NORTH-EAST ELECTRICITY AUTHORITY

KINGDOM OF THAILAND

NAM CHERN
HYDRO-ELECTRIC POWER PROJECT

FEASIBILITY REPORT

SEPTEMBER 1967

GOVERNMENT OF JAPAN

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PREFACE

The Government of Japan, in response to the request from the Government of Thailand entrusted the Overseas Technical Cooperation Agency to conduct a feasibility survey for the Nam Phrom Hydro-Electric Power Project.

Therefor, the Overseas Technical Cooperation Agency considering the present situation of the electric demand and supply in the country dispatched a survey mission consisting of six engineering experts head by Mr. H. Watanabe, Electric Power Development Company to Thailand during the period from November 26, 1966 to March 3, 1967, being fully aware of the significance of the mission for the economic growth caused by the development of hydro-electric power.

This survey was focused on the feasibility study of the Nam Chern Hydro-Electric Power Project at the upper reaches of the Nam Pong.

Fortunately, the spot survey work by the mission in Thailand was carried out amicably, hence this report has been completed at this time successfully.

Nothing would be more gratifying to our Agency than if this report could be of any use for developing hydro-electric power or any other industries, and also for promoting closer relationships as well as economic interchange between Thailand and Japan.

In conclusion, our Agency takes this opportunity to express its hearty thanks for the kind co-operation and assistance extended to our mission by the Government of Thailand and it's agencies during the mission's stay there.

September 1967

S. Shibusawa

Shinichi Shibusawa
Director General
Overseas Technical Cooperation Agency

LETTER OF TRANSMITTAL

September 25, 1967

Mr. Shinichi Shibusawa, Director General
Overseas Technical Cooperation Agency
Tokyo, Japan

Dear Sir:

Transmitted herewith is a report on the feasibility studies of the Nam Chern Hydro-electric Power Project in Thailand which were undertaken by the Electric Power Development Company (hereinafter referred to as "EPDC") at your request on behalf of the Government of Japan in accordance with the request of the Government of Thailand.

EPDC sent a team of six engineers during the period of November 26, 1966 to March 3, 1967, to conduct feasibility field investigations on the Nam Phrom Project and the Nam Chern Project on the upper reaches of the Nam Pong. Based on the "Preliminary Study of Upper Nam Pong Basin Hydro-electric Project" which the Government of Japan submitted to the Government of Thailand in August 1966, the team conducted topographical and geological surveys including material investigations, hydrologic investigations and power demand studies, in addition to collection of relative data and information necessary for project formulation.

After the team returned to Japan, EPDC mobilized engineers in the fields of hydrologic data analysis, power demand studies, detailed studies of scheme, preliminary designs, construction cost estimates and economic evaluations. Based on the data and information collected, these engineers conducted studies of the scheme and prepared this report under the direction of the Chief Engineer of the company.

The Nam Chern Hydro-electric Power Project will produce economical energy by diverting water from the Huai Chan to the Nam Chern and by utilizing a head of about 390 meters. The catchment area at the dam site on the Huai Chan is 158 sq. km and the annual run-off is 52,000,000 cu. m approximately. The effective storage capacity of 41,000,000 cu. m of the reservoir created by the dam will enable regulation of the river run-off for the effective production of energy. The powerhouse will be situated on the left bank of the Nam Chern and will produce 40,000,000 KWH annually with an installed capacity of 15,000 KW. The energy produced will be transmitted by the newly proposed transmission line to Khonkaen Substation to supply demands in the northeastern region of Thailand.

For the execution of this scheme, a construction period of approximately two years and a construction expenditure of approximately 150. 5 million Bahts will be required for case (B) as referred on Table 9-1. The benefit-cost ratio of the scheme for power only will be 0. 81 in case the Nam Chern Project is developed as an isolated project. In case both the Nam Chern and Nam Phrom Projects are realized and the construction costs of the common structures including access road and transmission line are duly allocated to each project, the benefit-cost ratio will be 0. 97. Moreover, if the abovementioned cost is borne only by the Nam Phrom Project, the benefit-cost ratio will become 1. 05.

In addition to this benefit, other benefits such as saving of imported fuel for diesel or steam power generation, the effect on irrigation in the downstream area along the Nam hern and the effect on the economic development in this region will be expected. If these benefits are taken into consideration, the economic feasibility will be improved.

In view of the power demand in the northeastern region which has recently been growing at a remarkably high rate, it is thought necessary to add generating capacity before the end of 1973 at the latest. It might become necessary to move up the start of its operation one or two years earlier depending on national policy, unexpected rapid load growth or available power transmitted through the tie line. As a new supply capability, the Nam Phrom Project should be selected firstly, of which the feasibility report has already been submitted. In case that the deficiency of supply capability occurs after the realization of the Nam Phrom Project or that the project which needs smaller investment than the Nam Phrom Project is preferable to be realized first, the Nam Chern Project should be executed.

The Survey Team takes this opportunity to express its sincere gratitude to the officials of the North-East Electricity Authority, especially to Dr. Boonrod Binson, Executive Agent for the Managing Director, Mr. Udom Panyaphol, Managing Director, Dr. Archomphon Khambanonda, Director of Engineering Department, Mr. Sommart Boonpirugsa, Chief of Planning Division of

Engineering Department, Mr. Phyakorn Ratanakul, Head of Survey Section, and to all others with whom the team came into contact during the course of their stay in Thailand for their generous as-assistance and cooperation.

Respectfully yours,

H. Watanabe

Hiroshi Watanabe, Chief
Japanese Survey Team for
Upper Nam Pong Hydroelectric
Project
Civil Engineer,
(Electric Power Development Co.)

NAM CHERN HYDRO-ELECTRIC POWER PROJECT
FEASIBILITY REPORT
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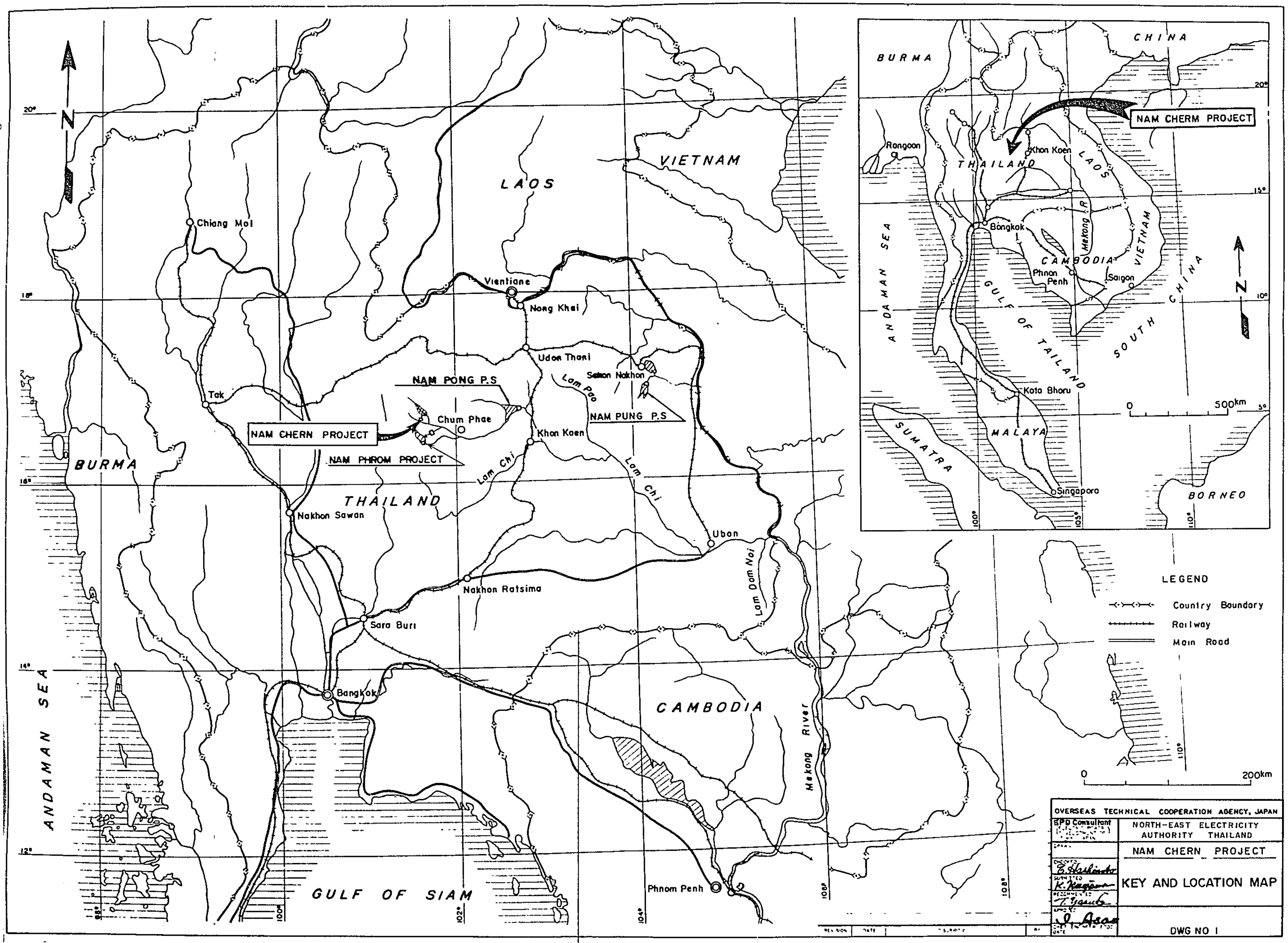

OVERSEAS TECHNICAL COOPERATION AGENCY, JAPAN

EPD Consultant

NORTH-EAST ELECTRICITY
AUTHORITY THAILAND

NAM CHERN PROJECT

E. Hashimoto

KEY AND LOCATION MAP

I. Asao

DWG NO 1

CHAPTER 1. INTRODUCTION

CHAPTER 1. INTRODUCTION

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CHAPTER 1. INTRODUCTION

1.1 HISTORY AND AUTHORIZATION

To cope with the power demand in the northeastern region of Thailand which has been growing at a remarkably high rate in recent years, the North-East Electricity Authority (hereinafter referred to as "NEEA") which is in charge of power supply to this region has planned to develop hydro power sources in the Upper Nam Pong Basin.

On March 28, 1966, Dr. Boonrod Binson, Executive Agent for the Managing Director, on behalf of the Government of Thailand, requested the Japanese Government to carry out reconnaissance investigations and feasibility investigations concerning the project to develop hydro power sources in the Upper Nam Pong Basin. Accepting this request, the Japanese Government delegated the execution of this undertaking to the Overseas Technical Cooperation Agency (hereinafter referred to as "OTCA"). In view of the fact that this project primarily aims at the development of power sources, OTCA in turn transferred the practical implementation of this work to Electric Power Development Company (hereinafter referred to as "EPDC").

The feasibility investigations requested by the Government of Thailand are concerned with two projects: the Nam Phrom Project and the Nam Chern Project. However, the present report has been compiled concerning the Nam Chern Project only. With respect to the Nam Phrom Project, a separate report has already been submitted to the Government of Thailand. Since there are some parts common between the studies of these projects, those which have been explained in the Feasibility Report of the Nam Phrom Project are omitted or briefly described in this report.

1.2 OBJECTIVE AND SCOPE OF REPORT

1.2.1 Objective

To meet the urgent deficiencies of power supply in the northeastern region, NEEA is planning to execute the earliest possible development of power sources in the Upper Nam Pong Basin and is preparing to submit an application to the Government of Thailand for approval of the execution of the project and also for budgets appropriation The present report concerns the investigations and studies of the engineering and economic feasibility of the Nam Chern Project and has been prepared with a view of offering firm, detailed and reliable information when NEEA applies to the Government of Thailand.

1.2.2 Scope

The Nam Chern Project aims mainly at power generation and its benefits will be realized by the power generation. Therefore, the scope of the investigations and studies contained in the this report is confined to the formulation of a development plan for the Nam Chern which will be most suitable and economical to supply power requirements for the northeastern region.

1.3 SURVEY AND STUDY

1.3.1 Field Surveys of EPDC Engineers

Field surveys were carried out mainly during the period of about 40 days from January 24 to March 4, 1967. The last ten days of this period were spent in collecting necessary data in Bangkok and conducting discussions with NEEA engineers. The field surveys covered both the Nam Phrom Project and the Nam Chern Project.

The EPDC Survey Team consisting of the undermentioned six engineers was sent to the project site for the above-mentioned field surveys:

Chief	Mr. Hiroshi Watanabe, Civil Engineer	Jan. 24 to Mar. 4, 1967
Team members		
	Mr. Tatsuo Hashimoto, Planning Engineer	Jan. 24 to Mar. 4, 1967
	Mr. Nobuya Hagihara, Civil Engineer	Nov. 26, 1966 to Mar. 4, 1967
	Mr. Yoshihiro Sano, Materials Engineer	Jan. 24 to Mar. 4, 1967
	Mr. Taketoshi Fujita, Geologist	Jan. 4 to Mar. 4, 1967
	Mr. Tetsuro Shirakawa, Electrical Engineer	Feb. 1 to Mar. 4, 1967

1.3.2 Studies in Japan

After the return of the Survey Team, the Nam Chern Project was studied from the beginning of July to the end of August by the engineers of EPDC on the basis of the data and information collected in the project area. The present report covers the analysis of hydrologic data, study of power demand, detailed studies of the scheme, preliminary designs, estimation of construction cost, economic evaluation, etc.

1.4 SOURCE OF DATA

The basic data required in studying meteorology, hydrology, power demand, etc. were furnished by NEEA.

The survey of the topography of the sites where the main structure such as dam, penstock, powerhouse, etc. are to be constructed, the core drilling to examine the geological conditions of the dam site and materials to be used in construction of the strucltures were undertaken by Universal Engineering Consultant Company (hereinafter referred to as "UECC") in accordance with a contract between NEEA and UECC. The results of these surveys were furnished to the Survey Team by NEEA.

The laboratory tests of soil and rock materials to be used for construction of the dam were entrusted to Chulalongkong University in Bangkok by the Survey Team. These tests were carried out during the period of February - March 1967.

CHAPTER 2. CONCLUSIONS AND RECOMMENDATIONS

CHAPTER 2. CONCLUSIONS AND RECOMMENDATIONS

2.1 CONCLUSIONS 5

2.2 RECOMMENDATIONS 8

2.3 GENERAL CONCLUSIONS AND RECOMMENDATIONS FOR THE NAM PHROM AND NAM CHERN PROJECT 8

CHAPTER 2. CONCLUSIONS AND RECOMMENDATIONS

2.1 CONCLUSIONS

The following conclusions have been reached from the studies and investigations of the Nam Chern Project.

(1) In the northeastern region of Thailand, which is the supply territory of NEEA, power demand has been rapidly increasing since 1965. The reason seems attributable to factors, such as, the rise of living standard of the people in the region due to the implementation of the "5-Year Development Plan for North-Eastern District (1962 - 1966)", the turning up of potential demand prompted by the development of hydroelectric power resources of the Nam Pong and the Nam Pung, as well as by the extension of transmission lines, and economic prosperity motivated by establishment of the military bases. The Government of Thailand further prepared the "Second 5-Year Plan for Economic Development (1967 - 1971)" in its continued efforts for the economic development of the region. It is anticipated that through the implementation of the plan, development of the northeastern region will progress, industries will be encouraged, agricultural productivity will be increased and road net work will be expanded and improved. It is foreseeable that the power demand will continue to increase at a considerable rapid rate in this region, resulting in 65 MW in 1970 and 84 MW in 1975.

(2) If and when the power demand of this region increases as stated above, the power supply facilities operated by NEEA at present will no longer be able to meet the demand in as early as 1968. To cover this imminent shortage of supply capability, NEEA has decided to install a 15 MW gas turbine power plant at Khorat very soon. At the same time, it is understood that the Government has approved the construction of a transmission line interconnecting the Anthong Substation of YEA System with the Khorat Substation of NEEA System. The line is expected to be completed in 1969. Upon completion of this tie line, it will become possible to supply power from the YEA System to the NEEA System. Furthermore, it has been decided to construct a hydroelectric plant at Lam Dom Noi by the National Energy Authority, and this new power plant is expected to start supplying power in 1970 into NEEA's network. Thus the NEEA's system capability will increase by these new such increase of power supply projects, however in 1974, the power received from YEA through the tie line will exceed the reserve capacity of NEEA System. Should the supply capability of YEA be short at that time, or should a fault occur to the tie line resulting in the suspen-

sion of power supply from YEA System, NEEA System will face a serious problem as the reserve capacity of NEEA System cannot compensate the supply capability through the tie line. For this reason, it is essential for the stability of the system that NEEA develops a new source of supply within its system before 1973 at the latest.

(3) With regard to the new source of power supply stated above, the feasibility of development of the Upper Nam Pong Basin, namely the Nam Phrom project and the Nam Chern Project, was investigated. The results of studies for the Nam Phrom project is summarized in the feasibility report on the Nam Phrom project previously submitted, and the results of studies for the Nam Chern project are given in this report.

(4) The Nam Chern project consists in diverting the water of the Huai Chan, a tributary of the Nam Chern, to the Nam Chern and thereby making use of the high head for power generation. It comprises the facilities consisting of a dam, an intake, a headrace and a power-house, and the transmission line on which the generated power is sent to the network.

The dam is a 36 m high rockfill dam to be installed across the Huai Chan. The reservoir made by this dam has an effective storage capacity of about 41,000,000 cu.m. The intake takes a maximum of 5.0 cu.m/sec of water from the reservoir. The headrace consists of a pressure tunnel which is 1.8 m in diameter and about 1.6 km in length, and a penstock of welded steel tube. A surge tank is installed at the end of the pressure tunnel. The power-house, provided with a unit of turbine and generator, generates about 40,000,000 KWH of energy anually with a maximum output of 15,000 KW, by making use of the about 375 m high effective head and a maximum water discharge of 5.0 cu. m/sec. The power produced is sent to the system by the newly constructed transmission line connecting the power plant and the Khonkaen Substation. There are no unusual or difficult problems anticipated in the design and construction of the project. That is, the Nam Chern Project is technically feasible.

(5) The construction cost required for the implementation of the Nam Chern project and the benefit-cost ratio of the project are determined as to the undermentioned three cases, as shown in the table given below.

(A) When the Nam Chern project alone is constructed, not the Nam Phrom Project.

(B) When both the Nam Phrom project and the Nam Chern project are put in force, and the construction cost for access road and transmission line etc. which are common to the two projects is shared pro rata.

(C) The above-mentioned cost is borne by the Nam Phrom project only, not charging to the Nam Chern project.

The interest rates are taken at 4.5% per annum for the foreign currency and at 6.0% per annum for the domestic currency. The oil burning steam electric power plant of a plant output capacity of 250 MW (125 MW x 2 units) to be constructed near Bangkok was used for the measure of economic evaluation.

The calculation of the benefit cost ratio is as follows.

	Construction Cost (in 1,000 Bahts)			Benefit/Cost ratio
	Total	Foreign Currency	Domestic Currency	
(A)	180,700	97,200	83,500	0.81
(B)	150,500	82,700	67,800	0.97
(C)	139,800	77,700	62,100	1.05

This table indicates that the Nam Chern Project, even if the cost of access road and transmission line etc. which is common to the both project should be duly allocated to each project, is economically feasible. That is, the benefit cost ratio is nearly one or 0.97.

Besides, the Nam Chern project will bring about such other benefits as savings of imported fuel for steam or diesel power generation, the favorable effect on the irrigation of downstream basin and the effect on the development of the district. When such additional benefits are taken into account, the aforementioned benefit-cost ratio will be improved.

If the project is carried out after the highway linking Khonkaen with Lom Sak planned by the Royal Highway Department is completed, the economy of the Nam Chern project will be better because the cost of constructing the access road is reduced to a minimum.

(6) The Nam Chern Project will produce sufficient revenues to meet all the financial obligations including the amortization for foreign and domestic borrowings.

2.2 RECOMMENDATIONS

Based on the conclusions stated in 2.1, the following matters are recommended.

(1) When the Nam Chern Project alone is put in force, it does not bring very good economies compared to the Nam Phrom Project. Therefore, it will be better to consider the implementation of the Nam Chern project after the Nam Phrom project.

(2) The most appropriate construction period of the Nam Chern project will be 25 months after the completion of access road. Before the work is started, preparatory works, including the field offices and lodgings of NEEA, etc., as well as the access road need to have been completed.

(3) It is necessary to make further investigations to make detailed designs of this project, and, efforts will have to be paid to the accurate topographical survey in particular.

2.3 GENERAL CONCLUSIONS AND RECOMMENDATIONS FOR THE NAM PHROM AND NAM CHERN PROJECT

Based on the conclusions and recommendations for both projects, the following final conclusions and recommendations are made.

(1) Considering the investigations and studies for both project, the Nam Phrom Project should be carried out firstly to provide a new source of power supply stated above, in the light of both the economic aspect and the adequacy for the size of the load demand.

(2) But if it is desired to carry out a project with less funds than the Nam Phrom Project by reason of the National Policy, or if further increase of supply capability becomes necessary after the realization of the Nam Phrom Project, there will arise a possibility of implementing the Nam Chern Project.

(3) Whichever the decision by the Government of Thailand to implement the first project will be, preparations for the construction including definite plan study and preparatory works should be undertaken at the earliest practical date.

(4) The date of implementation of the first project in the above mentioned conclusions and recommendations are based on the two basic considerations. The first is that the Nam Ngum Power Plant in Laos was considered as reserve capacity as shown in the table on page 26 of the feasibility

report of the Nam Phrom Project. The second is that the supply capability through the tie line from the YEA System was considered to have ample capacity to cover the power shortage in the Khorat Area in the first few years of its operation. This supply capability was assumed to be more than 35 MW at the latter part of 1973.

These two basic considerations will be governed to some extent by the policy of the Government of Thailand in respect of power supply in the northeast district. It is, therefore, considered that further study in connection with these basic considerations is necessary, not only from policy matters, but also from technical standpoint.

Therefore, depending on the conclusions of this study, it might be necessary to move up the date of implementation of the first project one year or so.

CHAPTER 3. LOAD FORECAST

CHAPTER 3. LOAD FORECAST

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Fig.3-1 Load Forcast in MWH and MW for the Year 1967~1981

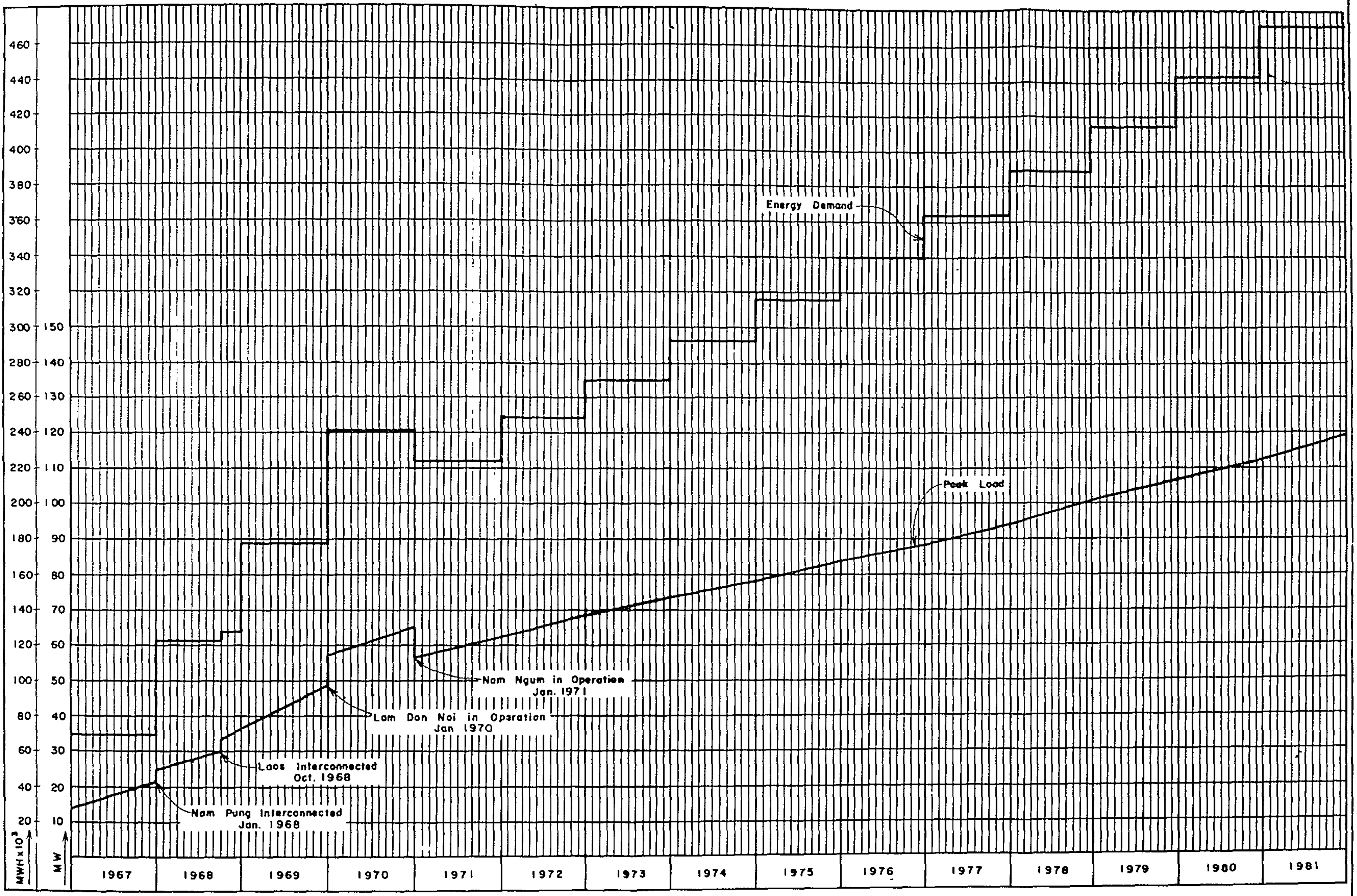


Fig. 3-1 Load Forcast in MWH and MW for the Year 1967~1981

Table 3-1 Load Forecast in MWH and MW for the Year 1967 - 1981

Years Service area	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Nam Pong															
Demand (MWH)	65,277	95,561	119,329	147,240	167,194	183,872	196,798	211,968	226,526	242,317	259,908	278,262	296,709	316,764	338,648
Peak load (MW)	19.7	27.4	33.6	39.3	43.0	46.8	50.0	52.7	56.2	60.2	63.2	67.8	71.9	75.4	80.7
Nam Pung															
Demand (MWH)	-	5,845	6,979	7,975	8,691	9,525	10,174	10,970	11,812	12,661	13,570	14,577	15,483	16,462	17,501
Peak load (MW)	-	2.7	3.0	3.2	3.4	3.6	3.7	3.9	4.1	4.3	4.5	4.7	4.9	5.2	5.4
Lam Dom Noi															
Demand (MWH)	-	-	-	28,408	32,850	37,315	40,938	44,364	47,764	51,018	54,522	57,917	61,668	65,639	69,393
Peak load (MW)	-	-	-	8.7	9.6	10.6	11.5	12.2	12.9	13.3	14.0	14.9	15.4	16.5	17.3
Nam Ngum															
Demand (MWH)	-	15,700	42,000	42,000	-	-	-	-	-	-	-	-	-	-	-
Peak load (MW)	-	3.0	8.0	8.0	-	-	-	-	-	-	-	-	-	-	-
Total load (MWH)	65,277	117,106	168,308	225,623	208,735	230,712	247,910	267,302	286,102	305,996	328,000	350,756	373,860	398,865	425,542
at Substation (MW)	19.7	33.1	44.6	59.2	56.0	61.0	65.2	68.8	73.2	77.8	81.7	81.4	92.2	97.1	103.4
Loss in the for MWH (%)	7.1	5.0	5.6	6.3	6.9	7.5	8.1	8.7	9.3	9.9	9.9	9.9	9.9	9.9	9.9
system for MW (%)	10.8	7.6	8.3	9.3	10.0	10.8	11.5	12.2	13.0	13.8	13.8	13.8	13.8	13.8	13.8
Total load at sending and															
Demand (MWH)	70,000	123,300	178,000	241,000	224,000	248,500	269,500	293,000	316,000	340,000	364,000	389,500	415,000	443,000	472,500
Peak load (MW)	22.1	35.8	48.6	65.3	62.3	68.5	73.7	78.5	84.1	88.5	94.8	101.5	107.0	112.7	120.0

CHAPTER 3. LOAD FORECAST

3.1 LOAD FORECAST

The Nam Chern project area is located in the northeastern district of Thailand as shown in DWG. No. 1, and the power generated in this project is to be supplied to the NEEA system as in the case of the Nam Phrom Project. Detailed explanation of the load forecast for this system has been made in the feasibility report on the Nam Phrom project submitted before. Therefore, the present report gives only the result of the load forecast. For the details of the load forecast, it is requested that reference be made to the aforementioned feasibility report on the Nam Phrom project.

The result of the load forecast is shown in Fig. 3-1 and Table 3-1.

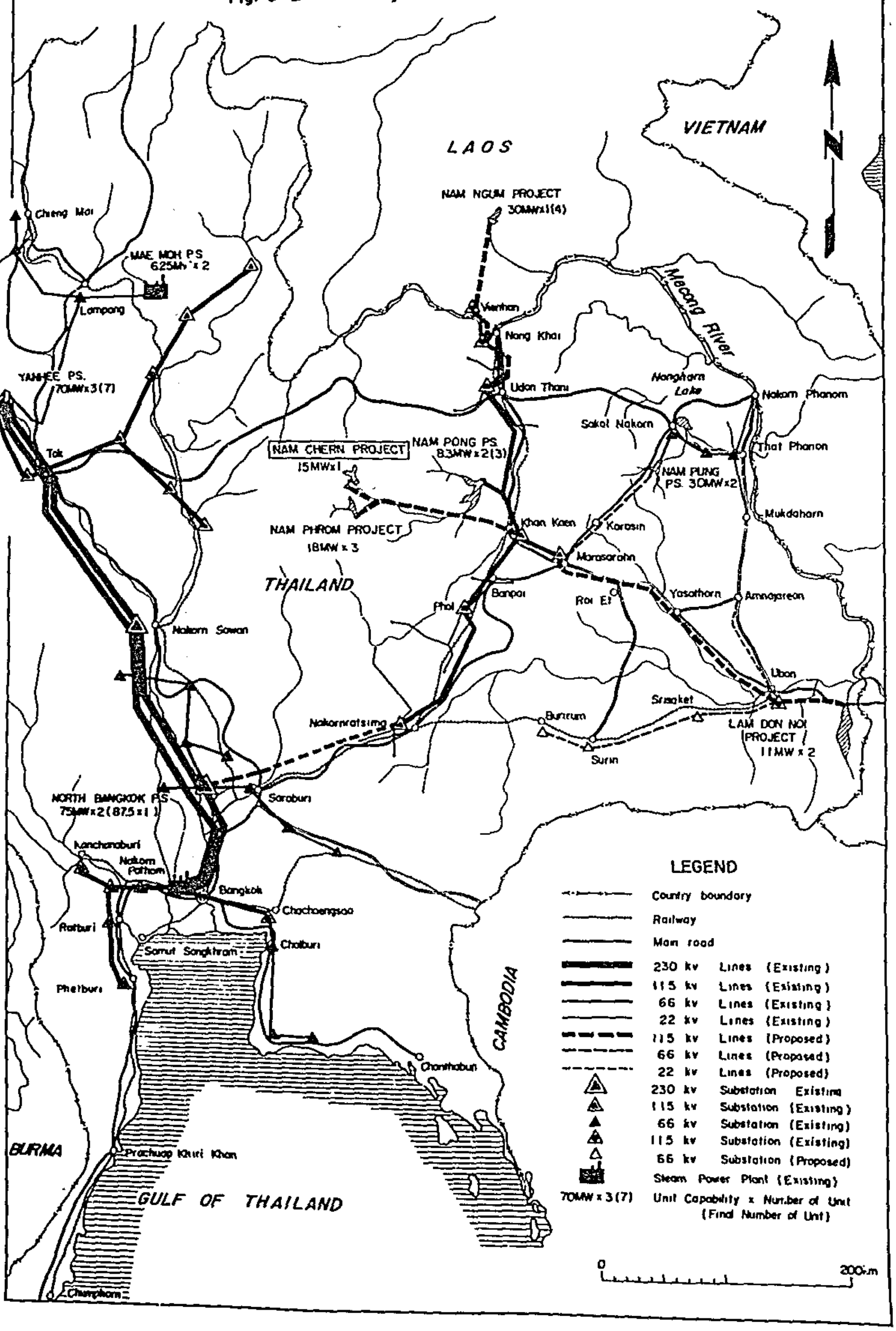
3.2 IMPLEMENTATION OF DEVELOPMENT

The balance of the demand and the supply capability of the system was considered, and study was made on the necessity of development of new source of power supply and on the time when this development would have to be carried out. The supply capability of the system is shown in Fig. 3-2 and Table 3-2.

Table 3-2 Supply Capability in Northeastern Region

	Name	Installed Capacity in MW	Dependable Capability in MW	Annual Energy Production in 103 MWH		Remarks
				Average Year	Dry Year	
Existing Power Plant	Nam Pong Hydro Power Plant	16.6 (*1)	16.6 (*1)	62.0	43.0	(*1) 2 units, (*2) 3 units Unit No. 3 will come into operation in Mar. 1968.
	(Ubolratana)	24.9 (*2)	24.9(*2)			
	Nam Pung Hydro Power Plant	6.0	6.0	15.0	15.0	
	Diesel Power Plant	10.9	6.5	19.9	19.9	L.F. = 35%
	Total	41.8	37.4	96.9	77.9	Nam Pong P.P.: 3 units
Power Project	Lam Dom Noi Hydro Power Plant	22.0	20.0	73.0	60.0	Expected to come into operation in Jan. 1970
	Gas Turbine Power Plant in Kovat	15.0	15.0	-	-	Expected to come into operation in June 1968.
	Tie Line connecting Angthon Substation of YEA system and Korat substation of NEEA system	115KV (1 c.c.t.)	(50.0)	-	-	Expected to be completed towards the end of 1969.
	Total	37.0	35.0	-	-	Tie Line excluded.

Fig. 3-2 Power System in NEEA and YEA



The balance of demand and supply capability was studied on the basis of the daily load curves for June and December. This study was made by the same method that was used in the study of the Nam Phrom project. The method is detailed in the feasibility report on the Nam Phrom project. Therefore, the present report gives only the result of the study as Fig. 3-3 and Fig. 3-4.

As stated in the feasibility report on the Nam Phrom project, the power supplied from the YEA System to the NEEA Network through the tie line will, in 1974, exceed the reserve supply capacity of the NEEA System. Should a fault occur in this tie line or the YEA system and the supply of power from the YEA System suspended at that time, the NEEA System will suffer a serious supply failure as its reserve capacity is not large enough to cover the stoppage of power received from the YEA System. For this reason, it is necessary to provide a new source of power supply not later than the end of 1973.

In CHAPTER 7, study is made on the balance of supply capability and demand after 1974 as would be when the Nam Chern Power Plant is constructed as a new source of power supply. The result of the study indicates that the power the NEEA receive through the tie line after 1974 when the Nam Chern Power Plant starts operation, will remain within the reserve capacity of the NEEA System until 1976 or thereabout.

Fig 3 - 3 Estimated Maximum Power and Energy Demand 1968 to 1971 and Dry Year Supply Capability.

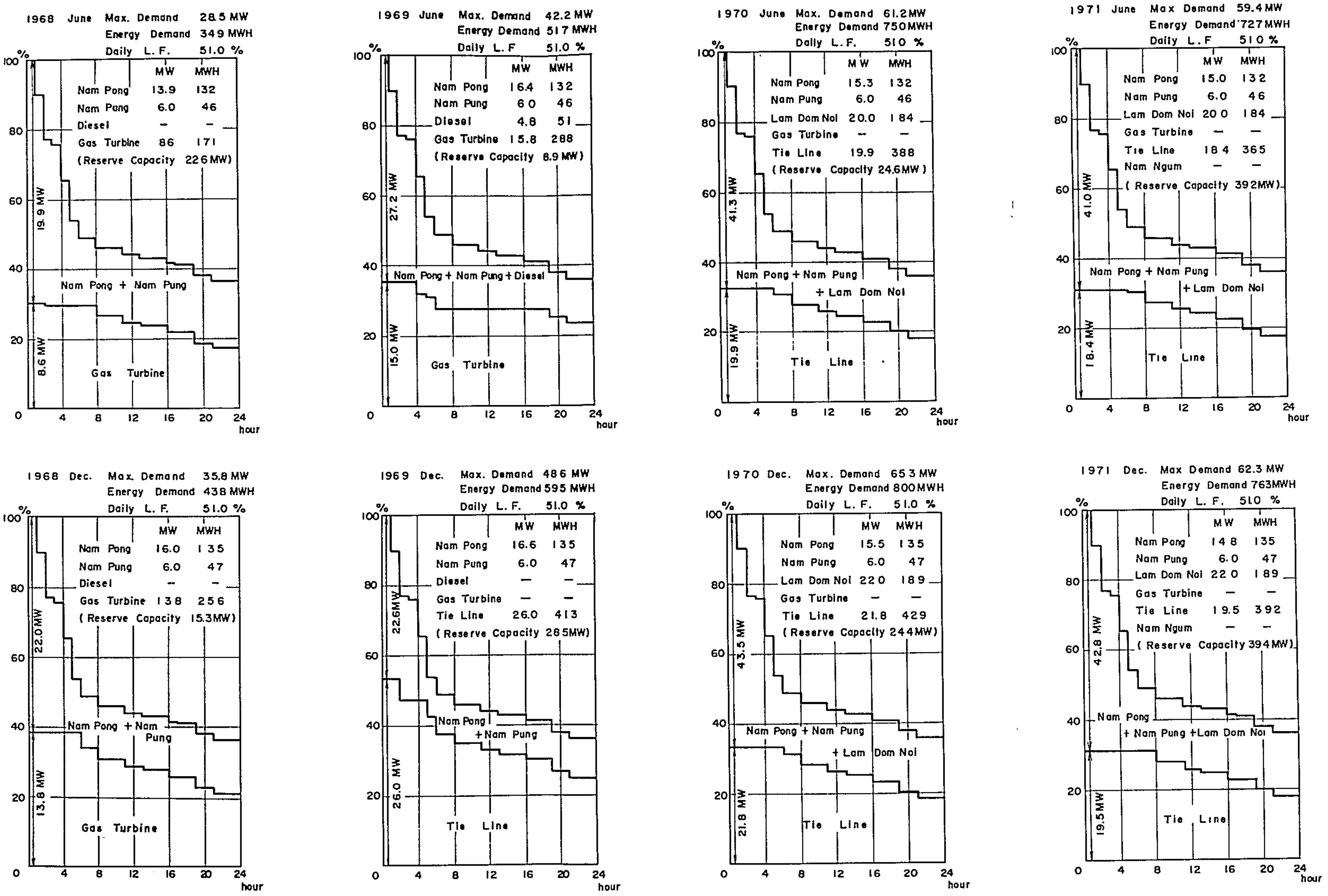


Fig 3-3 Estimated Maximum Power and Energy Demand 1968 to 1971 and Dry Year Supply Capability.

Fig 3-4 Estimated Maximum Power and Energy Demand 1972 to 1974 and Dry Year Supply Capability.

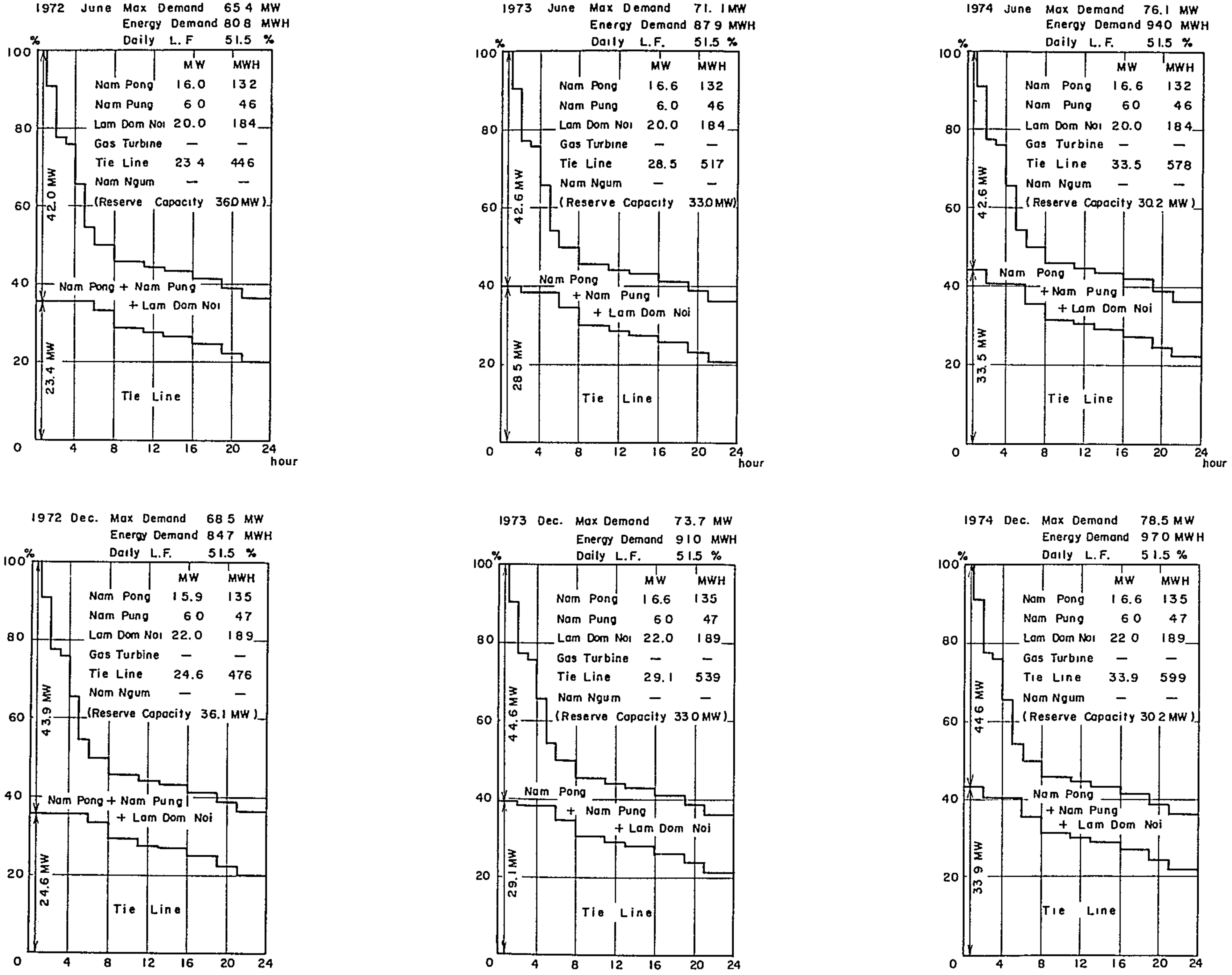


Fig 3-4 Estimated Maximum Power and Energy Demand 1972 to 1974 and Dry Year Supply Capability.

