is assumed to be of an earlier deposit than the sand layer on the right bank.

(d) Lower Stretch of the Left Bank

The land on the east side of Phnom Samboc slopes out toward the eastern hills and rocks are found at depths of approximately 1-3m from the ground surface.

A hill of El. +26m with bed rocks at small depths is found approximately 2 km to the south of Phnom Samboc at DH 6411 in the vicinity of the hill, the surface layer is quite similar to that in the northern part of the left bank, and bed rocks are found at El. +15.7m.

Except in areas around these hills, bed rocks are found at greater depths.

At DH 6403 and 6406 on Route H, the upper layers consist of organic clay, laterite clay, silty-clay or clayey silt similar to the upper layer of the northern part of the left bank. At DH 6403 a layer of silty sand is found beneath these layers, while at DH 6406, the lower layer consists of sand with sandstones found at depths of El. -40m.

At DH 6407, the soil layers show the same tendency as observed at DH 6403 and DH 6406, but a sand gravel layer of 5m is found beneath the sand layer, and shale is found at El. -8.6m. The existence of sand and sand gravel beneath the layer of clay is a phenomenon which cannot be observed in the upper stretches of the left bank, indicating that different conditions may have prevailed in the early periods of soil deposit.

5.1.4 Soil Tests

A rough account of the results of soil tests of specimens collected by the thin walled sampler will be given in the following paragraphs.

(a) Water Ratio

According to the results of tests on the water ratio, specimens collected at boring holes drilled during the present survey generally showed very small ratios between 16-35%, the largest number of specimens with ratios of 22-23%, while very few showed ratios over 30%. Laterite near the surface layer is very compact with a low water content (16-27%). In holes bored with hand auger in the low marsh land, a relatively large water content was observed in the surface layer for a depth of 50cm, but the soil below was in a desiccate state. Forming an impermeability layer, the lower layers are not affected by the ground water. However, in the silty clay layer at depths of 8-12m from the ground surface, the water content increases to 26-32%, and 35-36% in the clayey silt layer at depths of 18m, but on the whole the water content is small.

(b) Specific Gravity

The specific gravity of soil grain is 2.49-2.68, the majority being around 2.60.

(c) Dry Density

Tests reveal values of 1.42-1.78gr/cm^3, with the largest number giving values around 1.63.

The large values of 1.75 and 1.78 belong to the laterite layers at depths of 5-7m from the ground surface at DH 6407.

(d) Void Ratio

The void ratio obtained was relatively small with values between 0.48-0.88, with the majority in the range of 0.55-0.69.

(e) Degree of Saturation

The degree of saturation of a large number of the specimens was over 90%, and the majority was nearly 100%, revealing that the soil is very compact.

(f) Plasticity Index

The liquid limit LL is 31-52%, the plastic limit PL is 15-23%, and the plasticity index is in the range of 14-32%.

(g) Grading

The majority of the specimens passed through a 2,000μ sieve with a record of 100%, a 420μ sieve with a record of 97-99%, and a 74μ sieve with a record of 78-97%, falling into the classification of clay particles.

(h) Uniaxial Compression Test

The uniaxial compressive strength qu range between 0.7-3.6kg/cm^2, Specimens obtained from the upper laterite layer possess an average strength of 1.86kg/cm^2, with a wide range of values. Specimens obtained from the silty clay layer showed strengths of 0.7-2.2kg/cm^2 with an average of 1.3kg/cm^2, and specimens from the lower layers of clayey silt are weaker, with an average of 0.75kg/cm^2.

In the case of remoulding, silty specimens show a decrease in strength with a sensitivity ratio of 1.3-10.0, while specimens of clay with a small water content, on the other hand, show an increase in strength with a ratio below 1.0.

(i) Standard Penetration Test

Standard penetration tests were applied in few cases as sandy soil was found in very few locations contrary to the original estimation.

In the surface layer of laterite deposit, at several spots, stamping was repeated 39-47 times for a penetration capacity of 30cm, and the value of N is generally high. In the silty clay layer at depths of 12-18m from the surface ground, the value of N 17-23, 14-67 in the silty sand layer and 35-43 in the sand and sand gravel layers.

5.2 Development of the Naviating Channel

5.2.1 Outline of the Inland Navigating Channel

The program for the development of inland navigation in relation to the Sambor Project must be determined in regard to the scale of the development program, and its effect on the economic development of the Mekong district. With the construction of a dam at Sambor, maintaining the water level in the upper stretchs at El. +40-39m, and connecting the surface of the lake and the lower stretches of the river with adequate navigation facilities, inland navigation may be extended as far as Stung Treng. The opening of a new navigating route will contribute largely to the economic well-being of the district, stimulating the development of forestry and other industries in the district.

However, until the completion of a dam at Stung Treng and several dams further upstream, the construction of the Sambor Dam will merely benefit areas in the vicinity of Stung Treng and the Ratanakiri district, and a drastic change cannot be expected in the development of the entire district.

On the other hand, the construction of navigation facilities at the Sambor Dam will involve an enormous amount of construction cost. The construction of a single dam at Sambor will not contribute greatly to the development of inland navigation at the present stage.

The program for the development of the Mekong Proper includes not only flood prevention, power generation, and irrigation, but also the development of economical transportation routes to stimulate the development of various industries along the river.

It is assumed that a large volume of natural resources remain undeveloped in the middle and lower basin of the Mekong in the territory of Laos, due to the lack of adequate transportation facilities or the high cost of transportation. The construction of a series of proposed dams on the Mekong Proper will open the way for economical means of transportation of various resources.

Navigation facilities at the Sambor Dam will contribute to the development of natural resources in the upper stretches beyond Stung Treng, paticularly to the development of mineral resources and forestry resources in the middle basin of the Mekong in the territory of Laos. The construction of the Sambor Dam may be considered as the first step in the program of a large scale development of the district to be expected in the future, and the purpose of the construction of the Dam will materialize only when the dams in the upper stretches are completed in the future, and favorable effects to any large extent cannot be expected during the intermediate period.

Therefore, the improvement of navigation from the construction of the Sambor Dam must be considered in relation to the convenience to be enjoyed in the river basin area, and the total cost of the construction of navigation facilities. With various uncertain factors involved, it is extremely difficult to draw any conclusion on the problem.

Moreover, the scale of navigation facilities at the Sambor Dam must be determined in relation to all dams to be constructed in the future, and planned to meet the demand of transportation in the countries along the river. However, as there will be intervals of long periods between the construction of each dam, the scale of the Sambor Dam program must be determined after careful study of various problems involved.

The program may be divided into two stages from the standpoint of the period of construction and the cargo traffic to be expected.

1. Cargo traffic to be expected in the period following the construction of the Sambor Dam (The First Stage of the Program)
2. Cargo traffic to be expected in the period following the construction of several dams along the Mekong Proper.
   (The Second Stage of the Program)

There is a wide difference in the amount and type of cargo to be expected in the two stages, and navigation facilities to meet the demand of each program will naturally be of a different scale. The scale of facilities to be constructed at the Sambor Dam should be determined upon estimating the cost of construction and studying the advantages and disadvantages of the two programs.

The following factors must be studied in drawing plans for the navigation facilities.

1. Cargo and passenger traffic
2. Navigation traffic
3. Plan of the canal and locks
4. Excavation of the canal
5. Construction of locks
6. Construction of bridges
7. Dredging works

5.2.2. Future Cargo and Passenger Traffic

(a) Traffic to be expected in the First Stage of the Program

Cargo traffic to be expected in the period following the construction of the Sambor Dam and before the beginning of any works on other dams on the Mekong Proper may be expected to be of the following scale.

Under the present conditions of the river, difficulties in navigation are encountered even in the wet season, with hardly any traffic in the dry season, but the construction of the Sambor Dam will open the river to navigation throughout the year as far as Stung Treng. Beyond Stung Treng on the Mekong Proper, the river will be navigable as far as the Khone Falls (approximately 50 km) in the wet season, but vessels will not be able to go further upstream. The tributaries of the Se Kong and Srepok will be open to navigation in the wet season.

Therefore, the following products may be considered to depend on water transport in the future.

i. Cargo to be expected from the industrial development of the basin of the main river and tributaries beyond Kratie.

ii. Cargo transported overland between Stung Treng and Kratie at present may be turned over to water transport.