CHAPTER 4. SCHEME OF DEVELOPMENT

CHAPTER 4. SCHEME OF PROJECT

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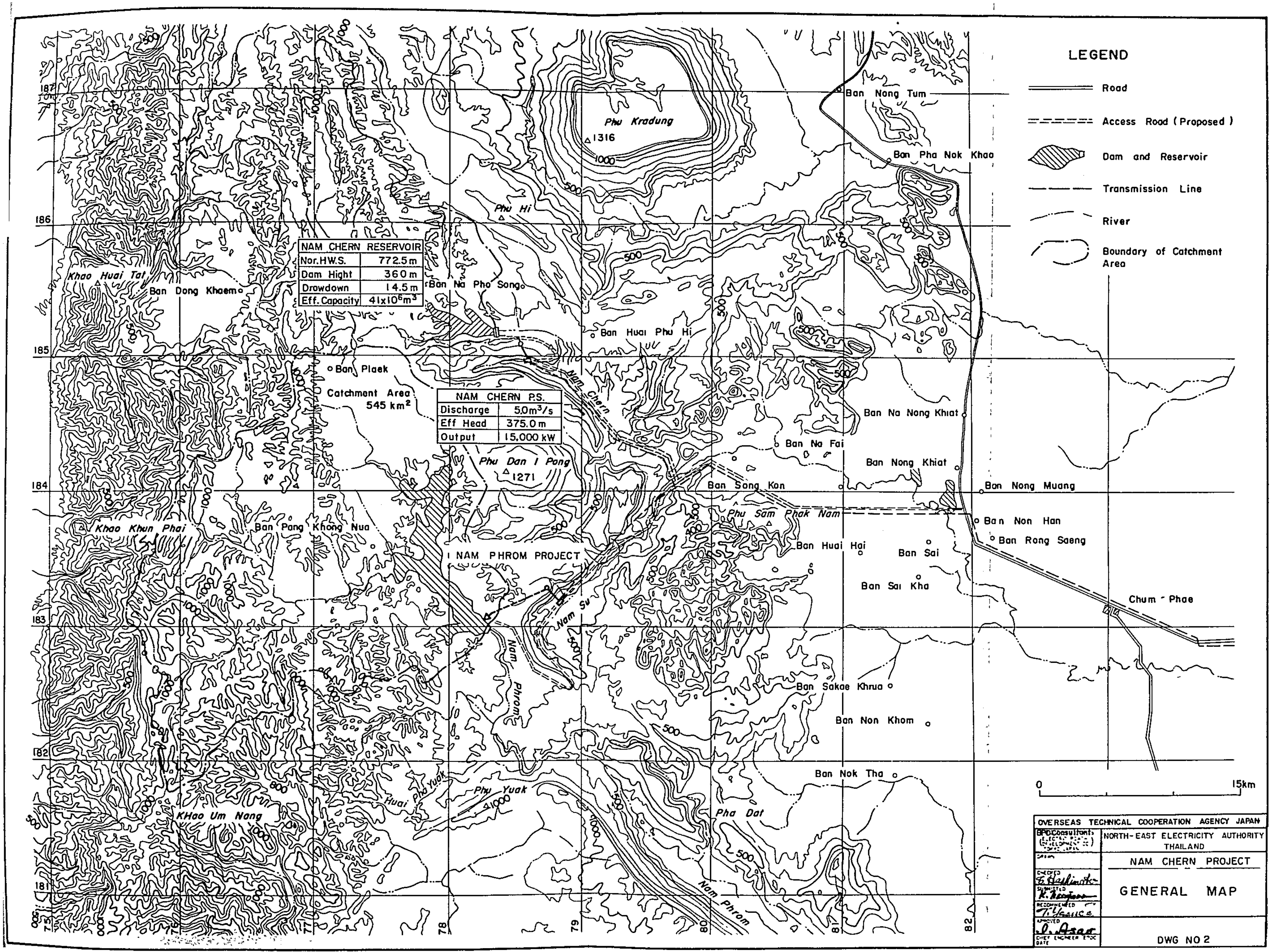

NAM CHERN RESERVOIR	
Nor.HW.S.	772.5 m
Dam Hight	360 m
Drowdown	14.5 m
Eff. Capacity	$41 \times 10^6 m^3$

NAM CHERN P.S.	
Discharge	$5.0 m^3/s$
Eff Head	375.0 m
Output	15,000 kW

OVERSEAS TECHNICAL COOPERATION AGENCY JAPAN

EPDC Consultants

NORTH-EAST ELECTRICITY AUTHORITY
THAILAND

NAM CHERN PROJECT

GENERAL MAP

DRAWN

CHECKED
E. Hashimoto

SUBMITTED

RECOMMENDED

APPROVED
I. Asao

CHIEF ENGINEER EPDC
DATE

DWG NO 2

Table 4-1 Basic Data of Project

Item	Unit	Nam Chern Project	Remarks
Method of Power Generation		Dam-Waterway type	
Catchment Area	sq. km	158	
Reservoir			
Annual Inflow	10^6 cu. m	52	
Annual Average Inflow	cu. m/s	1.65	
Reservoir			
Maximum Water Surface Level	m	773.6	Design Flood: 850 cu. m/s
Normal High Water Surface Level	m	772.5	
Water Surface Area	sq. km	5.3	Nor. H.W.S.L.
Total Storage Capacity	10^6 cu. m	45.0	Nor. H.W.S.L.
Effective Storage Capacity	10^6 cu. m	41.0	
Available Drawdown	m	14.5	
Dam			
Type		Rock-fill	
Height x Crest Length	m	36.0 x 409.0	
Volume	10^3 cu. m	284	
Design Flood Discharge of Spillway	cu. m/s	435	
Waterway			
Headrace Diameter x Length	m	1.80 x 1,630	Pressure Tunnel
Power Production			
Standard Intake Water Level	m	768.0	
Tailwater Level	m	378.0	
Standard Effective Head	m	375.0	
Powerhouse Discharge			
Maximum	cu. m/s	5.00	
Dependable Peak	cu. m/s	4.90	
Firm	cu. m/s	1.55	

Item	Units	Nam Chern Project	Remarks
Output			
Installed Capacity	MW	15.0	
Dependable Capability	MW	14.5	
Annual Energy Production	10^3 MWH	40	
Transmission Line			
Section		Power Plant Khonkaen	
Distance	km	135	
Voltage	KV	115	
Number of Circuits		1	
Cinstruction Cost			
Generating End	10^3 Bahts	132,400	Case(C)
Transmission Line	10^3 Bahts	7,400	Case(C)
Total Construction Cost	10^3 Bahts	139,800	Case(C)
Cost of Energy	Bahts/KWH	0.250	Case(C)
Benefit-Cost Ratio		1.05	Case(C)

Note: "Case (C)" refers to CHAPTER 9. In this case, it is assumed that both the Nam Chern Project and the Nam Phrom Project are realized and that the construction costs of common parts of access road and transmission line between these project are borne by the Nam Phrom Project..

CHAPTER 4. SCHEME OF DEVELOPMENT

4.1 GENERAL DESCRIPTION OF PROJECT AREA

The Nam Chern Project area is situated in the western part of the Khorat Plateau in the north-east highlands of Thailand, and it adjoins the Nam Phrom Project area to its south.

The dam site proposed in this project is located on the Huai Chan which is a tributary of the Nam Chern. The Huai Chan originates in the moutainous zone rising on the western border of the Khorat Plateau and, flowing southeastward for about 30 km, joins the Nam Chern. The Nam Chern flows for about 200 km, combining with the Huai Nam Su and the Nam Phrom, and joins the Nam Pong at a point about 2.5 km upstream from the Ubolratana Dam. The Nam Pom flows into the Lam Chi, which traverses the Khorat Plateau southeastward, eventually joining the Mekong at the boundary of Thailand and Laos.

The catchment area of the Huai Chan at the proposed dam site is 158 km^2. The annual precipitation in this catchment area is 1,000 to 1,100 mm. The precipitation, for the most part, comes during the six months of the rainy season from May to October, and is concentrated particularly in September and October. On the contrary, there is little rain during the other six months of the dry season. This particular phenomenon of rainy season and dry season makes a great difference to the run-off which is large in September and October in the rainy season, and very small during the five months from December to April the next year.

The Huai Chan, after passing the mountainous zone forming its riverhead, flows for about 15 km through a relatively flat land with an elevation of 700 to 800 m. Then the stream gradient becomes so steep that the river flows down to an elevation of some 300 m in about 10 km. Near the end of the aforementioned flat land, the Huai Chan comes very close to the watershed on the south side. At the nearest spot to this watershed, the distance is only about 400 m. At about 2 km apart to the south from this watershed the Nam Chern flows eastward. Around here the difference of elevation between the Huai Chan and the Nam Chern is about 380 m. Such natural conditions indicate that a short headrace tunnel could divert the water of the Huai Chan into the Nam Chern and thus the high head could be made available for power generation. Furthermore, the Huai Chan permits the construction of a reservoir which is necessary to regulate the flow and use the water effectively.

The river condition stated above indicates that the water resources of the Huai Chan can be economically used for power generation.

4.2 SCHEME OF DEVELOPMENT

4.2.1 Power Generation

The power generation facilities of the Nam Chern Project consist of a dam, headrace, penstock and power-house. The maximum output will be 15,000 KW utilizing a discharge of 5.0 cu. m/s and an effective head of 375 m. The annual energy production will be about 40,000,000 KWH.

The flow of the Huai Chan fluctuates greatly not only by season, but also by year. For this reason, it is necessary to have a reservoir which can store the river run-off in the wet season and release it in the dry season, and moreover, can carry the river run-off of a wet year over to a dry year. For the reservaoir of this project, it is appropriate to have an effective storage capacity of 41 million cu. m as stated in CHAPTER 7.

The dam site is selected at a point near the end of the Plateau where the Huai Chan flows gently. Downstream from this point, the river becomes rapid and there are many water falls, providing no economical location for a dam. Upstream of this point, there is no suitable dam site commensurate with a reservoir having a large effective storage capacity.

The dam is to be about 36 m high, with a crest length of about 410 m and drawdown of 14.5 m. According to the study of the topography and geology of the dam site and the embankment materials for dam construction, it was revealed that a rockfill dam is the most economical of all types considered.

The powerhouse is to be located on the left bank of the Nam Chern. This location is appropriate considering the layout of headrace tunnel and penstock. It will be a surface type powerhouse and the main equipment will consist of one unit of a 16,000-KW vertical shaft Francis turbine and 18,000-KVA generator.

The intake will be located on the upstream right bank close to the dam, and will have a maximum capacity of 5.0 cu. m/s. The headrace is to be one pressure tunnel, 1.80 m in diameter and about 1.6 km in length. A surge tank will be installed at the end of the pressure tunnel. The penstock will be a single welded steel pipe line has an inner diameter tapering from 1.7 to 1.2 m and a length of 1,675 m.

4.2.2 Transmission System

The power energy produced at the Nam Chern Power Plant will be sent to the power system through the transmission line to be installed between the Nam Chern Power Plant and the Khonkaen Substation as shown in Fig. 4-1.

This transmission line will be about 135 km in length, and will have a voltage of 115 KV. The conductor will be 95 sq.mm ACSR, making one 3-phase 3-wire circuit, and it will be supported by zinc-galvanized steel towers. The route of the transmission line is located as close to roads as possible for facility of construction and maintenance.

4.2.3 Communication System

A power line carrier telephone line will be installed between the Nam Chern Power Plant and the Khonkaen Substation, constituting one direct circuit for power supply service.

Fig 4-1 Transmission Line Route Map

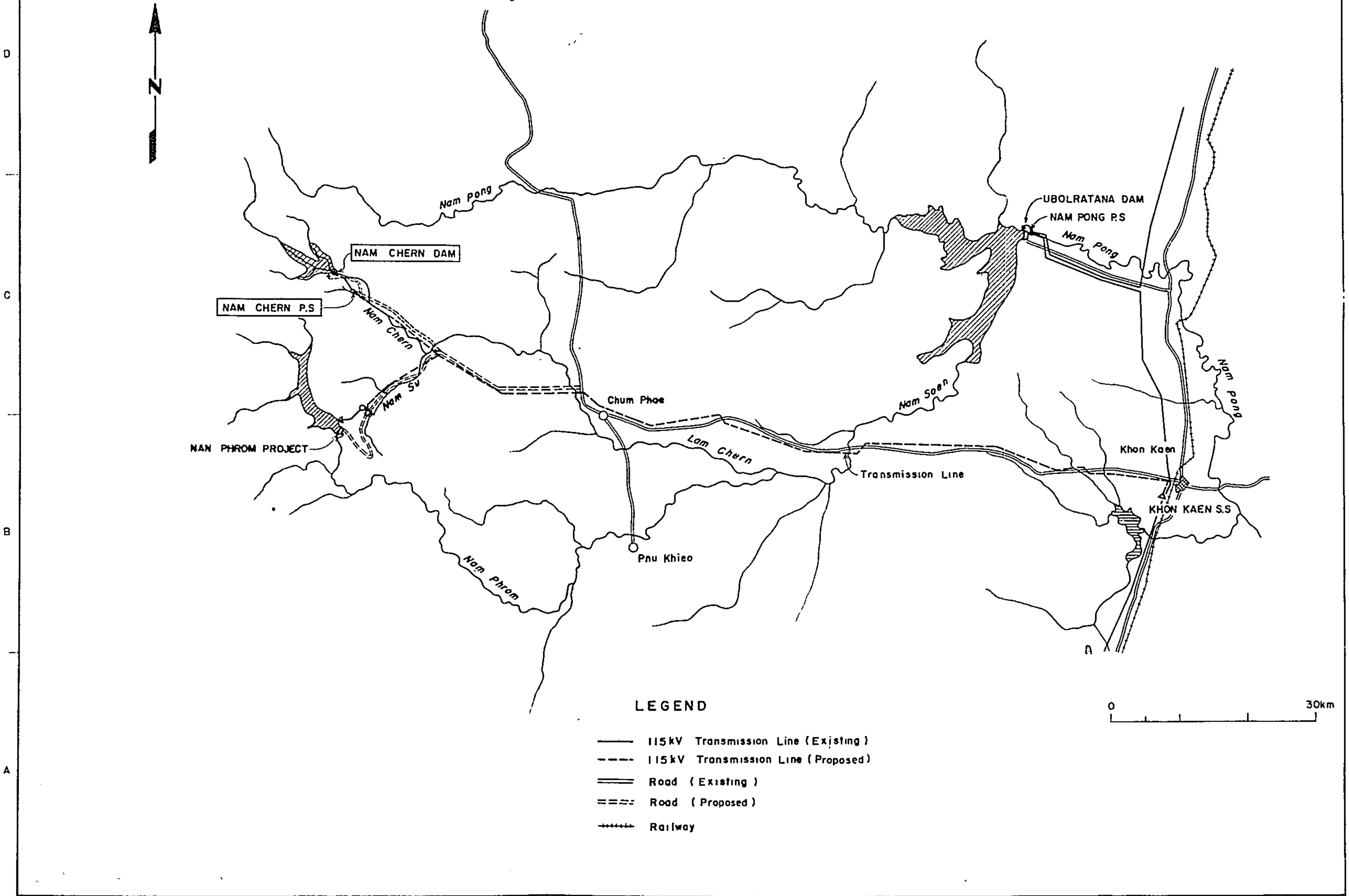

Fig. 4-1 Transmission Line Route Map

CHAPTER 5. HYDROLOGY

CHAPTER 5. HYDROLOGY

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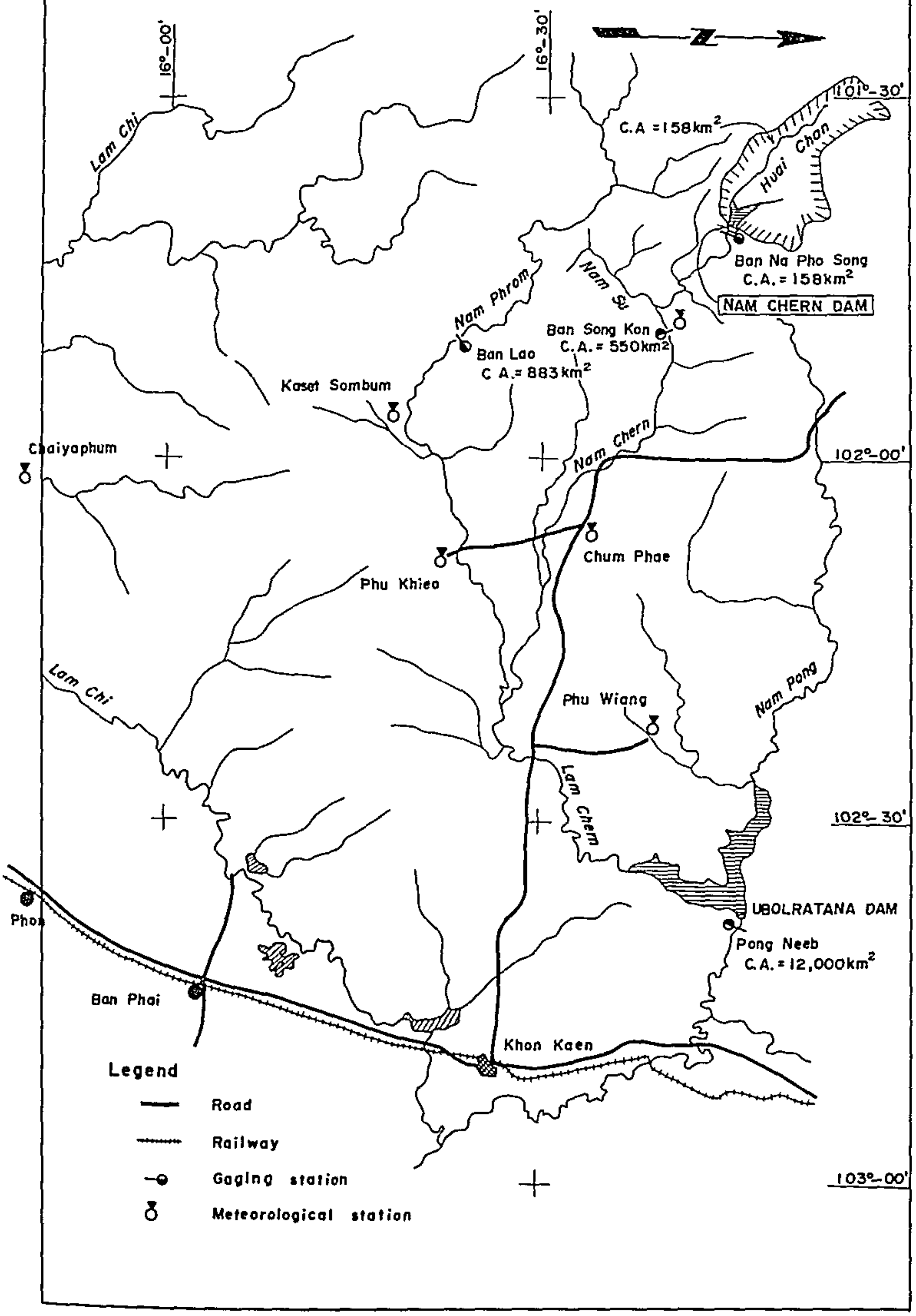


CHAPTER 5. HYDROLOGY

5.1 RUN-OFF GAGING STATIONS AND METEOROLOGICAL STATIONS

The locations of run-off gaging stations and meteorological stations in the catchment area and surrounding areas of the Nam Chern Hydroelectric Power Project are shown in Fig. 5-1, and the records of run-off and precipitation are shown in Table 5-1 and 5-2.

Table 5-2 Existing Runoff Data.

Station	River	C.A (sq kg)	Latitude	Longitude	'55	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66
Ban Song Kon	Chern	550	16°38' N	101°48'E								Sept.	—	—	—	—
Ban Na Pho Song	"	158	16°44' N	101°39'E												Sept.
Ban Lao	Phrom	883	16°20' N	101°51'E												June
Pong Neeb	Pong	12,000	16°49' N	102°35'E	June	—	—	—	—	—	—	—	—	—	—	—

Table 5-3 Existing Evaporation, Temperature and Wind Data.

Item	Station	'46	'47	'48	'49	'50	'51	'52	'53	'54	'55	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66
Temperature	Khon Kaen						—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Chaiyaphum												—	—	—	—	—	—	—	—	—	—
Wind Speed & Movement	Khon Kaen											—	—	—	—	—	—	—	—	—	—	—
	Chaiyophum																	—	—	—	—	—
Evaporation	Khon Kaen														—	—	—	—	—	—	—	—
	Chaiyaphum														—	—	—	—	—	—	—	—
	Chum Phae																			—		

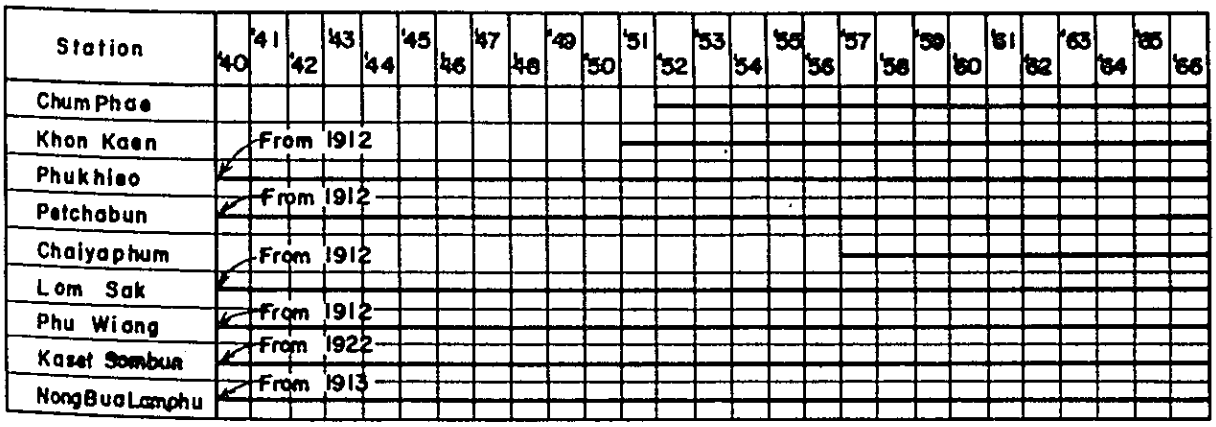
Although in the catchment area of the project site there is no precipitation observation station, the Chumphae Station, which is close to the project area, where daily precipitation records are available for a period of over fifteen years can be utilized for the estimation of river run-off for studying the power development scheme. Also, hourly precipitation records for a period over fifteen years, that are available at Khonkaen station which is located close to the catchment area of the project site, are useful for calculation of flood discharge. Data of other precipitation observatories are also used to supplement the studies.

There are two run-off gaging stations in the project area. One is located at Ban Na Po Song at the proposed damsite on the Huai Chan, which has records available only for 5 months from August to December in 1966. The other is located on the Nam Chern at Ban Song Kon and has records for a period of over 4 years from 1963 to 1966.

The river run-off at proposed dam site can be estimated with a fair degree of reliability for studying the power development scheme on the basis of the above-mentioned data by correlating the run-off between these gaging stations as well as by correlating the run-off and precipitation data.

Other meteorological data such as temperature, wind and evaporation are used for estimation of flood discharge and evaporation loss from the reservoir surface.

Table 5-1 Existing Precipitation Data.



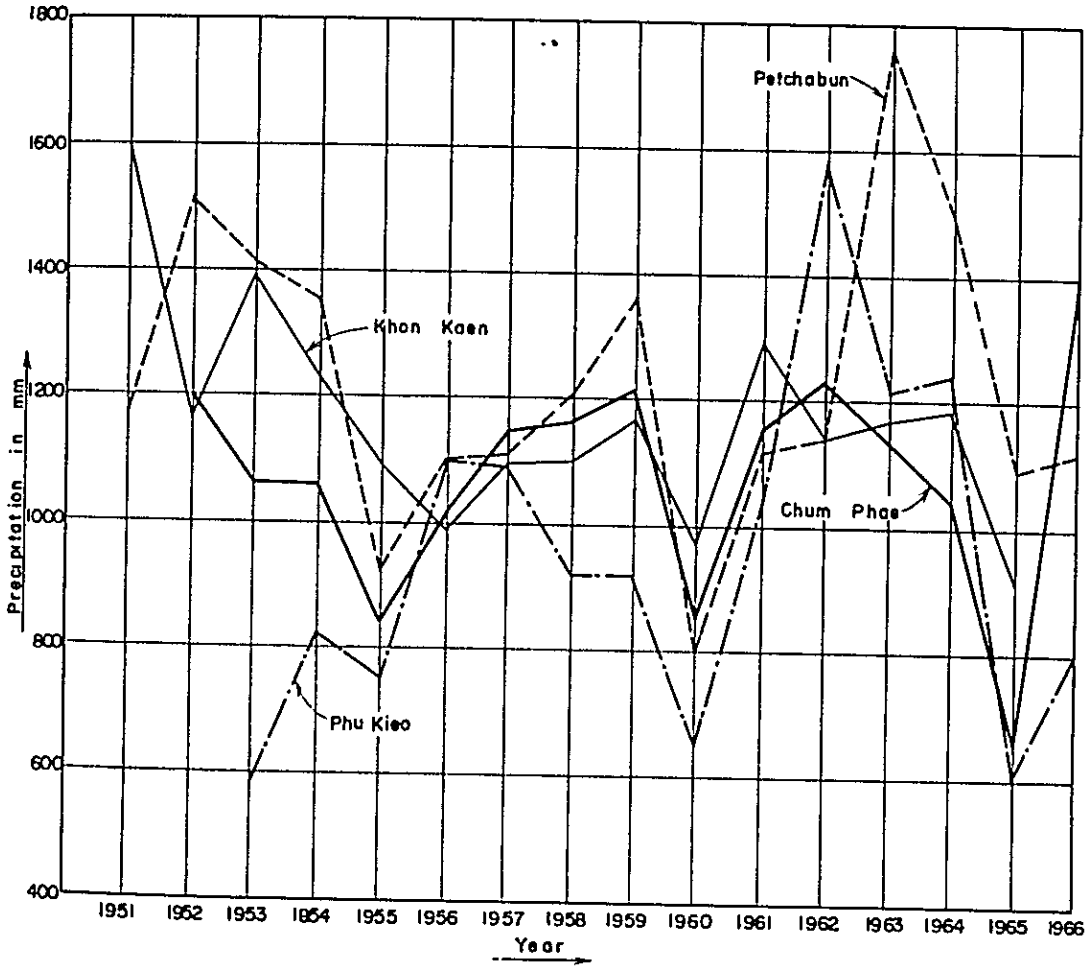
5.2 CATCHMENT AREA OF THE PROJECT SITE

The catchment area at the proposed dam site of the Nam Chern Project is estimated as 158 sq. km based on the topographical map on the scale of one to 50,000 prepared by the Royal Thai Survey Department.

5.3 PRECIPITATION

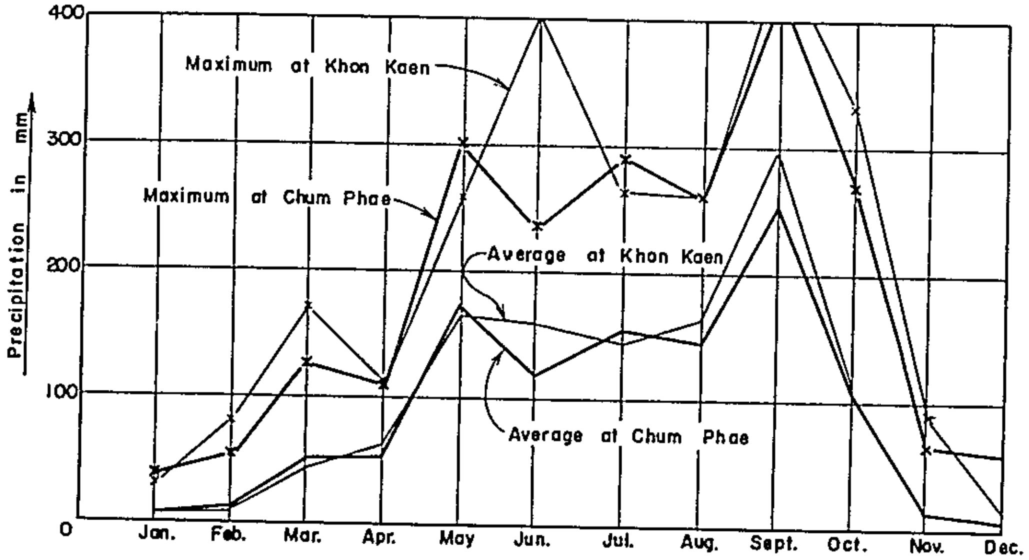
The annual precipitation in the project area for 15 years from 1951 to 1966 is shown in Fig. 5-2. According to this figure, it will be noted that there are considerable fluctuations each year. This suggests the necessity of a relatively large reservoir for the project in order to utilize the water resources effectively by carrying over the water of wet year to the dry year.

Fig. 5-2 Annual Precipitation



The variation of monthly precipitation is indicated in Fig. 5-3, and it can be understood that the rainy season is six months from May through October and the dry season is six months from November through April.

Fig. 5-3 Monthly Precipitation (1951 to 1966)



5.4 RIVER RUN-OFF

5.4.1 Method of Estimating Run-off

The correlation between the cumulative run-off at Ban Song Kon and the cumulative precipitation at Chumphae for each year was plotted in Fig. 5-4 for the period from 1963 to 1966, for which period run-off data are available at Ban Song Kon station. As shown in Fig. 5-4, there is a fairly good correlation between the run-off at Ban Song Kon and the precipitation at Chumphae except for the year of 1966. The reason why the correlation in 1966 is not good is considered as follows.

In that year, the precipitation at Chumphae was 1,364 mm, which is the maximum value during the past 15 years, whereas the precipitations at other surrounding stations were normal. On the other hand, the correlation of the precipitation data between Phukieo and Chumphae was studied for the purpose of checking the precipitation at Chumphae in the year 1966. This study which is shown in Fig. 5-5, indicates the existence of a good correlation between Chumphae and Phukhieo except for the year 1966. According to the correlation curve shown in Fig. 5-5, the precipitation data of 1966 at Chumphae should be about 850 mm against 1,364 mm which is the recorded data. Therefore, it is concluded that the year 1966 seemes to be extraordinary at Chumphae from the point of view of hydrology and the precipitation data of 1966 at Chumphae should be disregarded for the present study.

Fig. 5-4 Correlation between Runoff at Ban Song Kon and Precipitation at Chum Phae

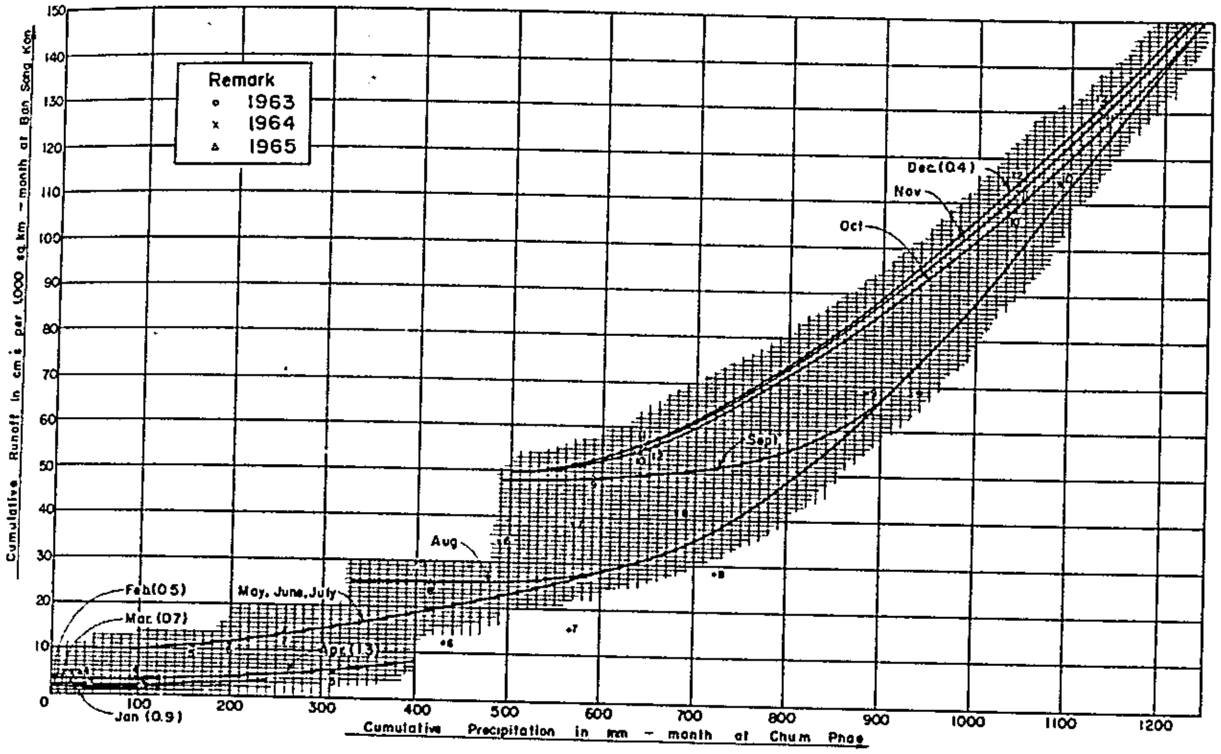
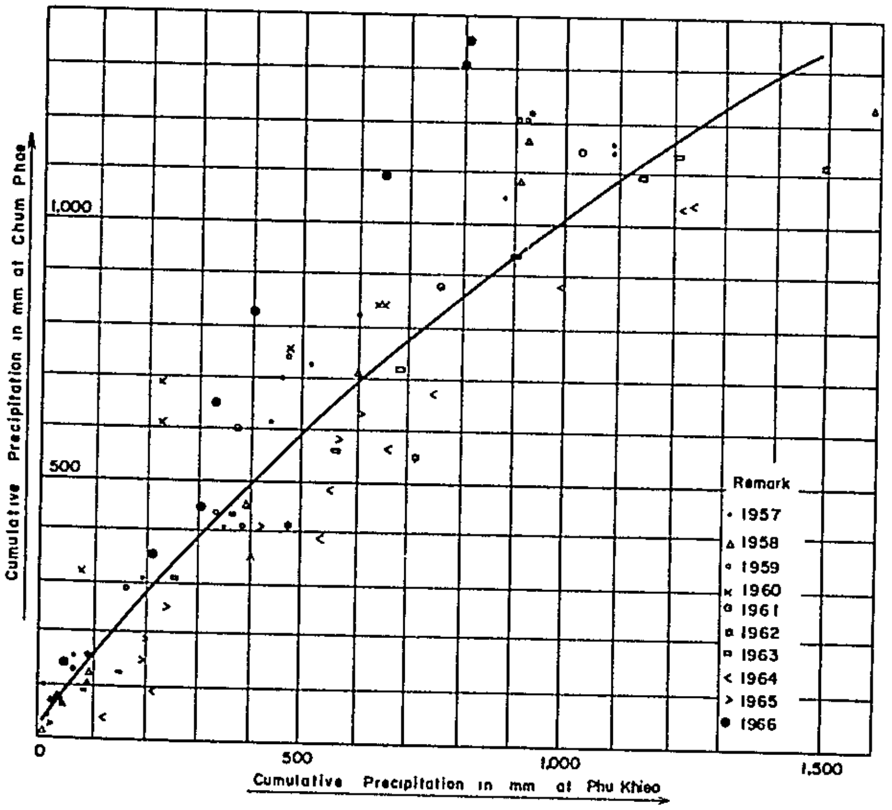


Fig. 5-5 Correlation between Precipitation at Phukleo and Chumphae



The river run-off at the proposed dam site was estimated on the basis of the Chumphae precipitation data and the Ban Song Kon run-off data. The run-off data at Ban Song Kon are available for only four years from 1962 to 1966. The run-off at Ban Song Kon for other nine years from 1952 to 1961 were estimated by utilizing the precipitation data at Chumphae on the basis of the correlation curve shown in Fig. 5-4.

The precipitation in this area is brought on by the monsoon which blows into the project area from southwest and gives an abundant precipitation at the watershed towards the monsoon route. About one half of the watershed of upstream area of Ban Lao Gaging Station on the Nam Phrom and of upstream area of the proposed dam site on the Huai Chan are located towards the monsoon route, whereas only about 20 percent of the watershed of Ban Song Kon Gaging Station on the Nam Chern is located towards the monsoon route.

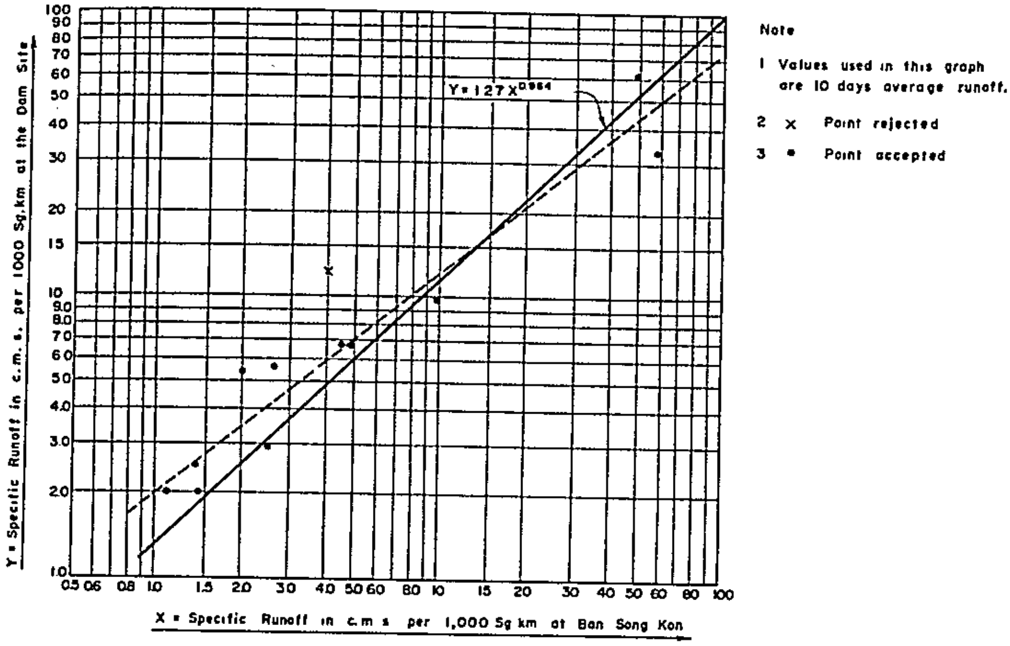
From the above-mentioned reason, it can be justified that the specific run-off at Ban Lao on the Nam Phrom and that at the proposed dam site on the Huai Chan (or Ban Na Pho Song) are nearly the same and that both are a little larger than the specific run-off at Ban Song Kon on the Nam Chern.

Correlation of the specific run-off between Ban Song Kon on the Nam Chern and the proposed dam site on the Huai Chan is indicated with a dotted line in Fig. 5-6. The data on Aug. 11 to 20 have been disregarded because they were judged to be outside the limit of reliability in accordance with statistical procedures. The solid line in Fig. 5-6 indicates the correlation of the specific run-off between Ban Lao on the Nam Phrom and Ban Song Kon on the Nam Chern. The average value of specific run-off calculated with the dotted line is almost the same as the one calculated with the solid line since these lines cross each other around the average specific run-off of 11 c.m.s.

The specific run-off at the proposed dam site which is more than 25 c.m.s. calculated with the dotted line is smaller than that of Ban Song Kon. Although this cannot be understandable theoretically, it is considered that this is because the data were not enough. If there had been enough data, the dotted line would have been approached to the solid line.

Consequently, as a conclusion, the specific run-off at Ban Lao on the Nam Phrom was adopted as the specific run-off at the proposed dam site on the Huai Chan. Therefore, for the estimation of the run-off at the proposed dam site, the correlation indicated in Fig. 5-6 as the solid line was used.

Fig. 5 - 6 Correlation of Specific Runoff between Ban Song Kon on the Nam Chern and the Proposed Dam Site on the Huai Chan



5.4.2 Run-off at the Proposed Dam Site

The run-off at the proposed dam site (C.A. = 158 sq.km) on the Huai Chan for the 13 years from 1954 to 1966 obtained by the above-mentioned procedure is tabulated in Table 5-4.

Table 5-4

RUN-OFF AT DAM SITE STATION NAM CHERN CATCHMENT AREA 158 sq km UPPER NAM PONG, THAILAND
CHERN RIVER, IN THE BASIN OF CHERN ELEVATION m UNIT c.m.s. S . W .