Forestry products, agricultural products, mineral output, and goods manufactured from these raw materials will be included in the former traffic, the majority of which will probably consists of forestry products.

The latter group will include foodstuffs, household utensils, and daily necessities, and the amount of cargo to be transported will probably increase in proportion to the increase of population and the higher standard of living to be expected in the future.

Forestry Products

At present forestry resources are abundant in Cambodia, and the government controls the cutting and sale of trees in the national forests. 200,000-400,000m^3 of lumber are produced from 8,800,000ha of forests per year, 15-20% of which come from the Kratie district.

In the future, the increase of population and a gradual change in the economic structure of the country with the development of various industries which will contribute to raise the standard of living, will inevitably increase the demand for forestry products. The Stung Treng district and the upper basin rich in forestry resources will be easily reached for development by the construction of the Sambor Dam, and the lumber will be carried down the tributaries, pass through the dam to the regions in the lower reaches. The amount of cargo traffic may be assumed to be about 50,000-150,000m^3, judging from the volume of lumber produced at present.

As the Stung Treng district is isolated from transportation routes at present, the production of charcoal is limited to 20 tons to provide for local consumption. The construction of the dam will provide means for transportation of charcoal to the lower regions, and factories may be established to produce charcoal on a larger scale.

In the Kratie district, lumber for the production of charcoal is transported over a distance of 15-40 km from the forests, and the overland transport cost amounts to 20-80 riel per 1m^3. At Stung Treng, as lumber may be obtained from forests in the vicinity, the water transport will not involve a long distance, so that even though the transport cost may somewhat exceed the overland transport cost, on the whole, lumber may be supplied at approximately the same price as lumber supplied to charcoal factories in Kratie. In Cambodia, the manufacturing of charcoal will be a promising industry as the demand for charcoal is expected to increase in the future.

The volume of charcoal which will be transported across the dam may be estimated to be between 7,000-15,000 tons, judging from the domestic production.

Agricultural Products and Mineral Output

Agricultural products and mineral resources have not been developed to any extent in the Stung Treng district, with slight prospects for the future, but the gradual increase of the population will necessarily call for a larger production of agricultural commodities and mining of mineral ores in the area.

The agricultural production cannot be expected to exceed the needs of the people in the district and be transported to other districts in large quantity. A very small amount of zircon and other stones are extracted from deposits in the Ratanakiri district, but further development of mineral resources will depend on future prospecting.

Daily Necessities

An estimate of cargo traffic in regard to daily necessities must be based on the study of the future population of the district. The present population of the entire country of Cambodia and the various districts of Kompong Cham, Kratie, and Stung Treng is given in Table 5-3. The population is scarce in districts to the north of the province of Kratie, and the population of the three provinces of Kratie, Stung Treng and Ratanakiri is merely 4% of the total population of the country. The population of Cambodia has been increasing at the rate of 3% per year since 1948, and in the past several years, it has shown an increase of 4-5% per year.

Table 5-3 Population (1962)

Location		Population	Density
Cambodia		person 5,740,000	person 31.7/km^2
Phnom Penh	(town)	403,500	
Kompong Cham	(province)	819,200	83.6
Kompong Cham	(town)	27,977	
Kratie	(province)	126,200	11.4
Kratie	(town)	11,908	
Stung Treng	(province)	34,500	3.1
Stung Treng	(town)	3,369	
Rattanakiri	(province)	49,340	4.6

In the event the population of the country of Cambodia increases to twice the present number, the rate of increase will vary according to the province, with a larger rate of increase in the province and towns with active industries, and a relatively low rate of increase in districts further north of the province of Stung Treng where the increase of population may be estimated to be 1.3-1.7 times the present figures.

In calculating the amount of daily necessities expected to be transported in the future, the future population will be assumed to 1.5 times the present number in the provinces, and 2 times the present number in the towns. The future population may be assumed to be as given in Table 5-4.

Table 5-4 Future Population

Location		Population
Kratie	(province)	190,000 persons
Kratie	(town)	23,000
Stung Treng	(province)	52,000
Stung Treng	(town)	7,000
Rattanakiri	(province)	75,000

According to Table 5-4, the future population of the town of Kratie will be approximately 80% of the present population of Kompong Cham, the population of the town of Stung Treng will be approximately 60% of the present population of the town of Kratie, and the total population of the provinces of Stung Treng and Rattanakiri will be approximately the same as the present population of the state of Kratie.

Considering the roles that the towns will play as ports of call following the construction of the Sambor Dam, Kratie which serves as the terminal of the navigation route at present will become an intermediate port of call, and Stung Treng will become the new terminal port of the route, with the states of Stung Treng and Rattanakiri as the hinterland. When a series of dams are constructed in the upper stream, Stung Treng will become the base for traffic with Laos, playing a new role in the transportation system.

In the future, it may be assumed that the scale of the port of Kratie will be 50-80% of the scale of the present port of Kompong Cham, and the port of Stung Treng will develop into a port with a scale of 60-80% of the scale of the present port of Kratie.

Assuming that the daily necessities to be transported, excluding the afore-mentioned lumber and charcoal, will be 0.2-0.3 tons per person,

	persons
Population in the hinterland of Stung Treng	127,000
	tons
Amount of daily necessities to be transported	25,000-38,000
Cargo to be transported through navigation routes (80% of the total cargo)	20,000-30,000 tons

Passenger Traffic

With the construction of the dam, a navigating channel will be developed for transport vessels as far as Stung Treng. At present the bus fare from Kratie to Stung Treng is 60 riel, while transport vessels will probably charge 25-30 riel. However, a certain number of passengers is expected to take the bus route as the time required by bus is about one half of the time that will be required for the journey by boat.

Of the passengers arriving at Kratie at present, approximately 80% come by boat and 20% arrive by bus, and the ratio is not expected to be changed to any large extent in the future. Today the number of passengers landing in the port of Kratie is estimated to be approximately 150,000 persons per year, and in the port of Stung Treng, the number of passengers disembarking may be estimated to be 60-80% of the above figure in the future. Therefore the total number of passengers arriving and departing from the port will be 180,000-240,000 passengers.

The cargo and passenger traffic expected to pass through the Sambor Dam in the first stage of the development program may be estimated as given in Table 5-5.

Table 5-5 Traffic in the First Stage of the Development Program

Type of Cargo	Volume
Lumber	50,000 - 150,000 m^3
Charcoal	7,000 - 15,000 ton
Daily necessities	20,000 - 30,000 ton
Total	80,000 - 200,000 ton
Passengers	180,000 - 240,000 person

(b) Traffic to be Expected in the Second Stage of the Program

In the upper streams beyond the Khone Falls, as reefs are found in several spots, and very swift currents prevail in one stretch, the waters are closed to navigation except for small boats running between short distances.

With the construction of a series of dams on the Mekong Proper, provided with necessary locks, vessels will be assured of safe navigation as far as Vientiane, the capital of Laos. The district beyond the Khone Falls as far as Vientiane is an undeveloped area, very scarcely populated, with a trunk road running along the river as the sole means of transportation.

Though the middle basin of the Mekong Proper is rich in forestry resources, the district has not yet been greatly developed due to the difficulty of transportation.

Mineral resources such as gold, copper, lead, tin, iron, coal, plaster, and rock-salt are known to exist in this district, but have hardly been exploited.

The problem of transportation has obstructed the mining and processing of the minerals, but the development of water transport at a low cost will greatly help to develop the resources on an economical basis.

From the topography of the area, and the distance involved, products coming from the vicinity of Vientiane will probably be transported to Bangkok over land for economical reasons. The development of the water transport along the Mekong will be of advantage for the transportation of forestry products and mineral output in the Tahkek, Savannakhet, and Pakse districts.

Sufficient prospecting has not been carried out to ascertain the exact amount of mineral deposits, but recently investigations are under way and the necessary information will gradually be available.

Therefore, the calculation of the amount of cargo expected to be transported in the future will be based on figures given in the Flood Control Series No. 12 of the ECAFE Report. The amount of cargo to be transported along the Mekong Proper may be estimated as given in Table 5-6.