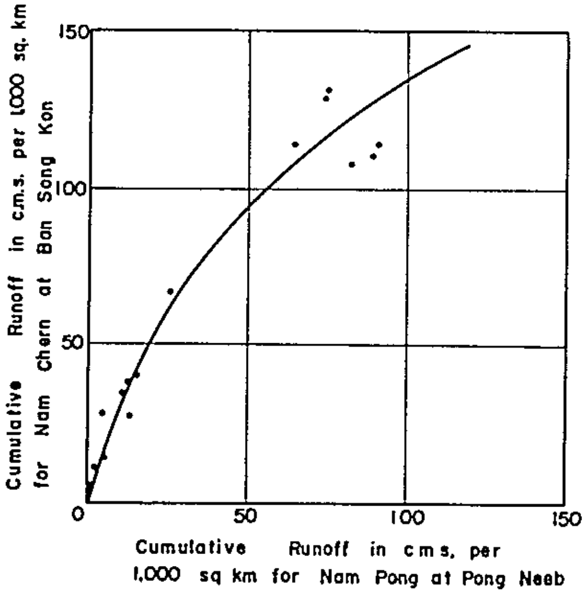
YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	ANNUAL TOTAL
1954	0.2	0.1	0.1	0.3	1.6	0.4	0.9	2.2	7.8	6.1	0.8	0.4	1.7
1955	0.2	0.1	0.1	0.3	1.6	1.5	0.4	1.5	4.6	3.5	0.3	0.2	1.2
1955	0.2	0.1	0.1	0.3	1.9	0.8	2.0	2.0	7.8	2.8	0.6	0.4	1.6
1957	0.2	0.1	0.1	0.3	2.0	0.8	1.8	1.7	10.4	4.7	0.9	0.4	2.0
1958	0.2	0.1	0.1	0.3	1.5	1.0	0.8	2.8	11.6	3.9	0.6	0.4	2.0
1959	0.2	0.1	0.1	0.3	2.1	0.8	3.0	2.8	13.9	0.4	0.9	0.4	2.1
1960	0.2	0.1	0.1	0.3	2.3	0.8	1.6	1.0	3.1	4.4	0.4	0.2	1.2
1961	0.2	0.1	0.1	0.3	2.3	0.8	1.5	2.1	4.1	10.2	0.9	0.4	1.9
1962	0.2	0.1	0.1	0.3	2.3	0.5	1.2	1.7	13.4	6 7	1.5	0.2	2.4
1963	0.1	0.1	0.1	0.1	0.7	1.3	0.7	2.2	6.5	7.7	2.7	0.4	1.9
1964	0.3	0.1	0.1	0.4	4.4	1.0	0.8	0.4	4.6	6.7	0.8	0.4	1.7
1965	0.2	0.1	0.2	0.4	1.1	0.3	0.5	2.1	3.9	1.0	0.3	0.1	0.8
1966	0.1	0.1	0.1	0.6	1.3	0.4	*0.6	*1.5	*5.5	*2.0	*0.5	*0.3	1.1
AVERAGE	0.2	0.1	0.1	0.3	1.9	0.8	1.2	1.9	7.5	4.6	0.9	0.4	1.7

* Those value were calculated from the run-off observed at Ban Na Pho Song at the proposed dam site on the Huai Chan.

5.4.3 Study of River Run-off at the Proposed Dam Site on the Basis of Run-off Data Available at Pong Neeb

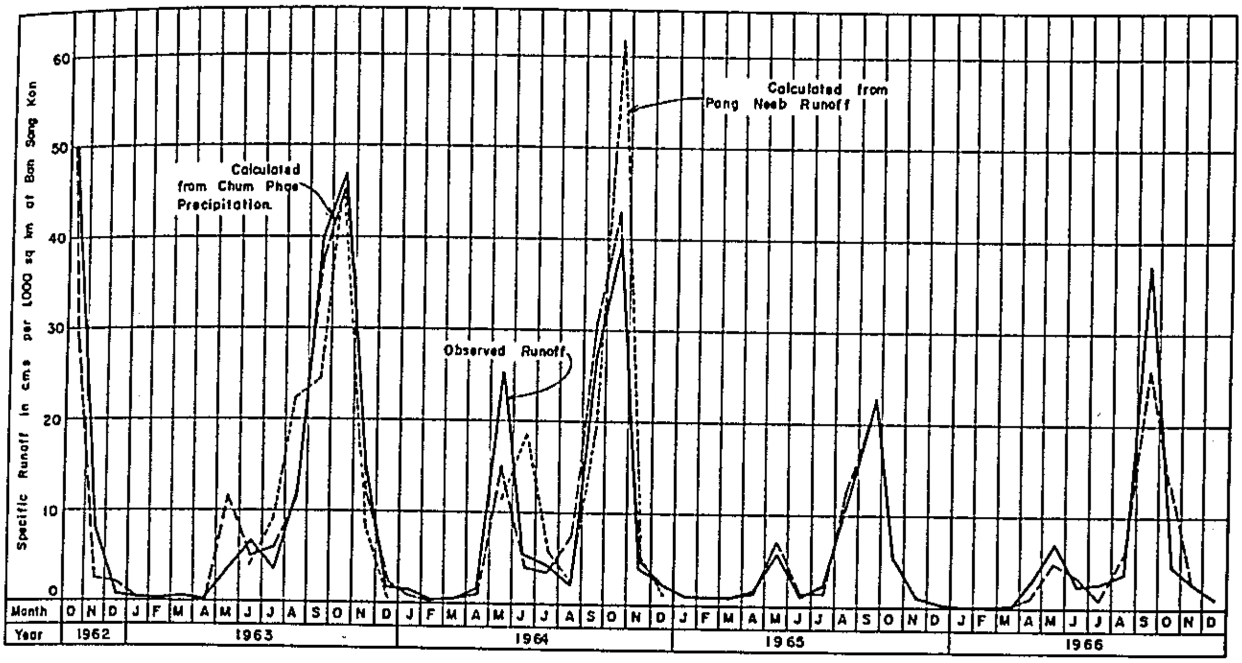
The possibility to use the river run-off data available at Pong Neeb instead of the precipitation data at Chumphae, in the estimation of the river run-off at the proposed dam site, has been studied. The correlation of the cumulative specific run-off between Ban Song Kon and Pong Neeb is shown in Fig. 5-7. The period covered is from 1963 to 1964, which are the years where data exist at both stations. Using this correlation for the purpose of comparison, the river run-off at the Ban Song Kon was calculated and plotted in Fig. 5-8. The graph in the Figure also gives the calculated river run-off on the basis of the Chumphae precipitation data and actually observed river run-off.

Fig. 5-7 Correlation between Runoff at Pong Neeb and Ban Song Kon



The Fig. 5-8 shows that the calculated river run-off on the basis of the Chumphae precipitation coincides much better with the observed river. Therefore, the use of the precipitation data of Chumphae has been considered more preferable than the use of run-off data at Pong Neeb.

Fig. 5-8 Hydrograph of the Nam Chern at Ban Song Kon.



5.5 FLOOD FLOW

As the proposed dam is a rockfill structure, the probable maximum flood discharge at the dam site was studied for spillway design purpose. In this study, statistical and physical methods were employed.

5.5.1 Statistical Method

In the statistical method, probability calculation should be made based on flood records covering many years. Since the run-off data in the project area is available for only 5 years, it is impossible to estimate probable maximum flood discharge based on the run-off data. Therefore, the rainfall frequency was studied and the flood discharge was estimated by employing the Rational Formula.

Rational Formula is expressed as follows:

$$Q = 0.2778\ f \cdot r \cdot A$$

where Q : Design flood discharge (cubic meter per second)

f : Coefficient of flood flow

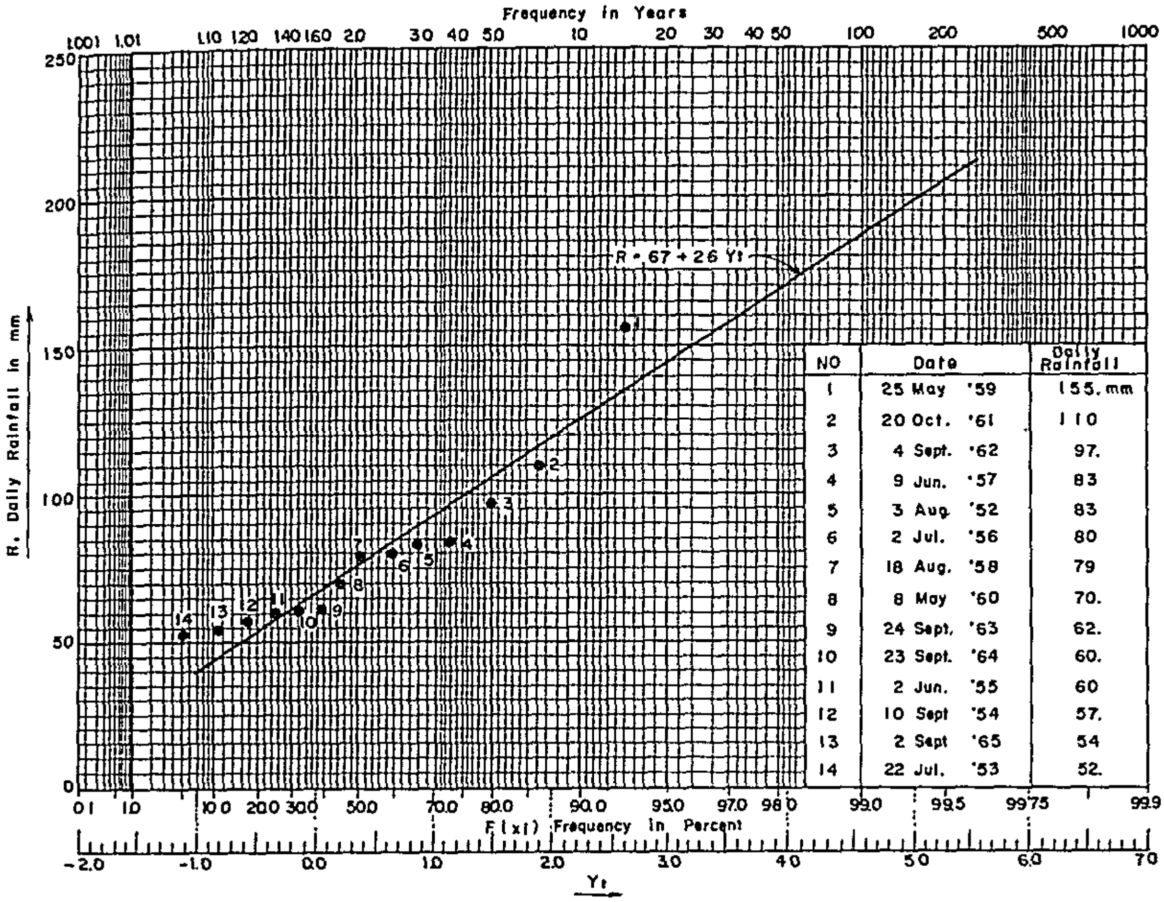
r : Average intensity of precipitation within flood arriving time (mm per hour)

A : Catchment area (square kilometer)

Coefficient of flood flow "f" was set uniformly at 50 percent for large-scale floods and 40 percent for small-scale floods in consideration of vegetation, topography, size and other factors of the catchment area. The coefficient of flood flow calculated from the actual data ranges from 30 to 40 percent and the annual run-off coefficient ranges from 20 to 30 percent. According to our experience, the coefficient of flood flow is generally 1.2 times of the annual run-off coefficient. Therefore, it is deemed that the estimated coefficient of flood flow can be considered as reasonable. "r" was estimated on the basis of daily precipitation by depending upon the time required for flood discharges to arrive from the farthest point upstream and by the pattern of hourly rainfall distribution. Arrival time was calculated by Rziha's formula for the mountain district (length = 5 km, slope = 1/63), by Kraven's formula for the plain district (length = 20 km, slope = 1/333) and by the half speed of wave propagation for the reservoir area (length = 10 km, average water depth = 20 m). The total arrival time was found to be 4.0 hours comprising of 0.8, 2.8, 0.4 hours for the respective areas. The pattern of hourly rainfall was estimated from hourly rainfall data at Khonkaen as shown in Fig. 5-10. Catchment area "A" is 158 sq. km at the proposed dam site. The relation between the amount of daily precipitation and its frequency which was determined on the basis of data available at Chumphae station by employing Gumbel's method is shown in Fig. 5-9. The value of "r" corresponding to each frequency can be derived from Fig. 5-9. Flood frequency at the proposed dam site calculated by the above-mentioned method is as follows:

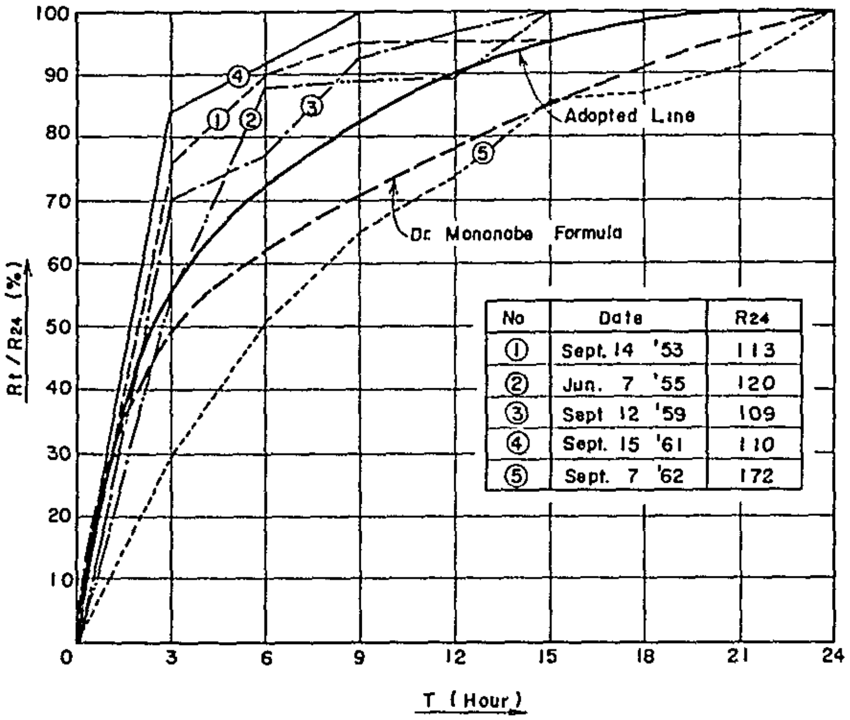
Frequency Year	Probability Rainfall at Chumphae		Coefficient of Flood Flow (f)	Catchment Area (A)	Flood Flow at the proposed dam site (Q)
	Daily (r_{24})	Average for Arriving Time (r_4)			
3 year	90mm	14.0mm	0.40	158 sq.km	250 c.m.s.
5	106	16.5	"	"	300
10	125	19.4	"	"	350
20	144	22.3	"	"	400
100	187	29.0	0.50	"	500
200	205	31.8	"	"	600
1,000	250	38.8	"	"	700
5,000	285	44.2	"	"	800
10,000	307	47.6	"	"	850

Fig. 5-9 Rainfall Frequency at Chum Phae



NO	Date	Daily Rainfall
1	25 May '59	155. mm
2	20 Oct. '61	110
3	4 Sept. '62	97.
4	9 Jun. '57	83
5	3 Aug. '52	83
6	2 Jul. '56	80
7	18 Aug. '58	79
8	8 May '60	70.
9	24 Sept. '63	62.
10	23 Sept. '64	60.
11	2 Jun. '55	60
12	10 Sept '54	57.
13	2 Sept '65	54
14	22 Jul. '53	52.

Fig. 5-10 Distribution of Hourly Rainfall at Khon Kaen



No	Date	R24
①	Sept. 14 '53	113
②	Jun. 7 '55	120
③	Sept 12 '59	109
④	Sept. 15 '61	110
⑤	Sept. 7 '62	172

R_{24} : Rainfall in 24 hrs.
R_t : Rainfall in T hrs.

5.5.2 Physical Method

The physical method gives the probable maximum precipitation that may happen if all factors contributing to the generation of a precipitation were to reach their most critical condition simultaneously, from which the probable maximum flood can be obtained.

It is customary to consider dew point and wind speed as the factors which contribute to the generation of a precipitation. Dew point is used for the determination of precipitable potential water, which is the maximum amount of moisture that can be retained in a vertical column of air and has been found by reliable research observations to vary almost directly according to surface dew point (or air temperature). For the estimation of precipitable potential water, it is convenient to use a diagram prepared by the U.S. Weather Bureau (See Appendix -B). Wind movement is the measure required to replenish the air with moisture that has been precipitated. The product of precipitable water in the atmosphere and wind speed is defined as "Moisture Inflow Index". Ordinarily, in the study of depressive storms, such as monsoon, a maximum 12-hour persisting dew point and a maximum 24-hour average wind speed are used.

At the project site of the Upper Nam Pong Basin, the humidity is considered to be close to 100 % during a storm, therefore air temperature can be used instread of dew point.

As regards to wind speed, the upper stratospheric wind speed should be considered in addition to the ground wind speed. Observations of such data, however, are very limited, particularly in Southeast Asia. The observatory with reliable data concerning the upper stratospheric wind speed exists only in Bangkok. Therefore, only the ground wind speed data available at Khonkaen were taken into consideration.

The probable maximum precipitation can be calculated by the following formula.

$$\text{P.M.P.} = \text{D.D.A.} \times \frac{\text{M.I.I. for P.M.P.}}{\text{M.I.I. for H.S.}}$$

where : P.M.P. = Probable Maximum Precipitation

D.D.A. = Depth Duration Area

M.I.I. for P.M.P. = Moisture Inflow Index for P.M.P.

= Precipitable water for maximum 12-hour persisting dew point (or air temperature) for P.M.P. x Maximum 24-hour average wind speed for P.M.P.

M.I.I. for H.S. = Moisture Inflow Index for Historical Storm
= Precipitable water for maximum 12-hour persisting dew point (or air temperature) for H.S. x Maximum 24-hour average wind speed for H.S.

Seasonal variation of several factors, such as, the maximum dew point (temperature in this study), precipitable water, wind speed and moisture inflow index anticipated in the project area are shown in Fig. 5-11.

If D.D.A. is substituted by the actually measured flood flow at Ban Song Kon in the above-mentioned formula, it will give the probable maximum flood at Ban Song Kon.

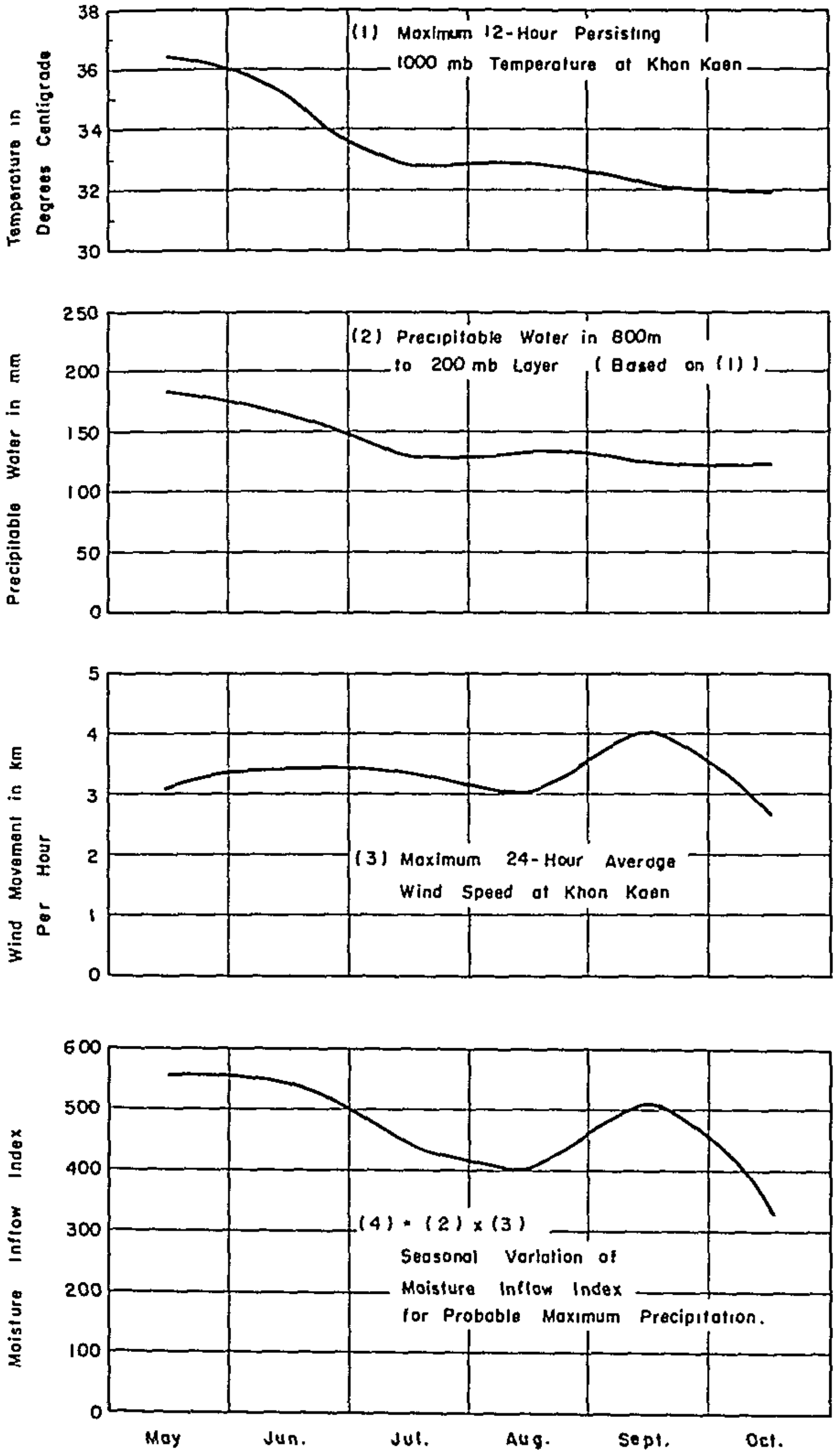
The use of actual flood flow record instead of D.D.A. can be justified in this case, because the time lag beween precipitation and run-off and charge in retention rate can be considered negligible due to the small catchment area and the relatively short arrival time of flood.

The maximum flood flow so far recorded at the Ban Song Kon gaging station for the five years from 1962 to 1966 was 656 c.m.s. at 12 o'clock on 30 September in 1962, and maximum 12-hour persisting 1000 mb temperature and maximum 24-hour average wind speed at that time have been recorded as 27.9 degrees centigrade and 1.6 km per hour respectively. The precipitable potential water corresponding to the temperature of 27.9 degree centigrade is 84 mm assuming a barrier height of the catchment area as 800 m above mean sea level. The moisture inflow index for this flood is calculated as 135 multiplying the precipitable water of 84 mm by the wind speed of 1.6 km per hour. On the other hand, the maximum inflow index in September is 510 according to Fig. 5-11. Therefore, the probable maximum flood discharge at Ban Song Kon can be estimated as follows:

$$656 \times \frac{510}{135} = 2,500 \text{ c.m.s.}$$

It can be considered from Fig. 5-6 that specific run-off during storm at the proposed dam site on the Huai Chan is almost the same as that at Ban Song Kon on the Nam Chern. Therefore, the probable maximum flood discharge physically obtained at the proposed dam site can be considered 750 c.m.s. which is obtained by multiplying the flood discharge at Ban Song Kon, 2,500 c.m.s., by the ratio of catchment area between the proposed dam site and Ban Song Kon as follows:

Fig. 5-11 Seasonal Variation of Several Factors for Probable Maximum Precipitation

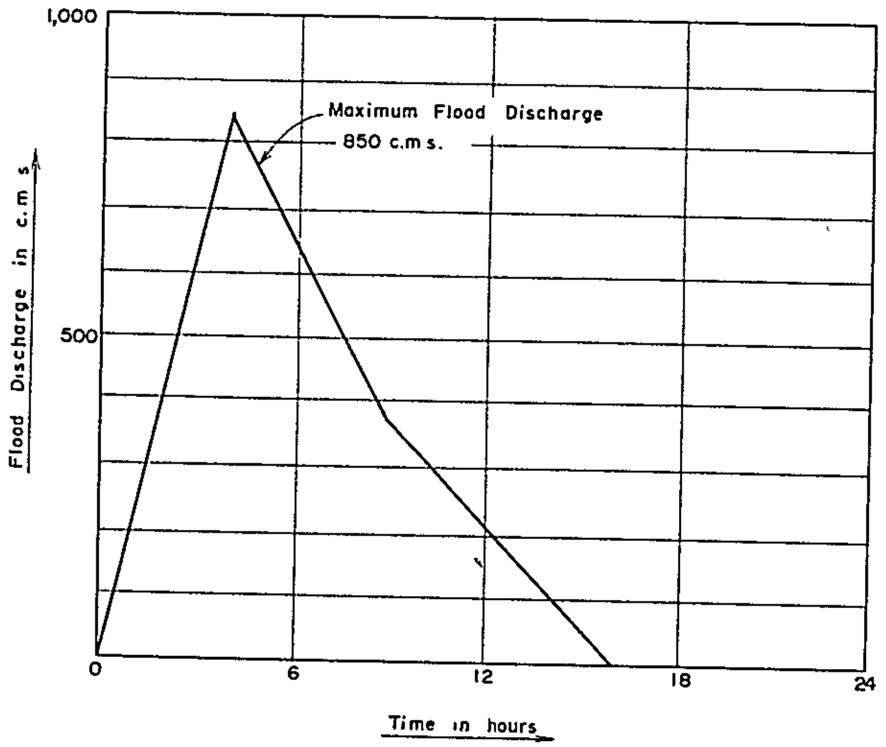


$$2,500 \times \frac{158}{545} = 750 \text{ c.m.s.}$$

According to the result of studies stated in the preceeding paragraph, the flood discharge with a frequency of once in 10,000 years will be 850 c.m.s.. The flood discharge of such an extremely rare frequency will be regarded as the practically probable maximum. On the other hand, studies employing physical method revealed that the maximum flood discharge at the proposed dam site will be probably 750 c.m.s. under critical condition. Although data available for physical method studies might be insufficient, the result coincides well with the result obtained by the statistical method. Therefore, the flood discharge to be used for the spillway design was determined as 850 c.m.s.

The flood hydrograph was determined according to Possentio triangle method taking into consideration the flood arrival time which is 4.0 hours, as determine in the preceeding studies, and shown in Fig. 5-12.

Fig. 5-12 Flood Hydrograph of Probable Maximum Flood Discharge at the Proposed Dam Site



5.6 EVAPORATION

Annual evaporation loss measured at Ban Song Kon in 1964 was 750 millimeters, and those measured at Chayaphum in 1960 through 1966 were as follows:

1960	1230 mm	1964	1371 mm
1961	1174 mm	1965	1430 mm
1962	1214 mm	1966	1534 mm
1963	1312 mm	Average	1308 mm

According to these values, it is noted that the value in 1964 is almost the same as the average value. Therefore, annual evaporation loss of 750 mm measured at Ban Song Kon in 1964 can be considered tha average value.

Since these values were measured by class A pan, 60 to 80 % of the values should be used in the calculation of evaporation loss from the reservoir surface. Assuming a coefficient of 80 %, the evaporation loss from the reservoir surface of the project will be 600 mm annually. Evapo- ranspiration which should be deducted from the evaporation loss was neglected in this study to be n the conservation side.

.7 SEDIMENTATION

Since no data are available in connection with sedimentation in the project area, the sedi- entation at the reservoir of the project was estimated on the basis of past records of sedimenta- on observed in reservoirs in Japan.

Sedimentation of 52 reservoirs in Japan with a catchment area of more than 60 sq. km and orage capacity of more than one million cu. m were plotted in Fig. 5-13, in relation to the geo- gical characteristics, topographical features and the rainfall in the catchment area. The geological aracteristics of the catchment area are classified into three groups according to the rock forma- n in the catchment area, namely,

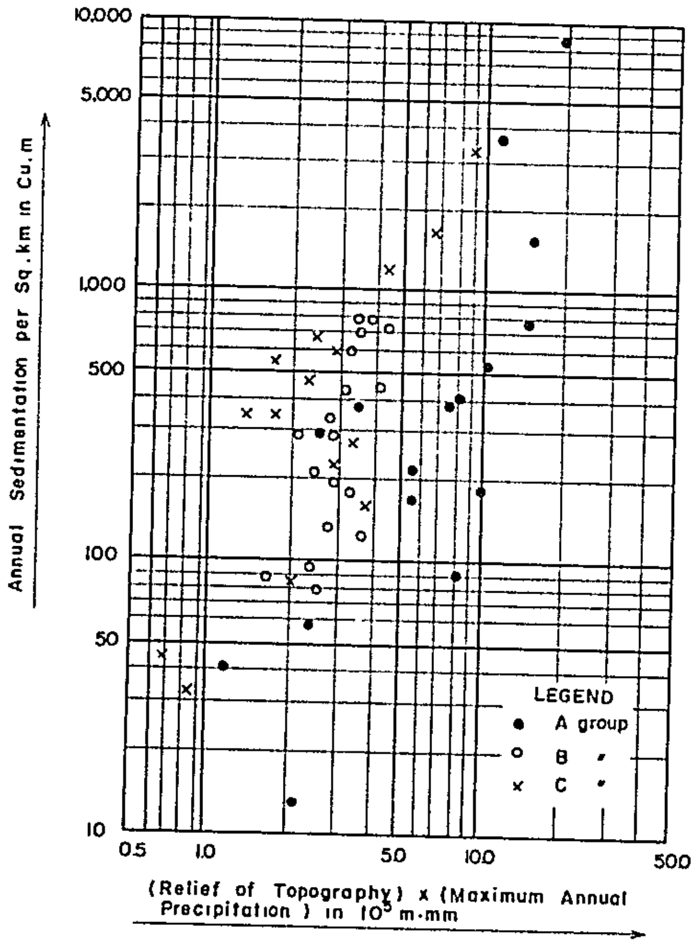
A: Catchment area consisting mainly of Paleozoic and Mesozoic sedimentary rocks

B: Catchment area consisting mainly of acidic plutonic, hypabyssal and their metamorphic rocks represented by granite and schist

C: Catchment area consisting mainly of Cenozoic sedimentary rocks and effusive rocks

Sedimentation for each group are plotted in Fig. 5-13 as a function of the product of the maximum annual precipitation and the relief. During rainfall, the clastic rocks eroded in the catchment area were transported into the reservoirs. The relief is defined as an average of the difference between the highest and lowest levels in each square grid, which is 16 sq. km in area and was established by dividing the whole catchment area.

Fig 5-13 Correlation between the Sedimentation in Reservoirs and Relief and Maximum Annual Precipitation



As for the catchment area at the proposed dam site, the basic values which govern sedimentation are as follows:

Geology: Belongs to A group

Maximum Annual Precipitation: About 1,300 mm

Relief: About 150 m

(Maximum Annual Precipitation) x (Relief) = $2 \times 10^5 m \cdot mm$

Therefore, according to Fig. 5-13, the sedimentation for a year is estimated as 250 cu.m per square kilometer taking the volume in the upper range of A group.

CHAPTER 6. GEOLOGY AND MATERIALS

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CHAPTER 6. GEOLOGY AND MATERIALS

6.1 GEOLOGY

6.1.1 Geological Survey

(1) Field Survey

The topographical maps used for geological survey are the map of a 1/50,000 scale published by the Royal Thai Survey Department for the whole project area. Beside this, a topographical map of 1/1,000 covering the site of dam, penstock and powerhouse, and a topographical map of 1/2,000 covering the right bank ridge of reservoir. Also, an photogrammetric map of 1/10,000 scale was made in Japan by the Survey Team after it's return to Japan, and it is used for DWG. No. 3. In conducting the geological survey, aerial photographs furnished by NEEA was additionally used, and they were of much help to know general features of the geology.

(2) Drilling and Water Pressure Test

As indicated in Table 6-1, eight drillholes were sunk at the dam site, the right bank ridge of reservoir and the quarry. Water pressure tests were also carried out at the dam site by using the drill holes. The locations of drill holes are given in DWG. No. 3, the geologic logs of drill holes, in Appendix Fig. A6-1 - 8 and Fig. A6-13 - 18, and the result of water pressure tests, in Appendix Table A6-1.

Table 6 - 1 List of Drillings

Site	Hole No.	Hole Size	Depth of Hole (m)	Depth of Overburden (m)	Length of Rock Drilling (m)	Total Length of Core (m)	Core Recovery (%)	Fig. No.
Dam Site	D - 1	NX	30.20	3.00	27.20	26.58	98	A6-1, 2
	D - 2	NX	30.20	1.50	28 70	28.70	100	A6-3, 4
	D - 3	NX	30.05	3.00	27.05	27.05	100	A6-5, 6
			90.45		82.95	82.33	99	
Ridge	R - 1	BX	20.00	6.60	13.40	12.28	92	A6-7
	R - 2	BX	20.00	5.50	14.50	11.82	82	A6-8
			40.00		27.90	24.10	86	
Quarry	Q - 1	BX	30.00	3.00	27.00	26 08	97	A6-13, 14
	Q - 2	BX	30.05	3.00	27.05	26.65	99	A6-15, 16
	Q - 3	BX	30.06	1.75	88.31	27.96	99	A6-17, 18
			90.11		82.36	80.69	98	
Total			220.56		193.21	187.12	97	

The drilling work and the water pressure tests were done by UECC, whom NEEA awarded contracts.

6.1.2 Geology of Project Area

The Nam Chern project area is located in the mountainous zone of the northwestern Khorat plateau. The base rock in and around the project area consists of the Kanchanaburi series covering the Silurian to Carboniferous periods of the Paleozoic era, the Rat Buri series of the Permian period of the Paleozoic era, the Khorat group covering the Triassic to Jurassic periods of the Mesozoic era, and the andesites of the Tertiary period of Cenozoic era. The stratigraphy and types of rocks of these geologic units are shown in Table 6-2.

The project area is dominated by the Kanchanaburi series, one of the strata mentioned above. The principal area of distribution of the Kanchanaburi series is the Petchabun mountain range which runs north to south at about 25 km to the west of the dam site. The Kanchanaburi series of the project area is a 10 to 15 km wide zone extending southeastward from this principal distribution, and is surrounded by the Khorat group on its north and south and by the Rat Buri limestone on its southeast border. According to the geologic map of 1/750,000 compiled in the Ground Water Bulletin No. 2 (Department of Mineral Resources of the Government of Thailand, 1966), the project area belongs to the area where the Khorat group is distributed. However, the field survey and the photogeologic interpretation have definitely revealed that it is covered by the Kanchanaburi series. Fig. 6-1 is copy of part of the aforesaid geologic map, as modified in respect of the range of distribution of the Kanchanaburi series just stated.

The Kanchanaburi series of the project area consists of sedimentary rocks of various grain sizes ranging from claystone to conglomerate. Rocks distributed in the project area are entirely free from the effect of metamorphism. But, black slate somewhat affected by metamorphism is found near Ban Ta Da, about 15 km to the west of the dam site. The rocks are generally grayish. Rock is tight and hard. The rock formation has few separated planes such as bedding, joint and crack, the segments cohering to each other. The properties of the rocks are outlined below. Additionally, the microphotographs and result of microscopic observation of rock sections are presented in APPENDIX B Fig. A6-9, 10.

Claystone and very fine grained sandstone: with fairly much calcareous contents, somewhat soft and friable as compared with coarse grained rocks, generally unstratified and massive. Laminated bedding plane develops in some claystone.

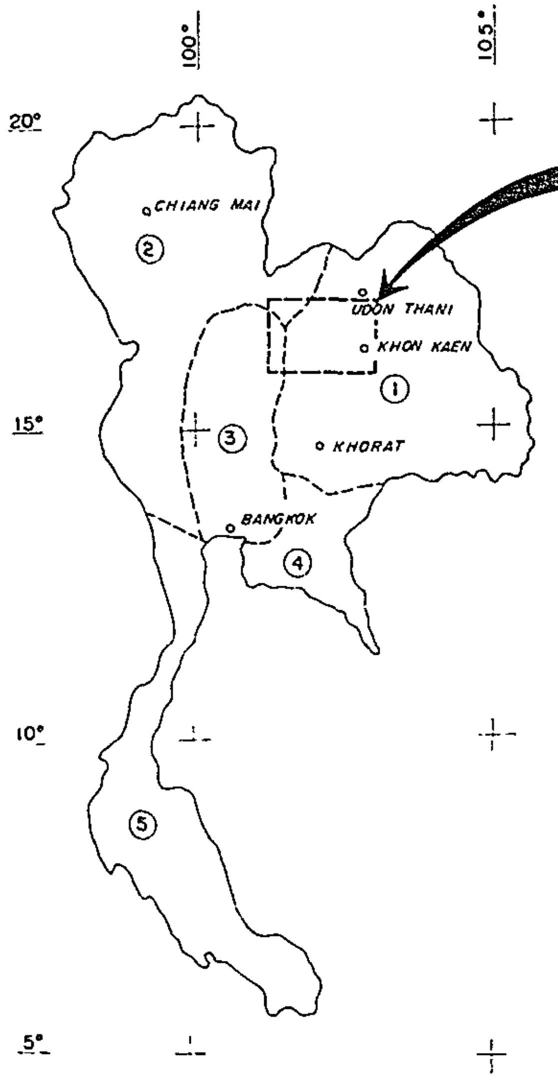
Table 6-2 Generalized Stratigraphic Classification in Northwestern Khorat Plateau

Era	Period	Rock Unit	Thickness	Lithologic Description
CENOZOIC	Quaternary	Alluvium and terrace deposits	–	Alluvial sand & gravel
	Tertiary	Andesite and Rhyolite porphyry	–	
MESOZOIC	Jurassic? and Younger	Salt formation	610 m	Pale red to reddish brown sandstone, sandy shale and siltstone. Gypsum and thick rock salt
		Khok Kruat formation	709 m	Grayish red to reddish brown sandstone, siltstone and shale having greenish gray mottling. Gypsum occurs as thin beds in the upper part.
	Jurassic	Phu Phan formation	82 - 183 m	Yellowish gray to grayish pink, pale orange and pale red, massive, thick bedded and cross bedded sandstone and conglomeratic sandstone. Thin beds of sandy shales and siltstone. Also thin beds of calcarious conglomerate.
	Triassic? and Younger	Phra Wihan formation	460 - 856 m	Grayish red to olive gray to white, massive sandstone; with dark reddish brown micaceous siltstone. In part cross bedded or thick bedded with numerous joints.
	Triassic	Phu Kadung formation	2,466 m	Predominantly dark brown, grayish red-purple, micaceous shale, siltstone; and grayish brown to grayish red slabby to massive micaceous sandstone. Occasionally the very fine grained sandstone and siltstone are calcareous.
PALEOZOIC	Permian	Rat Buri Series	750 - 2,350 + m	Limestone, gray dense, crystalline, massive to thin bedded, with fossiliferous beds and some interbedded slaty shale and sandstone.
	Carboniferous Devonian Silurian	Kanchanaburi Series	1,000 - 3,000 +m	Shale, sandstone and sandy shale, gray-green; in places metamorphosed to phyllite, slate and quartzite. Local thin beds of limestone.

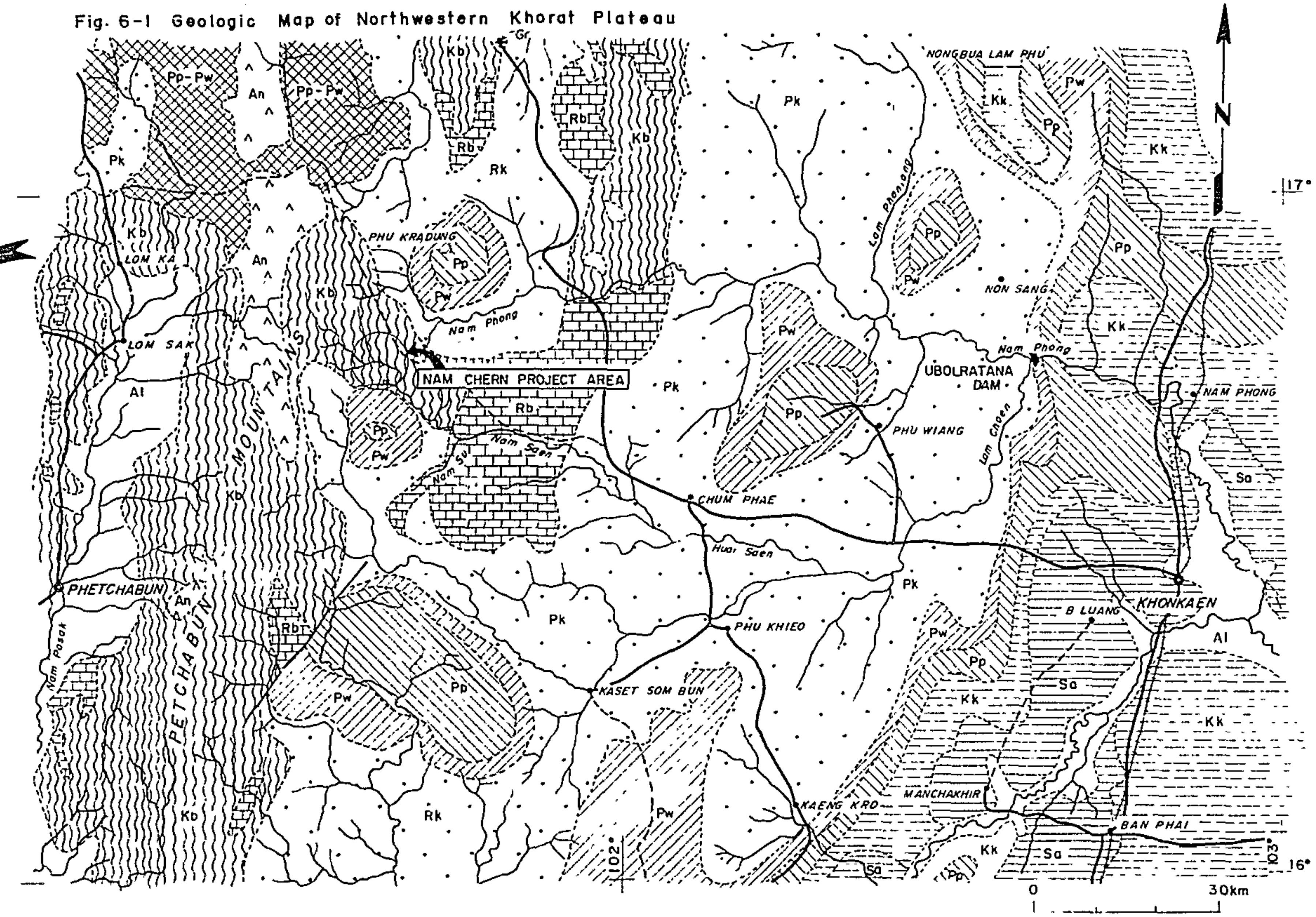
* This table was prepared from Ground Water Bulletin No. 2 (Dept. of Mineral Resources Kingdom of Thailand, 1966.
The classification of the Khorat Group in the Bulletin was based on the paper of D. E. WARD (1964).
The chronological classification of the Khorat Group has not so far been defined.
J. IWAI et al. in their paper on paleontological study (1964) proposed a stratigraphical and chronological classification different from that of D. E. WARD.

Fig. 6-1 Geologic Map of Northwestern Khorat Plateau

Physiographic Provinces of Thailand



① KHORAT PLATEAU
② NORTHWEST HIGHLANDS
③ CHAO PHRAYA CENTRAL PLAIN
④ CHANTHABURI
⑤ THAILAND PENINSULA



This Geologic Map was taken from Ground Water Bulletin NO 2 (1966)

LEGEND

SEDIMENTARY AND METAMORPHIC ROCKS

Al ALLUVIUM AND TERRACE DEPOSITS (Quaternary to Recent)

KHORAT GROUP
- Sa SALT FORMATION
- Kk KHOK KRUAT FORMATION
- Pp PHU PHAN FORMATION
- Pp-Pw
- Pw PHRA WIHAN FORMATION
- Pk PHU KADUNG FORMATION

(Jurassic & Younger)

(Triassic & Jurassic)

Rb RAT BURI SERIES (Permian)

Kb KANCHANABURI SERIES (Carboniferous~Silurian)

IGNEOUS ROCKS

An ANDESITE AND RHYOLITE PORPHYRY (Tertiary)

Gr GRANITE AND GRANODIORITE (Triassic)

FAULT

Fig 6-1 Geologic Map of Northwestern Khorat Plateau

Fine grained sandstone, medium grained sandstone and coarse grained sandstone: arkosic and angular, and very hard. At many places bedding develops at an interval of 50 cm.