Table 5-6 Traffic in the Second Stage of the Development Program

Type of Cargo	Location	Volume (ton)
Ammonium sulphate		520,000
Aluminum	Khone	45,000
Alumina	"	90,000
Tin	Pakse	1,500
Lead and zinc	"	10,000
Bronze		10,000
Paper pulp		1,000,000
Soda ash		115,000
Coal		590,000
Teak	Coast	60,000
Miscellaneous goods	"	158,500
Lumber	"	2,000,000
Total		4,800,000

5.2.3 Canal Routes and Lock Sites

(a) Outline of the Plan

In constructing a dam in a river, and providing for navigation by a lock, the lock is generally constructed at the intersection of the dam axis line and the lower bank of the river. However, in the case of the Sambor Dam, it is difficult to apply this general principle because,

i. In the river road downstream from the dam, to Phnom Samboc, reefs of El. +6-10m are scattered in the water, and protrude above the water surface in the dry season. In order to assume safe navigation to vessels throughout the year, the reefs must be removed to maintain the necessary depth of water below the lowest water level, and the reefs are found over a distance of 6 km. The removal of the reefs in the muddy water will be extremely difficult involving a large increase in the cost of construction and period of time required.

ii. Even in the case the dredging works were completely carried out, as the spillway is to be located on the right bank of the river, the water between the dam and the spillway outlet will be still, likely to cause an accumulation of sand and silt in the wet season, decreasing the depth of the navigable channel.

For reasons mentioned above, it is not advisable to pass vessels into the river bed immediately below the dam through a lock, and the following plan will be a more advisable solution to the problem.

A lock will be installed on the right or left bank of the river in the dam, and a canal will be excavated on either bank of the river downstream from the dam, with another lock installed at an exit in a location which will not require difficult dredging and construction works. The excavation of a canal on land will be easier with more reliable results than the dredging of reefs in the river.

Therefore vessels sailing down the river will take the following course.

Lake-lock on the dam axisline-canal-lock on the river bank-river road.

(b) Plan of Canal

As shown in the attached drawings, three plans have been drafted for a canal on the left bank, and three plans for a canal on the right bank. Considering the topography of the area, the locations have been selected so that the dredging of reefs in the stretches of water leading to the lock on the river bank will be unnecessary or of the minimum degree.

Route D.

The canal will be excavated along the training wall on the landward of the spillway on the right bank, and locks will be installed at either end of the canal. The length of the canal will be 2.5 km.

Route E.

The canal as proposed in Route D will take a turn near the downstream end, and run parallel to the river bank approximatelly 150-200m west of the road on the levele, and a lock will be installed about 8 km downstream from the dam. The length of the canal will be 7.4 km.

Route F.

The canal will follow a route similar to that proposed in Route E, but will be excavated further inland approximately 650m west of the road, and the lock will be installed about 1.8 km further downstream. The canal will extend over a distance of 9 km.

Route G.

From the lock at the dam axis on the left bank, the canal will be excavated approximately parallel to the river bank at a distance of 400-500m, bending its course in two or three sections, pass through the low hills on the east foot of Phnom Samboc, and turn to the west south direction. The lock on the river bank will be installed approximately 11 km downstream from the dam. The length of the canal will be approximately 11.3 km.

The canal will cross the Prek Kampi River and two small tributaries, but the outlets of the rivers will be blocked up, and a small lake will be provided for in the north of Phnom Samboc. As there are no tributaries to the south of Phnom Samboc, embankments of standard width will be constructed for the canal.

Route H.

As the canal proposed in Route G runs into a hill of El. +26m approximately 1.5 km south of Phnom Samboc, according to Route H, the canal will evade the hill, deviate its course towards the river bank and join the river at the same location as proposed in Route G. The length of the canal will be 12.5 km.

Route I.

The canal proposed in Route G will take a turn to the west with the lock on the river bank approximately 1 km north of Phnom Samboc. The length of the canal will be 6.5 km. Vessels will pass through the lake which will be formed by blocking the flow of the tributaries.

Problems to be studied in comparing the advantages of the various routes will be,

i. Geological features

ii. Difficulty of construction works

iii. Cost of construction

iv. Difficulty of navigation

v. Effects on dwellings and other properties

vi. Miscellaneous problems.

The details of each problem will be studies later in relation to the design of the structures, and a brief outline of the problems involved will be stated in the following paragraphs.

i. Geological Features

A rock bed or a good gravel sand layer at a suitable depth will be desirable as the foundation of the lock. At the lock site on the dam, the layers will be found at desirable depths on the right bank, while on the left bank, they will be found at slightly greater depths. At the lock site on the river bank downsteam, the rock bed on the right bank will be found at lower depths, while at the site proposed in Route D, the rock bed must be removed to acquire the necessary depths.

In the excavation of a canal, rock beds found in upper layers will increase the cost of construction. On the whole, rock beds on the right bank of the upper basin are found in upper layers, calling for the removal of rock beds in excavating the canal, and along the left bank of the upper basin, rock beds must also be removed in certain sections. On the left bank in the lower basin, canals, proposed in Route G and Route H run into rock beds.

In excavating a canal, a surface layer of laterite is more desirable than sand as dry work will be possible. On the right bank of the lower basin, the surface layer consists of sand. For dredging works, it is desirable that the river will be free of rock beds. Route D and Route I will involve a small amount of dredging of rock beds.

ii. Difficulty of Construction

The difficulties to be encountered will depend on the above mentioned geological features, and difficulties in transporting construction material. The inundation of the low areas in the wet season will also be a problem for future study.

iii. Cost of Construction

The cost of construction will include the cost of constructing the canal and locks, bridges, roads, and dredging works.

Following the construction of the dam, as the minimum outflow from the dam will be larger than the present minimum discharge of the river, the water level in the dry season is expected to be higher. The dredging program must be planned on the basis of the lowest water level to be expected in the future.

The construction of roads and bridges may be necessary to avoid any inconvenience to transportation from the construction of the canal.

iv. Difficulty of Navigation

The velocity of the current will increase in the wet season, particularly in the narrow stretches of the river approximately 8 km downstream from the dam. The velocity at the center line of stream is assumed to be about 5 knots, and small vessels may encounter some difficulty in navigating upstream the river in the cases of Route I and Route D.

v. Effects on Dwellings

The construction of the canal and locks may cut off roads, call for the removal of dwellings, and take up dwelling lots and farm lands. Transportation may become very inconvenient in certain sections. These problems must all be taken into consideration in determing the route of the canal and the site of the locks.