Conglomerate: consists of round pebbles of diameter of 4 to 8 cm, of quartzite, trachyte, sandstone and limestone. The matrix is arkosic, medium to coarse grained sand. Rocks are unstratified and massive, and very hard.

The aforementioned rocks alternate in the project area, and very fine grained, fine grained and medium grained sandstone is predominant. Claystone, coarse grained sandstone and conglomerate are very few. In the former group the stratum is sometimes as thick as 10 m, and in the latter the stratum does not exceed 3 to 4 m in thickness. Some of the conglomerate is inserted lenticulary, or gradually shifts to sandstone. The strike of strata is E-W to N 65°E, and is almost constant throughout the area. The dip of strata is 25 to 40° S in the project area, but 8° N around the spot of about 15 km to the east of the dam site. The present survey did not find a fault. Considering the distribution of the strata, there seems to be no tectonic line.

On the river bed of the Huai Chan, bed rock is exposed at some places, and detaining water is found at other places. There is little deposit of gravel, and where it exists, its thickness is small. In the project area, the hillside and ridge are for the major part covered by 3 to 7 m thick residual clay, but there are outcrops in almost all the hill stream and in part of the ridge. On the slope where it is planned to install the penstock, rocks are generally exposed well and there is but a thin overburden.

6.1.3 Geology of Dam Site

(1) Topography

Both banks at the dam site are a gently undulating plateau of an altitude of about 800 m, and the hillside has many short and shallow hill streams which flow into the Huai Chan, the dam site lying between hill streams upstream and downstream. The altitude of the river bed at the dam axis is 741 m, and the difference of elevation between the river bed and the ridge is small.

(2) Overburden

The hillside at the dam site is covered with residual soil. Its thickness is 3 m on both banks according to the drillings, No. D-1 (left bank) and No. D-3 (right bank). The hill streams whose water flows into the Huai Chan, and the Huai Chan itself, have outcrops at many places, and narrow gravel deposite, of which depth is also small.

(3) Base rock

Distributed at this site are claystone, very fine grained sandstone, fine grained sandstone, medium grained sandstone, coarse grained sandstone and conglomerate belonging to the Kanchanaburi series. All these rocks are tight and hard, and, though they have some separating planes such as bedding, joint and crack, they cohere to each other. Therefore, the core recovery in the drilling is good, being 95% in No. D-1 and 100 in No. D-2 and No. D-3. The weathering of rock is generally shallow. It is 3 to 4 m on the hillside and, the river bed rocks are little weathered according to the drilling.

The strike and dip of strata are N 60° - 80°E and 20° - 30° SE. The strata run roughly parallel with the river and dip towards the right bank side. Fault was not found.

(4) The permeability of foundation rock

Approximate Lugeon unit values determined from the result of water pressure test are given in Table A6-1. The water pressure test at this spot was carried out by the method of pressing water (pressure : 1.5, 3.0 and 4.5 kg/sq.cm) into the drill hole (3 m long) between the packer and the hole bottom by using a pump. In calculating the Lugeon value, the hydro-static head was neglected.

The test was made with three drill holes at 18 sections, of which the 22.5 - 25.5 m section of drill hole No. D-1 showed the largest Lugeon unit number, registering 87.1 Lugeon, and the 27.0 - 30.0m section of drill hole No. D-2 showed the smallest number, or 1.8 Lugeon. Therefore, the permeability of the foundation rock does not pose a problem, and it has been determined that there will be no difficulty for grouting.

No definite correlation is observed among the Lugeon value, the length of core and the kind of rock.

Judging from all the foregoing findings, it can be said that there is no problem at all converning the geology of the Nam Chern dam site.

6.1.4 Geology of Right Bank Ridge of Reservoir

(1) Topography

A low and gentle ridge of an altitude changing 770 to 790m siretches on the right bank the Huai Chan for about 2 km upstream from the dam site, forming the watershed between the Huai Chan and the Nam Chern. At three places this ridge is lower than the maximum water surface of the proposed dam, and dikes totaling 470 m long are planned to be embanked there. The top of the ridge is generally flat and wide. The slope of the Huai Chan side is very gentle with a gradient of 10° or less. The slope of the Nam Chern side is steeper than the Huai Chan side, but it is still mild enough, being limited to 15°.

It is determined that there is no problem, as explained later, converning the permeability of the foundation of proposed dikes and the narrower portions of the ridge even at the maximum water surface.

(2) Overburden

Except for the outcrop of sandstone found in some part, the ridge is generally covered with surface soil. On the slopes of both sides of the ridge, rock is exposed only in the hill streams. The two drill holes made at the proposed dikes on this ridge have revealed an overburden of 6.6 m and 5.5 m respectively. However, the ridge as a whole is presumed to have an overburden of 3 to 4 m or less in general, and 6 to 7 m at the maximum, considering the fact that the rock is exposed in some part of the ridge, and that the drill holes and test pits sunk for the geological survey of the dam site and for the investigation of materials reached rock in 3 m or less.

The overburden is silty residual soil derived from base rock composed mainly of sand stone. The laboratory test on earth material conducted with the specimens taken from the test pit on the left bank of the Huai Chan has disclosed that this soil belongs to ML or MH*, with its coefficient of permeability ranging from 10^{-6} to 10^{-7} cm/sec (See Table A6-2). The soil of the ridge and the above mentioned tested soil are the same in respect of their origin rock, but so far as the macroscopic observation is concerned, the soil of the ridge is silter and a little more permeable.

(3) Base rock

The base rock consists mainly of very fine grained, fine grained and medium grained sandstones, and contains thin layers of claystone, coarse grained sandstone and conglomerate as insertions. When they are fresh these rocks are tight and hard; with little bedding, joint and crack, and cohere to each other. Therefore, the drilling core of the fresh part is mostly 50 cm or more in length. But the surface layer is generally weathered; at the drill hole No. R-1, the rock is found weathered for 5 m (to 11.6 m from the ground surface) after reaching to the base rock,and drill hole No. R-2, for 11.5 m (to 17 m from the ground surface). The majority of cores are 20 cm or less in length, and some contain a clay seam.

The strike and dip of the strata are N75° - 90°E and 30° - 40°S, and the strata run in parallel with the direction of the ridge, dipping towards the opposite side of the reservoir.

The rocks distributed in this area are generally less permeable as stated in 6. 1. 3. (4).

No particular treatment for leakage is considered necessary from the result of overall study of the hydro-static head, the width of ridge and the permeability of the soil. However, it will be necessary in future to make a field permeability test of the overburden and rock for more detailed examination.

6.1.5 Geology of Headrace Tunnel

(1) Topography

The headrace tunnel is to pass under the gentle and wide ridge of an altitude of 780 to 795 m which forms the watershed between the Huai Chan and the Nam Chern. As the altitude of the top of the tunnel is about 748 m, the depth between the gound surface and the tunnel is about 30 m at the shallowest point.

(2) Overburden

This ridge is generally covered with residual soil, of which thickness in part was ascertained to be 5. 5 m and 6. 6 m by two drillings (No. R-1 and No. R-2) made on the westward extension of the ridge. But, the average overburden is estimated to be about 3 m thick, because fine grained sandstone outcrop is observed in many parts of the ridge.

(3) Base rock

Rocks distributed along the tunnel route are claystone, sandstone, conglomerate, etc. as at the dam site. These rocks are tight and hard, and have very few clefts such as bedding, joint and crack. The drill holes No. R-1 and No. R-2 has revealed that the rock is weathered for 5 m and 11. 5 m, respectively. It is concluded that the tunnel as a whole is located in the fresh rock, because it lies about 30 m below the ground surface even at the point of the ground surface is lowest. No fault was found in the present survey. It is believed the geology will pose no problem to the construction of the tunnel.

6.1.6 Geology of Surge Tank, Penstock and Powerhouse Sites

(1) Topography

The left bank of the Nam Chern where the surge tank, penstock and powerhouse are proposed is a slope of a height of about 400 m with an average gradient of about 15 degrees. The surge tank and some part of penstock is located on the curved and narrow ridge, but these installations as a whole are planned to be constructed on the stable ridge running in the NNW-SSE direction. The left bank of the Nam Chern near the powerhouse site makes an about 6 m high steep cliff.

(2) Overburden

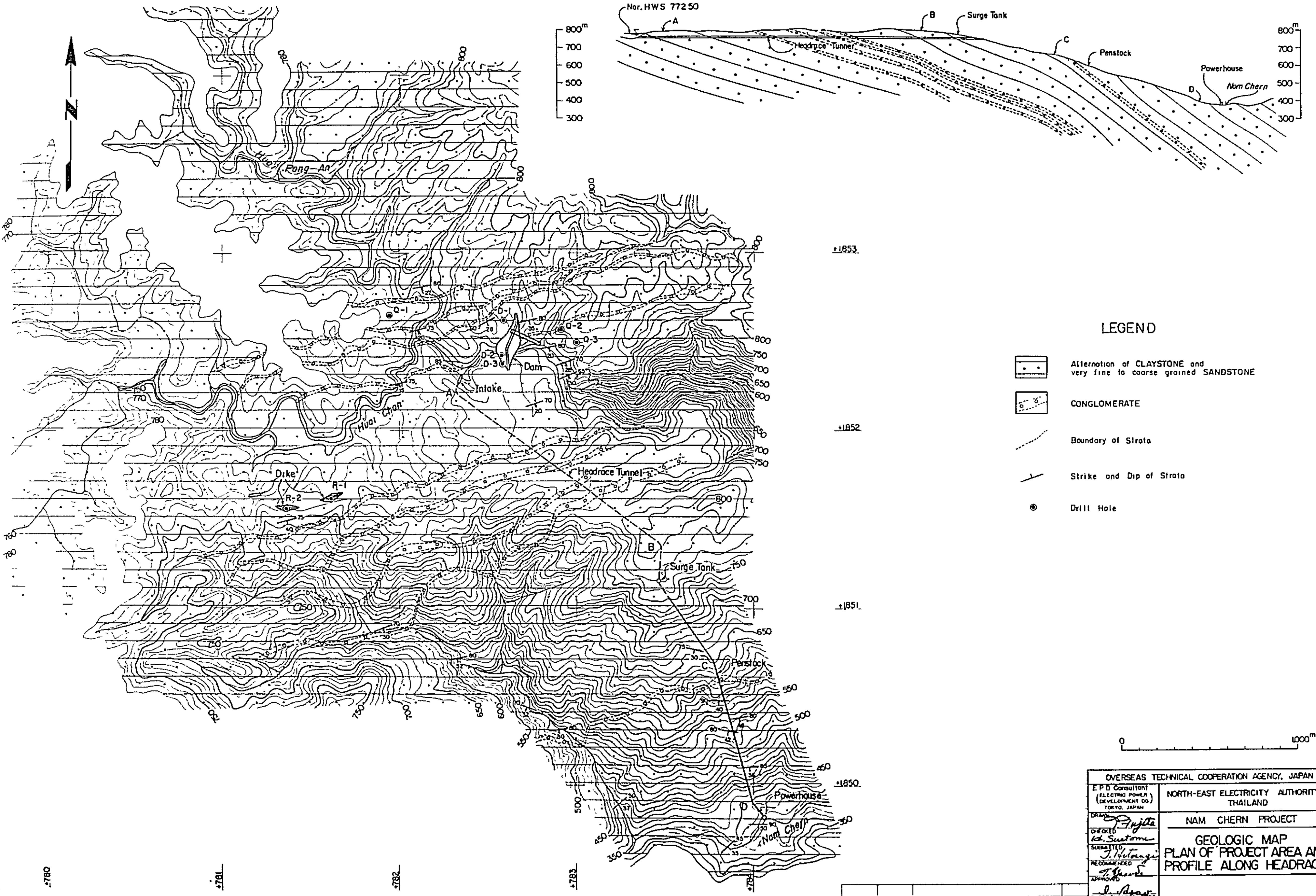
The ridge where the surge tank, penstock and powerhouse are proposed has the attitude of 380 m at the river bed and of 790 m in summit. At the intermediate part of an altitude between 490 m and 590 m, there is little surface soil and rock exposes everywhere, with trees like a kind of oak (called Tong Tig by the indigenous people) growing sparsely. In contrast, the upper and lower part is full of bamboo forest, or grassland studded with big trees, where outcrops are few and the ground is covered with surface soil of probably 3 m in thickness. Very fine grained sandstone is exposed on the left bank cliff of the Nam Chern. On the river bed of the Nam Chern sub-angular cobble whose diameter is 1 m or less is deposited, but its thickness is thin, and rock is exposed at some places.

(3) Base rook

The sedimentary rock belonging to the Kanchanaburi series is distributed at this area also. The outcrop is very fine grained to coarse grained sandstone only, but there seems to be some claystone and conglomerate under the surface soil. The exposed rocks have fairly many cracks, but they are hard. Judging from the result of the field survey and the drilling carried out at other spots, the rock at the site of surge tank is probably weathered to a considerable depth, but for the foundations of the anchor block and powerhouse, it seems possible to obtain rocks having a sufficient bearing power at a few meters below the ground surface. The strike of the strata are generally E-W, 30° - 50°S, and dip is in the same direction as the dip of the slope. But, inasmuch as the bedding plane is coherent and the gradient of the slope is gentle, there is no danger of landslide or land fall.

PLAN OF PROJECT AREA

PROFILE ALONG HEADRACE



LEGEND

▤	Alternation of CLAYSTONE and very fine to coarse grained SANDSTONE
▨	CONGLOMERATE
⋰	Boundary of Strata
⊥	Strike and Dip of Strata
◉	Drill Hole

REVISION	DATE	DESCRIPTION	BY

OVERSEAS TECHNICAL COOPERATION AGENCY, JAPAN

E P D Consultant
(ELECTRIC POWER DEVELOPMENT CO.)
TOKYO, JAPAN

NORTH-EAST ELECTRICITY AUTHORITY
THAILAND

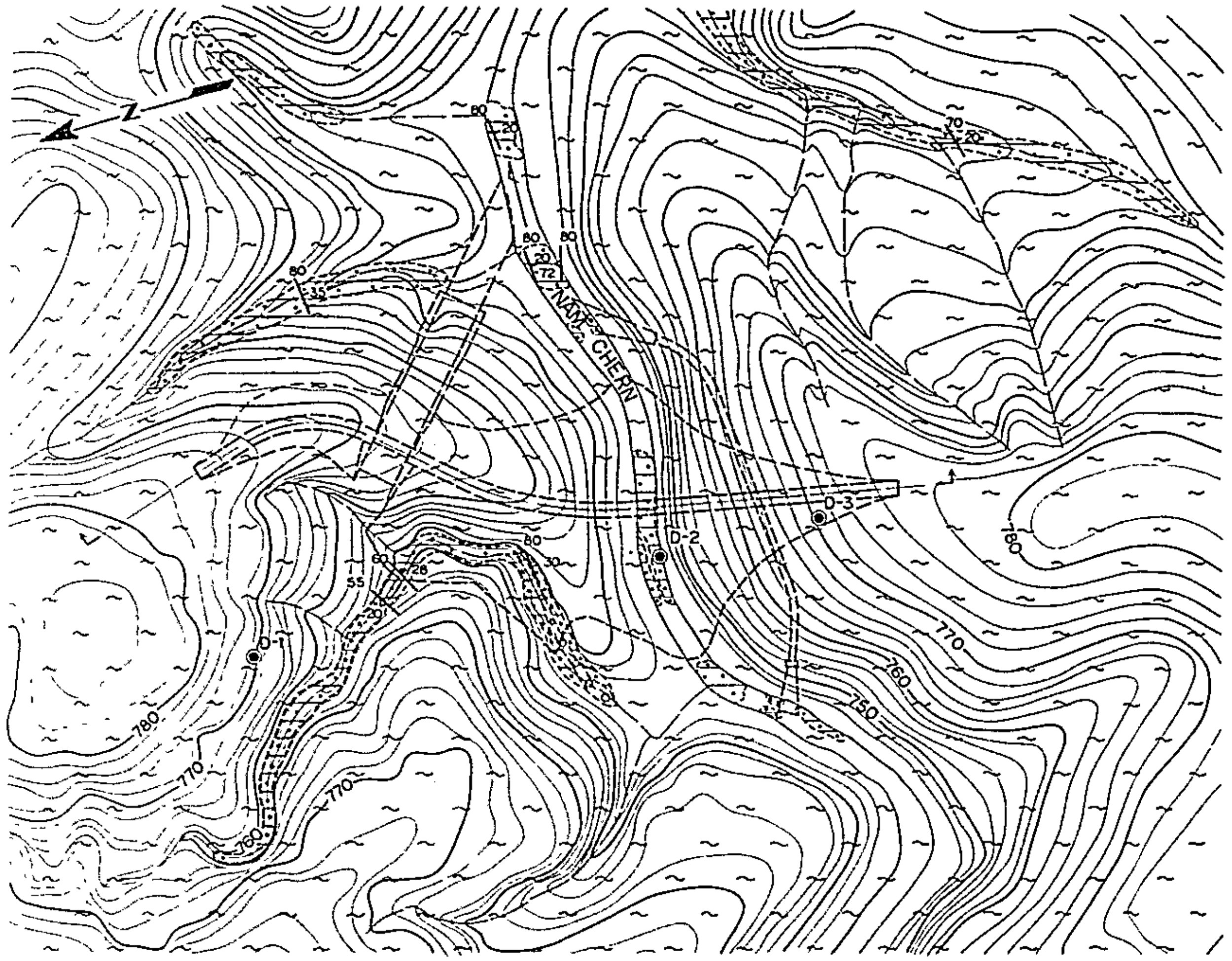
DRAWN T. Fujita
CHECKED K. Suetomi
SUBMITTED T. Hitonagi
RECOMMENDED T. Yasuda
APPROVED
CHIEF ENGINEER, EPDC
DATE

NAM CHERN PROJECT

GEOLOGIC MAP
PLAN OF PROJECT AREA AND
PROFILE ALONG HEADRACE

DWG. NO 3

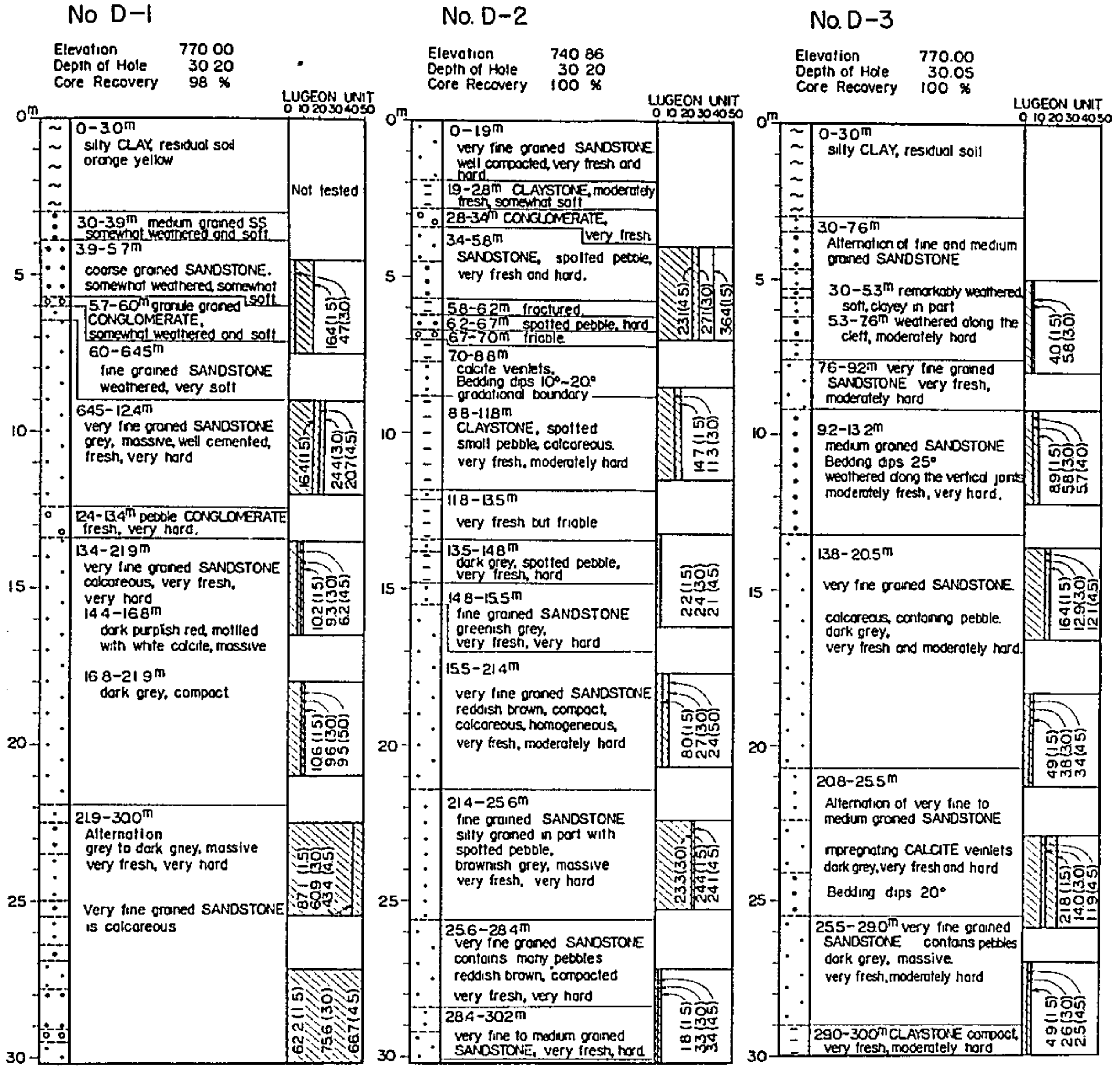
PLAN



LEGEND

- Silty CLAY.
- Alternation of CLAYSTONE and very fine to coarse grained SANDSTONE
- CONGLOMERATE.
- Boundary of Strata
- Strike and Dip of Strata
- Strike and Dip of Joint
- ● Drill Hole.

LOG OF DRILL HOLE



No D-1

Elevation 770 00
Depth of Hole 30 20
Core Recovery 98 %

- 0-3.0m silty CLAY, residual soil orange yellow
- 3.0-3.9m medium grained SS somewhat weathered and soft
- 3.9-5.7m coarse grained SANDSTONE. somewhat weathered, somewhat soft
- 5.7-6.0m granule grained CONGLOMERATE, somewhat weathered and soft
- 6.0-6.45m fine grained SANDSTONE weathered, very soft
- 6.45-12.4m very fine grained SANDSTONE grey, massive, well cemented, fresh, very hard
- 12.4-13.4m pebble CONGLOMERATE fresh, very hard.
- 13.4-21.9m very fine grained SANDSTONE calcareous, very fresh, very hard
  - 14.4-16.8m dark purplish red, mottled with white calcite, massive
  - 16.8-21.9m dark grey, compact
- 21.9-30.0m Alternation grey to dark gney, massive very fresh, very hard
  Very fine grained SANDSTONE is calcareous

No. D-2

Elevation 740 86
Depth of Hole 30 20
Core Recovery 100 %

- 0-1.9m very fine grained SANDSTONE well compacted, very fresh and hard
- 1.9-2.8m CLAYSTONE, moderately fresh, somewhat soft
- 2.8-3.4m CONGLOMERATE, very fresh
- 3.4-5.8m SANDSTONE, spotted pebble, very fresh and hard.
- 5.8-6.2m fractured.
- 6.2-6.7m spotted pebble, hard
- 6.7-7.0m friable
- 7.0-8.8m calcite veinlets. Bedding dips 10°~20° gradational boundary
- 8.8-11.8m CLAYSTONE, spotted small pebble, calcareous. very fresh, moderately hard
- 11.8-13.5m very fresh but friable
- 13.5-14.8m dark grey, spotted pebble, very fresh, hard
- 14.8-15.5m fine grained SANDSTONE greenish grey, very fresh, very hard
- 15.5-21.4m very fine grained SANDSTONE reddish brown, compact, calcareous, homogeneous, very fresh, moderately hard
- 21.4-25.6m fine grained SANDSTONE silty grained in part with spotted pebble, brownish grey, massive very fresh, very hard
- 25.6-28.4m very fine grained SANDSTONE contains many pebbles reddish brown, compacted very fresh, very hard
- 28.4-30.2m very fine to medium grained SANDSTONE, very fresh, hard

No. D-3

Elevation 770.00
Depth of Hole 30.05
Core Recovery 100 %

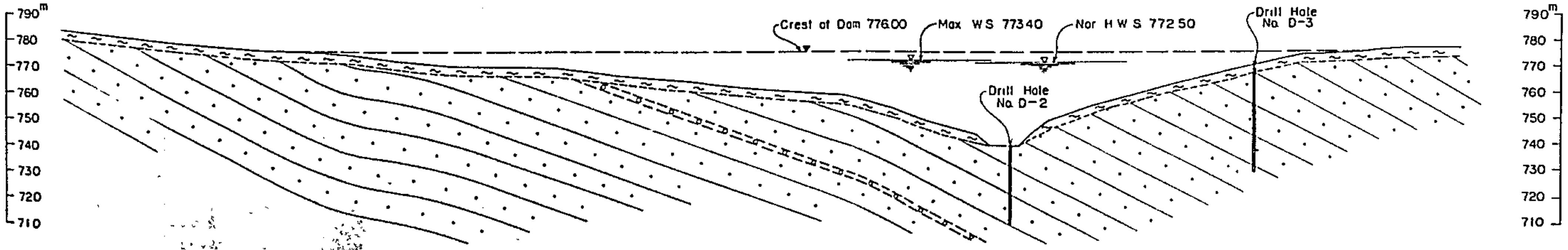
- 0-3.0m silty CLAY, residual soil
- 3.0-7.6m Alternation of fine and medium grained SANDSTONE
  - 3.0-5.3m remarkably weathered, soft, clayey in part
  - 5.3-7.6m weathered along the cleft, moderately hard
- 7.6-9.2m very fine grained SANDSTONE very fresh, moderately hard
- 9.2-13.2m medium grained SANDSTONE Bedding dips 25° weathered along the vertical joints moderately fresh, very hard.
- 13.8-20.5m very fine grained SANDSTONE. calcareous, containing pebble. dark grey, very fresh and moderately hard.
- 20.8-25.5m Alternation of very fine to medium grained SANDSTONE impregnating CALCITE veinlets dark grey, very fresh and hard Bedding dips 20°
- 25.5-29.0m very fine grained SANDSTONE contains pebbles dark grey, massive. very fresh, moderately hard
- 29.0-30.0m CLAYSTONE compact, very fresh, moderately hard

Note (1) In this case LUGEON UNIT is calculated by proportionally converting the test result into the value under the water pressure of 10kg per sq cm.
A hydrostatic head is neglected in calculation

(2) Figures in parentheses are tested water pressure in kg per sp cm

(3) SS indicates SANDSTONE

SECTION ON AXIS OF DAM



0 200m
(Plane)

0 100m
(Section)

REVISION	DATE	DESCRIPTION	BY

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NORTH-EAST ELECTRICITY AUTHORITY
THAILAND

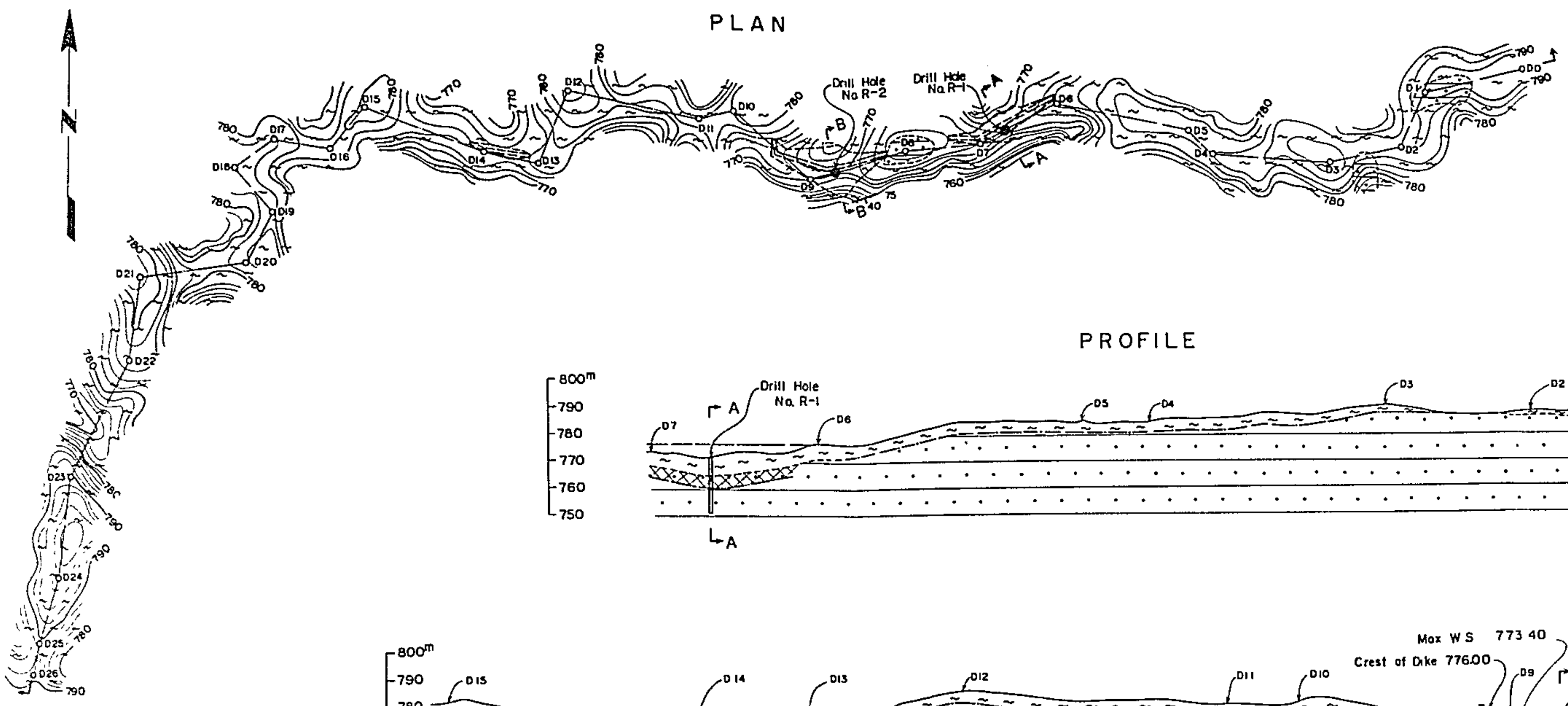
DRAWN Fujita
CHECKED Suetomi
SUBMITTED T Hitosugi
RECOMMENDED
APPROVED I. Asao
CHIEF ENGINEER EPDC
DATE

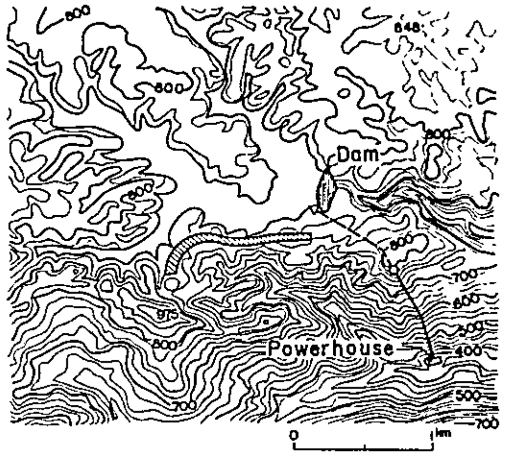
NAM CHERN PROJECT

GEOLOGIC MAP
DAM
PLAN AND SECTION

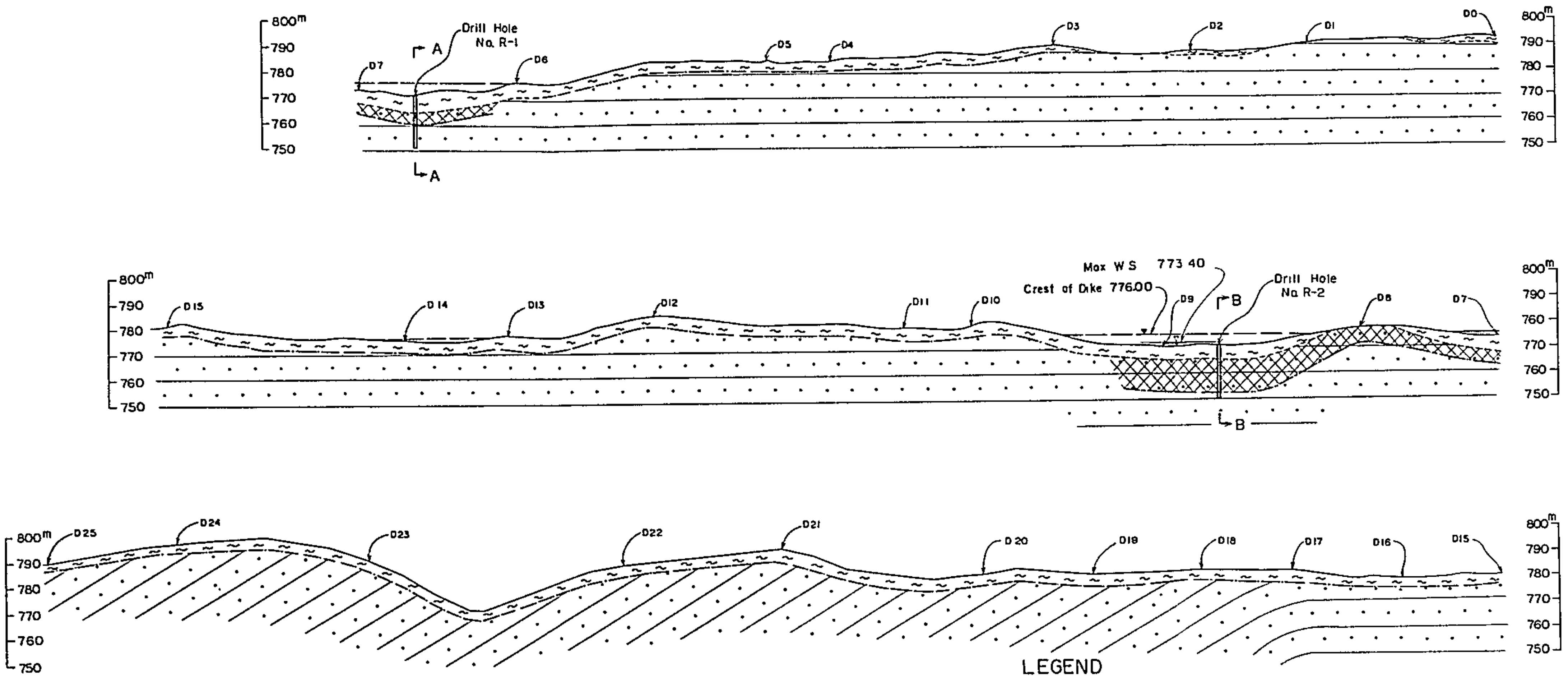
DWG. NO 4

PLAN





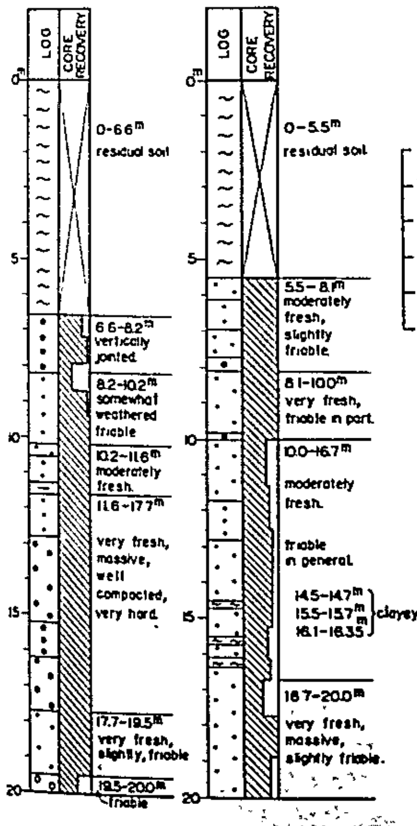
PROFILE



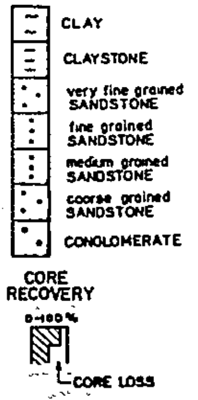
LOG OF DRILL HOLE

No R-1 CORE RECOVERY 91 5 %

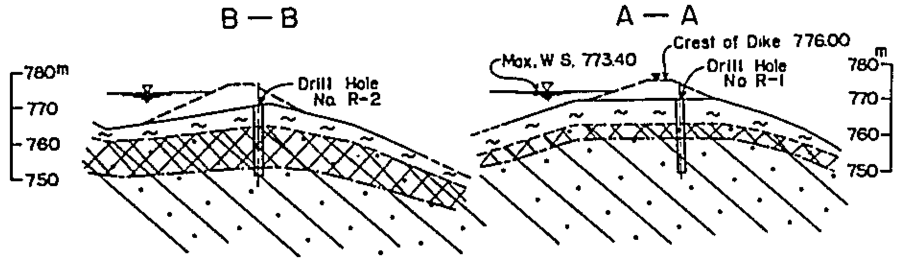
No R-2 CORE RECOVERY 81.5 %



LEGEND OF LOG

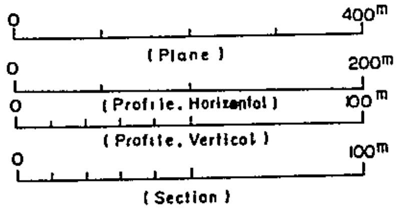


SECTION



LEGEND

~	Silty·CLAY
▤	Alternation of CLAYSTONE, very fine to coarse grained- SANDSTONE and CONGLOMERATE
▩	Weathered Zone.
- - - -	Rock surface.
——	Assumed rock surface.
70 30	Strike and Dip of Strata.



REVISION	DATE	DISCRIPTION	BY

OVERSEAS TECHNICAL COOPERATION AGENCY, JAPAN

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RECOMMENDED
APPROVED
CHIEF ENGINEER, EPDC.
DATE

NAM CHERN PROJECT

GEOLOGIC MAP
RIGHT BANK RIDGE OF RESERVOIR
PLAN, PROFILE AND SECTION

DWG NO. 5

6.2 MATERIALS

6.2.1 Material Surveying

The objects of investigation of materials herein stated are the earth and rock to compose a fill-type dam, and the concrete aggregate required to construct spillway, headrace, tunnel powerhouse and so on. In conducting the present investigation, a field survey was carried out on the basis of a map on a 1/50,000 scale issued by the Royal Thai Survey Department. For the investigation of the earth material, twelve test pits of about 3 meters deep were sunk to explore residual soil and sand deposit, and to investigate rock, three vertical drill holes were sunk to a depth of 30 m. Their locations are shown in Fig. 6-2. Laboratory test was carried out by test specimens from the test pits, drilling cores and outcrops. The logs of test pits, the logs of drill holes and the results of laboratory test are summarized in Appendix B. The laboratory test was entrusted to Chulalongkorn University in Bangkok.

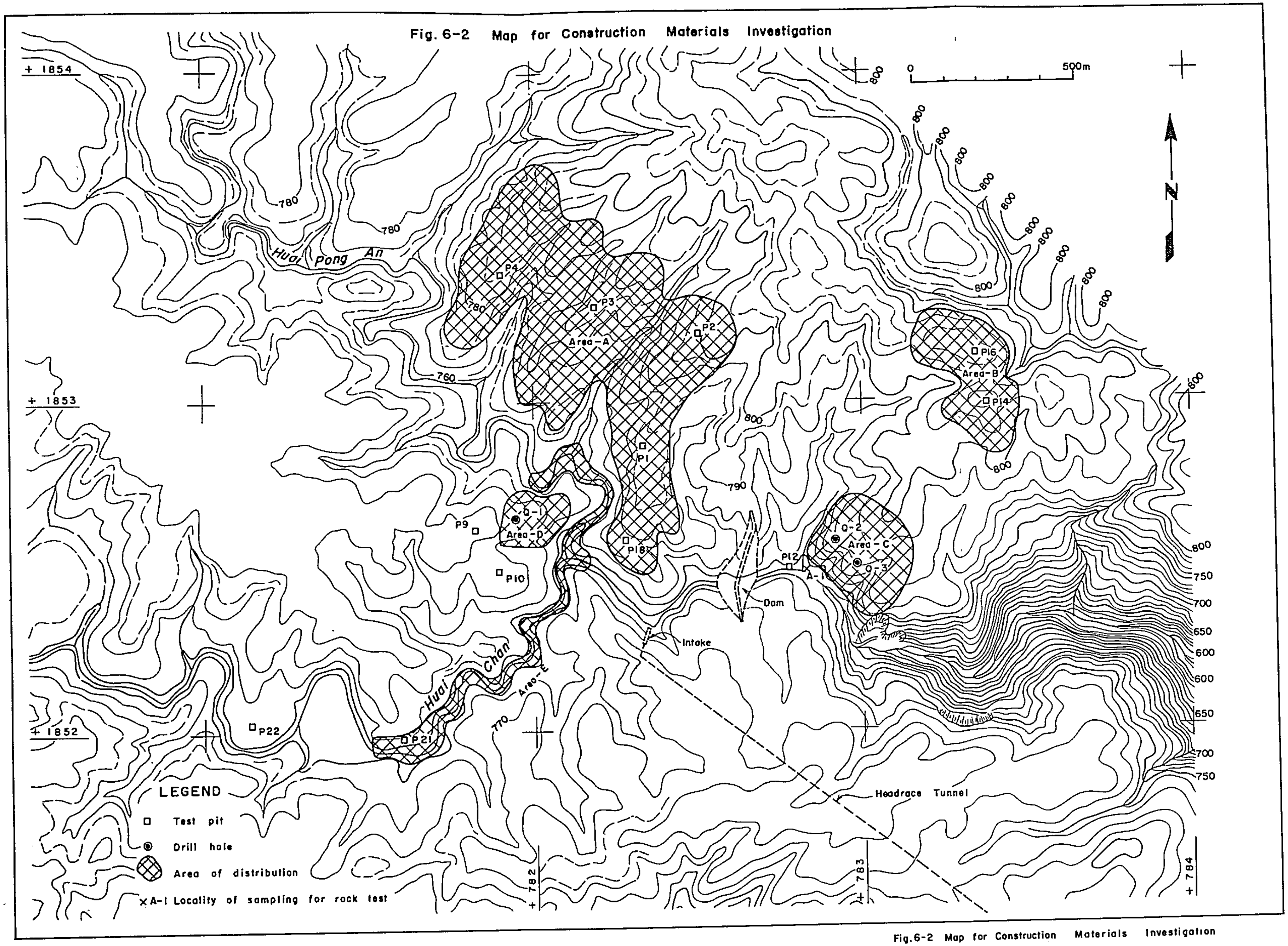

Fig.6-2 Map for Construction Materials Investigation

6.2.2 Results of Material Surveying

(1) Earth

Loamy residual soils substantially consisting of silt and clay are extensively distributed in a depth of several meters broadly speaking, in the area encompassing the dam site. Within the area and scope of the present investigation, soils suitable for the material of the impervious zone of the rockfill dam are found to be distributed in Area A and Area B shown in Fig. 6-2. Area A is located about several hundred meters to the northwest of the proposed dam site, Area B is located about 1 km to the northeast of the proposed dam site. Outside of these two areas, silty soil is widely distributed and soils suitable for the impervious materials are distributed only sporadically.