Figure 5-1 Location of Proposed Navigation Canals

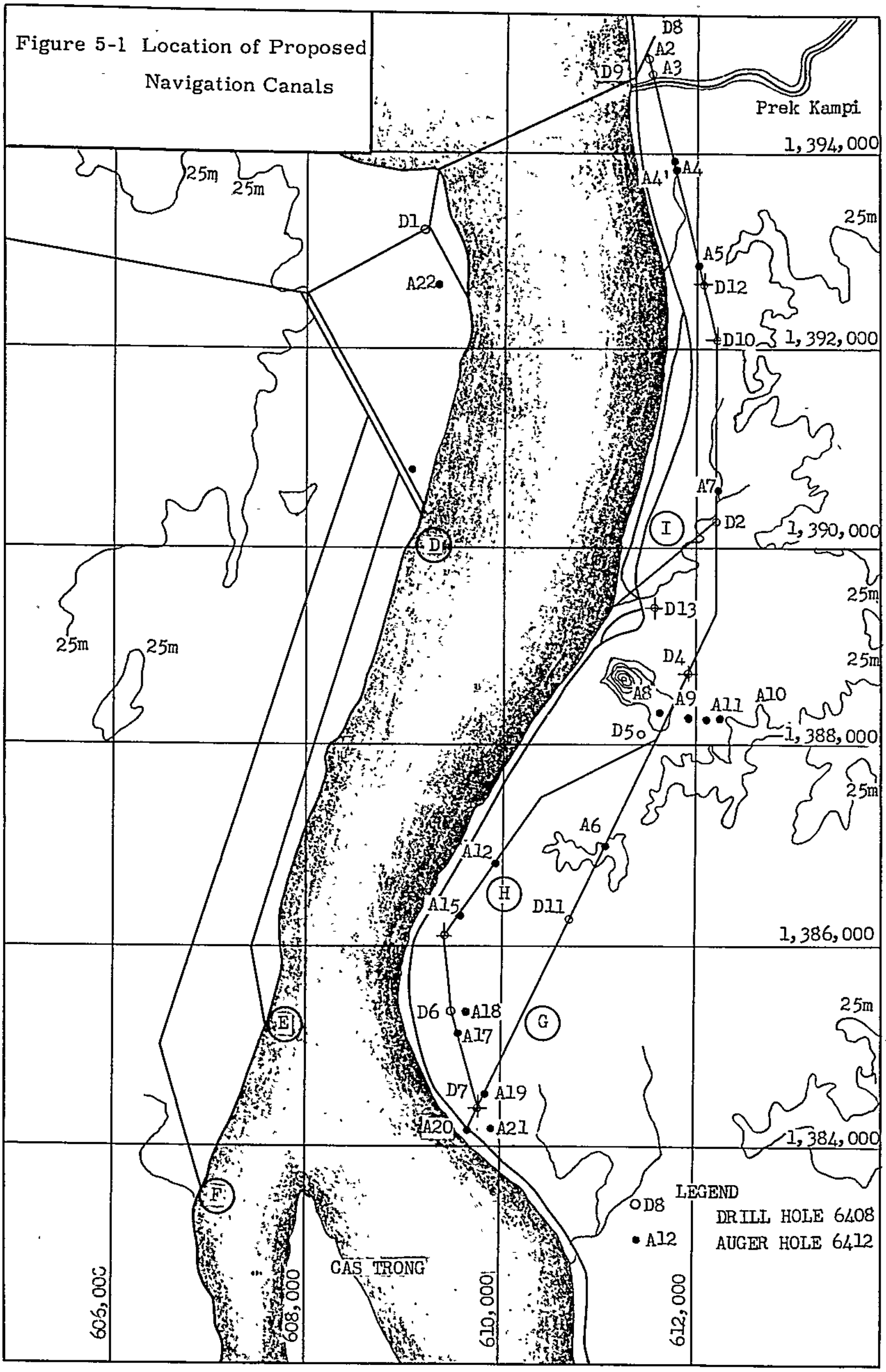


Figure 5-2 Profiles of Proposed Navigation Canals

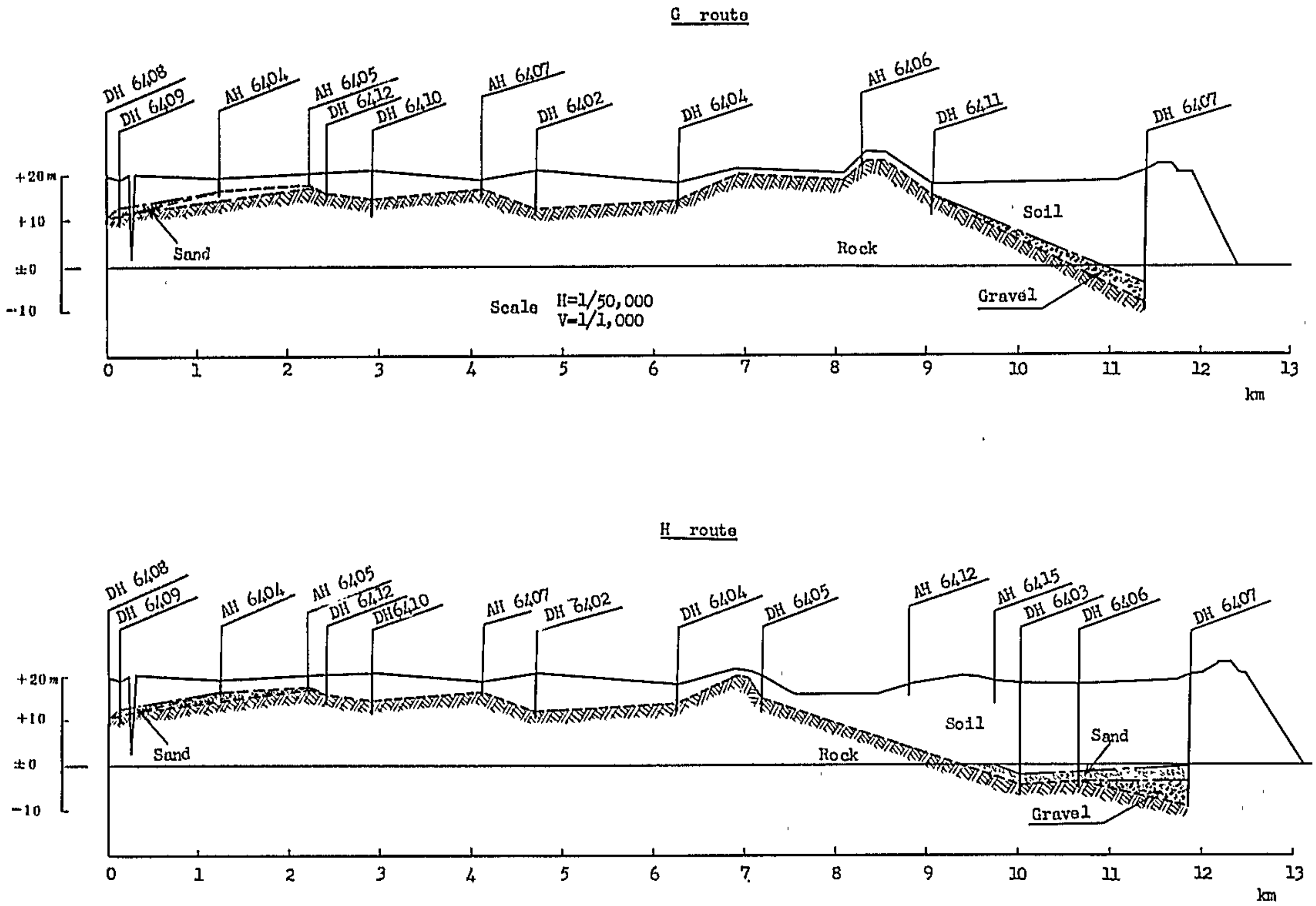


Table 5-7 Soil Tests on Hand-operated Auger-boring Soil Samples

Items / Nos. of samples		Water ratio	Absolute specific gravity of soil grain	Grading by sieve analysis (percentage passing %)					
		W %	GS	Gravel	2000μ	420μ	74μ	Classification	
AH6402	2.5M	17.6	2.613	2.0	98.0	94.4	81.8	Silty loam	
AH6402	5.0M	30.4	2.570	29.1	70.9	62.7	52.7	Silty loam with gravel	
AH6403	2.5M	18.8	2.607	4.8	95.2	91.6	78.5	Silty loam	
AH6403	5.0M	21.0	2.558	4.0	96.0	94.8	66.5	Clayey loam	
AH6404	2.2M	29.8	2.612	0	100.0	93.5	53.2	Sandy loam	
AH6405	2.5M	18.7	2.579	8.3	91.7	56.4	51.6	ditto	
AH6407	2.0M	14.9	2.559	0.4	99.6	92.3	53.3	ditto	
AH6408	0.70M	6.9	2.578	22.2	77.8	71.8	55.0	ditto	
AH6409	2.5M	26.3	2.608	0.8	99.2	94.2	71.9	Clayey loam	
AH6409	4.0M	27.0	2.584	24.9	75.1	54.3	38.6	Sandy loam with gravel	
AH6410	0.80M	9.3	2.579	29.1	70.9	49.4	33.8	ditto	
AH6411	0.70M	7.8	2.561	4.0	96.0	84.8	40.9	Sandy loam	
AH6412	2.5M	17.7	2.545	34.2	65.8	52.9	47.4	Silty loam with gravel	
AH6415	2.5M	23.3	2.616	0	100.0	99.6	95.2	Clay	
AH6415	5.0M	38.2	2.627	0	100.0	99.5	90.8	ditto	
AH6417	2.5M	22.9	2.639	0	100.0	99.6	95.6	ditto	
AH6417	5.0M	21.1	2.621	0	100.0	100.0	96.0	ditto	
AH6418	2.5M	18.6	2.640	0	100.0	100.0	98.8	ditto	
AH6419	2.5M	23.2	2.645	0	100.0	99.2	93.5	ditto	
AH6419	5.0M	20.9	2.622	0	100.0	98.0	92.0	ditto	
AH6420	1.5M	32.8	2.602	0	100.0	99.2	91.7	ditto	
AH6421	2.5M	37.6	2.625	0	100.0	97.2	88.0	ditto	
AH6421	5.0M	29.1	2.562	0	100.0	98.7	91.4	ditto	
AH6422	1.0M	18.7	2.618	66.4	33.6	19.0	4.0	Sand & gravel	
AH6422	2.5M	11.9	2.669	18.7	81.3	64.0	16.3	ditto	
AH6423	2.5M	15.2	2.658	0	100.0	99.6	64.6	Sandy loam	
AH6423	5.0M	24.6	2.658	0.4	99.6	98.8	69.4	ditto	