The distribution of soils in Area A and Area B is compared in the table below. Since the quantity of the deposit of impervious soil in each of Area A and Area B is well over the requirement, about 130,000 cubic meters, either of them is available as borrow area. In respect of the hauling distance, Area A seems better.

Comparison of Soil Between Area A and Area B

Item	Area A	Area B
Topography	Gentle hilly zone	Gentle ridge
Vegetation	Grassland and pine forest	Pine forest
Thickness of surface soil	15 cm	15 cm
Range of distribution	More than several 100 thousand sq. m	More than several decade thousand sq. m
Depth of distribution	2 m or more	2 m or more
Volume of deposit	More than 5 hundred thousand cu. m	More than 150 thousand cu. m
Quality of material	Silty clay - Silty clay loam	Same as the left

It is also conceivable to change the rock fill-type of the low height portion of the both bank terminals of the proposed dam to an earth dam type. In that case, the soils of Area A and Area B and their vicinity could be used for shell materials.

(2) Sand

In Area E shown in Fig. 2, i. e. on the banks of the Huai Chan and the Huai Pong An, barely about 20,000 cu. m of deposit sand is distributed. This is fine sand containing much silt, as indicated by the test results given in Appendix B. In quality it is more suitable for the semi-pervious material (filter material) of dam. But when the volume of its deposit and the method of borrowing are considered, it does not seem available for the semi-pervious material of dam. There is no water deposit sand other than this in the vicinity of the proposed dam site.

Therefore, it must be considered to use crushed rock for the semipervious material of dam. This problem will be dealt with in following passages regarding rock.

(3) Rock

The drill holes for material investigation were sunk, as shown in Fig. 6-2, two in Area C and one in Area D. Area C is a table land along the Huai Chan covered by sporadic forests and cultivated fields. It is believed that the strata which are distributed in this Area C are the same stretch as the strata that crop out in the rapid stream part of the Huai Chan towards its downstream. At the drilling sites, the thickness of top soil is two or three meters and the layer beneath is composed of very fine grained to medium graned sandstone with the insertion of claystone layers. The logs of drill holes No. Q-2 and Q-3 sunk there and the result of rock test are shown in Appendix B. These data indicate that this sandstone is hard, and suitable not only for the rockfill dam material, but also for concrete aggregate. Since the volume of its deposit is estimated at more than cu. m. it is believed sufficient to provide about 120,000 cu. m for the rockfill material of dam, about 40,000 cu. m for the filter material and about cu. m for the concrete aggregate. As the distance from the dam site to Area C is only 400m, Area C has an advantageous location as a quarry for rockfill material. An appropriate rock crushing plant is necessary to produce the filter material.

Area D is situated on the hillside of the right bank ridge of the Huai Pong An, and covered with grassland. The result of the drilling carried out at the site Q-1 shown in Appendix B has revealed that fine grained sandstone is distributed in Area D. This sandstone is brittle, and is anticipated to become the fragments through crushing when its processing, so it is presumed to be usable for the semi-pervious material of dam. The deposit is estimated to be about cu. m at the least, lying immediately under the top soil of 2 m thick. The distance from the dam site to Area D is shorter than 1 km. As the rockfill material of dam and the aggregate material will be taken from Area C, it will be more economical to take the filter material also from Area C, even though it requires installation of rock crushing equipment. However, these problems should be finally decided after detailed investigation of Area C is carried out in the stage of definite plan study.

CHAPTER 7. POWER PRODUCTION

CHAPTER 7. POWER PRODUCTION

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Fig. 7-1 Mass Curve

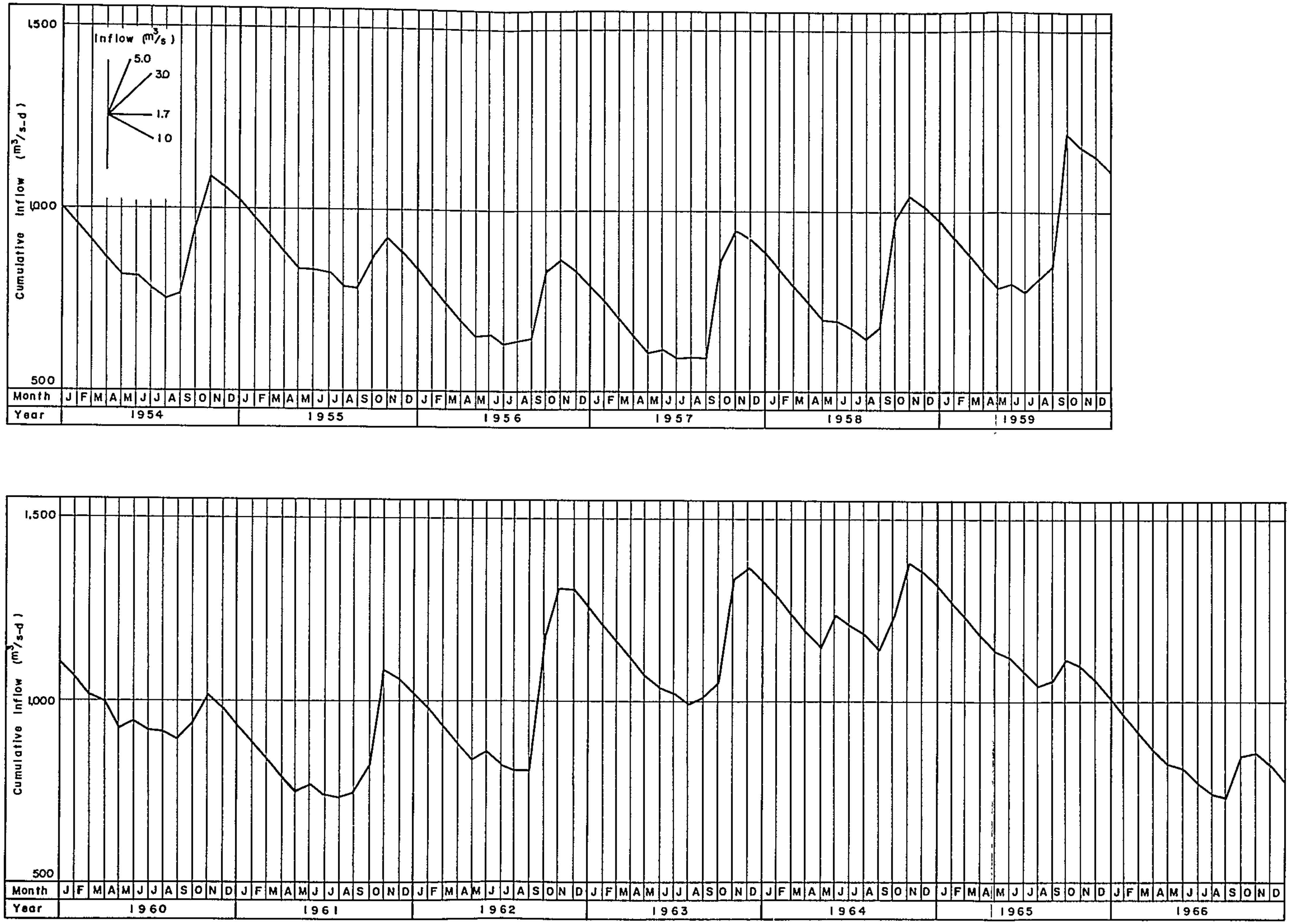


Fig. 7-1 Mass Curve

CHAPTER 7. POWER PRODUCTION

7.1 STUDY ON OPTIMUM STORAGE CAPACITY OF RESERVOIR

Seasonal fluctuations and yearly fluctuations of run-off of the Huai Chan at the proposed dam site are as shown in Fig. 7-1, Mass Curve. This mass curve is based on the run-off data covering the 13 years from 1954 as stated in Chapter 5 HYDROLOGY. At the dam site, the run-off during the six month rainy season from May to October of an average year is 46 x 10^6 cu. m. Against this, the run-off for the dry six months from November to April is only 6 x 10^6 cu. m. The average annual run-off is 52 x 10^6 cu. m, whereas the annual run-off for wet years is 73 x 10^6 cu. m and that for dry years, 26 x 10^6 cu. m. To regulate the run-off against such a fluctuation and make use of the water resources to the maximum, it is necessary to construc a reservoir which enables the run-off to be regulated over a period of years. In the present study, the effective storage capacity was taken for four cases, namely, 31 x 10^6 cu. m, 36 x 10^6 cu. m, 41 x 10^6 cu. m and 46 x 10^6 cu. m, and the surplus benefit and energy cost were calculated for each case and comparisons were made. The benefit and cost were calculated on the same basis as the Nam Phrom Project.

The results of the comparative study of the effective storage capacity are shown in Fig. 7-2 and Table 7-1. As seen in Fig. 7-2, the optimum size of the reservoir is given where the effective storage capacity is around 41 x 10^6 cu. m.

In this way, the reservoir of the present plan was decided to be 772.5 m normal high water surface level, 14.5 m in available draw-down and 41 x 10^6 cu. m in effective storage capacity.

Table 7-1 Study on Optimum Storage Capacity of Reservoir

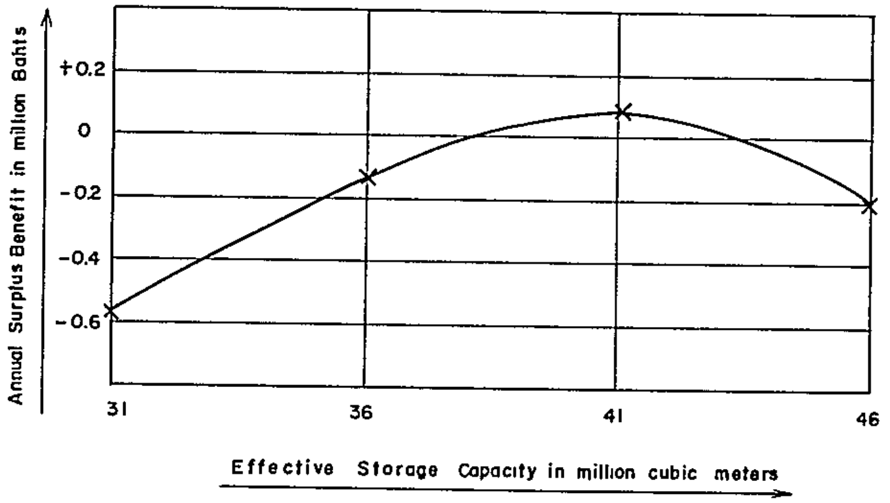
Effective Storage Capacity of Reservoir	10^6cu.m	31	36	41	46
Reservoir					
Normal High Water Surface Level	m	770.6	771.5	772.5	773.4
Minimum Water Surface Level	m	758.0			758.0
Available Drawdown	m	12.6	13.5	14.5	15.4
Total Storage Capacity	10^6cu.m	35	40	45	50
Effective Storage Capacity	10^6cu.m	31	36	41	46
Dam					
Type		Rock-fill			Rock-fill
Height x Crest Length	m	34.1x340	35.0x380	36.0x410	36.9x440
Volume	10^3cu.m	222	252	284	307
Waterway					
Headrace: Diameter	m	1.80			1.80
Length	m	1,630			1,630
Power Production					
Intake Water Level: Standard	m	766.1	767.0	768.0	768.9
Minimum	m	758.0			758.0
Tailwater Level	m	378.0			378.0
Effective Head: Standard	m	373.1	374.0	375.0	375.9
Minimum	m	363.1	364.0	365.0	365.9
Powerhouse Discharge: Maximum	cu.m/s	4.3	4.5	4.9	5.1
Dependable	cu.m/s	4.2	4.4	4.8	5.0
Firm	cu.m/s	1.35	1.45	1.55	1.62

Effective Storage Capacity of Reservoir	10^6 m^3	31	36	41	46
Output: Maximum	MW	13. 1	14. 0	15. 0	15. 2
Dependable	MW	12. 6	13. 6	14. 5	14. 6
Annual Firm Energy	10^3MWH	34. 9	37. 4	40. 2	40. 9
Economic Comparision					
Construction Cost*	10^3 Bahts	135, 000	140, 000	144, 500	150, 000
Cost Energy*	Bahts/KWH	0. 39	0. 37	0. 36	0. 37
Annual Surplus Benefit*	10^3 Bahts	-570	-230	100	-200

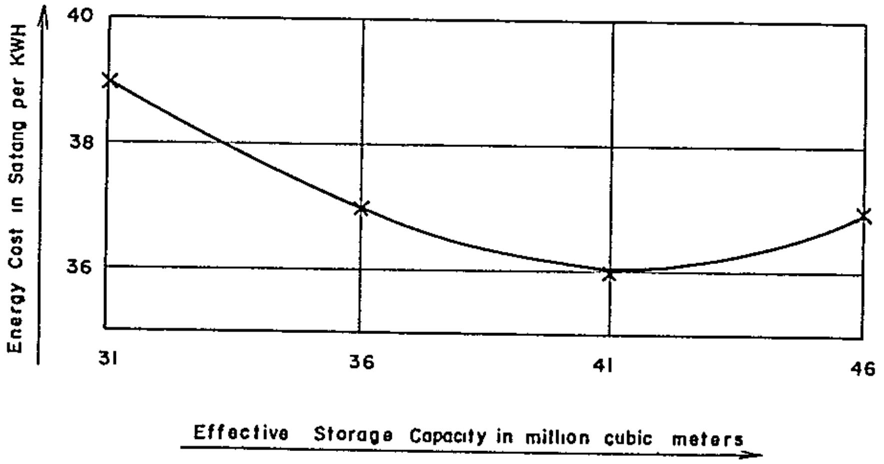
Note: (*) These values exclude the construction cost of transmission line.

Fig.7-2 Results of Study on Optimum Storage Capacity of Reservoir

Annual Surplus Benefit



Energy Cost



7.2 RESERVOIR OPERATION

The operation rule was provided for the reservoir of the project on the assumption that the inflow will be stored in rainy seasons and released in dry seasons, and further, the inflow stored in wet years will be released in dry years so as to secure as much firm discharge for power as possible through the most effective control of run-off. Fig. 7-3 shows the operation rule thus determined. This operation rule is laid down for the purpose of calculating the available discharge for power production, therefore a more elaborate one must be prepared after scrutiny when the reservoir is actually created and is put into operation.

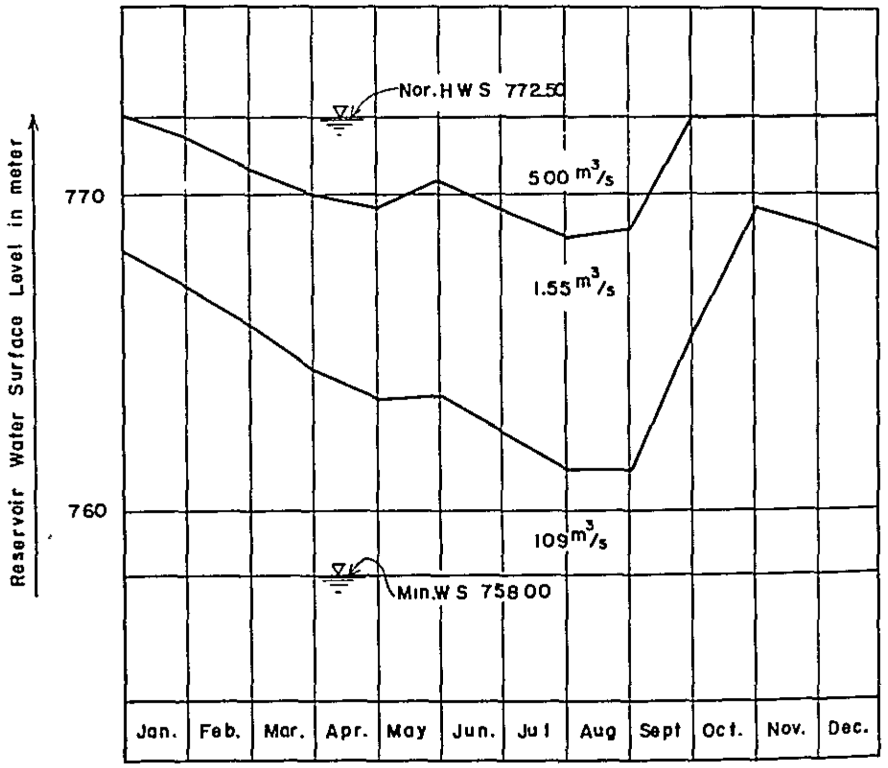
The available discharge for power, overflow and reservoir water surface level were calculated based on the reservoir operation rule shown in Fig. 7-3. The result is shown in Fig. 7-4.

In conducting the calculation above, the evaporation losses of water from the reservoir water surface were taken into account. The evaporation was assumed as 600 mm a year, as stated in CHAPTER 5. Seasonal fluctuation of evaporation was not considered.

The seepage losses from the reservoir were disregarded for the following reasons. As the reservoir area is for the most part covered by an overburden which is relatively impervious, the seepage loss is deemed negligible in the calculation of discharge for power. Furthermore, the sediments to be deposited in the reservoir over the years will presumably add to the imperviousness of the reservoir.

Fig. 7-3 Temporary Operation Rule of Reservoir

Month	V_u		V_L		Month
	m	10^6 m^3	m	10^6 m^3	
Jan.	771.8	41.0	767.1	21.0	Jan.
Feb.	770.8	36.0	765.8	17 0	Feb.
Mar.	770.0	33.0	764.5	14.0	Mar.
Apr.	769 6	30.3	763.5	12.0	Apr
May	770.4	34 0	763.5	12 0	May
Jun	769.5	30.0	762.2	9.5	Jun.
Jul.	768.7	27.0	761.3	8.0	Jul.
Aug.	769.0	28 0	761 3	8 0	Aug.
Sept.	772.5	50.0	765.8	17.0	Sept
Oct.	772 5	51.6	769.7	31.0	Oct.
Nov.	772.5	50.5	769 1	28.5	Nov
Dec.	772 5	45.5	768.3	25.0	Dec.



Symbols (Unit: cu. m per second-month)

V_{n-1} : Storage at the end of previous month
V_n : Storage at the end of current month
V_u : Standard upper limit of storage
V_L : Standard lower limit of storage
V_{max} : Maximum storage
V_{min} : Minimum storage
f_n : Overflow in current month
Q_u : Standard upper limit of run-off
Q_M : Standard run-off
Q_L : Standard lower limit of run-off
q_n : Inflow in current month
Q_n : Discharge for power in current month
Q_{max} : Maximum discharge for power
Q_s : Standard discharge for power
Q_{min} : Minimum discharge for power
E_v : Evaporation loss in current month
E_{v1} : Standard evaporation loss at high water surface level
E_{v2} : Standard evaporation loss at low water surface level

Constants (Unit: cu. m per second-month)

Q_u	= 5.08	Q_{max}	= 500	E_{v1}	= 0.08
Q_M	= 1.63	Q_s	= 1.55	E_{v2}	= 0.04
Q_L	= 1.13	Q_{min}	= 1.09		

Basic Formulae

$$V_{max} \geqq V_{n-1}+q_n - Q_n - E_v \Longrightarrow V_n = V_{n-1} + q_n - Q_n - E_v$$

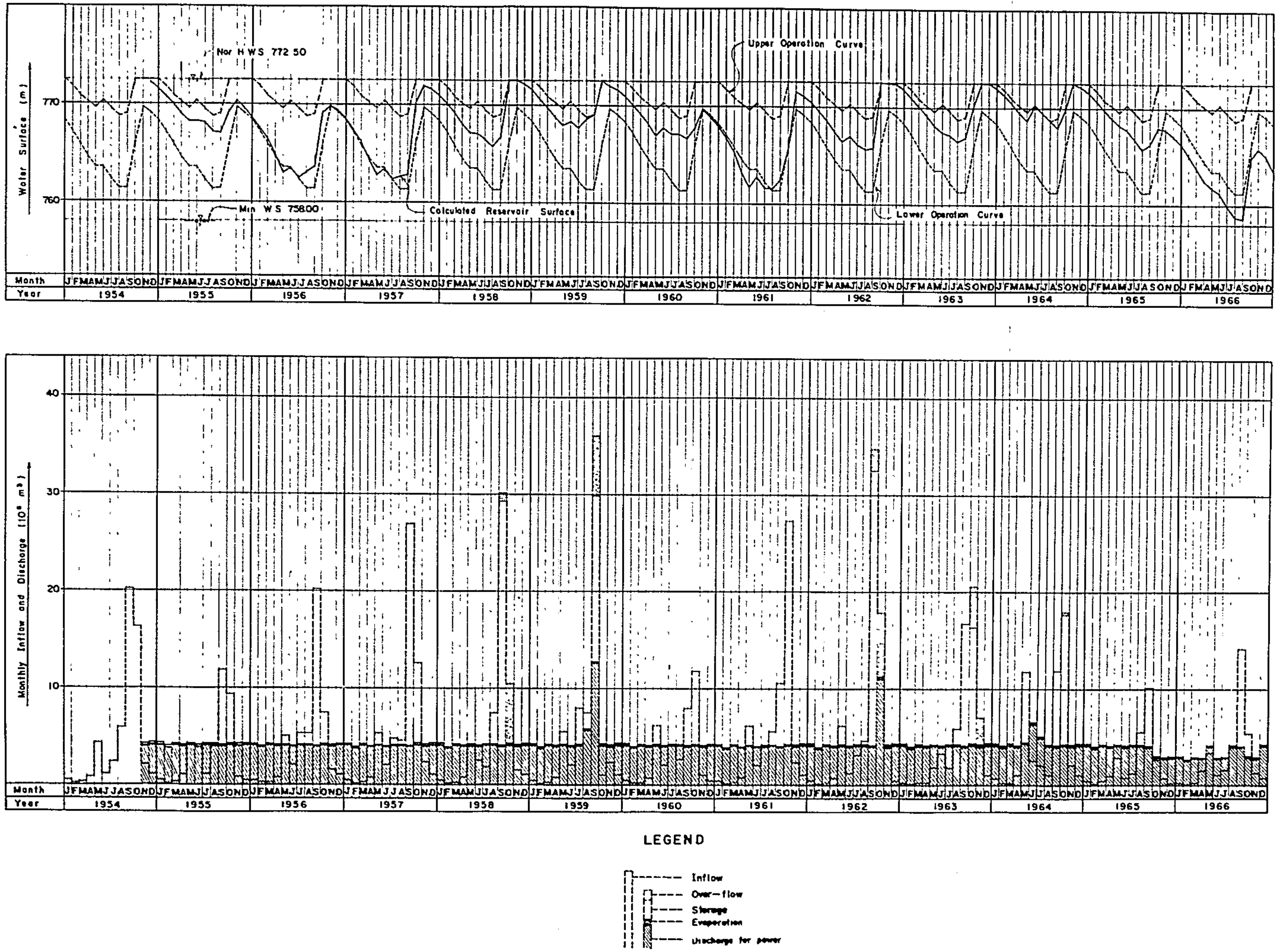
$$V_{n-1}+q_n - Q_n - E_v > V_{max} \Longrightarrow \begin{cases} V_n = V_{n-1} + q_n - Q_n - E_v - f_n \\ f_n = V_{n-1} + q_n - Q_n - E_v - V_{max} \end{cases}$$

Operation Rule

1. $V_{n-1} + q_n > V_u$
   - (1) $V_{n-1} + q_n - V_u \geqq Q_u \Longrightarrow Q_n = Q_{max}$
   - (2) $Q_u > V_{n-1} + q_n - V_u > Q_M \Longrightarrow Q_n = V_{n-1}+q_n-V_u-E_{v1}$
   - (3) $Q_M \geqq V_{n-1} + q_n - V_u \Longrightarrow Q_n = Q_s$
2. $V_u \geqq V_{n-1}+q_n \geqq V_L \Longrightarrow Q_n = Q_s$
3. $V_L > V_{n-1} + q_n$
   - (1) $V_{n-1}+q_n - V_{min} \geqq Q_L \Longrightarrow Q_n = Q_{min}$
   - (2) $Q_L > V_{n-1}+q_n - V_{min} \Longrightarrow Q_n = V_{n-1}+q_n-V_{min}-E_{v2}$

Fig. 7-3 Temporary Operation Rule of Reservoir

Fig.7—4 Reservoir Operation 1955 to 1966



7.3 FIRM DISCHARGE FOR POWER

According to Fig. 7-4 mentioned in the preceding paragraph, it is noticed that 1.55 cu.m/sec of discharge for power can be secured for about 11 years from the beginning of 1955 to September, 1965. For one year and 3 months from October, 1965 to the end of 1966, the discharge available for power is 1.09 cu.m/sec. As is apparent in Table 5.4 of CHAPTER 5, the years 1964, 1965 and 1966 are respectively the average year, the driest year and the second driest year in the 12 years. In other workds, two driest years come after the average year.

It seems rare that the average year is followed by two driest year in a row. On the same basis as in the study of the Nam Phrom Project, it would be rational to consider covering up the power output shortage which will arise in such a rare case with the reserve capacity kept in the system and to set the firm discharge at 1.55 cu.m/sec which is guaranteed for 11 years of the 12 years. In this case, the deficiency in output will be about 4 MW, which can be safely supplemented by the reserve capacity of the NEEA system.

From the foregoing grounds, the firm discharge for power of the Nam Chern Power Plant is set at 1.55 cu.m/sec.

7.4 MAXIMUM DISCHARGE FOR POWER

The maximum discharge for power, and consequently the maximum capacity of equipment of the Nam Chern Power Plant must be decided in such a way that the shortage of supply capability of the NEEA System can be most economically made up for. With this in view, it is necessary to study what position the Nam Chern Power Plant will hold in the demand and supply balance of this system.

As explained in CHAPTER 3, the start-up of the Nam Chern Power Plant would be in the latter half of 1973, if this project is executed prior to the Nam Phrom Project. The study of load demand and supply capability was made for the years beginning in 1974, based on the daily load curve in June and December for each year. Basic assumptions for this study are the same as the ones in the study of the Nam Phrom Project.

Fig. 7-5 Estimated Maximum Power and Energy Demand 1974 to 1977 and Dry Year Supply Capability

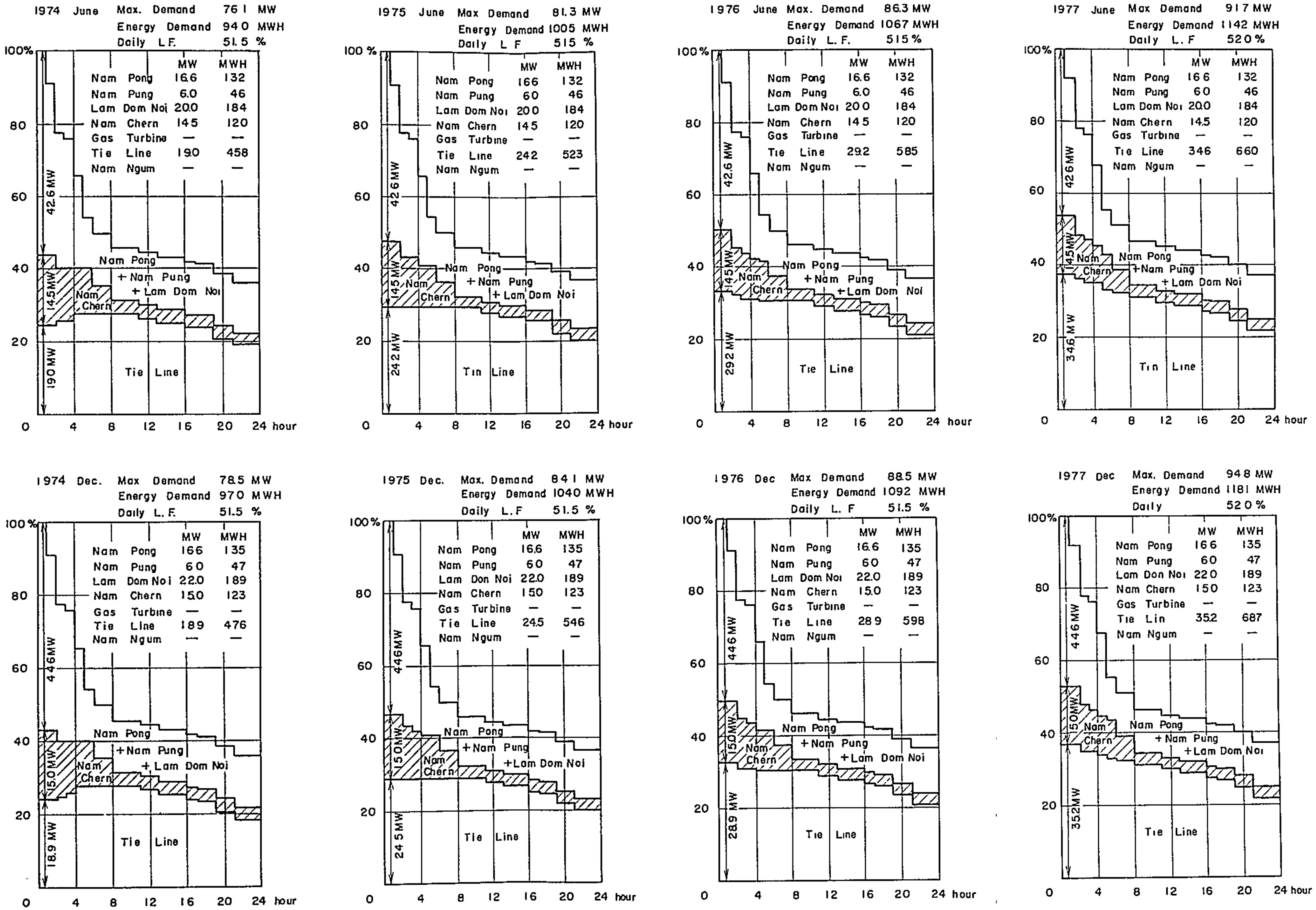
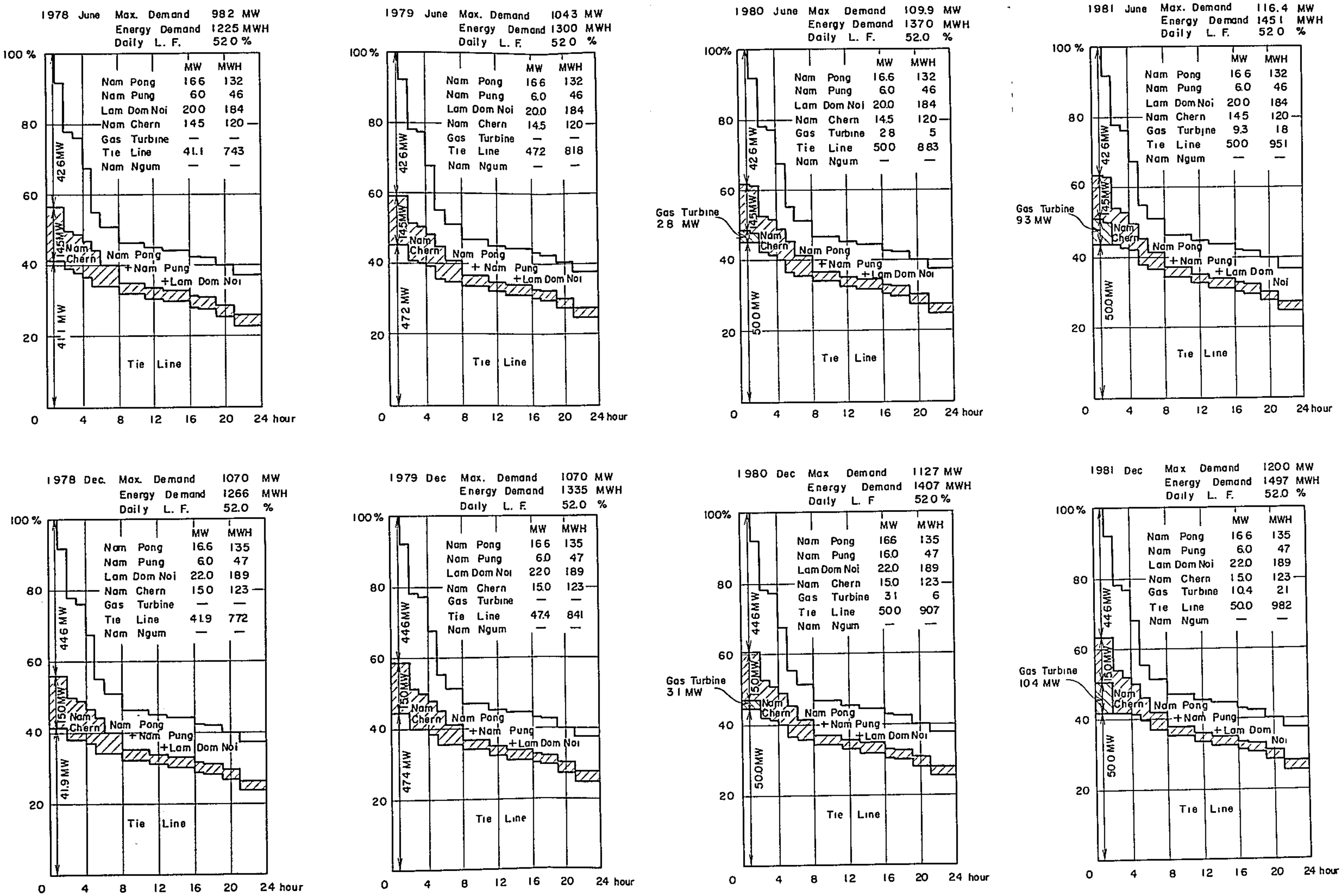


Fig.7-5 Estimated Maximum Power and Energy Demand 1974 to 1977 and Dry Year Supply Capability.

Fig. 7-6 Estimated Maximum Power and Energy Demand 1978 to 1981 and Dry Year Supply Capability



1978 June Max. Demand 982 MW
Energy Demand 1225 MWH
Daily L. F. 520 %

	MW	MWH
Nam Pong	166	132
Nam Pung	60	46
Lam Dom Noi	200	184
Nam Chern	145	120
Gas Turbine	—	—
Tie Line	41.1	743
Nam Ngum	—	—

1979 June Max. Demand 1043 MW
Energy Demand 1300 MWH
Daily L. F. 520 %

	MW	MWH
Nam Pong	166	132
Nam Pung	6.0	46
Lam Dom Noi	20.0	184
Nam Chern	14.5	120
Gas Turbine	—	—
Tie Line	472	818
Nam Ngum	—	—

1980 June Max Demand 109.9 MW
Energy Demand 1370 MWH
Daily L. F. 52.0 %

	MW	MWH
Nam Pong	16.6	132
Nam Pung	6.0	46
Lam Dom Noi	20.0	184
Nam Chern	14.5	120
Gas Turbine	28	5
Tie Line	500	883
Nam Ngum	—	—

1981 June Max. Demand 116.4 MW
Energy Demand 1451 MWH
Daily L. F. 520 %

	MW	MWH
Nam Pong	166	132
Nam Pung	6.0	46
Lam Dom Noi	200	184
Nam Chern	145	120
Gas Turbine	9.3	18
Tie Line	500	951
Nam Ngum	—	—

1978 Dec. Max. Demand 1070 MW
Energy Demand 1266 MWH
Daily L. F. 52.0 %

	MW	MWH
Nam Pong	16.6	135
Nam Pung	6.0	47
Lam Dom Noi	22.0	189
Nam Chern	150	123
Gas Turbine	—	—
Tie Line	41.9	772
Nam Ngum	—	—

1979 Dec Max. Demand 1070 MW
Energy Demand 1335 MWH
Daily L. F. 52.0 %

	MW	MWH
Nam Pong	166	135
Nam Pung	6.0	47
Lam Dom Noi	220	189
Nam Chern	15.0	123
Gas Turbine	—	—
Tie Line	47.4	841
Nam Ngum	—	—

1980 Dec Max Demand 1127 MW
Energy Demand 1407 MWH
Daily L. F 520 %

	MW	MWH
Nam Pong	166	135
Nam Pung	16.0	47
Lam Dom Noi	22.0	189
Nam Chern	15.0	123
Gas Turbine	31	6
Tie Line	500	907
Nam Ngum	—	—

1981 Dec Max Demand 1200 MW
Energy Demand 1497 MWH
Daily L. F. 52.0 %

	MW	MWH
Nam Pong	166	135
Nam Pung	6.0	47
Lam Dom Noi	22.0	189
Nam Chern	1 5.0	123
Gas Turbine	10.4	21
Tie Line	50.0	982
Nam Ngum	—	—

Fig 7-6 Estimated Maximum Power and Energy Demand 1978 to 1981 and Dry Year Supply Capability

Fig. 7-5 and 7-6 indicate that the Nam Chern Power Plant should be operated as a peak load station. On the other hand, since it is a reservoir type hydro-electric plant under high head, the Nam Chern Power Plant is suitable for peak load station.

The determination of its plant factor depends upon other supply capabilities which are to be newly constructed. Fig. 7-5 and Fig. 7-6 indicate that, for a few years after the start of operation, the Nam Chern Power Plant will be operated at such a load factor as 25 to 30%. After a few years, however, the Nam Phrom Power Plant will be implemented, which will result in that the load factor of the Nam Chern Power Plant comes up higher. In case that the Nam Chern Project is executed after the Nam Phrom Project, the load factor of the Nam Chern Power Plant will be also higher than the above-mentioned values, as is apparent in the Feasibility Report of the Nam Phrom Project.

From this point of view, the Nam Chern Power Plant must be so designed that the plant factor is 30%, the maximum discharge for power is 5.00 cu. m/sec and the installed capacity is 15,000 KW.

7.5 DISCHARGE FOR DEPENDABLE CAPABILITY

The discharge for power of the Nam Chern Power Plant, in calculating its dependable capability, is taken at 4.90 cu. m/sec, the maximum discharge for power which the turbine system of this plant can take at the lowest water surface level of the reservoir.

7.6 INSTALLED CAPACITY AND DEPENDABLE CAPABILITY

The installed capacity, the dependable capacity and their calculations are shown in Table 7-2. The intake water level is taken at the standard water surface level for the installed capacity and at the lowest surface water level of the reservoir for the dependable capability. The tailwater surface level is taken at the presumed water level in the tailrace of the plant at the time of maximum discharge for power.

Table 7-2

Item	Installed Capacity	Dependable Capacity
Discharge (m^3/sec)	5.00	4.90
Intake water surface level (m)	768.0	758.0
Tailwater water surface level (m)	378.0	378.0
Net head (m)	375.0	365.0
Output (MW)	15.0	14.5

7.7 NUMBER OF UNITS OF TURBINE AND GENERATOR

It is considered reasonable that the Nam Chern Power Plant will be equipped with one unit (15 MW) of turbine and generator, because the reserve capacity owned by NEEA system is much larger than the installed capacity of the Nam Chern Power Plant and one unit is the most economical system in this case.

7.8 POWER PRODUCTION

Using the available discharge for power and reservoir water surface level calculated on the basis of the reservoir operation rule, the monthly power production for the 12 years from 1955 to 1966 were worked out. The results are shown in Fig. 7-7 and Table 7-3. As indicated, the average annual energy production for the 12 years is as follows :

Firm energy	40, 160, 000 KWH
Secondary energy	1, 430, 000 KWH
Total	41, 590, 000 KWH

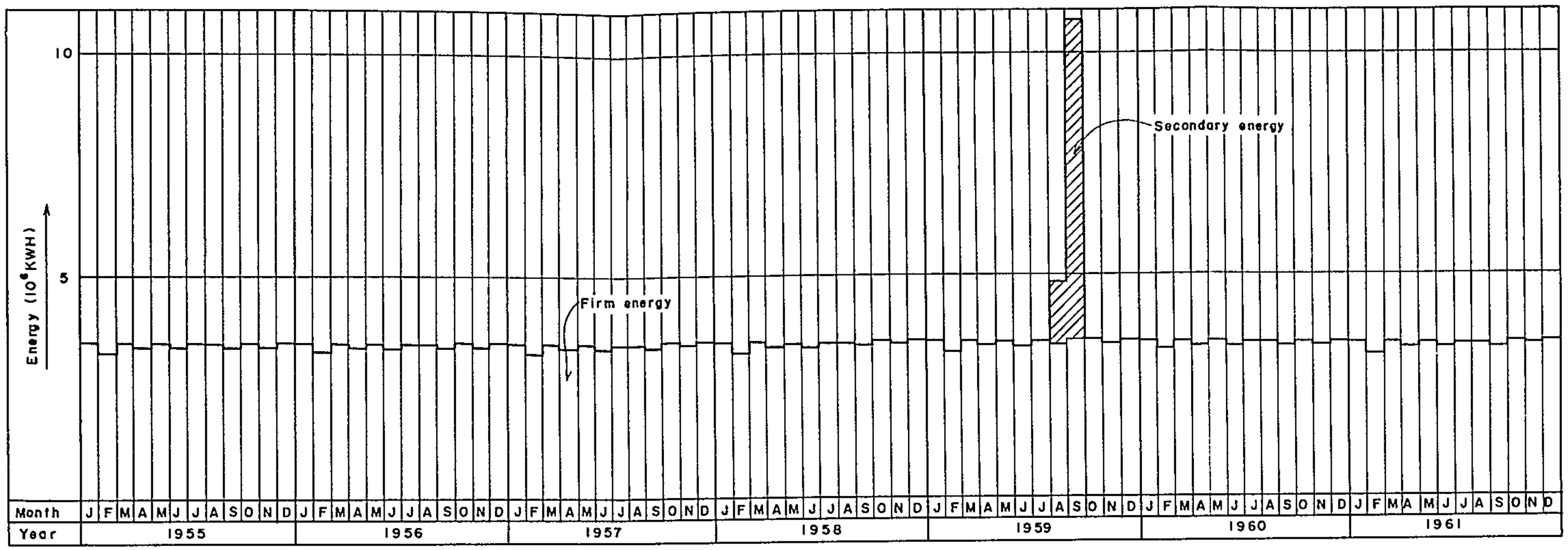
The secondary energy stated above is defined as energy produced with the discharge for power in excess of the firm discharge for power.