Table 5—8' Soil Tests on Thin-walled Soil Samples

Items / Nos. of Samples	Water ratio	Absolute specific gravity of soil grain	Apparent specific gravity	Dry density	Void ratio	Degree of saturation	Liquid limit	Plastic limit	Plastic index	Grading by sieve analysis (percentage passing %)					Uniaxial compression test			Consolidation test		Compression index	Coefficient of volume compressibility	Coefficient of permeability	Coefficient of consolidation	Consolidation preload	Cohesion	Angle of internal friction
	W %	GS	γ_t g/cm^3	γ_d g/cm^3	e	Sr %	LL %	PL %	PI	Gravel	2000μ	420μ	74μ	Classification	q_u kg/cm^2 Undisturbed	q_{ur} kg/cm^2 Remoulding	Sensitivity ratio St	Load kg/cm^2	Void ratio	Co	mv cm^2/g	K cm/sec.	Cv cm^2/sec.	Po kg/cm^2	C /cm^2	
DH6402 T1	23.4	2.638	2.01	1.63	0.62	99.6	52.6	23.3	29.3	0	100	99.6	97.4	Clay	3.11											
DH6403 T1	24.2	2.621	1.93	1.55	0.69	91.9	45.5	20.2	25.3	0	100	99.6	95.5	Clay	1.08			0.05 12.8	0.851 0.550	0.200	0.592 1.40×10^{-5}	0.473 12.95×10^{-8}	0.800 1.638×10^{-3}	0.54	0.42	26.0
DH6403 T2	24.3	2.603	2.03	1.63	0.60	100	45.8	21.0	24.8	1.2	98.8	97.2	92.6	Clay	2.51	1.39	1.81	"	0.702 0.559	0.115	0.362 0.23×10^{-5}	0.604 3.31×10^{-8}	0.705 4.01×10^{-3}	1.72	0.90	20.5
DH6403 T3	31.8	2.629	1.92	1.46	0.84	99.5	37.1	17.5	19.6	4.5	95.5	93.8	89.8	Silty clay	0.79	0.21	3.76	"	0.868 0.533	0.270	0.784 4.54×10^{-5}	1.41 4.78×10^{-8}	1.107 1.798×10^{-3}	1.12	0.28	21.5
DH6404 T1	22.9	2.640	1.98	1.61	0.64	94.5	29.7	12.7	17.0	0.8	99.2	89.0	46.9	Sandy silty loam	0.64	0.48	1.33	"	0.923 0.560	0.266	0.665 1.43×10^{-5}	0.745 16.78×10^{-8}	0.112 0.290×10^{-3}	1.08	0.32	7.6
DH6405 T1	25.8	2.567	1.80	1.43	0.80	82.8	42.0	24.0	18.0	0.8	99.2	89.6	66.7	Clayey loam	1.13	0.86	1.31	"	0.693 0.404	0.193	0.543 6.34×10^{-5}	0.0231 37.04×10^{-8}	0.426 12.1×10^{-3}	1.16	0.50	35.0
DH6405 T2	21.1	2.577					37.4	17.7	19.7	8.6	91.4	66.7	16.1	Sand	-	-	-	"	0.612 0.433	0.147	0.479 4.03×10^{-5}	0.201 1.29×10^{-8}	0.396 0.670×10^{-3}	1.05	0.34	54.0
DH6405 T3	16.9									66.9	33.1	22.3	5.9	Sand & gravel	-	-	-									
DH6406 T1	23.6	2.570	1.98	1.60	0.61	88.9	45.8	20.6	25.2	0	100	99.6	94.7	Clay	1.94		-									
DH6406 T3	19.5	2.580	1.98	1.66	0.55	91.5	51.5	19.8	31.7	0	100	99.2	94.8	Clay	3.67			"								
DH6406 T4	21.5	2.490	1.97	1.62	0.54	100	39.7	16.8	22.9	0	100	97.6	88.3	Clay	1.64		-	"	0.605 0.516	0.0647	0.263 2.02×10^{-5}	0.244 0.969×10^{-8}	0.183 0.980×10^{-3}	0.97	1.72	21.0
DH6406 T5	25.8	2.516	1.98	1.57	0.60	100	40.1	17.8	22.3	0	100	98.8	94.5	Clay	1.54	0.68	2.26	"	0.743 0.487	0.180	0.676 5.75×10^{-5}	1.60 51.9×10^{-8}	1.31 9.99×10^{-3}	1.75	0.42	19.5
DH6406 T6	32.5	2.616	2.01	1.52	0.72	100	34.4	20.3	14.1	0	100	98.7	90.3	Silty loam	0.69	0.11	6.27	"	0.917 0.602	0.191	0.675 8.40×10^{-5}	5.05 56.4×10^{-8}	3.26 8.67×10^{-3}	1.34	0.29	6.5
DH6406 T7	35.7	2.589	1.93	1.42	0.82	100	35.0	20.2	14.8	0	100	99.0	78.2	Silty loam	0.81	0.08	10.13	"	1.003 0.621	0.415	1.12 9.03×10^{-5}	3.52 31.5×10^{-8}	3.13 8.29×10^{-3}	2.98	0.42	19.0
DH6407 T1	26.3	2.577	1.90	1.50	0.72	94.1	47.2	23.3	23.9	0	100	97.4	86.6	Clay	0.65	0.80	0.81	"	0.784 0.575	0.206	0.62 3.91×10^{-5}	1.10 67.7×10^{-8}	1.591 20.1×10^{-3}	1.85	0.58	37.0
DH6407 T2	27.6	2.684	1.99	1.56	0.72	100	37.4	15.7	21.7	2.5	97.5	95.9	94.7	Clay	1.65	0.86	1.92	"	0.881 0.607	0.167	0.463 9.68×10^{-5}	0.568 5.91×10^{-8}	0.645 1.965×10^{-3}	0.49	0.38	4.32
DH6407 T3	26.4	2.625	2.12	1.68	0.56	100	38.3	15.9	22.4	0	100	97.9	92.1	Clay	1.95	1.78	1.10	"								
DH6407 T5	24.3	2.644	2.06	1.66	0.59	100	37.6	15.5	22.1	0.4	99.6	98.0	89.8	Clay	1.13	0.79	1.43									
DH6407 T6	18.2	2.628	2.07	1.75	0.50	95.7	36.3	15.3	21.0	0.4	99.6	98.4	87.3	Clay	2.96		-	"	0.729 0.396	0.228	0.835 8.76×10^{-5}	1.07 4.73×10^{-8}	0.232 1.167×10^{-3}	0.93	0.29	6.5
DH6407 T7	20.1	2.626	2.14	1.78	0.48	100	35.0	16.0	19.0	0.4	99.6	98.0	84.4	Clay	2.11	0.64	3.30	"	0.546 0.337	0.148	0.574 5.83×10^{-5}	0.103 3.62×10^{-8}	0.793 0.903×10^{-3}	0.68	0.24	34.5
DH6407 T8	20.6	2.624	1.97	1.63	0.61	88.6	33.6	15.0	18.6	0	100	97.6	78.0	Clayey loam	1.41	0.38	3.71									
DH6407 T9	35.2	2.607	1.88	1.39	0.88	100	33.7	15.1	18.6	0.5	99.5	98.1	91.7	Clay	0.71	0.13	5.46	"	0.856 0.532	0.288	0.849 21.01×10^{-5}	1.51 16.65×10^{-8}	0.600 4.63×10^{-3}	2.19	0.31	31.0
DH6407 T10	27.7	2.595	1.99	1.56	0.66	100	31.5	17.5	14.0	0.8	99.2	98.4	84.0	Clay	0.81	0.14	5.79									
DH6408 T1	22.0	2.641	1.96	1.61	0.64	90.8	39.2	18.3	20.9	0.4	99.6	97.2	87.1	Clay	1.73	1.10	1.57	"								
DH6408 T2	20.3	2.641	2.01	1.67	0.58	92.4	37.3	16.9	20.4	0	100	98.8	92.4	Clay	2.19	1.67	1.31	0.05 12.8	0.621 0.450	0.141	0.488 6.17×10^{-5}	0.604 10.93×10^{-8}	0.867 4.38×10^{-3}	1.35	0.62	39.5
DH6408 T3	20.0	2.607	2.02	1.68	0.55	94.8	37.7	10.7	17.0	1.2	98.8	95.2	76.8	Clay	2.50		-									
DH6409 T1	20.2	2.615	2.03	1.69	0.55	96.0	46.2	19.9	26.3	0.8	99.2	92.4	83.2	Clay	2.79			"	0.674 0.487	0.195	0.437 6.00×10^{-5}	1.30 19.41×10^{-8}	2.25 3.25×10^{-3}	0.74	0.38	30.0
DH6409 T2	22.5	2.610	2.01	1.64	0.59	99.5	51.1	18.6	32.5	0	100	97.6	91.5	Clay	1.67	0.90	1.86									
DH6413 T1	25.8	2.608	2.01	1.60	0.63	100	45.4	22.7	22.7	0	100	97.5	89.1	Clay	0.86	0.84	1.02									

6. AGRICULTURE

6.1 Service Area

The service area of the Sambor Irrigation Project covers about 67,000 ha which extends over 3 Sroks of Kratie Province, i.e., Kratie, Prek Prasap and Chhlong.

Of this 67,000 ha, about 55,000 ha extending for about 40 km along both banks of the Mekong with El. 40 m or less is expected to be irrigated by gravity flow or pumping up. The area extends, on the left bank of the Mekong, from the Dam Site as far southward as to the right bank of Prek Chhlong. On the right bank, it covers the area from the Dam Site to Phnom Kampong Kor (Srok Prek Prasap) situated opposite to Chhlong.

Adjacent to this is an area which extends farther southward over the left bank of Prek Chhlong and the right bank of the main stream (opposite to Prek Chhlong) and constitutes the center of upland cultivation in Cambodia, where substantial irrigation benefits can be expected by pumping up the water of the Mekong and its tributaries. This area is integrated into the overall Sambor Irrigation Project Area.

6.2 Present State

6.2.1 Soil Distribution

The investigations revealed that the distribution of soil groups in the surveyed area is generally subjected to the topographic conditions. The five different soil groups as classified according to the results of the soil survey are as given below.

A. Alluvial area

a. Silty alluvial soil

b. Clayey alluvial soil) 44,000 ha

B. Plateau area

c. Lateritic residual soil 5,600 ha

d. Hydromorphic soil 12,100 ha

C. Buried river bed area

e. Alluvial soil of the buried river bed of the Mekong 5,300 ha

It may be added that 200 soil specimens brought back to Japan are now being put to laboratory analysis to clarify the nature of each soil group. Findings of the laboratory analysis will be quite important in planning the land use. In the next investigations, the soil survey will be conducted for the subdivision of soil groups as well as for the preparation of soil maps.

6.2.2 Meteorology and Hydrology

(a) Climate

The climate of Kratie and its vicinities is classified as tropical as that of other areas of the Lower Mekong Basin, and has such features as given below.

(1) In summer, the Lower Mekong Basin is under the influence of the Asian Monsoon which brings the wet season normally lasting from mid-April to October. In winter, the continental high atomospheric pressure overlies the area, with the dominant north-east monsoon which brings the dry season lasting from winter to spring when there scarcely is rainfall.

(2) The rainfall in the wet season is mostly squallic, showing considerable fluctuations by time and place.

(3) The Lower Mekong Basin is within the Pacific Ocean typhonic zone. However, retarded by the mountain ranges of Indo-China peninsula, most of typhoons loose their energy when passing the area. Nevertheless, a great amount of rainfall is brought by these typhoons, especially by those rising towards the end of the south-west monsoon which cause the maximum flood of rivers.

The average wind velocity is about 2 m/sec throughout the year, with slightly higher values recorded during the period from January to April.

(4) The difference in the average monthly temperatures recorded within a 12 month period is quite small. For example, the average monthly temperature recorded in April and December is 29.6°C and 23.9°C respectively in Stung Treng, while it marks 29.1°C and 25.1°C respectively in Kompong Cham. It is noted that the temperature difference is larger between day and night, often marking more than 10°C in dry season.

(b) Rain fall

Not only in the project area but also in the entire Mekong Basin, the rainfall is the main source of irrigation water. The beginning and ending of the wet season, therefore, has a significant influence on agriculture. In the past 55 years (1907 - 1963, excluding 1961 and 1962), the wet season began and ended during the months given below.

Beginning of wet season		Ending of wet season		Period	
Month	Frequency (yrs)	Month	Frequency (yrs)	No. of month	Frequency (yrs)
Feb	1	Sep	0	6	2
Mar	7	Oct	7	7	28
Apr	20	Nov	44	8	16
May	26	Dec	4	9	8
Jun	1	Jan	0	10	1
Total:	55		55		55

Although the average annual rainfall during the above 55 years is 1,380 mm, the lowest annual rainfall recorded is lower than two thirds of this average. Fluctuations are even greater at the beginning or ending of the wet season, so that no rainfall at this particular time can be expected as the source of irrigation water.

(c) Humidity

The relative humidity is comparatively high ranging from 60 to 69% throughout the year. The highest humidity occurs in or about September, and the lowest in or about March. It is known that the humidity in the Mekong Delta exceeds 100% during the wet season.

(d) Evaporation

The highest evaporation is recorded in April, i.e., just before the wet season, and the lowest in August, but the difference by season or district seems to be almost negligible. To give an evidence, the average annual evaporation recorded in 1963 is as given below.

Battambang	5.78 mm/day
Phnom Penh	5.60 mm/day
Stung Treng	5.67 mm/day

It is expected that detailed data will be obtained in the future including daily changes of evaporation from self-recording evaporimeters installed in Kratie and Phnom Chheutea Phluos (Kh. Kanhchar in Srok Chhlong).

(e) River water

The water level of the Mekong repeats a periodic 12 month pattern, i.e., with the advent of the wet season, it rises gradually from late April or May, and reaching a peak in August or September, drops rapidly at the end of the wet season, then recedes gradually during the ensuing dry season.

The water level of a number of tributaries is influenced by that of the main stream on account of its back water. In the case of smaller tributaries, however, the water level shows marked fluctuations in the above-mentioned annual pattern due to rainfall.

Since the planning of the irrigation project is not possible until sufficient data have been obtained regarding inundations of smaller tributaries, water gauges and rain gauges were installed during the present investigations at 21 points and 10 points respectively on these tributaries. It is expected that these equipment will make clear, though to a limited extent, the difference of rainfall between districts relatively close to each other as well as run off condition of tributaries.

(f) Well water

In area lying along the Mekong and its tributaries, a good number of wells is found to obtain drinking water. Ordinarily, each Phum has one or two such wells which are in public use, most of them being 6 - 10 meter in depth. In areas as far down as Kratie, the water level is 1.5 - 4 m below the ground surface during the period from December to January. It starts rising from around May, reaches a peak high during July-September period, and falls off to the lowest in March or April when some of the wells run dry. The difference between the highest and lowest levels is in the range of 3 - 5.5 m.

6.2.3 Present State of Water Use

(a) General situation

The land use is noted to have been carried out depending upon the rainfall and river water conditions in the project area, precluding such areas as poor, sparse forest lands where the surface soil has been washed off, dense forest lands that can be exploited only with great difficulty, or swamps where the water is retained throughout the year.

In other words, the water use in the project area is subjugated at present to natural environments, and is not stabilized in many cases. The installation of irrigation facilities is therefore urgently called for.

Among different varieties of rice planted in the wet season, the early and medium maturing rice plants are generally cultivated depending on natural inundations, while the late maturing rice plant is normally cultivated in the rain-fed paddy fields.