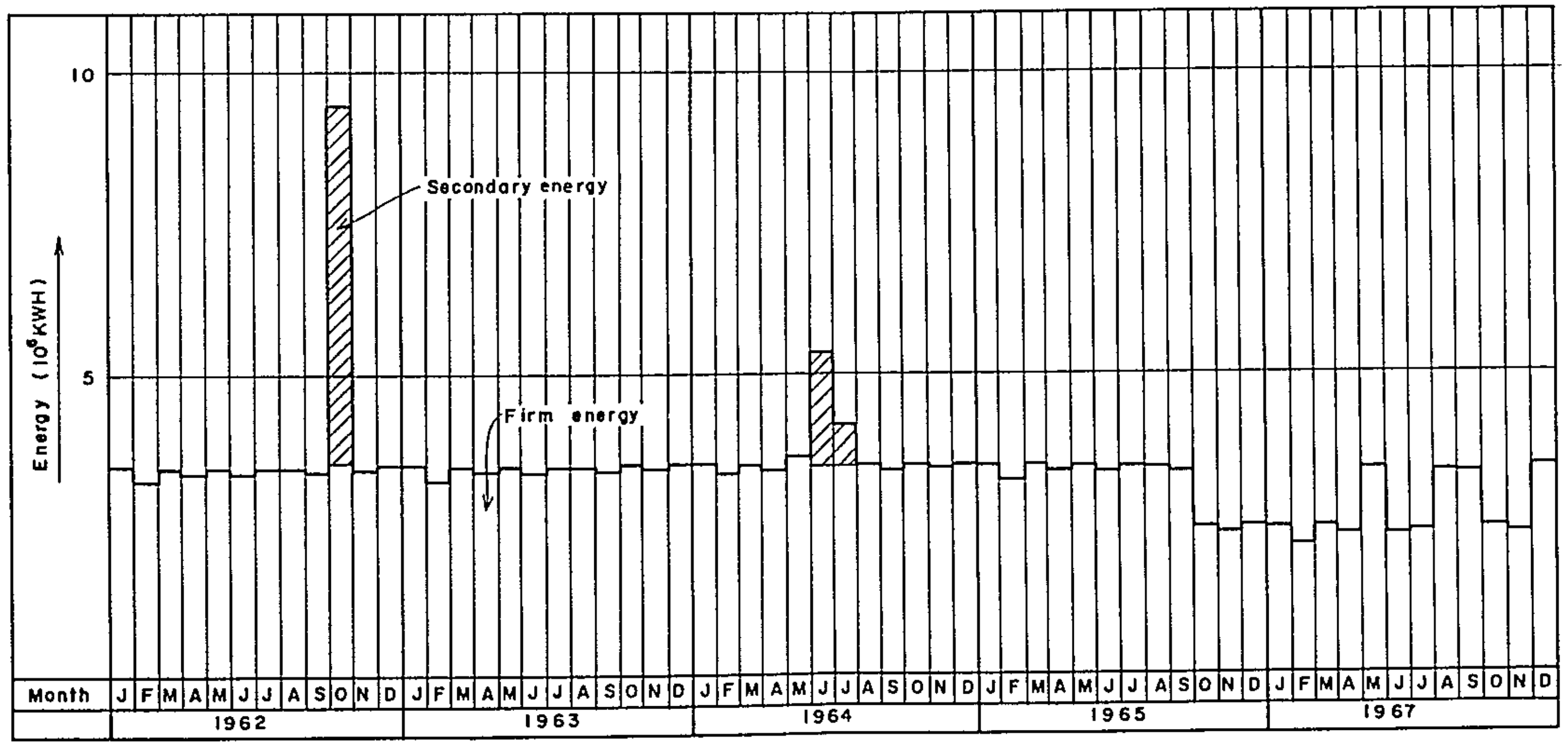
Table 7-3 Energy Production (Unit : 10^6KWH)

Month / Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1955	3.50	3.24	3.49	3.39	3.47	3.39	3.47	3.46	3.39	3.49	3.40	3.48	41.17
1956	3.47	3.29	3.45	3.35	3.43	3.34	3.42	3.43	3.38	3.49	3.40	3.48	40.93
1957	3.46	3.21	3.45	3.35	3.43	3.34	3.42	3.42	3.38	3.50	3.42	3.50	40.88
1958	3.49	3.23	3.48	3.38	3.46	3.38	3.46	3.46	3.41	3.51	3.43	3.51	41.20
1959	3.50	3.24	3.48	3.40	3.47	3.39	3.47	3.44 (4.84)	3.55 (10.75)	3.51	3.42	3.50	41.37 (49.97)
1960	3.49	3.32	3.48	3.38	3.47	3.38	3.46	3.46	3.38	3.48	3.40	3.48	41.18
1961	3.46	3.20	3.44	3.34	3.42	3.34	3.41	3.41	3.35	3.48	3.42	3.50	40.77
1962	3.49	3.23	3.47	3.38	3.46	3.37	3.45	3.45	3.40	3.53 (9.43)	3.43	3.51	41.17 (47.07)
1963	3.50	3.24	3.49	3.39	3.47	3.38	3.46	3.46	3.39	3.50	3.43	3.51	41.22
1964	3.51	3.33	3.49	3.40	3.56 (3.66)	3.46 (5.36)	3.46 (4.16)	3.48	3.40	3.50	3.43	3.51	41.53 (44.23)
1965	3.49	3.24	3.49	3.39	3.47	3.38	3.46	3.45	3.38	2.46	2.37	2.46	38.04
1966	2.44	2.18	2.42	2.33	3.41	2.33	2.40	3.39	3.34	2.44	2.36	3.44	32.48
Average	3.40	3.16	3.39	3.29	3.46 (3.47)	3.29 (3.45)	3.36 (3.42)	3.44 (3.56)	3.40 (3.99)	3.32 (3.81)	3.24	3.41	40.16 (41.59)

Note: Figures in parentheses contain secondary energy.

Fig. 7-7 Energy Production





(10^6 kwh)

Item / Year	Firm energy	Secondary energy	Total
1955	41 17	0	41 17
1956	40.93	0	40 93
1957	40 88	0	40.88
1958	41.20	0	41 20
1959	41.37	8.60	49 97
1960	41.18	0	41.18
1961	40.77	0	4077
1962	41.17	5 90	4707
1963	41.22	0	41.22
1964	41.53	2.70	44.23
1965	38.04	0	38 04
1966	32.48	0	32.48
Total	481.94	17 20	499.14
Average	40.16	1.43	41 59

Note ; Based on temporary operation rule.

Fig. 7-7 Energy Production

CHAPTER 8. PRELMINARY DESIGN

CHAPTER 8. PRELIMINARY DESIGN

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CHAPTER 8. PRELMINARY DESIGN

8.1 Design

8.1.1 Civil Engineering Structures

(1) Dam

Comparative studies have been made of various types of dam according to such factors as topographical and geological conditions of the dam site, dam construction materials, flood flow control, etc. As a result, it has been found that a fill type dam is most economical. A concrete dam is not economical for various reasons including the high cost of cement and its expensive transportation charges to the project site. An arch dam is not advantageous in view of the topographical and geological conditions of the dam site.

With respect to the type of fill dam, it has been decided to adopt a zone type rock fill dam. Since there is enough suitable soil for core material near the dam site, it is contemplated to use relatively thick layers of core material in consideration of economy. Generally, the construction of a thick core dam needs a longer embankment period because of its large quantity of earth material than a thin core dam. However, in this case, there will be no substantial effect on the construction schedule of the present dam.

River diversion during construction will be carried out by installing a tunnel of 3 meters diameter at the right bank. The maximum flood discharge anticipated to occur during construction works is estimated at 220 m^3/sec, taking into account the maximum flood flow in the past ten years, with November to July period of each year as a base. The water level upstream of this tunnel is raised up to 759 meters by constructing a coffer dam, and with this head, tunnel has a capacity of 85 m^3/sec. Since, in this case, part of the flood discharge is stored on the upstream side of the coffer dam, the flow will be reduced by 135 m^3/sec. Therefore it will be possible to divert safely the flood discharge of 220 m^3/sec on which the present construction plan is based.

Further detailed investigations for fill type dam materials will be required for the definite plan study, and the final design of the dam will have to be determined from the results of these investigations.

(2) Spillway

As described in Chapter 5, the design flood discharge at the dam site is 850 m^3/sec. Of which amount 415 m^3/sec will be stored in the reservoir by raising its normal full water level of 772.5 meters by 1.1 meters, and the remaining 435 m3/sec will be released downstream from the spillway. This spillway is of a chute type, and capable of discharging 435 m3/sec at the reservoir surface level of 773.6 m.

The control gates of the spillway are three radial gates. This arrangement is from the consideration that in case failure should take place in gate operation, a large number of gates and a broader width of a spillway will ensure greater safety.

(3) Intake

The intake will be of an inclined type and located on the right bank about 300 meters upstream from the dam site. In front of the intake there will be provided a trash screen and a guide rails for a trash rake. The headrace tunnel will have a roller gate provided at the entrance for checking and maintenance.

(4) Headrace

The headrace will be a pressure tunnel having a horseshoe section. Due to the small quantities of discharge the diameter of tunnel will be 1.80 m, the minimum size for economical construction.

The route of the headrace tunnel has been determined in order to have a sufficent depth between the ground surface and the tunnel.

It will be necessary to line the tunnel with concrete for the entire length. Reinforced concrete will be necessary in some parts of the tunnel particularly at the sections where there are relatively thin depths of overburden, or where the geological condition is not satisfactory.

As mentioned in Chapter 6, however, the region through which the headrace tunnel will pass is not deemed to raise any problems from the geological point of view. A work shaft will be provided at a point midway in the tunnel. This will make possible construction to be completed within the proposed schedule.

(5) Surge Tank

The surge tank is of a single type. The tank will be so designed as to meet the requisite conditions that when a 100% load is shut off at the normal full water level of the reservoir or when the load is suddenly increased 50% at the lowest reservoir level, neither headrace nor water turbine will be affected in either case.ther case.

(6) Penstock

One penstock composed of welded steel pipes will be installed. The material of the penstock will consist mainly of high tension steel SM 58 (JIS) or equivalent grades. In determining the inner diameter of the penstock, several inner diameters were compared to obtain the optimum one which produces the least sum of annual expense plus decrease in income due to loss of head. As shown in Fig. 8-1, an average diameter of 1.44 m has been decided on as a result of studies. The actual diameter of the penstock thus chosen will vary from 1.20 to 1.70 meters between the top and bottom.

At the top horizontal section of the penstock there will be installed an automatic butterfly valve and air valve against penstock failure. The end of the penstock will also be provided with a rotary valve.

(7) Power Plant and Switching Station

The power plant will be constructed on the ground. The draft tube will be of an L type and its outlet will be fitted with a gate. An outdoor switch yard will be built adjacent to the power house along with a repair shop, warehouse and emergency generating equipment.

8.1.2 Turbine and Generator

The present power plant will have a rated head of 375 meters and a maximum discharge of 5.0 m^3/sec. A Francis or Pelton type is considered suitable under these conditions. The Francis type will give a higher rotation speed, less weight of machinery including a generator, and will cost less. Considering this economic advantage and the ease of operation and maintenance, a vertical shaft Francis turbine is adopted. A skeleton diagram of the power station and the transmission system are presented in DWG. No. 9 and 10.

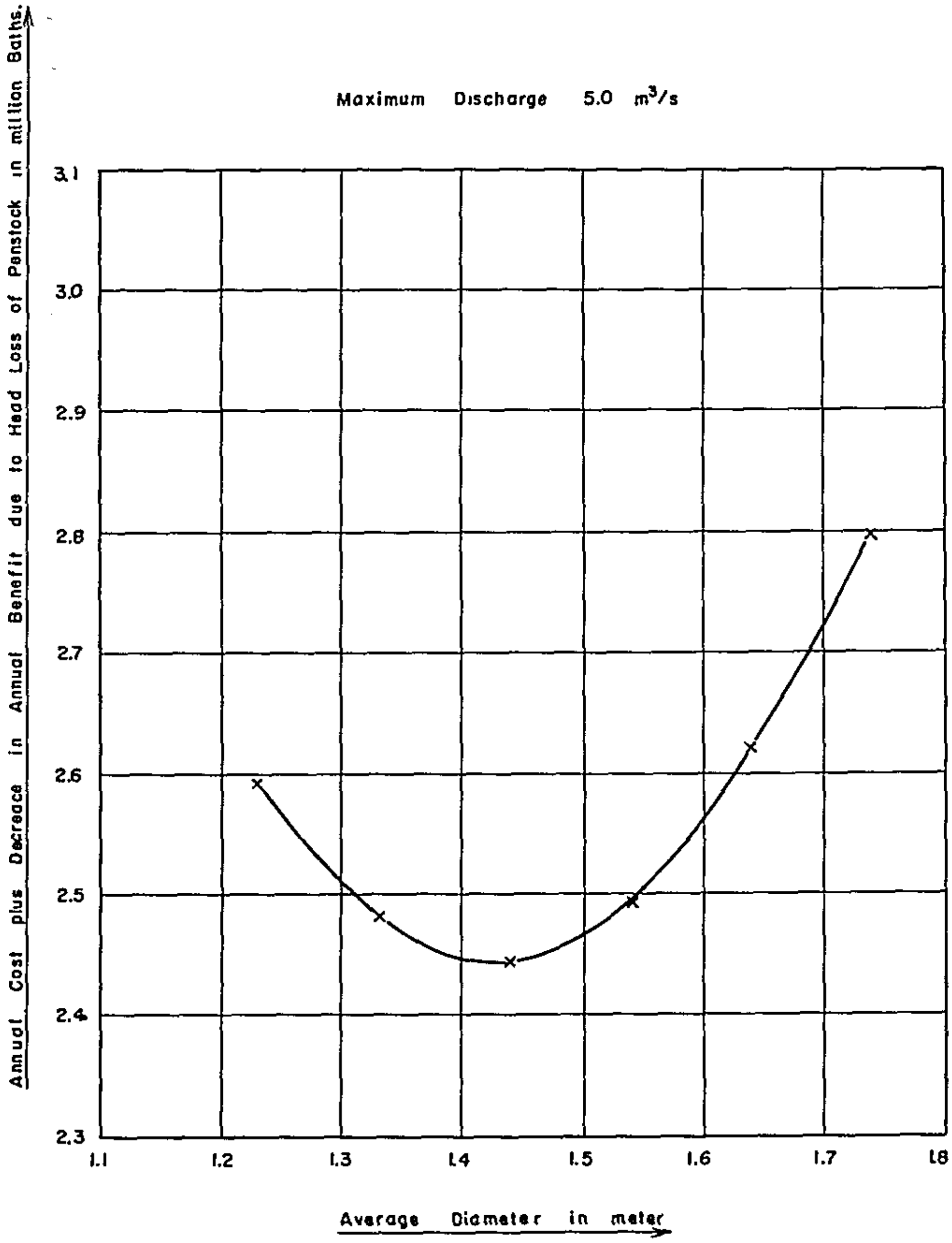
8.1.3 Transmission Line and Telecommunication Equipment

(1) Transmission Line

The route of transmission line has been decided to run along the existing national highway for the section between Khonkaen and Ban Non Han and along the new road to be built for the section between Ban Non Han and the Nam Chern Power Plant.

The voltage of the new transmission line will be set at 115 KV in consideration of connection with the existing transmission systems. It is contemplated to use 240 sq. mm ACSR for the conductor if it is premised to connect the transmission lines from the Nam Chern Power Plant and the Nam Phrom power plant at Ban Song Kon. If otherwise, a 95 sq. mm ACSR conductor will be employed. The outline of a suspension and a tension type steel towers are presented in DWG. No. 10.

Fig. 8-1 Study on Diameter of Penstock



(2) Substation

Unless connected to the transmission line from the Nam Phrom Power Plant, the transmission line from the Nam Chern Power Plant will be connected to the 115 KV transmission line of the Nam Pong System at the Khonkaen Substation. In such case the substation will be provided with additional apparatuses such as a circuit breaker and disconnecting switch.

(3) Telecommunication Equipment

One telephone circuit for power supply will be set up between the Nam Chern Power Plant and the Khonkaen Substation using a power line carrier system.

8.1.4 General Features of Structures

The general features of various structures involved in the Nam Chern Project are presented below :

Item	Description	
Hydraulic Structures		
Dam	Core type, Rockfill dam	
	Level of crest above MSL	776.0 m
	Length of crest	409.0 m
	Width of crest	8.0 m
	Height (foundation to crest)	36.0 m
	Freeboard (above Nor. H.W.S.)	3.5 m
	Slope of upstream face	1:2, 1:2.5
	Slope of downstream face	1:1.8, 1:2
	Volume of dam	284,000 m^3
Spillway	Shute spillway with control gates	
	Design flood discharge	435 cu.m/s
	Type of gate	Radial gate
	Number of gates	3
	Dimension of gate	5.4 m (width) x 4.5 m (height)
Intake	Inclined type, reinfarced concrete structure	
	Maximum intake	5.0 cu.m/s
	Type of gate	Roller gate
	Number of gates	1
	Dimension of gate	1.8 m (width) x 2.5 m (height)
	Screen	3.0 m (width) x 34.0 m (length)

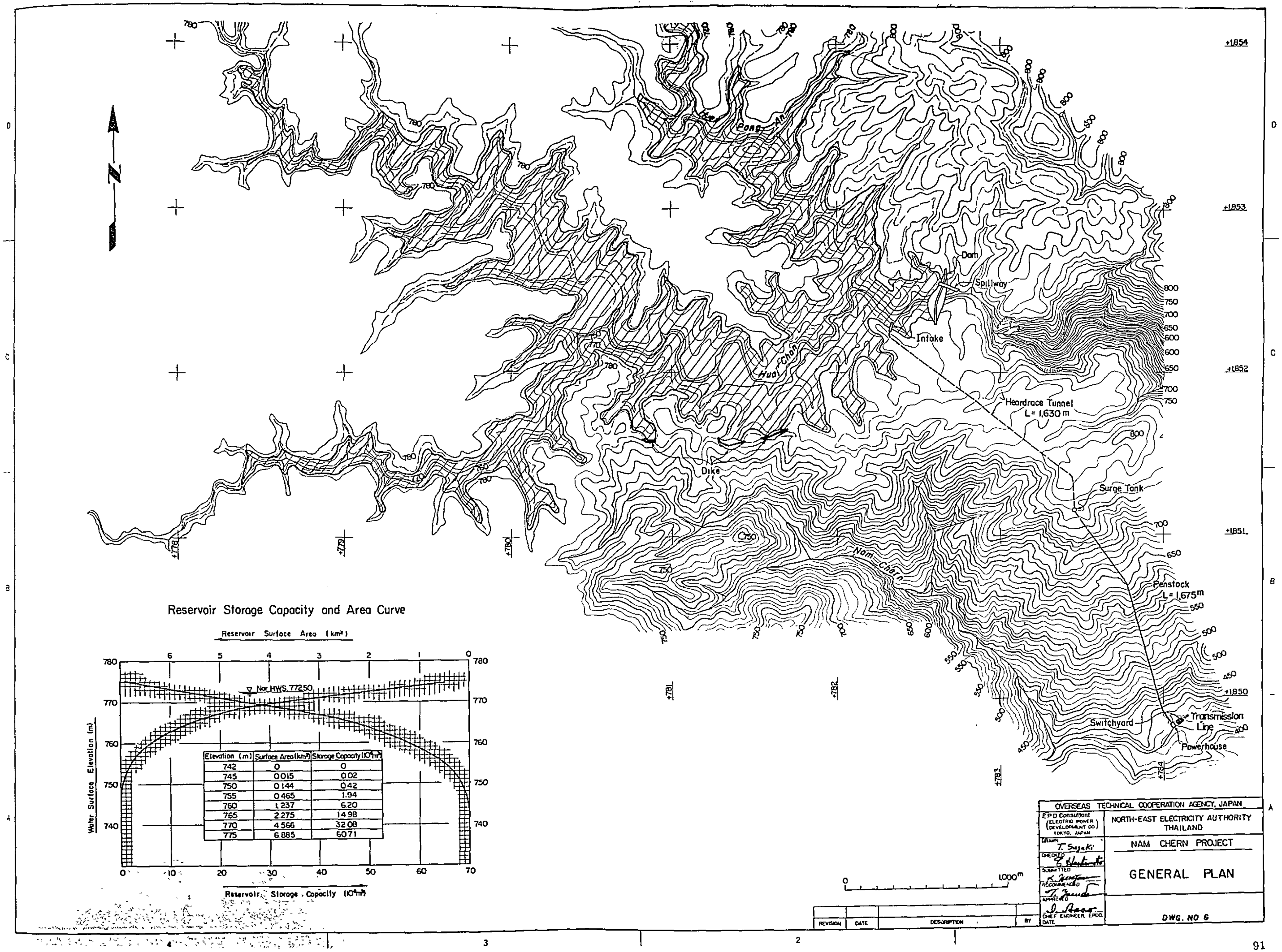
Item	Description	
Headrace	Pressure tunnel	
	Length	1,630 m
	Shape	Upper half: semicircular
		Lower half: rectangular
	Inside dimension	1.8 m
	Maximum discharge	5.0 cu.m/s
Surge Tank	Simple type	
	Inside diameter	5.0 m
	Height	35.0 m
Penstock	Welded steel, ring girder type	
	Materials	SM58, SM50 and SM41(JIS)
	Length	1,675 m
	Number of lines	1
	Inside diameter	1.70 - 1.20 m
	Type of control valve	
	(Upper)	Butterfly valve, 1.70 m in diameter
	(Lower)	Rotary valve, 1.20 m in diameter
Powerhouse	Reinforced concrete structure	

Item	Description	
Electric Equipment		
Turbine	Vertical shaft Francis type	
	Output	16,000 KW
	Maximum discharge	5.0 cu.m/s
	Revolutions	750 r.p.m.
	Number of units	1
Generator	Three-phase synchronous generator, vertical shaft, rotating field, closed type	
	Capacity	18,000 KVA
	Voltage	6.6 KV
	Frequency	50 cycles
	Number of units	1
Transformer	Three-phase outdoor, oil-immersed self-cooled type	
	Capacity	18,000 KVA
	Voltage	6.6/115 - 110 - 120 KV
	Number of units	1
Outdoor Switchyard	Transmission voltage	115 KV
	Area	14 m x 22 m

Item	Description	
Transmission Line	Distance	135 km
	Voltage	115 KV
	Number of circuits	1 cct
	Conductor	240 or 95 sq. mm ACSR
	Insulator	250 mm suspension insulator ball & socket
	Overhead ground wire	55 sq.mm GSC
	Support	Zink Galvanized steel tower
Telecommunication System		
Power Line Carrier Telephone	One channel between Nam Chern Power Plant and Khonkaen Substation, for power dispatching service.	

8.2 CONSTRUCTION SCHEDULE

The most appropriate construction period of the Nam Chern Project will be twenty-five months after completion of a access road. The recommended construction schedule is presented in DWG. No. 12.



Reservoir Storage Capacity and Area Curve

Elevation (m)	Surface Area (km²)	Storage Capacity ($10^6 m^3$)
742	0	0
745	0.015	0.02
750	0.144	0.42
755	0.465	1.94
760	1.237	6.20
765	2.275	14.98
770	4.566	32.08
775	6.885	60.71

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THAILAND

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APPROVED
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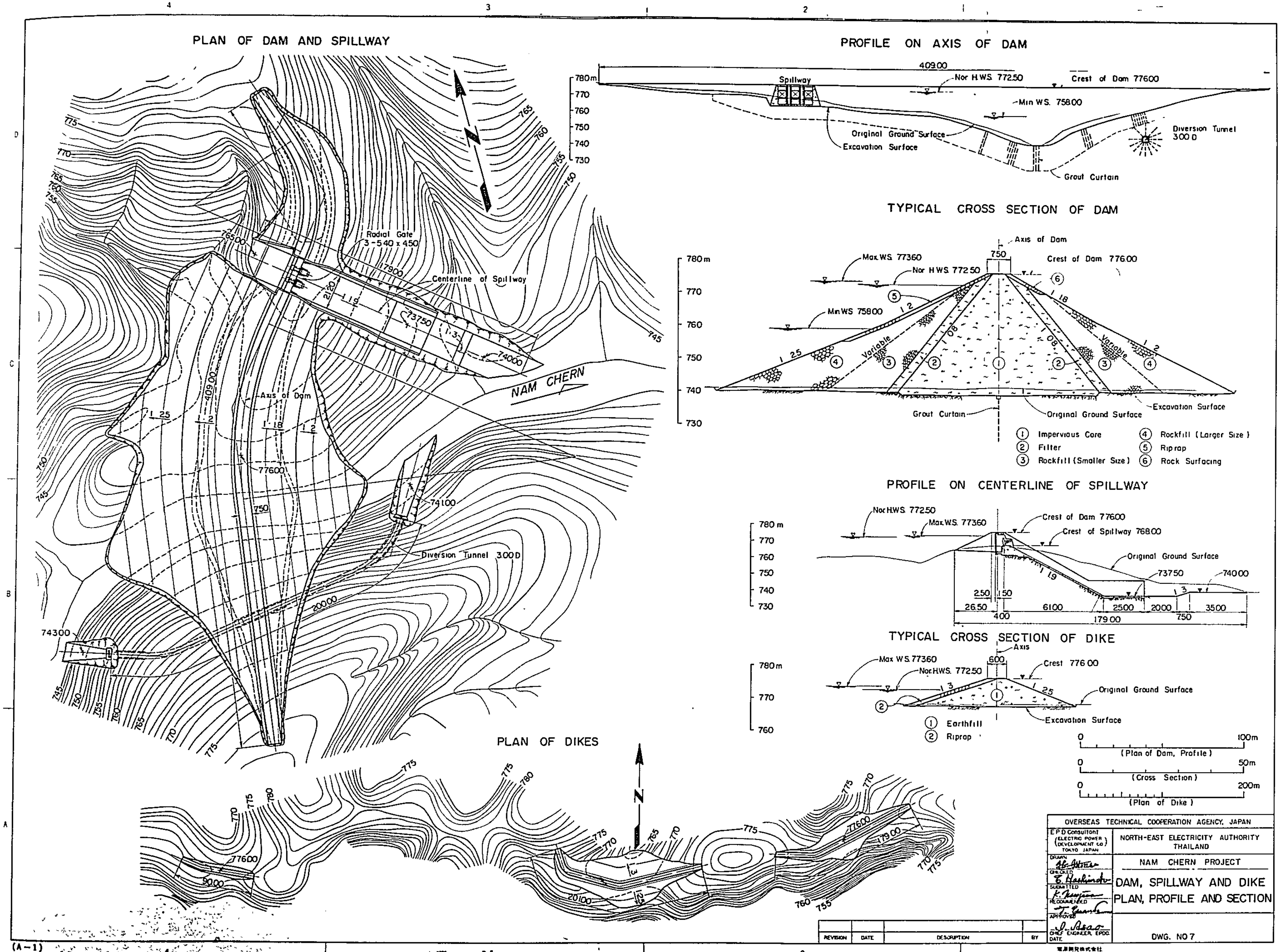
DATE

NAM CHERN PROJECT

GENERAL PLAN

DWG. NO 6



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NAM CHERN PROJECT

DAM, SPILLWAY AND DIKE
PLAN, PROFILE AND SECTION

DRAWN
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SUBMITTED
RECOMMENDED
APPROVED I. Asao
CHIEF ENGINEER, EPDC
DATE

DWG. NO 7

REVISION	DATE	DESCRIPTION	BY

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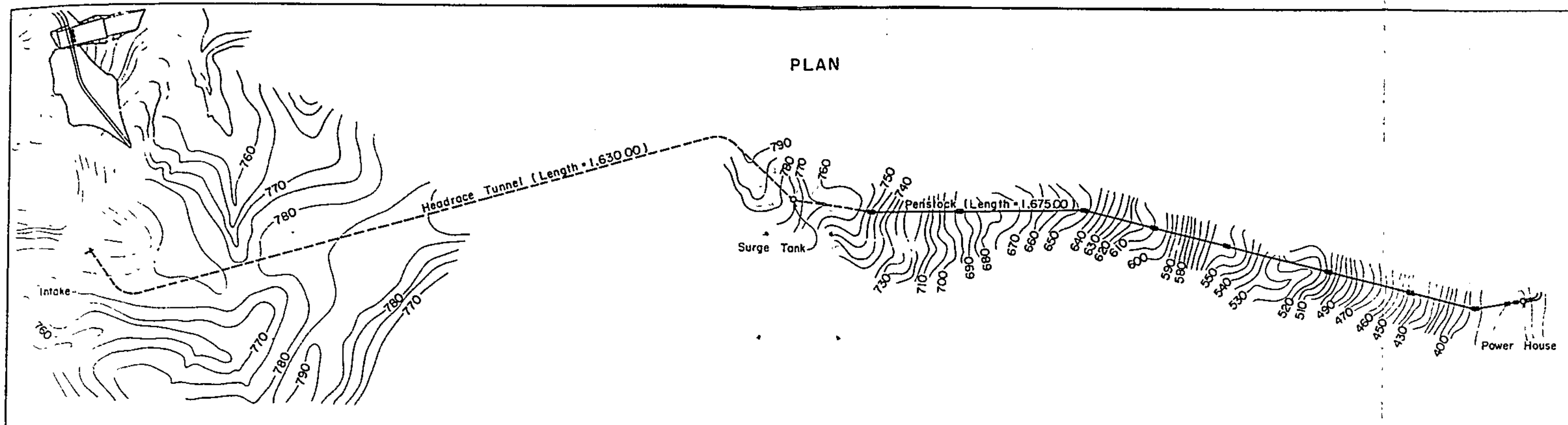
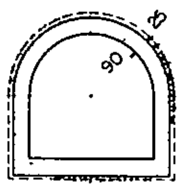
(A-1)

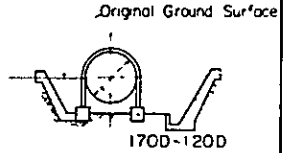
PLAN



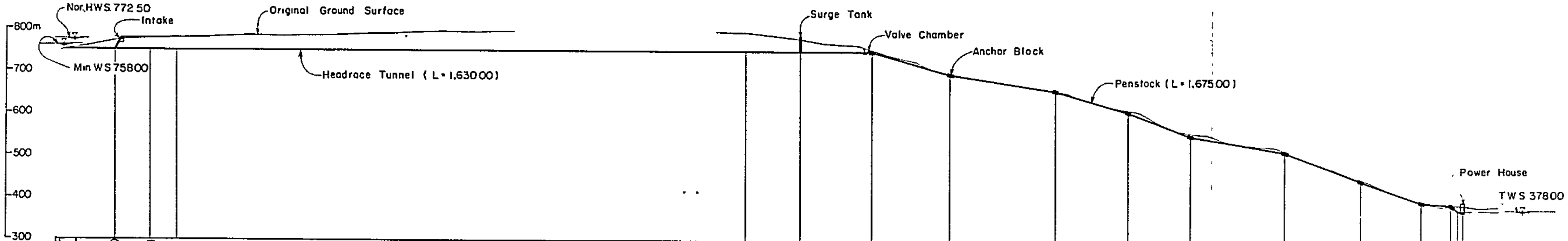
SECTION OF TUNNEL



SECTION OF PENSTOCK

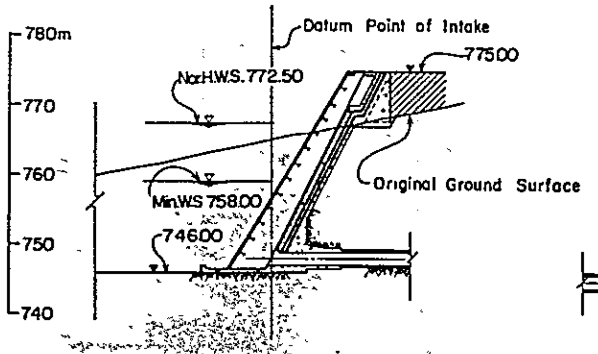


PROFILE

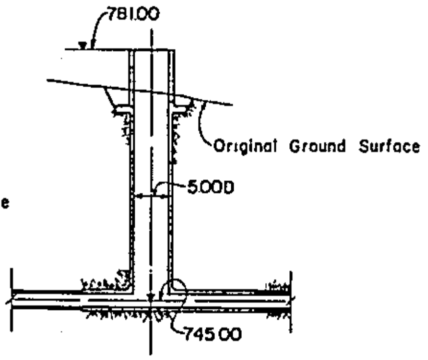


Formation Height	74800	74784	74771	74500	74500	74500	69250	65500	60250	54750	52000	44000	39000	385.00	372.50	372.50
Total Distance	0.00	82.00	14500	1,50000	1,63000	1,80000	1,98500	2,23500	2,41000	2,56000	2,78500	2,96500	3,11000	3,18000	3,19750	3,21000
Distance	0.00	82.00	63.00	1,35500	13000	17000	18500	25000	17500	15000	22500	18000	14500	7000	1750	1250
Station	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

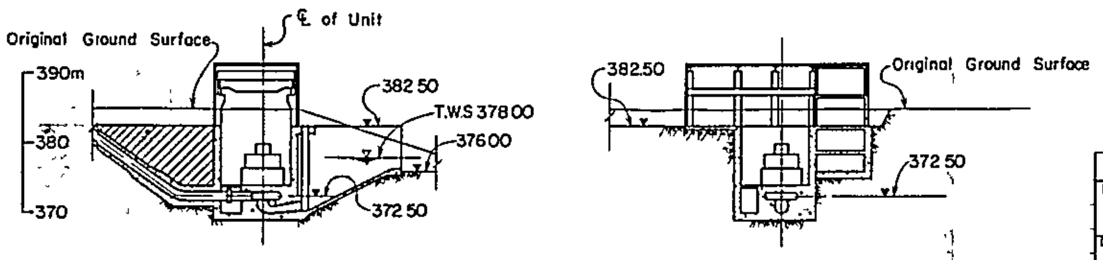
INTAKE

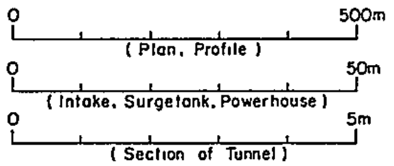


SURGE TANK



POWERHOUSE





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NAM CHERN PROJECT

WATER WAY
PLAN, PROFILE AND SECTION

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SUBMITTED K. Kuwata
RECOMMENDED T. Yasuda
APPROVED I. Aso
CHIEF ENGINEER, EPDC
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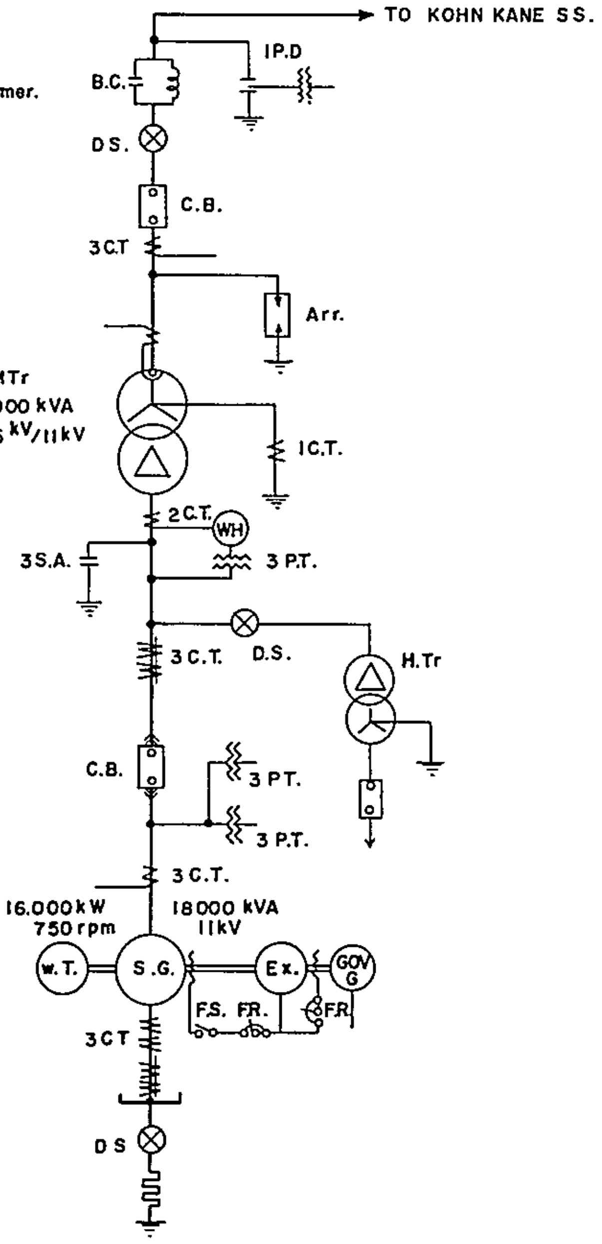
LEGEND

S.G.	Synchronous Generator.
M.Tr	Main Transformer.
C.B.	Circuit Breaker.
D.S.	Disconnecting Switch.
B.C.T.	Bushing Current Transformer.
P.T.	Potential Transformer.
C.T	Current Transformer.
B.C.	Blocking Coil.
P.D.	Potential Device
Arr.	Arrester
S.A.	Surge Absorber.
W.H.	Watt-Hour Meter.



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POWER PLANT SINGLE-LINE DIAGRAM

T. Kato

APPROVED
I. Asao
CHIEF ENGINEER EPDC
DATE

DWG. NO. 9

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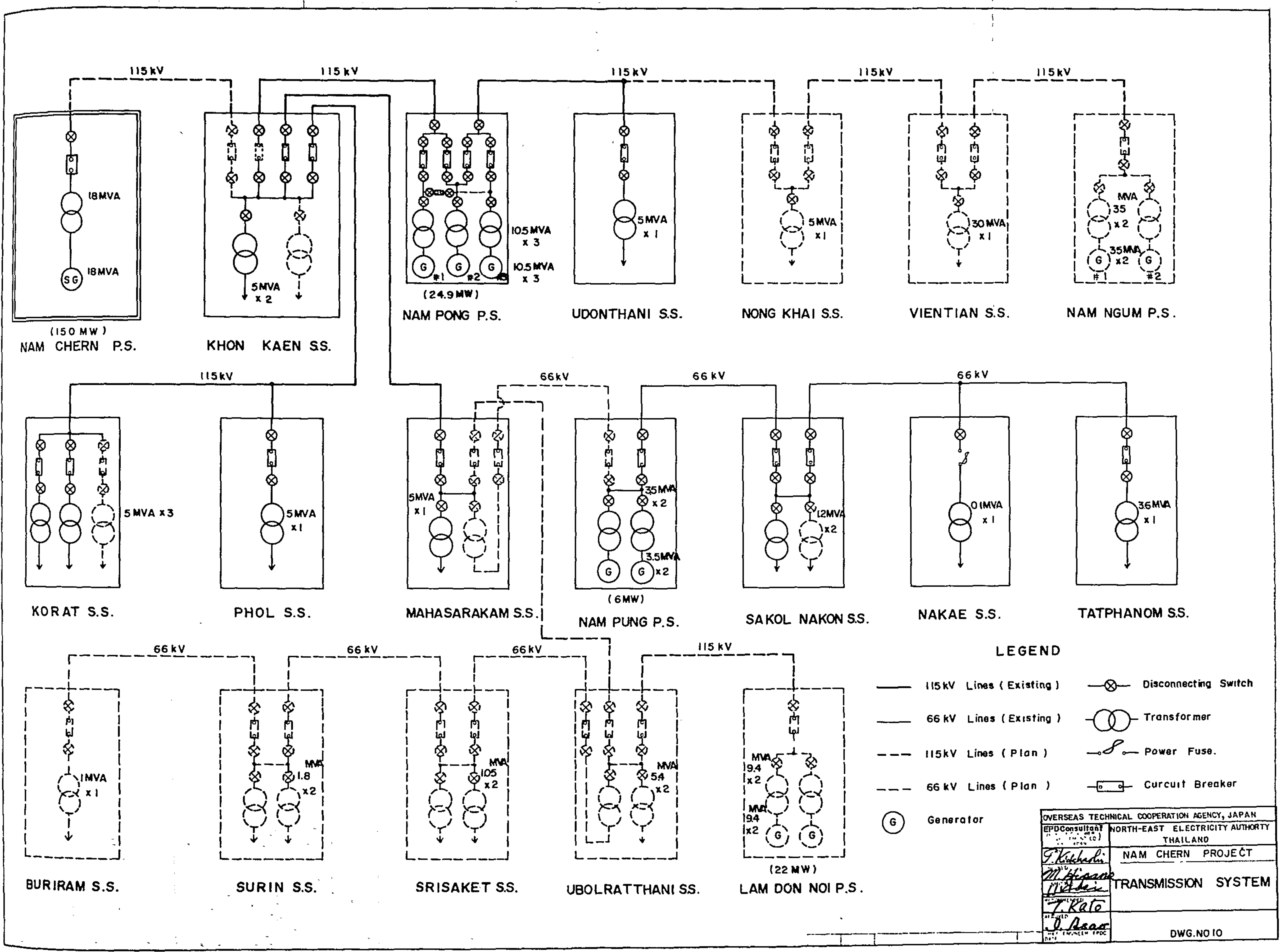

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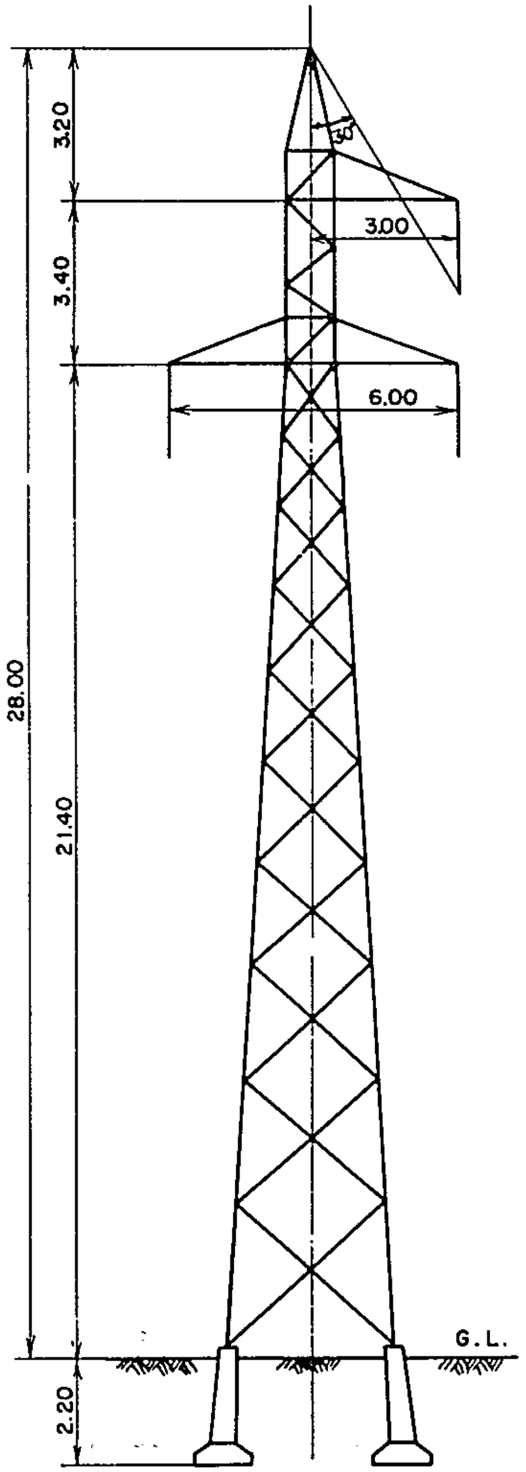
TRANSMISSION SYSTEM

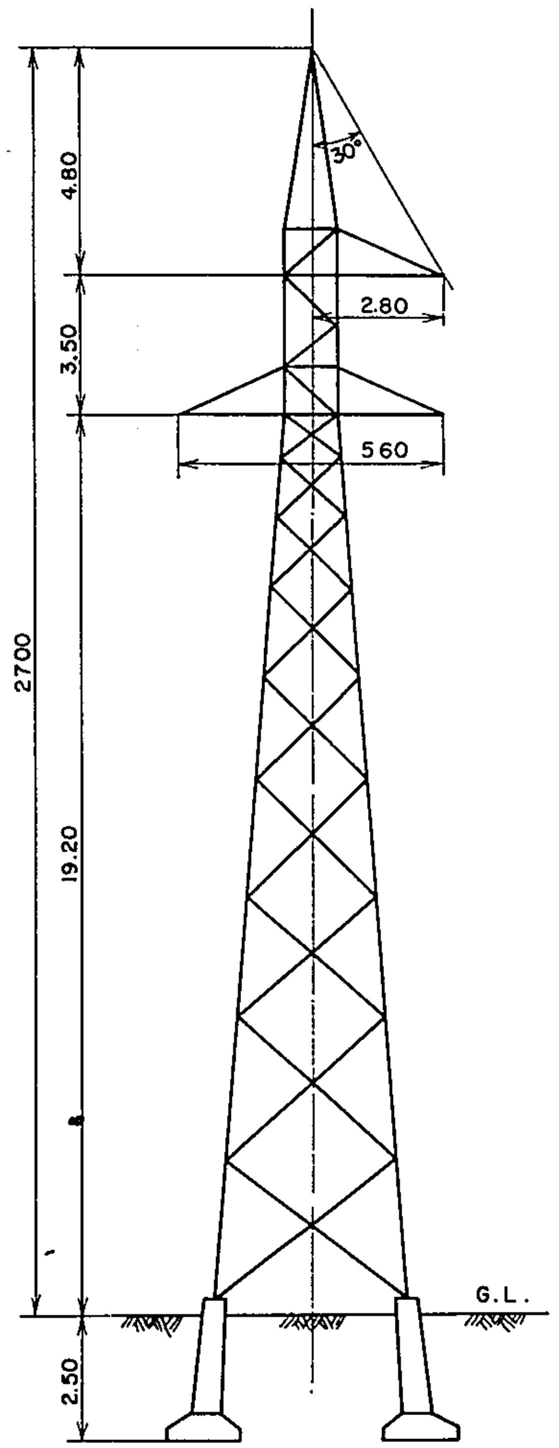
T. Kato

DWG.NO 10

SUSPENSION TOWER



TENSION TOWER



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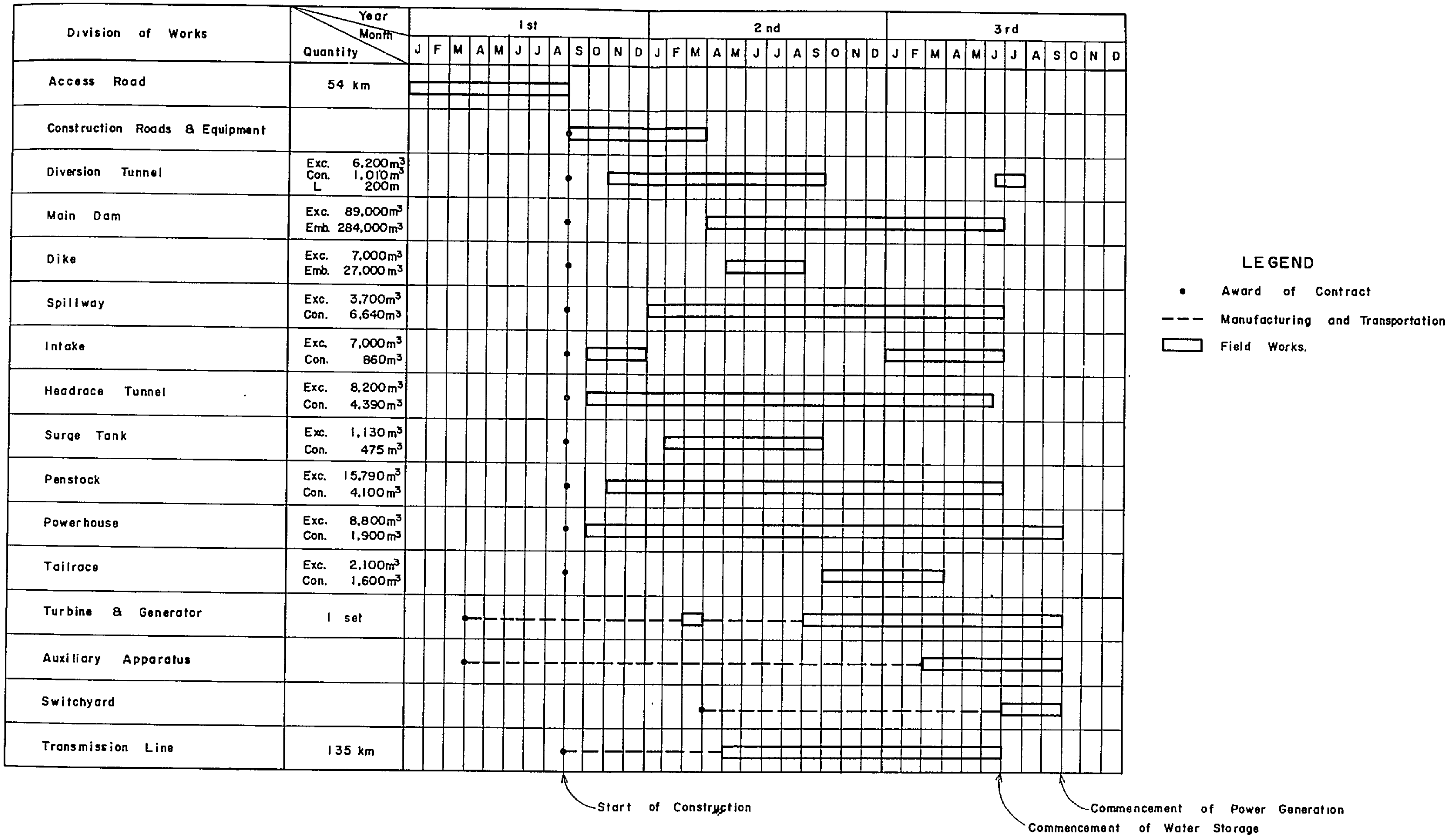
TRANSMISSION LINE
STANDARD TOWERS

DWG.NO.11



Division of Works	Quantity
Access Road	54 km
Construction Roads & Equipment	
Diversion Tunnel	Exc. 6,200m^3 Con. 1,010m^3 L 200m
Main Dam	Exc. 89,000m^3 Emb. 284,000m^3
Dike	Exc. 7,000m^3 Emb. 27,000m^3
Spillway	Exc. 3,700m^3 Con. 6,640m^3
Intake	Exc. 7,000m^3 Con. 860m^3
Headrace Tunnel	Exc. 8,200m^3 Con. 4,390m^3
Surge Tank	Exc. 1,130m^3 Con. 475 m^3
Penstock	Exc. 15,790m^3 Con. 4,100m^3
Powerhouse	Exc. 8,800m^3 Con. 1,900m^3
Tailrace	Exc. 2,100m^3 Con. 1,600m^3
Turbine & Generator	1 set
Auxiliary Apparatus	
Switchyard	
Transmission Line	135 km

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NAM CHERN PROJECT

CONSTRUCTION SCHEDULE

DWG. NO 12

REVISION | DATE | DESCRIPTION | BY

(A-3)

CHAPTER 9. COST ESTIMATES

CHAPTER 9. COST ESTIMATES

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CHAPTER 9. COST ESTIMATES

9.1 SUMMARY OF CONSTRUCTION COST

The costs of carrying out the Nam Chern Project have been estimated for the following three cases.

(A) The Nam Phrom Project will not be executed, only the Nam Chern Project will be realized. So, the cost such as access road and transmission line which is common to both project is borne only by the Nam Chern Project.

(B) The two project will be realized, and above cost is duly allocated to each project.

(C) The above-mentioned cost will be borne only by the Nam Phrom Project.

The estimated construction costs of each case are summarized in Table 9-1 and Table 9-2.

Table 9-1 Summary of Estimated Construction Cost

(Unit: Thousand of Bahts)

Case / Item	(A)	(B)	(C)
Generating Facilities	144,600	135,100	132,400
Foreign Currency	73,600	72,900	72,800
Domestic Currency	71,000	62,200	59,600
Transmission Line	36,100	15,400	7,400
Foreign Currency	23,600	9,800	4,900
Domestic Currency	12,500	5,600	2,500
Total Construction Cost	180,700	150,500	139,800
Foreign Currency	97,200	82,700	77,700
Domestic Currency	83,500	67,800	62,100

Table 9-2 Estimated Construction Cost

(Unit : Thousands of Bahts)

Item	Case A			Case B			Case C		
	Total Cost	Foreign Currency	Domestic Currency	Total Cost	Foreign Currency	Domestic Currency	Total Cost	Foreign Currency	Domestic Currency
1. Generating Facilities	128, 700	65, 100	63, 600	121, 000	65, 100	56, 000	118, 700	65, 100	53, 600
Civil Works	83, 600	31, 700	51, 900	76, 000	31, 700	44, 300	73, 600	31, 700	41, 900
Access Roads	18, 700	-	18, 700	12, 000	-	12, 000	10, 100	-	10, 100
Dam	29, 100	16, 500	12, 600	29, 100	16, 500	12, 600	29, 100	16, 500	12, 600
Waterway and Power house	24, 800	11, 000	13, 800	24, 800	11, 000	13, 800	24, 800	11, 000	13, 800
Contingencies	11, 000	4, 200	6, 800	10, 100	4, 200	5, 900	9, 600	4, 200	5, 400
Hydraulic Equipments	24, 600	17, 700	6, 900	24, 600	17, 700	6, 900	24, 600	17, 700	6, 900
Penstocks	12, 200	10, 600	1, 600	12, 200	10, 600	1, 600	12, 200	10, 600	1, 600
Gates	3, 000	2, 700	300	3, 000	2, 700	300	3, 000	2, 700	300
Installation Cost	4, 900	3, 500	1, 400	4, 900	3, 500	1, 400	4, 900	3, 500	1, 400
Contingencies	1, 100	900	200	1, 100	900	200	1, 100	900	200
Import Taxes	3, 400	-	3, 400	3, 400	-	3, 400	3, 400	-	3, 400
Electric Equipments	20, 500	15, 700	4, 800	20, 500	15, 700	4, 800	20, 500	15, 700	4, 800
Turbines	2, 700	2, 600	100	2, 700	2, 600	100	2, 700	2, 600	100
Generators	4, 000	3, 900	100	4, 000	3, 900	100	4, 000	3, 900	100
Transformers	2, 500	2, 400	100	2, 500	2, 400	100	2, 500	2, 400	100
Accessories	5, 000	4, 700	300	5, 000	4, 700	300	5, 000	4, 700	300
Installation Cost	1, 900	1, 300	600	1, 900	1, 300	600	1, 900	1, 300	600
Contingencies	900	800	100	900	800	100	900	800	100
Import Taxes	3, 500	-	3, 500	3, 500	-	3, 500	3, 500	-	3, 500
2. Transmission Line	33, 300	21, 800	11, 500	14, 000	8, 900	5, 100	6, 700	4, 400	2, 300
Transmission Line	26, 200	19, 400	6, 800	10, 800	8, 000	2, 800	4, 100	3, 800	1, 300
Substation	900	800	100	300	200	100	-	-	-
Communication System	700	600	100	500	400	100	500	400	100
Contingencies	1, 300	1, 000	300	500	300	200	300	200	100
Import Taxes	4, 200	-	4, 200	1, 900	-	1, 900	800	-	800
3. Engineering Fee	5, 800	5, 800	-	4, 800	4, 800	-	4, 600	4, 600	-
4. Administration Cost	2, 400	-	2, 400	2, 000	-	2, 000	1, 900	-	1, 900
Sub-total	170, 200	92, 700	77, 500	141, 800	78, 800	63, 000	131, 900	74, 100	57, 800
5. Interest during Construction	10, 500	4, 500	6, 000	8, 600	3, 900	4, 700	7, 900	3, 600	4, 300
Grand Total	180, 700	97, 200	83, 500	150, 500	82, 700	67, 800	139, 800	77, 700	62, 100

Table 9-3 presents the breakdown of the stimated construction costs.

The annual fund requirements based on the construction schedule is as shown in Table 9-4. In this case, it is assumed that payments will be made upon the following terms and conditions, that is, 10 percent of the amounts payable for the civil work completed during the year will be retained, and these retained moneys will be paid to the contractor when operation of the plant is begun. Payments for machinery and equipment will be made at the rate of 10 percent at the conclusion of contract, 60 percent at shipment, 20 percent upon arrival of machinery and equipment at the work site and 10 percent at start of plant.

Table 9-3 Breakdown of Estimated Construction Cost

(Unit : Thousands of Bahts)

Item	Case A			Case B			Case C			A - B	A - C
	Total Cost	Foreign Currency	Domestic Currency	Total Cost	Foreign Currency	Domestic Currency	Total Cost	Foriegn Currency	Domestic Currency	Total Cost	Total Cost
(A) Generating Facilities											
Civil Works	83,600	31,700	51,900	76,000	31,700	44,300	73,600	31,700	41,900	△ 7,600	△ 10,000
Hydraulic Equipments	24,600	17,700	6,900	24,600	17,700	6,900	24,600	17,700	6,900	-	-
Electric Equipments	20,500	15,700	4,800	20,500	15,700	4,800	20,500	15,700	4,800	-	-
Engineering Fee	4,800	4,800	-	4,300	4,300	-	4,300	4,300	-	△ 500	△ 500
Administration Cost	2,000	-	2,000	1,800	-	1,800	1,800	-	1,800	△ 200	△ 200
Sub-total	135,500	69,900	65,600	127,200	69,400	57,800	124,800	69,400	55,400	△ 8,300	△ 10,700
Interest during Construction	9,100	3,700	5,400	7,900	3,500	4,400	7,600	3,400	4,200	△ 1,200	△ 1,500
Total	144,600	73,600	71,000	135,100	72,900	62,200	132,400	72,800	59,600	△ 9,500	△ 12,200
(B) Transmission Line											
Transmission Line and Substation	33,300	21,800	11,500	14,000	8,900	5,100	6,700	4,400	2,300	△ 19,300	△ 26,600
Engineering Fee	1,000	1,000	-	500	500	-	300	300	-	△ 500	△ 700
Administration Cost	400	-	400	200	-	200	100	-	100	△ 200	△ 300
Sub-total	34,700	22,800	11,900	14,700	9,400	5,300	7,100	4,700	2,400	△ 20,000	△ 27,600
Interest during Construction	1,400	800	600	700	400	300	300	200	100	△ 700	△ 1,100
Total	36,100	23,600	12,500	15,400	9,800	5,600	7,400	4,900	2,500	△ 20,700	△ 28,700
(C) Sum of Generating Facilities and Transmission Line											
Civil Works	83,600	31,700	51,900	76,000	31,700	44,300	73,600	31,700	41,900	△ 7,600	△ 10,000
Hydraulic Equipments	24,600	17,700	6,900	24,600	17,700	6,900	24,600	17,700	6,900	-	-
Electric Equipments	20,500	15,700	4,800	20,500	15,700	4,800	20,500	15,700	4,800	-	-
Transmission Line and Substation	33,300	21,800	11,500	14,000	8,900	5,100	6,700	4,400	2,300	△ 19,300	△ 26,600
Engineering Fee	5,800	5,800	-	4,800	4,800	-	4,600	4,600	-	△ 1,000	△ 1,200
Administration Cost	2,400	-	2,400	2,000	-	2,000	1,900	-	1,900	△ 400	△ 500
Sub-total	170,200	92,700	77,500	141,900	78,800	63,100	131,900	74,100	57,800	△ 28,300	△ 38,300
Interest during Construction	10,800	4,500	6,000	8,600	3,900	4,700	7,900	3,600	4,300	△ 1,900	△ 2,600
Total	180,700	97,200	83,500	150,500	82,700	67,800	139,800	77,700	62,100	△ 30,200	△ 40,900

9.2 BASIC ASSUMPTIONS

The construction costs are estimated on the basis of prices in March, 1967, taking into account the natural and local conditions of the project site, construction scale and technical level to be expected at the present time. The basic assumptions in estimating the construction cost are as follows :

(1) Scope of cost estimates

The cost estimates include the Nam Chern Power Plant, transmission lines between said power plant and the Khonkaen Substation and the installation of switching equipment in said substation to accommodate the line. The estimates also include a communication system between the Nam Chern Power Plant and Khonkaen Substation and access roads from Ban Non Han to the project site. In case (B) and case (C), however, the aforementioned conditions will be taken into consideration.

(2) Cost of civil works

a) The amount of works has been estimated according to the preliminary design drawings attached to this report and, where required, according to more detailed design drawings.

b) In respect of primary costs, the costs of materials and laborers to be procured in Thailand are estimated on the basis of prices in March, 1967 and the costs of materials and construction equipment to be imported are computed on the basis of the CIF quotations prevailing in March, 1967.

c) The unit price of construction work is estimated from the records in Thailand and data obtained from experience in the same type of work in Japan with the local conditions taken into account. The unit prices of major items of work, such as excavation of dam foundation, embankment of dam, excavation of tunnel, production of concrete aggregates and concrete work, are calculated by the daily quantity method. The type of construction equipment used and the necessary operation hours are first calculated according to the construction schedule and the amount of work required, and then the costs of labour, materials and machinery are computed on the results obtained to determine the direct construction costs. The unit price of construction work is then found by adding the costs of temporary facilities and contractor's administration expense required for the operation of various machinery and equipment to the direct construction costs.

d) Custom duties on the imported materials and construction equipments are all included in the unit price of construction work.

e) Included in the costs of civil work are 15 percent for contingencies.

(3) Cost of equipment

a) Equipment such as gates and penstock, and electric, transmission, substation and communication equipments, etc. are all assumed to be manufactured in and exported from Japan.

b) Cost of equipment is estimated on the basis of FOB prices in Japan plus ocean freight, insurance costs, custom duties, landing costs, and cost of inland transport in Thailand and installation at the work site.

c) Contingencies are included in an amount equivalent to 5 per cent of the cost of all equipment.

(4) Engineering fee

The engineering fee includes the cost of detailed design and supervision of construction work.

(5) Administration cost

Administration cost includes work site allowances for NEEA personnel working at the site, and necessary office expenses, housing, vehicles and other facilities required by NEEA and consulting engineers.

(6) Cost of land

Since the project site is located on state-owned land, cost for acquisition of land will not be required. Only part of the transmission line traverses private areas, but the amount of compensation is estimated to be small, and they are therefore not presented under a separate item of cost of land, assuming that they will be covered by the contingencies.

(7) Interest during construction

Interest during construction is estimated on the basis of the annual fund requirements listed in Table 9-4. The rate of interest on foreign funds is assumed at 4.5 percent per annum, and the domestic currency funds is assumed to bear an interest of 6 percent per annum.

(8) Classification of domestic and foreign currency funds

The construction costs are estimated by breaking them down into domestic and foreign currency requirements. The domestic currency includes the wages of local workers, living expenses at site for foreign workers and engineers, costs of materials procured in Thailand, custom duties charged on imported materials and construction equipments, and freight cost thereof in Thailand. All other costs are included in foreign currency requirements. The exchange rate is on the official basis of 1 U.S. dollar = 20.8 Bahts = 360 Yen.

Table 9-4 Fund Requirement in Each Year

	Case A							
	Total		1st Year		2nd Year		3rd Year	
	Foreign Currency	Domestic Currency	Foreign Currency	Domestic Currency	Foreign Currency	Domestic Currency	Foreign Currency	Domestic Currency
(A) Generating Facilities								
Civil Works	31,700	51,900	4,800	23,700	15,600	16,600	11,300	11,600
Hydraulic Equipments	17,700	6,900	3,500	-	7,000	2,800	7,200	4,100
Electric Equipments	15,700	4,800	3,200	-	6,300	1,800	6,200	3,000
Engineering Fee	4,800	-	3,800	-	500	-	500	-
Administration Cost	-	2,000	-	1,200	-	400	-	400
Sub-total	69,900	65,600	15,300	24,900	29,400	21,600	25,200	19,100
Interest during Construction	3,700	5,400	400	700	1,300	2,100	2,000	2,600
Total	73,600	71,000	15,700	25,600	30,700	23,700	27,200	21,700
Cumulative Total	-	-	15,700	25,600	46,400	49,300	73,600	71,000
(B) Transmission Line								
Transmission Line and Substation	21,800	11,500	-	-	11,000	5,800	10,800	5,700
Engineering Fee	1,000	-	-	-	800	-	200	-
Administration Cost	-	400	-	-	-	200	-	200
Sub-total	22,800	11,900	-	-	11,800	6,000	11,000	5,900
Interest during Construction	800	600	-	-	200	200	600	400
Total	23,600	12,500	-	-	12,000	6,200	11,600	6,300
Cumulative Total	-	-	-	-	12,000	6,200	23,600	12,500
(C) Sum of Generating Facilities and Transmission Line								
Total	97,200	83,500	157,000	25,600	42,700	29,900	38,800	28,000
Cumulative Total	-	-	15,700	25,600	58,400	55,500	97,200	83,500

Case B								Case C							
Total		1st Year		2nd Year		3rd Year		Total		1st Year		2nd Year		3rd Year	
Foreign Currency	Domestic Currency	Foreign Currency	Domestic Currency	Foreign Currency	Domestic Currency	Foreign Currency	Domestic Currency	Foreign Currency	Domestic Currency	Foreign Currency	Domestic Currency	Foreign Currency	Domestic Currency	Foreign Currency	Domestic Currency
31,700	44,300	4,800	16,800	15,600	16,100	11,300	11,400	31,700	41,900	4,800	14,900	15,600	15,800	11,300	11,200
17,700	6,900	3,500	-	7,000	2,800	7,200	4,100	17,700	6,900	3,500	-	7,000	2,800	7,200	4,100
15,700	4,800	3,200	-	6,300	1,800	6,200	3,000	15,700	4,800	3,200	-	6,300	1,800	6,200	3,000
4,350	-	3,500	-	400	-	400	-	4,300	-	3,500	-	400	-	400	-
-	1,800	-	1,400	-	200	-	200	-	1,800	-	1,400	-	200	-	200
69,400	57,800	15,000	18,200	29,300	20,900	25,100	18,700	69,400	55,400	15,000	16,300	29,300	20,600	25,100	18,500
3,500	4,400	300	500	1,300	1,600	1,900	2,300	3,400	4,200	300	500	1,300	1,600	1,800	2,100
72,900	62,200	15,300	18,700	30,600	22,500	27,000	21,000	72,800	59,600	15,300	16,800	30,600	22,200	26,900	20,600
-	-	15,300	18,700	45,900	41,200	72,900	62,200	-	-	15,300	16,800	45,900	39,000	72,800	59,600
9,000	5,100	-	-	4,500	2,600	4,500	2,500	4,400	2,300	-	-	2,200	1,200	2,200	1,100
500	-	-	-	500	-	-	-	300	-	-	-	200	-	100	-
-	200	-	-	-	100	-	100	-	100	-	-	-	-	-	100
9,500	5,300	-	-	5,000	2,700	4,500	2,600	4,700	2,400	-	-	2,400	1,200	2,300	1,200
300	300	-	-	100	100	200	200	200	100	-	-	100	-	100	100
9,800	5,600	-	-	5,100	2,800	4,700	2,800	4,900	2,500	-	-	2,500	1,200	2,400	1,300
-	-	-	-	5,100	2,800	9,800	5,600	-	-	-	-	2,500	1,200	4,900	2,500
82,700	67,800	15,300	18,700	35,700	25,300	31,700	23,800	77,700	62,100	15,300	16,800	33,100	23,400	29,300	21,900
-	-	15,300	18,700	51,000	44,000	82,700	67,800	-	-	15,300	16,800	48,400	40,200	77,700	62,100

CHAPTER 10. ECONOMIC JUSTIFICATION

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CHAPTER 10. ECONOMIC JUSTIFICATION

10.1 SALABLE ENERGY

The annual firm energy of the Nam Chern Project is 40, 160, 000 KWH at the sending end as described in CHPATER 7. All this firm energy will be consumed immediately after the operation of the Nam Chern Power Plant (see Fig 7-5 and Fig. 7-6). Assuming the KWH loss rate in transmission line between the Power Plant and Khonkaen Substation to be a value of 3. 1%, the salable energy at the Khonkaen Substation will be 38, 920, 000 KWH.

10.2 ANNUAL COST AND ENERGY COST

10.2.1 Annual Cost

The estimated construction costs of the Nam Chern Project according to kinds of facilities and the serviceable life of each are shown in Table 10-1.

Table 10-1 Construction Cost and Serviciable Years of Facilities

(Unit Million of Bahts)

Item	Serviceable Years	Case A			Case B			Case C		
		Total Cost	Foreign Currency	Domestic Currency	Total Cost	Foreign Currency	Domestic Currency	Total Cost	Foreign Currency	Domestic Currency
1 Generating Facilities										
Civil Works	50	83 6	31.7	51.9	76.0	31.7	44 3	73 6	31.6	41.9
Hydraulic Equipments	50	24.6	17.7	6.9	24.6	17.2	6 9	24.6	17.7	6 9
Electric Equipments	30	20.5	15.7	4 8	20 5	15 7	4.8	20.5	15 7	4 8
Engineering Fee		4 8	4.8	-	4 3	4.3	-	4.3	4.3	-
Administration Cost		2 0	-	2 0	1 8	-	1.8	1.8	-	1.8
Interest during Construction		9.1	3 7	5 4	7 9	3.5	4 4	7.6	3.4	4.2
Total		144.6	73 6	71.0	135.1	72.9	62 2	132.4	72.8	59.6
2 Transmission Line										
Transmission Line	50	33.3	21.8	11.5	14.0	8.9	5 1	6 7	4 4	2 3
Engineering Fee		1.0	1.0	-	0.5	0.5	-	0.3	0.3	-
Administration Cost		0 4	-	0.4	0.2	-	0.2	0.1	-	0.1
Interest during Construction		1.4	0.8	0 6	0 7	0.4	0.3	0.3	0.2	0.1
Total		36.1	23.6	12 5	15.4	9.8	5 6	7.4	4.9	2.5
3. Total Construction Cost		180.7	97 2	83.5	150.5	82 7	67 8	139.8	77 7	62 1

Table 10-2 gives the uniformly distributed annual costs over the 50 years serviceable life of facilities of the project, applying the interest rates stated in CHAPTER 9, i. e. 4.5% to the foreign currency requirement and 6.0% to the domestic currency.

In Thailand, the authorities such as NEEA are exempted from taxation. However, contribution is to be made to the government equal to the business tax on the net income after interests and other expenses have been deducted. Since the electric power industry is state-operated in Thailand, it should be the prime purpose for NEEA to supply electricity at the lowest rate rather than securing a net income by selling electricity at a high rate. Therefore, in this estimation of annual cost, the contribution was estimated at nill on the condition that NEEA does not obtain a net income.

10.2.2 Energy Cost

By dividing the annual cost determined in 10.2.1 by the salable energy determined in 10.1, the energy cost per KWH delivered at the Khonkaen Substation of the Nam Chern Power Plant is found as follows:

(A)	(B)	(C)
0.324 Bahts	0.270 Bahts	0.250 Bahts

Table 10-2 Annual Cost

	(1) Investment Cost			(2) Annual Cost			Remarks
	Case 1	Case 2	Case 3	Case 1	Case 2	Case 3	
1. Maintenance and Operation Salaries and Wages	-	-	-	700	700	700	
Maintenance of Generating Facilities	144,600	135,100	132,400	720	680	660	(1)x0.005 = (2)
Maintenance of Transmission Line	36,100	15,400	7,400	540	230	110	(1)x0.015 = (2)
Subtotal				1,960	1,610	1,470	
2. Replacement of Electric Equipments	22,900	22,800	22,700	250	250	250	(1)x0.1741x0.06344 = (2)
3. Amortization of Initial Investment							
Foreign Currency	97,200	82,700	77,700	4,920	4,180	3,930	(1)x0.05060 = (2)
Domestic Currency	83,500	67,800	62,100	5,300	4,300	3,940	(1)x0.06344 = (2)
Subtotal				10,220	8,480	7,870	
4. Administration Expense	180,700	150,500	139,800	180	150	140	(1)x0.001 = (2)
5. Tax and Others				0	0	0	
6. Total Annual Cost				12,610	10,490	9,730	

B/C 0.809 0.972 1.049

10.3 ANNUAL BENEFIT

10.3.1 Basis of Economic Justification

The economic justification of the Nam Chern Project was made on the same basis as the one in the study of the Nam Phrom Project. A 250 MW oilfired steam power plant of two units of 125 MW, proposed to be constructed near Bangkok, was selected as a standard steam power plant for economic justification. Details are refered to the Feasibility Report of the Nam Phrom Project.

10.3.2 Construction Cost and Annual Cost of the Standard Steam Power Plant

The construction cost of the standard steam power plant, or a steam power plant burning heavy oil only and having two units of 125 MW each, is estimated as shown in Table 10-3.

Table 10-3 Construction Cost of Oil Fired Steam Power Plant

(125 MW x 2 Units)

(Unit : Thousand of Bahts)

Land	-	1,100	1,100
Buildings	39,990	31,940	71,930
Plants and equipments	27,010	18,460	45,470
Boiler	241,270	57,860	299,130
Turbine generator	249,190	61,270	310,460
Miscellaneous equipments	15,760	10,510	26,270
Subtotal	591,410	185,620	777,030
Interest during construction	38,440	12,070	50,510
Over head cost	26,240	8,240	34,480
Total	656,090	205,930	862,020

Table 10-4 Estimated Cost of Oil Fired Steam Power Plant

Installed capacity	(MW)	250
Unit capacity x No. of unit	(MWxUnit)	125 x 2
Annual plant factor	(%)	60
Thermal efficiency at sending end	(%)	32.7
Annual energy supply	(10^3 MWH)	1,310
Fuel consumption	(10^6 ℓ)	348.6
Construction cost	(10^3 Bahts)	862,020

Item	Fixed Cost	Variable Cost	Notes
Interest and depreciation (10^3 Bahts)	62,630		Capital recovering factor: 0.07265 (Interest: 6%, Service life: 30 years)
Operation and maintenance cost (10^3 Bahts)	18,202	3,448	
Salaries and wages (10^3 Bahts)	2,688		96 persons x 28,000 Bahts/person
Repairing expense (10^3 Bahts)	13,790	3,448	Construction cost x 0.02 (Fixed cost 0.8, Vairable cost 0.2)
Miscellaneous expense (10^3 Bahts)	1,724		Construction cost x 0.002
Administration cost (10^3 Bahts)	1,165	291	Oper. & maint. costs x 0.08 (Fixed cost 0.8, Variable cost 0.2)
Tax and others (10^3 Bahts)	0		
Fuel cost (10^3 Bahts)		158,549	0.455 Bahts /ℓ
Total (10^3 Bahts)	81,997	162,288	
Annual cost at sending end			
Cost per KW (10^3 Bahts)	328		
Cost per KWH (10^3 Bahts)		0.124	Fuel cost per KWH: 0.121 Bahts

The annual cost of the standard steam power plant is broken down into fixed cost and variable cost, as shown in Table 10-4. The fixed cost is estimated at 328 Bahts per KW and the variable cost at 0.124 Bahts per KWH. In this calculation, tax and contribution were considered to be nil on the same basis as stated in Paragraph 10.2.1.

Table 10-4

10.3.3 Unit Value of Benefit

The annual benefit of a hydro plant is calculated on the basis of the benefit per KW and per KWH.

The KW adjustment factor is applied as in the case of the Feasibility Report of the 3rd Nam Phrom Project. Reference should be made to 11.3.4. of the said report.

Thus the benefit per KW and the benefit per KWH are calculated as follows :

Benefit per KW	361 Bahts
Benefit per KWH for firm energy	0.124 Baht

10.3.4 Annual Benefit of the Nam Chern Project

The annual benefit of the Nam Chern Project was calculated by using the benefit per KW and per KWH stated in the preceding paragraph.

As the standard steam power plant is adopted for the purpose of the economic justification, the output and energy production of the Nam Chern Power Plant are assumed to be wholly consumed. The transmission loss between the Nam Chern Power Plant and the Kohnkaen Substation is considered to offset the transmission loss incurred between the standard steam power plant and the Khorat Substation, and as such, it is not counted.

The annual benefit of the Nam Chern Power Plant thus determined is as shown in Table 10-5, which gives the value at 10,200,000 Bahts.

Some other points may be considered as the benefits of the Nam Chern Project, such as savings of imported fuel for steam or diesel power generation, the favorable effect on agriculture in the downstream area and the economic development of the region. If these benefits should be taken into consideration, the value of above-mentioned benefit would be increased.

Table 10-5 Annual Benefit

Item	Unit	Annual Benefit
Dependable Capability	10^3 KW	15.0
Firm Energy	10^6 KWH	40.16
Value per KW	Baht	361
Value per KWH for firm energy	"	
Benefit of KW	10^3 Bahts	5.220
Benefit of KWH of firm energy	16^3 Bahts	4.980
Total Annual Benefit	10^3 Bahts	10.200

10.4 BENEFIT-COST RATIO

The annual costs of the Nam Chern Power Plant are 12,610,000 Bahts, 10,490,000 Bahts and 9,730,000 Bahts for case (A), case (B) and case (C) respectively, as shown in Table 10-2. The annual benefit is 10,200,000 Bahts as given in Table 10-5. Therefore, the benefit-cost ratio are as follows :

(A)	(B)	(C)
0.81	0.97	1.05

CHAPTER 11. FINANCIAL PROGRAM

CHAPTER 11. FINANCIAL PROGRAM

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CHAPTER 11. FINANCIAL PROGRAM

11.1 FUND REQUIREMENTS

The total estimated construction cost of this project is 150, 500, 000 Bahts in case (B), as stated in Chapter 9, of which 82, 700, 000 Bahts are to be financed with foreign currency and 67, 800,-000 Bahts with domestic currency. The funds requirements in each year are as follows.

(UNIT: Thousand Bahts)

Year	Foreign currency	Domestic currency	Total
1st	(300) 15,300	(500) 18,700	(800) 34,000
2nd	(1,300) 35,700	(1,600) 25,300	(2,900) 61,000
3rd	(1,900) 31,700	(2,300) 23,800	(4,200) 55,500
Total	(3,500) 82,700	(4,400) 67,800	(7,900) 150,500

Note: Figure in parentheses are interest during construction and are included in the figure for respective years

11.2 FINANCE OF FUNDS

11.2.1 Source of Funds

It is desirable for this kind of project to be financed with long-term loans at low interest rate. As the financial program of this project was made on the same basis as the one in the study of the Nam Phrom Project, it is assumed that the funds required in foreign currency will be financed with loan from international financing institute or foreign government and the funds required in domestic currency will be made available by the Government of Thailand through budgetary appropriations.

11.2.2 Interest and Amortization

From such consideration, the following conditions which are the same as the Nam Phrom Project are applied to the foreign and domestic currency requirements.

(1)	Foreign currency	
	Interest	4.5% per annum
	Amortization	in 20 years after start of operation, in equal instalments of principal plus interest
(2)	Domestic currency	
	Interest	6% per annum
	Amortizatation	in 50 years after start of operation, in equal instalments of principal plus interest

11.3 Repayment Capability

11.3.1 Revenues from Sale of Electricity

(1) Cost per unit delivered at substation

Electricity produced by the project is to be delivered at Khonkaen Substation. Therefore, a selling price at Khonkaen Substation must be established. For the first 20 years of operation, an energy rate which would produce revenues sufficient to defray operation and maintenance expenses administration expenses and capital cost (interest charges) and to amortize borrowings is estimated at 0.32 Bahts per KWH. On the other hand, the energy rate of Nam Pong System presently operated by NEEA is 0.35 Bahts per KWH after voltage step down at substation, and that of the Nam Pung System is 0.40 Bahts per KWH. Therefore, 0.32 Bahts is believed reasonable to study on the project financing.

However, in the 20 years after start of operation, the foreign currency borrowing will be complety amortized and thereafter there will be created a sizeable net revenue. Therefore, at that stage it will be possible to reduce the wholesale rate of the Nam Chern Project to 0.17 Bahts per KWH.

(2) Energy available at Khonkaen Substation

The Energy available at the Khonkaen Substation calculated with a transmission KWH loss of 3.1% is stated in the preceding chapter.

(3) Revenues

The estimated revenues from power delivered to the Khonkaen Substation are shown in Table 11-1.

Case B

Table 11-1 Statements of Income

(Unit: Thousand of Bahts)

Year	1	2	3	4	5	6	7	8	9	10	11	12	13
(A) Revenue													
Salable Energy (10^3 KWH)	38,920	38,920	38,920	38,920	38,920	38,920	38,920	38,920	38,920	38,920	38,920	38,920	38,920
Unit Sales Price (10^3 KWH)	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
Revenue from Sales	12,454	12,454	12,454	12,454	12,454	12,454	12,454	12,454	12,454	12,454	12,454	12,454	12,454
(B) Cost of Operations													
(1) Maintenance and Operation Expenses Generating Plant	675	675	765	675	675	675	675	675	675	675	675	675	675
Transmission Line	231	231	231	231	231	231	231	231	231	231	231	231	231
Salaries & Wages	700	700	700	700	700	700	700	700	700	700	700	700	700
(2) Depreciation	2,978	2,978	2,978	2,978	2,978	2,978	2,978	2,978	2,978	2,978	2,978	2,978	2,978
(3) Administration Cost	151	151	151	151	151	151	151	151	151	151	151	151	151
Total	4,735	4,735	4,735	4,735	4,735	4,735	4,735	4,735	4,735	4,735	4,735	4,735	4,735
(C) Operating Income	7,719	7,719	7,719	7,719	7,719	7,719	7,719	7,719	7,719	7,719	7,719	7,719	7,719
(D) Financial Expenses (Interest)													
(1) Foreign loans	3,722	3,603	3,479	3,349	3,214	3,072	2,925	2,770	2,609	2,440	2,264	2,079	1,887
(2) Domestic loans	4,069	4,054	4,039	4,023	4,007	3,989	3,970	3,950	3,929	3,907	3,883	3,853	3,831
(E) Net Income (C - D)	- 72	62	201	347	498	658	824	999	1,181	1,372	1,572	1,787	2,001

Case B

Table 11-2 Statements of Cash Flow

(Unit: Thousand Bahts)

Year				1	2	3	4	5	6	7	8	9	10
(A) Cash Receipts													
(1) Net Income				- 72	62	201	347	498	658	824	999	1,181	1,372
(2) Depreciation				2,978	2,978	2,978	2,978	2,978	2,978	2,978	2,978	2,978	2,978
(3) Borrowing													
Foreign loans	15,300	35,700	31,700										
Domestic loans	18,700	25,300	23,800										
Total				2,906	3,040	3,179	3,325	3,476	3,636	3,802	3,977	4,159	4,350
(B) Cash Disbursements													
(1) Construction Expenditure	34,000	61,000	55,500										
(2) Repayment of Borrowing													
Foreign loans				2,636	2,755	2,879	3,009	3,144	3,286	3,433	3,588	3,749	3,918
Domestic loans				233	248	263	279	295	313	332	352	373	395
Total				2,869	3,003	3,142	3,288	3,439	3,599	3,765	3,940	4,122	4,313
(C) Cash Balance				37	37	37	37	37	37	37	37	37	37

11.3.2 Operation and Maintenance Expenses

The rates of operation and maintenance expenses of power generating plant and transmission lines as against the capital expenditure were assumed as follows.

Generating Plant	0.5%
Transmission line	1.5%

The number of operating staff required for the Nam Chern Power Station was estimated and the prevailing salary and wayges in Thailand were used as the basis of estimating the salary and wages.

11.3.3 Depreciation

The undermentioned servisable years were applied to compute depreciation by straight line method leaving a 10% residual value at the end of the serviceable life.

Civil works	50 years
Hydraulic equipment	50 years
Electric equipment	30 years
Transmission line	50 years

11.3.4 Administration Expenses

The administration expenses of the NEEA Headquarters chargeable to the Narm Chern Project is determined at 0.1% of the capital investment of the plants.

11.3.5 Net Income

The revenues from the project upon its completion are estimated for each year on the foregoing conditions. From the revenues are subtracted operation and maintenance expenses, depreciation, administration expenses and interest charges on foreign and domestic borrowings to arrive at the net income accruing from the Nam Chern Power Plant. This computation is given in Table 11-1.

It will be noted from the table that the Nam Chern Power Plant will produce sufficient net income from the year of start of operation, since its total energy output will be consumed immediately upon commencement of services.

11.4 AMORITIZATION SHCEDULE

The source of funds to be appropriated to the redemption of borrowed funds is the net income plus depreciation accruals. The amorization schedule of foreign loans and domestic loans calculated on the basis of the terms and conditions mentioned in 11.2.2 is shown in Table 11-3 and 11-4. The cash balance worked out from this fund requirement for debt service is shown in Table 11-2. The table reveals that the Nam Chern Power Plant will produce net revenues sufficient for payments to amortize both foreign currency and domestic currency borrowing, in accordance with the assumed terms and conditions.