(b) Water requirements of paddy fields

The reduction of water depth was measured on a dry season paddy field from December 1964 through February 1965. Further, the permeability and evaporation were measured on a shallow pond filled with water, about 2 m square in size and 40 cm in depth, which was formed as experimental plot on one of the wet season paddy fields harvested in December. Concurrently with the observation of consumptive water depth, the amount of permeable water was measured utilizing a cylinder with cap on both of the above experimental fields. Values thus obtained were deducted from the consumptive water depth in an attempt to estimate the volume of evaporation.

In designing the standard water requirements for the project area in the future, such elements as weighted appraisement of measured values, classification by soil textures, varieties of rice plants and changes in their growing period should be taken into consideration. To effect a rough estimate, however, the water requirements for both the wet and dry season rice plants may tentatively be considered to range from 15 to 20 mm/day including losses.

(c) Intake-rate experiment for irrigation of upland fields

In January 1964, the cylinder intake-rate of soil was measured under dry and wet (approx 24 hrs after submergence) conditions at 18 points located in different land categories of the project area, i.e., upland field, sparse forest, dense forest, grass land (in areas subject to inundations) and paddy field. Further, the water holding capacity Fc was obtained from the soil specimens in each experiment.

The basic intake-rate iB, which indicates the irrigation method for upland fields, was found to be below 40 mm/hr with a few exceptions. Since the standard iB value at which the use of sprinklers is required is as high as 75 mm/hr, it may safely be concluded that the surface irrigation is quite feasible in the project area.

6.2.4 Present State of Land Use

(a) Area of land classified by use   Unit: 1,000 ha

Land category	Paddy field			Upland field incl. orchard	Forest		Grassland (Unexploited submerged area)	Total
	Wet season paddy field	Dry season paddy field	Sub-total		Sparse forest	Dense forest		
Gravity irrigation area	3.2	0.6	3.8	4.8	22.0	4.9	19.8	55.3
Pumping irrigation area	0.7	0.3	1.0	4.9	0.2	0.4	5.2	11.7
Total	3.9	0.9	4.8	9.7	22.2	5.3	25.0	67.0

Remarks: Area adjoing the gravity irrigation area is exploitable by pumping up the water of the Mekong and its tributaries.

Note: Figures given above indicate areas of each land category estimated at the present stage of investigation, and are not to be considered as definite.

(b) Present state of agriculture

(1) Agriculture in service area

In the area extending on the left bank of the Mekong from the Sambor Dam Site down to Kratie, lands under cultivation are occupied for the most part by wet season paddy fields, while upland fields extend in limited areas along the natural levee of the Mekong where tobacco, maize, etc. are grown on a single crop basis and harvested during November-February period. Upland crops such as banana, cocopalm, orange, etc. are also cultivated on small garden patches within house compounds in the belt-like zone along the Mekong.

Southward from Kratie to Prek Te, and thence farther southward to Prek Chhlong, the upland fields extend wider in area. In the district between Prek Te and Prek Chhlong, paddy and upland fields equally share the cultivated lands, where orchards of banana, kapok, cocopalm, etc. are found together with small areas of dry season paddy field. Upstream of Prek Te, however, the area occupied by paddy fields of hydromorphic soil is larger than the upland field area.

The cultivated lands on the right bank of the Mekong likewise present the gradual and southward shift of land category from paddy field to upland field; and a wider area is occupied by upland fields than by paddy fields in the district opposite to Chhlong. Dry season paddy fields, which extend wider on the right bank, are cultivated with the irrigation water obtained from the Baeng (ponds) in the low-lying lands in areas subjected to inundation and from brooks that do not run dry during the dry season (though many of them run dry in February or March). In some cases, these dry season paddy fields are served by the small scale pumping irrigation (2 - 3 hp).

Generally speaking, the land use is practised fairly effectively taking full advantage of the natural conditions, and where the irrigation is made possible by the natural inundation during the wet season, practically every hectare of land is cultivated as paddy field. It is noted, however, that the land and water use during the dry season is inactive, leaving room for further improvement.

(2) Present state of farm management

Farmers in the project area may be classified broadly into the following five types.

A. Those who cultivate paddy fields in hydromorphic soil area or along rivers and brooks at El. 25 - 30 m, and grow wet season rice plants with the irrigation water provided by inundations of about 50 cm during the wet season which occur as a result of rainfall (rainwater from mountains) and floods.

B. Those who cultivate paddy fields in fluviatile alluvial soil area subjected to the inundation of the Mekong, and grow wet season rice plants with the irrigation water provided by inundations of about 50 cm during the wet season.

C. Those who grow dry season rice plants with the irrigation water provided by Baeng (ponds), small rivers and brooks in fluviatile alluvial soil area subjected to the inundation of the Mekong.

D. Those who cultivate upland fields extending in the belt-like zone along the Mekong.

E. Those who cultivate upland fields mentioned in D. together with paddy fields mentioned in A., B., or C.

Acreage under cultivation, either paddy or upland crops, ranges from 5 to 10 ha in case of large-scale farmers, and from 2 to 4 ha in case of medium-scale farmers, while the small-scale farmer has about 1 ha of cultivated land.

While there is a sizable number of farmers of A and B type, farmers of other types are rather few. Since the use of fertilizer is practically nil in the project area, cultivated lands are found mostly in fluviatile alluvial soil area, hydromorphic soil area at a slightly higher elevation, or in areas along small rivers and brooks. These areas are fed with fresh, fertile muddy soil containing lime, phospheric acid, etc. brought by the flood water caused by the annual inundation of the Mekong. Distinction between large- and small-scale farmers is made by the crop yields and the richness of soil rather than the area of the cultivated land. For example, a farmer will be classed large-scaled if his gross yields of paddy land rice ranges between 400 and 500 tons, while he would be classed medium- or small-scaled with the gross yields of 300 tons or 100 - 200 tons respectively. It follows that those who are called large-scale farmers should posses fertile and adequately irrigated paddy fields, instead of large areas of paddy field with low productivity and poor irrigation conditions.

Apart from the use of draft cows and buffalos, the farm labour is dependent solely on manpower. Works required for paddy production such as ploughing at the beginning of the wet season, harrowing, transplanting and harvesting are done by family members of farmers. Similarly, works required for upland cultivation involving ploughing, harrowing, levelling, sowing, and harvesting are covered by farmily labour (In the case of upland cultivation, it often happens that the entire farm labour is borne by family members). It has been noticed in many villages that besides employing casual workers or workers under a 1-year contract, villagers cooperate with each other by working jointly in a group of 2 - 10 families.

Farmers in the project area have, on an average, 2 draft cows or buffalos (grown-up), 2 pigs (for breeding) and 10 fowls.

During the dry season, farmers engage in such side works as bamboo cutting, gathering and processing of Dam Treang as well as felling of trees to be used as fuel or timber. However, farmers cultivating upland crops or dry season rice plants are seldom seen engaged in these sibsidiary works since their farming season coincides with the dry season.

(c) Present state of forest lands and grasslands, and their use

Because of the comparatively high water holding capacity resulting from lacking a fully developed profile of alluvial soils, there are rich varieties of trees in the project area forming dense forests with ferns and Dam Treang of extremely large size growing underneath. In areas formed by the lateritic residual soil which has low permeability and insufficient drainage capacity and consequently becomes dry to a considerable extent during the dry season, cycad-like plants and poaceous herbs grow wild with several kinds of plants of Dipterpocarpaceae family, and form sparse forests. These forest lands are all above El. 30 m.

Between El. 25 and 35 m, plants of Dipterocarpaceae family and Leguinosae family grow also forming sparse forests, with underneath herbage of Arudinaria spp. Among the plants belonging to Diptercarpaceae family, Khlong (Dept. tuberculatus) is found growing in groups. In these sparse forests, Dam Treang of smaller size is also found.

6.2.5 Market Survey

Since the market survey is quite important for the agricultural production, the following three cities were surveyed during the present investigations utilizing statistics issued by the Bureau of Agriclture of Cambodia in 1964.

1. Kratie, which is in the closest proximity and directly related to the surveyed area,
2. Kompong Cham, where commodities are considered to be gathered by overland transportation as well as by the Mekong, and
3. Phnom Penh, where commodities are gathered from all over the country.

6.3 Outline of Proposed Agricultural Development Project

6.3.1 Necessity for Agricultural Development

In view of the fact that more than 70% of inhabitants are farmers and the greater portion of national income is derived from agriculture, and considering the present state of economy on which the export of agricultural crops has a profound influence, it seems that the necessity for agricultural development in Cambodia hardly needs to be stressed. In the present-day Cambodia, it is truly a matter of vital importance to develop agriculture which should aim at the following three points, i.e., increased production to meet with the domestic demands, stabilized and increased production of such principal export crops as rice, maize and rubber, and enhancement of production within the country of processed agricultural products which have hitherto been imported.

Analyzed from such stand-point, the present Cambodian agriculture may be summarized as follows.

While statistics indicate that the rice production is on the steady upward trend, it is noted that the population is expanding rapidly with 2.8% of increase rate per annum. This fast population increase is to be welcomed in Cambodia where the population density is rather low, provided it be accompanied by the counterbalancing increase of rice crop. The fact, however, is that sizable fluctuations are often witnessed in the gross yields as well as yield per hectare of rice (unhulled), which is attributable chiefly to unfavourable climatic conditions. Although the annual increase rate of rice production is 3.7% which barely surpasses that of population, there are years during which the rice crop marks a drastic drop.

Pertinent to the production of rice (unhulled) as part of the overall agricultural development, a problem is raised as to how to check and alleviate the jarzardous production dorp that recurs once in several years and how to maintain the stabilized level of rice crop. As remedies to this problem, the following measures are considered to deserve due attention.

1. Improvement of the present system of cultivation which depends solely on the rainfall brought by the tropical monsoon, into the properly irrigated cultivation.
2. Allevation, and extermination if possible, of damages caused by disease and insects, through the use of agricultural chemicals.
3. Shifting to fertilized agriculture.

4. Improvement of rice varieties and of cultivation method.

5. Flood control for a number of smaller basins.

With regard to diversified crops other than rice, it may be justifiably concluded, from the recent situations of export of major agricultural crops and import of processed agricultural products, that stress should be placed on the stablized and increased production of maize, kapok, Phaseolus radiata, pepper, etc. which constitute main export items, as well as on production enhancement of such import items as sugar, vegetable, fruit (inclusive of canned fruit), cotton and jute sack. It is noted that the rate of production increase of these products surpasses that of population at present, which is indicative of the prospect that the increased and stablized production in the future can be reasonably warranted by the favourable natural environments.

Comparison between Kratie Province which is regarded as the center of the Project Area and other provinces of Cambodia, reveals such unfavourable features on the part of Kratie Province as lower percentage of arable land against its total area, lower population density and smaller cultivated land per capita, indicating that this province is still under-developed. These backwardness have been created chiefly by the topography of the Province which is mountainous. It is to be pointed out, however, that there still remains a sizable area of land available for cultivation in this province with the Mekong flowing through it.

In fact, the growth of population density in Kratie Province since 1948 has been most remarkable when compared with that of other provinces, and the yield per hectare of rice (unhulled) in recent years has not failed to rank among the best in the country. Further, being adjacent to Kompong Cham Province, the center of diversified cropping in Cambodia, Kratie Province may be considered to have enough potentials for future agricultural development.

From the standpoint of harmonious development desired for all provinces and of the policy of decentralizing development sites, the Sambor Project well deserves development though its construction may entail various difficulties.

6.3.2 Scale of Sambor Irrigation Project Area

A series of areas expected to be irrigated either by gravity flow or pumping within the Sambor Irrigation Project Area can be broken down as follows.

Sambor Irrigation Project Area

Unit : 1,000 ha

Extension of area	Land
Left bank of the Mekong	
Kratie & vicinity, area extending on both banks of Prek Te, and area extending along the Mekong in Srok Chhlong	41 (incl. paddy field 4 upland field 6)
Right bank of the Mekong	
Area extending from damsite as far southward as Khum Tamau Kach Tasug along the Mekong in Srok Prek Prasap	26 (incl. paddy field 1 upland field 4)
Total	67 (incl. paddy field 5 upland 10)

Areas unexplaitable due to topographic restrictions or required for purposes other than cultivation are included in the above Irrigation Project Area.

6.3.3 Land Use Plan

Since the proposed agricultural development has for its object, as already mentioned, increased production to meet the domestic demands, increased crop export, and enhancement of production within the country of processed agricultural products which are being imported, the planning of land use in the project area should be preceded by studies of crops now being cultivated or cultivable in the future in the project area. It is also indispensable that further detailed studies should be made for the assessment of the agriculture of the project area which will be made in relation to the economy of entire Cambodia. At the present stage of investigations, however, it may be justified to say that efforts should be directed, in the first place, to the expansion of paddy field area by about 1.5 times in Kratie Province to meet the existing demands for staple food, since the ratio of paddy field area in that province is far below that of other provinces. It is quite likely that more paddy fields will be demanded in the future in this province in order to meet with the expected population expansion. And, although it is naturally hoped that the paddy field area will be expanded throughout the country to maintain and increase the present export volume of rice (unhulled), the achievement of self-sufficiency will be a matter of utmost importance in so as the Project Area is concerned.

A fact worthy of notice is that the Project Area, which occupies about 5% of the country's total upland field area and produces such diversified crops as maize, sugar cane, sesame, Phaseolus radiata and tobacco, is serving as one of the major sources in the country of these crops.

The annual crop of sugar cane from an area of 560 ha in Kratie Province amounts to 58,000 tons (as of 1954) which accounts for 14% of the country's total production, and possibilities exist that the production could be increased. It is to be taken into account, however, that if the production of sugar cane as raw material of sugar is to be undertaken in this area, no success can be guaranteed without the introduction of new and improved varieties that will suit the existing natural conditions, inasmuch as virtually all of the upland fields within the area are subject to inundations during the wet season which can be successfully prevented only by proper flood control measures.

Plans for better and rational land use in the Project Area will be drawn up in due consideration of the views and facts mentioned above, as well as various physical conditions of the area such as topography, soil and irrigation, and the results of investigations to be conducted in the future.

6.3.4 Implementation of Irrigation Project

The proposed land and water use project involves extensive reclamation works and the construction of irrigation facilities on a large scale. Since the topographic conditions of the Project Area do not allow of any more than 3 km width of arable land along each 1 km of the main canal, it is expected that the main canal will be nearly 200 km in total length, while branch canal will be twice as long as the main canal.

In an attempt to overcome such adverse situation, a tentative plan is proposed whereby the Project Area will be divided into small sections capable of yielding substantial irrigation benefits within a short period of time against a comparatively small investment amount.

In case where the above-proposed plan is adopted, the overall Sambor Project will, in the ultimate, serve for the stabilization of irrigation water sources for its implementation which will be effected in advance of the overall Project, and will, at the same time, enhance the economic development of the area while maintaining close relations with the agricultural development, contributing to the balanced overall development of the Project Area.

It is considered that the development priority should be given to the irrigation and expansion of paddy and upland fields that could be improved without much difficulties, the reclamation of part of marshy areas, and to the flood control of small tributaries.

As regards the irrigation water and its conveyance, it is advisable to establish pumping stations near the mouth of tributaries and pump up the abundant water of the Mekong into the canal. If the tributary is capable of providing sufficient irrigation water, it may be pumped up into the canal. When in the future the construction of the Sambor Project makes it possible that these canal are linked to the main canal, the proposed pumping irrigation may either be abolished or continued with electricity to be supplied by the Sambor Power Plant.

The final planning of the agricultural development project should await the results of further studies to be made on the basis of aerial maps now under preparation in Cambodia as well as of the outcome of the flood survey.

It may be pointed out here that the tentative irrigation plan proposed above promises the increased production in the immediate future, hence its implementation is recommended to be materialized at an earliest possible date.

GENERAL PLAN OF SAMBOR IRRIGATION PROJECT

PROJECT AREA: 67,000 ha

▭ Area to be irrigated by Gravity flow: 55,000 ha
(includes lands to be reclaimed: 39,000 ha)
Irrigation by canal from Sambor Reservoir
Maximum water requirement: 60m /sec
Length of Main canal: appr. 200km

▨ Area to be served by Pumping-up: 12,000 ha
Irrigation by pumping up from the main stream