The Nam Chern Project is economically and financially sound.

Case B

Table 11-3 Amortization Schedule - Foreign Currency

(Unit: Thousand of Bahts)

Year	Borrowing			Redemption			Outstand-ing Balance	Remarks
	Generating Plant	Trans-mission Line	Total	Princi-pal	Inter-est	Total		
1	72,900	9,800	82,700				82,700	Interest rate: 4.5 % p.a.
2				2,636	3,722	6,358	80,064	Redeemable in equal annual
3				2,755	3,603	6,358	77,309	Instalments in 20 years
4				2,879	3,479	6,358	74,430	
5				3,009	3,349	6,358	71,421	Amortization rate: 0.07687614
6				3,144	3,214	6,358	68,277	
7				3,286	3,072	6,358	64,991	
8				3,433	2,925	6,358	61,558	
9				3,588	2,770	6,358	57,970	
10				3,749	2,609	6,358	54,221	
11				3,918	2,440	6,358	50,303	
12				4,094	2,264	6,358	46,209	
13				4,279	2,079	6,358	41,930	
14				4,471	1,887	6,358	37,459	
15				4,672	1,686	6,358	32,787	
16				4,883	1,475	6,358	27,904	
17				5,102	1,256	6,358	22,802	
18				5,332	1,026	6,358	17,470	
19				5,572	786	6,358	11,898	
20				5,823	535	6,358	6,075	
21				5,802	273	6,075	0	

Case B

Table 11-4 Amortization Schedule - Domestic Currency

(Unit: Thousand of Bahts)

Year	Borrowing			Redemption			Outstand-ing Balance	Remarks
	Generating Plant	Trans-mission Line	Total	Princi-pal	Inter-est	Total		
1	72,900	9,800	82,700				67,800	Interest rate: 6.0 % p.a.
2				233	4,069	4,802	67,567	redeemable in equal annual
3				248	4,054	4,302	67,319	instalment in 50 years
4				263	4,039	4,302	67,056	
5				279	4,023	4,302	66,777	
6				295	4,007	4,302	66,482	Amortization rate: 0.0634429
7				313	3,989	4,302	66,169	
8				332	3,970	4,302	65,837	
9				352	3,950	4,302	65,485	
10				373	3,929	4,302	65,112	
11				395	3,907	4,802	64,717	
12				419	3,883	4,302	64,298	
13				444	3,858	4,302	63,854	
14				471	3,831	4,302	63,383	
15				499	3,803	4,302	62,884	
16				529	3,773	4,302	62,355	
17				561	3,741	4,302	61,794	
18				594	3,708	4,302	61,200	
19				630	3,672	4,302	60,570	
20				668	3,634	4,302	59,902	
21				708	3,594	4,302	59,194	

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Table A5-1 (1) Runoff STATION Ban Song Kon C.A. = 550 sq.km Nam, Phrom Thailand

Chern RIVER, IN THE BASIN OF Chern ELEVATION UNIT c.m.s. YEAR 1962

DATE	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	DATE
1										139	1.92	0.74	1
2										52.9	2.08	0.68	2
3										29.5	3.84	0.68	3
4										17.8	23.4	0.68	4
5										52.0	20.1	0.62	5
6										55.7	27.2	0.62	6
7										46.6	35.4	0.62	7
8										60.7	2.24	0.62	8
9										57.5	2.08	0.62	9
10										25.3	1.76	0.62	10
11										29.9	1.60	0.56	11
12										17.2	1.44	0.56	12
13										12.2	1.44	0.56	13
14										10.7	1.28	0.56	14
15										14.0	1.28	0.56	15
16										18.6	1.28	0.56	16
17									262	8.24	1.12	0.56	17
18									43.1	6.86	1.12	0.56	18
19									30.3	5.74	1.12	0.56	19
20									22.1	5.30	0.96	0.56	20
21									19.5	4.64	0.96	0.56	21
22									18.9	3.02	0.96	0.56	22
23									10.5	3.48	0.80	0.56	23
24									10.2	3.12	0.80	0.50	24
25									9.70	2.76	0.74	0.50	25
26									16.0	2.58	0.74	0.50	26
27									9.20	2.40	0.74	0.50	27
28									81.4	2.24	0.74	0.50	28
29									56.1	2.08	0.74	0.50	29
30									525	2.08	0.74	0.50	30
31										1.92		0.50	31
TOTAL										696.06	140.62	17.78	

Annual Total ( )

Table A5-1 (2) Runoff STATION Ban Song Kon C.A. = 550 sq.km Nam Phrom, Thailand

Chern RIVER, IN THE BASIN OF Chern ELEVATION UNIT c.m.s. YEAR 1963

DATE	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	DATE
1	0.25	0.20	0.20	0.35	2.32	4.24	1.28	1.55	5.00	17.3	2.79	1.55	1
2	0.25	0.20	0.20	0.35	0.65	3.67	1.37	1.28	9.58	19.9	4.05	1.46	2
3	0.25	0.20	0.20	0.30	0.55	2.48	1.46	7.00	5.60	252	2.94	1.37	3
4	0.25	0.20	0.20	0.30	0.60	0.45	0.65	47.1	3.10	115	4.05	1.37	4
5	0.25	0.20	0.20	0.25	0.55	0.50	0.55	10.1	13.3	28.8	12.7	1.28	5
6	0.25	0.20	0.20	0.20	0.40	19.1	1.46	5.40	21.0	20.6	82.8	1.19	6
7	0.25	0.20	0.20	0.20	0.35	23.5	2.64	6.00	8.84	152	12.1	1.46	7
8	0.25	0.20	0.20	0.15	0.25	17.5	1.37	3.67	17.6	46.5	8.15	1.46	8
9	0.20	0.20	0.20	0.15	0.25	2.94	0.92	2.79	5.80	24.8	43.9	1.46	9
10	0.20	0.20	0.20	0.14	0.20	1.10	0.74	2.32	4.24	16.9	10.7	1.19	10
11	0.20	0.20	0.20	0.14	0.15	1.10	0.65	1.55	29.8	12.4	6.60	1.01	11
12	0.20	0.20	0.20	0.14	0.15	0.83	0.60	1.28	12.4	10.4	5.60	1.01	12
13	0.20	0.30	0.20	0.12	0.14	4.05	0.50	1.28	7.69	8.15	4.62	0.92	13
14	0.20	0.30	0.20	0.10	0.12	2.32	0.50	1.46	5.00	6.40	6.00	0.92	14
15	0.20	0.25	0.92	0.10	0.10	1.10	0.45	2.94	3.67	6.00	5.60	0.83	15
16	0.20	0.25	0.83	0.10	0.09	0.74	0.40	1.70	2.64	5.40	5.40	0.92	16
17	0.20	0.20	0.74	0.09	0.09	0.65	0.55	0.10	2.02	4.81	4.43	0.83	17
18	0.20	0.20	0.55	0.08	0.10	0.55	0.45	0.06	1.86	4.43	3.86	0.83	18
19	0.20	0.20	0.50	0.08	0.14	0.55	0.35	0.04	1.86	4.05	3.10	0.74	19
20	0.20	0.20	0.40	0.10	0.50	0.45	0.30	19.1	16.9	3.48	3.10	0.74	20
21	0.20	0.20	0.40	0.14	3.86	0.45	0.25	7.46	5.00	3.29	2.79	0.74	21
22	0.20	0.20	0.35	0.14	1.55	0.45	0.35	8.15	2.64	2.94	2.32	0.74	22
23	0.20	0.20	0.40	0.10	3.29	3.86	0.35	5.20	3.10	2.64	2.17	0.65	23
24	0.20	0.20	0.40	0.10	1.28	1.37	0.15	17.3	138	2.48	2.02	0.65	24
25	0.20	0.20	0.35	0.10	0.92	4.24	0.45	21.8	41.8	2.32	1.46	0.65	25
26	0.20	0.20	0.30	0.09	1.10	1.37	0.74	7.23	81.6	2.17	1.86	0.74	26
27	0.20	0.20	0.35	0.10	2.17	2.17	11.5	3.86	135	2.94	1.70	0.74	27
28	0.20	0.20	0.35	0.12	20.3	2.94	14.2	11.8	37.0	4.81	1.55	0.83	28
29	0.20		0.40	0.12	6.00	5.00	11.3	3.29	18.7	5.40	1.55	0.83	29
30	0.20		0.40	0.74	9.07	2.48	3.29	3.67	14.5	3.48	1.55	0.55	30
31	0.20		0.40		5.40		2.94	5.60		3.67		0.60	31
TOTAL	6.60	5.90	10.84	5.19	62.64	111.95	62.71	212.08	655.24	795.46	251.46	30.26	

Annual Total ( )

Table A5-1 (3) Runoff

STATION Ban Song Kon C.A. = 550 sq.km Nam Phrom, Thailand

Chern RIVER, IN THE BASIN OF Chern ELEVATION UNIT c.m.s. YEAR 1964

DATE	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	DATE
1	0.67	0.25	0.16	0.16	1.18	15.2	1.64	1.18	3.08	10.6	3.50	1.64	1
2	0.74	0.24	0.16	0.14	0.81	11.8	1.64	0.95	4.01	31.5	3.22	1.64	2
3	1.30	0.25	0.14	0.14	2.94	6.40	1.64	0.81	2.52	31.8	2.94	1.64	3
4	1.30	0.22	0.14	0.13	1.87	3.84	1.64	0.74	1.87	153	2.80	1.64	4
5	0.60	0.20	0.14	0.24	5.92	2.80	1.52	0.67	1.52	38.8	2.66	1.52	5
6	0.60	0.22	0.14	0.24	2.38	2.24	1.52	0.67	1.41	30.8	2.80	1.52	6
7	0.60	0.25	0.14	0.24	4.01	1.98	1.52	0.60	2.38	18.6	3.50	1.41	7
8	0.53	0.25	0.20	0.24	1.87	2.10	1.41	0.53	3.08	12.0	2.80	1.30	8
9	0.46	0.32	0.16	0.24	1.64	2.80	1.41	0.46	2.38	9.84	2.66	1.18	9
10	0.46	0.19	0.18	0.1	0.95	1.98	1.41	0.53	1.76	46.7	2.52	1.18	10
11	0.46	0.24	0.18	0.18	0.81	1.76	1.18	0.53	1.64	46.3	2.38	1.18	11
12	0.39	0.53	0.18	0.14	1.64	1.41	0.95	0.67	1.41	32.6	2.24	1.18	12
13	0.39	0.20	0.18	0.20	1.30	1.18	1.30	1.06	1.76	23.4	2.10	1.18	13
14	0.32	0.18	0.19	0.22	0.95	1.18	8.48	0.67	2.66	19.5	1.98	1.18	14
15	0.32	0.18	0.20	0.24	0.88	1.06	1.98	0.67	19.2	17.0	1.87	1.18	15
16	0.32	0.18	0.20	0.20	0.81	7.12	1.76	0.67	14.3	14.6	1.76	1.18	16
17	0.32	0.18	0.19	0.22	0.74	3.84	1.30	1.18	12.4	10.8	1.64	1.18	17
18	0.39	0.16	0.20	10.3	2.80	2.10	0.95	0.88	21.3	8.82	1.87	1.18	18
19	0.32	0.19	0.19	5.44	1.52	1.30	0.74	1.18	8.48	7.95	1.98	1.18	19
20	0.32	0.19	0.19	2.94	5.20	0.95	0.74	0.39	8.65	7.12	1.87	1.18	20
21	0.32	0.19	0.18	2.24	9.84	0.88	0.74	0.32	4.69	6.40	1.87	0.88	21
22	0.32	0.18	0.18	1.41	45.9	0.88	0.74	0.46	3.50	5.20	1.87	0.81	22
23	0.32	0.19	0.18	0.60	7.12	2.10	7.12	0.32	7.36	4.52	1.76	0.81	23
24	0.25	0.19	0.14	0.46	4.01	4.18	8.12	0.25	138	30.8	1.76	0.81	24
25	0.24	0.18	2.24	0.24	2.38	2.66	5.92	0.25	33.4	20.7	1.76	1.18	25
26	0.24	0.18	1.76	0.20	9.60	1.52	3.36	0.39	17.0	9.84	1.76	1.18	26
27	0.46	0.18	0.88	0.19	242	1.18	3.08	1.52	11.0	8.65	1.64	1.18	27
28	0.39	0.18	0.32	0.88	33.4	0.95	3.84	6.88	84.0	7.36	1.64	1.18	28
29	0.32	0.18	0.24	0.46	11.0	0.81	2.94	3.36	23.4	5.44	1.64	1.18	29
30	0.24		0.19	0.46	5.92	0.74	1.98	2.94	12.9	4.69	1.64	1.18	30
31	0.25		0.18		20.1		1.64	5.03		4.01		1.18	31
TOTAL	20.38	6.27	9.95	29.15	431.04	88.94	74.21	36.76	451.06	679.32	66.43	38.04	

Annual Total (   )

Table A5-1 (4) Runoff

STATION Ban Song Kon C.A. = 550 sq.km Nam Phrom, Thailand

Chern RIVER, IN THE BASIN OF Chern ELEVATION UNIT c.m.s. YEAR 1965

DATE	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	DATE
1	0.97	0.33	0.30	0.15	0.18	1.21	0.45	0.71	3.95	2.83	1.21	0.30	1
2	0.90	0.33	0.33	0.33	0.15	1.04	0.78	0.78	3.95	4.46	1.98	0.27	2
3	0.90	0.33	0.33	0.30	0.78	0.84	3.15	0.64	151	7.82	1.32	0.27	3
4	0.90	0.30	0.24	0.24	0.36	0.71	1.04	0.64	37.4	9.29	1.04	0.27	4
5	0.90	0.30	0.27	0.18	0.58	0.58	0.71	0.58	13.6	4.64	1.54	0.27	5
6	0.84	0.33	0.27	0.15	0.45	0.45	0.52	0.45	8.45	3.46	0.90	0.27	6
7	0.84	0.33	3.31	0.15	2.36	0.42	0.39	0.39	5.68	9.71	0.78	0.27	7
8	0.84	0.33	1.10	0.14	3.62	0.39	0.36	0.42	4.29	4.12	0.64	0.27	8
9	0.84	0.39	0.58	0.14	11.2	0.39	0.33	0.39	3.95	3.62	0.58	0.27	9
10	0.78	0.39	0.52	0.10	3.45	0.39	0.30	0.39	6.64	7.21	0.52	0.27	10
11	0.71	0.52	0.45	0.42	2.83	0.64	0.27	0.42	9.08	4.46	0.52	0.27	11
12	0.64	0.71	0.42	1.76	1.76	1.21	0.27	5.49	9.92	3.62	0.42	0.24	12
13	0.58	0.84	0.39	0.71	1.04	6.90	0.39	1.98	14.6	2.67	0.45	0.24	13
14	0.45	0.78	0.33	0.45	0.84	0.71	0.64	1.98	18.1	2.09	0.42	0.24	14
15	0.45	0.58	0.33	0.21	0.64	0.58	2.09	2.67	17.8	2.83	0.39	0.24	15
16	0.39	0.58	0.52	0.15	0.58	0.58	0.97	5.87	7.61	2.20	0.36	0.24	16
17	0.45	0.90	0.42	0.15	2.99	0.45	0.78	6.83	5.15	1.76	0.36	0.24	17
18	0.52	1.10	0.39	0.52	2.36	0.52	1.32	2.83	3.95	1.54	0.36	0.24	18
19	0.52	0.78	0.39	3.35	4.98	0.52	1.54	3.15	3.31	1.32	0.39	0.24	19
20	0.52	0.58	0.39	15 1	2.67	0.52	3.15	11.0	2.99	1.21	0.39	0.24	20
21	0.52	0.58	0.33	2.09	2.20	0.58	1.21	56.2	14.6	1.10	0.39	0.21	21
22	0.52	0.42	0.33	1.10	4.29	0.52	0.78	15.6	13.1	1.04	0.36	0.21	22
23	0.52	0.42	0.30	0.78	3.33	0.45	4 12	6.64	6.44	1.04	0.36	0.21	23
24	0.45	0.39	0.33	0.90	18.9	0.45	4.29	10.3	4.46	0.90	0.36	0.21	24
25	0.45	0.39	0.33	0.52	8.66	0.45	2.36	7.21	7 61	0.97	0.36	0.21	25
26	0.45	0.36	0.30	0.42	4.64	0.52	1.43	9.92	4.46	0.84	0.30	0.21	26
27	0.45	0.33	0.33	0.52	5.68	0.45	1.10	10.3	3.31	0.84	0.30	0.21	27
28	0.39	0.30	0.27	0.52	4.64	0.45	1.32	8.87	2.67	0.84	0.30	0.21	28
29	0.39		0.27	0.33	1.98	0.52	0.84	13.4	2.99	0.84	0.30	0.21	29
30	0.33		0.27	0 21	1.45	0.52	0.71	11.6	4.12	1.54	0.30	0.21	30
31	0.33		0.15		1.54		0.58	5.49		1.54		0.21	31
TOTAL	18.74	13.92	14.49	32.75	101.59	17.96	38.19	203.14	395.18	92.35	17.9	7.47	

Annual Total (   )

Table A5-1 (5) Runoff

STATION Ban Song Kon C.A.= 550 sq.km

Chern RIVER, IN THE BASIN OF Chern

ELEVATION UNIT c.m.s. YEAR 1966

DATE	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.	DATE
1	0.16	0.14	0.14	0.76	0.26	1.10	0.69	0.65	4.40	1.24	2.07	0.61	1
2	0.14	0.14	0.14	0.40	0.23	1.38	0.52	6.10	2.61	1.24	1.87	0.61	2
3	0.14	0.14	0.14	0.27	0.21	3.76	0.44	2.36	2.73	1.17	1.67	0.61	3
4	0.14	0.14	0.14	0.23	0.19	2.48	0.40	1.17	12 1	1.17	1.48	0.61	4
5	0.14	0.14	0.13	0.23	0.19	5.56	0.40	0.90	11.8	1.17	1.31	0.56	5
6	0.14	0.14	0.13	0.19	0.23	5.74	0.31	0.97	3.48	1.10	1.31	0.56	6
7	0.14	0.13	0.13	0.16	0.26	5.04	0.27	2.16	6 64	1.04	1.10	0.56	7
8	0.14	0.13	0.13	0.16	0.26	2.26	0.26	1.31	5.92	0.97	1.10	0.52	8
9	0.16	0.13	0.14	0.19	0.23	1.77	0.26	3.35	184	0.97	0.90	0.52	9
10	0.16	0.13	0.14	0.21	0.21	1.31	0.76	2.36	40.2	1.04	0.90	0.52	10
11	0.16	0.13	0.14	0.17	0.23	0.97	0.97	2.36	13.4	1.17	0.83	0.52	11
12	0.16	0.13	0.13	2.73	0.21	0.76	1.31	2.16	17.8	2.98	0.83	0.48	12
13	0.16	0.13	0.13	30.8	0.20	0.61	2.61	3.10	15.4	1.87	0.83	0.44	13
14	0.16	0.14	0.13	1.87	0.19	0.56	1.17	4.72	9.50	1.58	0.76	0.44	14
15	0.16	0.16	0.13	1.04	0.17	0.52	0.90	2.98	8.80	1.10	12.1	0.44	15
16	0.16	0.16	0.13	0.76	0.21	0.97	0.65	2.26	63.8	1.10	5.04	0.44	16
17	0.14	0.16	0.14	0.56	0.35	0.69	2.07	1.38	152	1.24	2.16	0.48	17
18	0.16	0.14	0.14	0.40	3.76	1.17	15.4	1.10	23.3	1.10	1.58	0.44	18
19	0.16	0.14	0.14	2.98	2.16	1.10	4.40	0.83	10.8	1.04	1.31	1.17	19
20	0.16	0.14	0.16	0.97	1.17	1.04	2.61	0.69	6.82	0.90	1.10	1.24	20
21	0.14	0.14	0.19	0.56	2.07	0 97	2.36	0.65	5.04	0.83	1.04	0.83	21
22	0.14	0.16	0.14	0.44	4.24	0.69	2.36	0.83	3.76	0.83	0.90	0.90	22
23	0.14	0.16	0.14	0.31	2.86	0.65	1.38	1.67	2.98	0.83	0.83	1.77	23
24	0.14	0.17	0.14	0.24	14.8	0.56	1.04	1.31	2.36	0.83	0.76	1.24	24
25	0.14	0.16	0.14	0.23	37.1	0.44	0.83	4.08	2 07	11.3	0.76	0.90	25
26	0.14	0.16	0.13	0.21	30.5	0.40	0.83	1.67	1.97	14.8	0.69	0.61	26
27	0.14	0.14	0.12	0.20	10.8	0.35	0.90	1.24	1.67	14.5	0.69	0.52	27
28	0.14	0.14	0.12	0.19	3.35	0.35	0.65	1.97	1.48	4.56	0.69	0.48	28
29	0.14		0.14	0.65	2.07	0.31	0.65	2.26	1.38	4.56	0.69	0.44	29
30	0.14		0.13	0.40	1.38	0.35	0.56	6.28	1.67	3.10	0.69	0.40	30
31	0.14		3.76		1.31		0.90	2.26		2.48		0.44	31
TOTAL	4.58	4.02	7.88	48.51	121.40	43.86	48.86	67.13	619.88	83.81	47.99	20.30	

Annual Total ( )

Table A5 - 2

Daily Runoff at Ban Na Pho Song on the Nam Chern

1966 year C.A. = 158 sq. km

Days	Aug.	Sept.	Oct.	Nov.	Dec.
1		2.65	0.66	0.75	0.44
2		1.78	0.66	0.70	0.39
3		1.38	0.66	0.52	0.34
4		1.89	0.52	0.48	0.34
5		15.00	0.48	0.44	0.34
6		1.78	0.75	0.39	0.30
7		15.60	0.89	0.39	0.30
8		8.20	0.70	0.34	0.30
9		32.00	0.62	0.34	0.30
10		17.30	2.65	0.30	0.30
11		3.15	2.00	0.30	0.30
12		4.22	1.24	0.30	0.30
13		2.55	0.89	0.30	0.30
14		9.75	0.75	0.30	0.26
15		1.45	0.70	6.00	0.26
16		11.30	1.03	1.17	0.26
17		12.00	0.70	0.66	0.26
18		4.22	0.62	0.57	0.26
19	0.30	2.33	0.48	0.48	0.48
20	0.39	1.78	0.44	0.44	0.48
21	0.30	1.67	0.39	0.39	0.39
22	3.35	1.56	0.39	0.34	0.48
23	0.70	11.31	0.39	0.34	0.96
24	2.44	1.17	0.39	0.30	0.57
25	1.89	1.03	5.48	0.30	0.39
26	1.10	0.96	2.95	0.30	0.34
27	0.89	0.82	2.75	0.30	0.30
28	2.75	0.75	1.67	0.30	0.26
29	2.22	0.75	1.24	0.30	0.26
30	2.00	0.70	0.96	0.30	0.23
31	3.62		0.75		0.23
Total	21.95	101.05	34.80	18.34	10.92
Mean	1.69	5.37	1.12	0.61	0.35
c.m.s. per 1000km^2	10.68	33.97	7.10	3.87	2.21

Table A5-3 (1) Precipitation STATION Chum Phae Nam Phrom, Thailand

RIVER, IN THE BASIN OF ELEVATION UNIT mm YEAR 1961

DATE	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	DATE
1					9.7					20.0			1
2							31.0	12.8	7.1	28.8			2
3					12.4	3.5	31.5			7.4			3
4						34.7		4.2		31.6			4
5													5
6			4.1		15.5			4.3					6
7			12.6		12.3	5.8			9 5				7
8						8.4			2.5				8
9			4.0			4.3			29.6	4.5			9
10			4.2			6.8	2.5						10
11						2 0							11
12									8.0				12
13						4.0			7.1	20.4			13
14								16.0					14
15				37.5	26.3			12.0			3.4		15
16									10.0				16
17				25.3	8.1			8.9	19.3				17
18		9.5					39.9						18
19							20.3						19
20					4.5		22.3	28.8		110.0			20
21					25.8	3.0	14.1						21
22					19.0		12.8	6.3		40.2			22
23					35.2				13.1	4.2			23
24					11.2								24
25				6.5	1.4	29.3			5.3				25
26				26.2		2.0							26
27					8.9			20.9					27
28					4.8				23.7				28
29								3.8					29
30				5.5									30
31								18.5					31
TOTAL		9.5	24.9	101.0	195.1	103.8	174 4	136.15	135.2	267.1	3.4		

Annual Total ( )

Table A5-3 (2) Precipitation STATION Chum Phae Nam Phrom, Thailand

RIVER, IN THE BASIN OF ELEVATION UNIT YEAR 1962

DATE	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	DATE
1				2.2		33.0			15.2	5.2			1
2							1.6		2.8				2
3													3
4									96.5	21.6			4
5					4.1	2.1			13.0				5
6								6.2		58.4			6
7							64.0			14.2			7
8				7.6			13.2						8
9						7.0			11.5	9.1			9
10						2.3		31.4		3.0			10
11													11
12									12.5				12
13					25.1		30.6	6.6	2.3				13
14							12.0						14
15			33.1										15
16					21.2		4.0	4.5					16
17						6.4			48.0				17
18				8.2	49.2				42.5				18
19													19
20				5.2	38.8								20
21					3.8								21
22					55.7			23.4					22
23								38.6	2.5				23
24							3.5	14.1					24
25			37.4						26.2				25
26							3.5						26
27						12.4			28.0				27
28									31.0				28
29				59.7					94.3				29
30						4.3			1.2				30
31								21.0					31
TOTAL	0	0	70.5	82.9	197.9	67.5	132.4	145.8	427.5	115.5	0	0	

Annual Total (1,236.0)

Table A5-3 (3) Precipitation STATION Chum Phae

RIVER, IN THE BASIN OF Nam Phrom, Thailand

ELEVATION UNIT YEAR 1963

DATE	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	DATE
1					22.2					14.5			1
2							3.3			2.5	17.0		2
3										37.8	2.3		3
4				3.6	9.1			17.4	20.8	25.4			4
5				4.4				10.0					5
6							20.9	17.1	23.0		6.5		6
7								19.0		57.9			7
8			40.9							10.7			8
9						29.5							9
10									3.7				10
11						36.2			12 0				11
12													12
13						9.7		16.3					13
14								37.4					14
15							9.4	9.2	10.0				15
16								11.8			17.9		16
17													17
18				18.9	23.9								18
19									7.3				19
20									5.7				20
21			2.9		21.0								21
22			10.5				8.3						22
23							3.0						23
24									61.5				24
25					20.8		5 5	4.2					25
26							50.4		9.4	7.0			26
27						38.6	19.6		52.5	2.6			27
28					7.3		15.0	14.9	1.5				28
29			43.5		39.5	5.2							29
30													30
31					42.9								31
TOTAL	0	0	97.8	26.9	186.7	119.2	135.4	157.3	207.4	158.4	43.7	0	

Annual Total (1,132.8)

Table A5-3 (4) Precipitation STATION Chum Phae

RIVER, IN THE BASIN OF Nam Phrom, Thailand

ELEVATION UNIT YEAR 1964

DATE	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	DATE
1					44.5					26.2			1
2									4.3				2
3						3.2	8.4			51.0			3
4													4
5					33.3								5
6							5.3			4.3			6
7					84.8		3 1						7
8							25.0		12.3				8
9					4.2				7.2	7.8			9
10													10
11				24.0	29.0	6.2			19.5				11
12													12
13													13
14				3.8			2.2	50.2	28.8				14
15								2.2	28.8	14.0			15
16													16
17				14.2							6.2		17
18					30.5	22.8		4.1					18
19		1.8						4.0					19
20		2.5			2.4								20
21							10.5						21
22						46.1	15.0		48.1				22
23						3.6			60.2	45.7			23
24			16.5										24
25						4.6		13.2					25
26					54.4			25.3					26
27					20.0	3.1	9.1	9.1					27
28													28
29			18.5	15.0									29
30													30
31													31
TOTAL	0	4.3	35.0	57.0	303.1	89.6	78.6	108.1	209.2	149.0	6.2	0	

Annual Total (1,040.1)

Table A5-3 (5) Precipitation STATION Chum Phae

Nam Phrom, Thailand

RIVER, IN THE BASIN OF ELFVATION UNIT YEAR 1965

DATE	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	DATE
1						5.7			16.9				1
2								9.4	54.0				2
3									5.4				3
4		3.0	2.8						3.2				4
5													5
6					21.2								6
7	12.5												7
8									4.8	26.0			8
9									26.5				9
10						16.6	8.9		2.3				10
11				4.5									11
12							3.7						12
13							25.4	4.5	7.7				13
14									5.2				14
15					3.2								15
16					50.2	6.5					1.7		16
17													17
18								20.2	1.4				18
19				6.0	10.3			4.8					19
20					18.1			18.1	17.4				20
21								8.0	16.4				21
22							7.9						22
23						6.9	4.0						23
24					13.0			21.1	3.4	3.0			24
25										2.5			25
26							3.5						26
27								25.0					27
28								9.4	3.0				28
29							5.8	12.2	4.2				29
30						7.5				20.7			30
31			5.5		6.0			23.5					31
TOTAL	0	15.5	8.3	10.5	122.0	43.2	59.2	156.2	171.8	52 2	1.7	0	

Annual Total (6406)

Table A5-3 (6) Precipitation STATION Chum Phae

Nam Phrom, Thailand

RIVER, IN THE BASIN OF ELEVATION UNIT YEAR 1966

DATE	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	DATE
1						6.0		12.3					1
2			18.7										2
3					0.8		2.0	5.9	86.0				3
4						20.2		4.2					4
5					5.2	4.9			7.0				5
6				2.0	15.8	5.8				1.2			6
7					7 2								7
8			8.8					17.4	53.0				8
9					1.5	2.0		1.0		43.0			9
10					5.2	2.7			5.8	41.7			10
11													11
12				15.1		3.0			5.5				12
13							4.3		1.1				13
14						2.0	0.8		8.0				14
15			12.0			8.4	0.9		73.0			3.9	15
16				5.8	2.6		52 4	3.5	31.7				16
17				1.0	7.6	30.0	111.2	2.6					17
18			8.0	34.7									18
19							10.6						19
20					19.5							54.4	20
21					17.7			44.0					21
22								4.0					22
23					7.7		6.3	9.0					23
24					32.5	3.9	2.8	11.3		99.3			24
25					6.3	3.0				29.0			25
26					10.9	2.0							26
27				3.3	64.8			41.5					27
28		11.0			4.3	9.1		5.2					28
29					2.4								29
30			7.7	7.4				3.0					30
31			8.9				1.4	3 0					31
TOTAL	0	11.0	64.1	69.3	212.0	103.0	192.7	167.9	271.1	214.2	0	58.3	

Annual Total (1,3636)

Table A5-4 Monthly Precipitation STATION Chum Phae CATCHMENT AREA sq km Nam Phrom, Thailand

RIVER, IN THE BASIN OF ELEVATION m UNIT mm S ° W °

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	ANNUAL
1952	0	0	125.3	34.3	155.8	131.7	66.7	226.9	339.7	128.2	0	0	1,208.8
1953	36.1	54.5	4.6	109.7	201.8	141.2	175.9	35.3	155.0	90.9	63.9	0	1,068.9
1954	3.8	0	1.0	31.6	171.9	70.7	132.6	161.7	370.8	118.7	0	0	1,062.8
1955	0	0	50.0	62.7	84.7	239.9	46.5	154.3	191.6	12.7	0	0	842.4
1956	0	42.1	102.0	66.7	66.8	118.5	220.5	128.5	256.1	12.3	0	0	1,013.5
1957	0	0	107.5	50.1	151.9	101.6	200.4	117.6	323.3	93.2	6.5	0	1,152.1
1958	16.7	50.5	37.7	19.5	69.5	161.0	102.7	258.8	365.1	78.5	0	0	1,160.1
1959	0	16.8	27.3	39.3	208.3	125.4	287.6	118.2	383.6	0	9.0	0	1,215.5
1960	0	0	25.7	32.5	265.9	115.5	178.4	73.2	61.6	96.2	0	0	849,0
1961	0	9.5	24.9	101.0	195.1	103.8	174.4	136.5	135.2	267.1	3.4	0	1,150.9
1962	0	0	70.5	82.9	197.9	67.5	132.4	145.8	427.5	111.5	0	0	1,236.0
1963	0	0	97.8	26.9	186.7	119.2	135.4	157.3	207.4	158.4	43.7	0	1,132.8
1964	0	4.3	35.0	57.0	303.4	189.6	178.6	108.1	209.2	149.0	16.2	0	1,040.1
1965	0	15.5	8.3	10.5	122.0	43.2	59.2	156.2	171.8	52.2	1.7	0	640.6
1966	0	11.0	64.1	69.3	212.0	103.0	192.7	167.9	271.1	214.2	0	58.3	1,363.6
AVERAGE	3.8	13.6	52.2	53.0	173.0	122.1	152.5	143.2	258.0	105.5	9.6	3.9	1,090.4

Table A5-5 (1) Precipitation STATION Phu Kieo CATCHMENT AREA sq km Nam Phrom, Thailand

RIVER, IN THE BASIN OF ELEVATION m UNIT S ° W °

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	ANNUAL
1912				57.5	99.7	59.4	215.1	164.0	116.9	36.0	173.1		921.7
1913		29.0	15.7		256.1	45.0	62.0	134.8	227.0	53.2	30.8		853.6
1914		10.0	86.5	55.0	174.1	46.0	136.0	123.9	152.7	94.5	69.0		974.7
1915			22.3	44.2	57.6	202.8	114.0	35.0	324.9	272.7	45.0		1,118.5
1916	56.5		75.7	29.9	133.3	156.8	119.6	87.4	303.8	114.5	46.5	56.5	1,180.5
1917			31.2	27.5	43.8		247.8	149.8	300.3	441.7			1,242.1
1918		23.0	53.1	185.0	104.6	74.3		199.8	170.0	10.0			819.8
1919		145.0	210.0	11.0	168.0	100.0	46.0	150.0	175.0	72.5	21.0		1,098.5
1920		12.0	10.5	57.0	210.0	101.6	163.3	91.0	263.4	83.2	66.0		1,058.0
1921	42.0			94.3	106.0	151.0	155.0	111.0	416.1	95.0			1,170.4
1922					218.0	285.0		62.0	382.7	16.5	33.1		997.3
1923		20.0		58.2	109.6	90.0	7.2	3.5	257.5	72.8			618.8
1924			42.0	52.5	45.0	58.2	49.0	260.2	162.7	48.0			717.6
1925		2.5	31.8	88.0	71.6	112.0	8 .0	139.4	218.5	88.0	10.0		847.8
1926		3.0	100.5		118.5	65.0	136.4	155.5	139.5	82.0			800.4
1927			40.0	70.5	76.2	37.5	26.0	84.5	228 4	124.0			687.1

Table A5-5 (2) Precipitation STATION Phu Kieo CATCHMENT AREA ________ sq km Nam Phrom, Thailand

________ RIVER, IN THE BASIN OF ________ ELEVATION ________ m UNIT ________ S ° W °

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	ANNUAL
1928		34.0		111.8	106.5	14.0		42.4	103.5	79.9			492.1
1929		30.5		68.5	36.5	36.0		159.0	66.1	45.5			442.1
1930				61.5	69.8	113.1		61.0	208.6	200.0			714.0
1931					10.0	50.0	100.0	127.9	223.8	209.0			713.7
1932				Records are missing									
1933				28.0	88.5	36 0		42.0	300.5	41.5	188.0		724 5
1934				27.0	144.5	136.0	206 5	423.0	214.2	40.0	75.0		1,266.2
1935			53.7	80.0	145.0	129.5	105.0	204.0	338.0	373.0	69.0		1,497.2
1936		70.0		99.3	273.7	94.5	236 5	4.0	97.0	112.0			987.0
1937				144.0	132.5	103.0	68.9	121.0	109.0	3.5	1.0		682.9
1938			115.0	375.0	275.0	86.5	241.0	21.0	154.0	180.5	20.0		1,468.0
1939		32.0	176.3	132.4	59.0		128.3	163.5		30.0			721.5
1940-52				Records are missing									
1953							73.0	138.1	258.7	30.6	100.5		600.9
1954	17.5	1.2	4.1	19.7	89.6	131.3	34.6	181.0	268.7	79.0			826.7
1955			4.9	177.5	164.2	333.6	56.6			9.4	12.0		758.2

Table A5-5 (3) Precipitation STATION Phu Kieo CATCHMENT AREA ________ sq km Nam Phrom, Thailand

________ RIVER, IN THE BASIN OF ________ ELEVATION ________ m UNIT ________ S ° W °

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	ANNUAL
1956		87.0	93.0	133.0	183.0	105.0	228.0	73.5	122.5	80.0			1,105.0
1957			16.6	50.5	131.0	155.5	85.5	76.5	372.5	203.3			1,091.4
1958		46.0	44.0	6.0	86.5	43.5	167.0	214.5	296.0	25.0			923.5
1959		12.0	15.0	19.5	123.0	215.6	74.5	149.0	300.0	10.5	6.5		926.5
1960			4.5	16.0	60.5	54.0	98.0	4.5	239.5	167.5	13.0		657.5
1961			14.5	54.0	218.5	55.5	30.5	98.0	290.5	269.5			1,031.0
1962			12.0	87.5	304.0	67.3	244.9	172.1	612.1	86.6			1,586 5
1963			88.0	64.7	101.2	113.9	194.8	126.5	202.4	254.1	66.3	6.1	1,218.0
1964		21.7	102.7	95.6	311.9	19.7	110.9	84.0	247.8	228.1	19.6		1,242.0
1965		9.2	21.9	82.1	91.1	15.2	30.6	190.6	129.2	41.8			611.7
1966		6.7	38.2	8.9	173.1	82.4	28.0	66.2	250.8	155.0		5.2	814.5

Table A5-6 Monthly Precipitation STATION Khon Kean CATCHMENT AREA ______ sq km Nam Phrom, Thailand

______ RIVER, IN THE BASIN OF ______ ELEVATION 160.6 m UNIT mm S 16° 20' W 102 ° 51'

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	ANNUAL
1951	9.8	23.5	22.9	80.7	180.3	208.1	265.8	134.0	354.1	308.9	8.1	0	1,596.2
1952	0	0.6	170.2	17.3	192.6	128.4	120.2	135.5	228.3	172.0	0	0	1,165.1
1953	4.3	63.2	20.9	102.7	208.0	201.9	145.2	129.3	397.3	95.8	24.3	0	1,392.9
1954	30.7	81.8	0	40.6	127.4	205.6	103.6	123.4	450.3	70.0	0	0.4	1,233.8
1955	0	0	13.5	71.4	112.2	413.4	61.5	233.3	180.3	4.2	2.6	0	1,092.4
1956	0	24.8	39.0	93.0	179.4	105.1	186.6	141.6	193.0	34.0	0	0	996.5
1957	0	1.8	106.0	58.0	129.2	185.1	126.8	169.8	267.6	55.1	0	0	1,099.4
1958	1.2	46.8	9.5	63 9	153.6	177.3	125.7	171.5	279.2	67.1	0	0	1,095.0
1959	0	8.7	16.6	33.0	196.6	94.9	193.1	109.1	483.0	33.2	0	0	1,168.8
1960	0	0	76.2	4.9	189.2	184.6	121.4	202.0	106.4	81.2	2.3	0	968.2
1961	0	7.5	73.6	66.3	141.3	118.8	39.8	258.3	360.9	228.8	0.3	0	1,895.6
1962	0.6	0	29.0	65.8	218.0	66.0	134.9	154.3	422.0	34.5	5.3	3.5	1,134.0
1963	0	3.5	28.4	47.9	125.5	119.3	210.7	194.2	185.1	157.0	88.4	0	1,160.0
1964	0	12.9	3.7	87.4	259.6	103.6	154.0	98.1	262.0	175.9	22.8	0	1,180.0
1965	0	3.9	25.9	113.6	82.8	65.9	123.3	208.3	181.9	91.8	8.3	0	905.7
1966													
Average	3.1	18.6	42.4	63.1	166.5	158.5	141.0	164.5	290.5	107.1	10.9	2.6	1,168.8

Table A5-7 Monthly Maximum 12-Hour Persisting Temperature STATION Khon Kean CATCHMENT AREA ______ sq km Nam Phrom, Thailand

______ RIVER IN THE BASIN OF ______ ELEVATION 160.6 m UNIT Centigrade ~~S~~ N 16° 20' ~~W~~ E 105 ° 51'

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	ANNUAL
1951					32.4	30.6	30.9	30.6	30.9	*30.7			
1952					33.9	31.6	31.5	29.5	*31.0	29.6			
1953					31.6	31.7	30.9	30.3	30.0	30.3			
1954					31.6	31.5	*31.5	30.6	29.8	29.4			
1955					33.7	30.1	30.1	30.5	30.0	29.4			
1956					31.0	31.2	30.8	29.4	29.6	29.7			
1957					34.7	31.3	31.0	30.9	29.7	29.8			
1958					34.1	32.5	29.9	*31.7	29.2	29.0			
1959					34.3	*33.9	30.3	31.7	29.1	28.5			
1960					*35.2	31.2	30.7	30.2	29.4	28.1			
1961					32.4	31.0	31.1	30.8	29.0	28.7			
1962					31.8	30.7	30.4	31.2	28.1	28.9			
1963					32.4	30.5	29.4	28.7	28.7	28.9			
1964					29.6	30.1	30.0	29.3	29.5	28.6			
1965					32.9	29.5	29.6	29.4	28.8	28.6			

* Maximum from 1951 to 1965

Table A5-8 (1)

Daily Wind Movement

STATION Khon Kaen

RIVER, IN THE BASIN OF

ELEVATION

UNIT

Nam Phrom, Thailand

YEAR 1962

DATE	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	DATE
1	79.1	124.9	75.5	17.0	23.8	20.5	17.4	48.1	12.2	20.4	19.0	51.5	1
2	62.1	67.1	103.0	30.5	12.0	10.9	15.2	35.4	33.1	24.0	15.4	41.3	2
3	63.9	49.6	73 1	37.3	20.1	20.0	15.9	43.1	1.4	12.6	35.2	45.4	3
4	13.0	88.4	28.5	52.8	13.8	42.8	17.8	39.5	16.6	11.8	71.4	19.6	4
5	39.5	68.5	19.5	46.4	13.2	27.1	28.2	25.4	27.7	28.5	53.0	55.4	5
6	35.8	54.3	23.6	32.2	14.7	14.1	7.3	46.8	17.9	11.9	34.8	50.9	6
7	28.9	35.2	35.2	28.3	30.8	15.6	0.4	19.6	41.4	21.7	22.7	41.5	7
8	24.8	24.1	15.8	42.8	16.9	13.9	20.1	17.7	33.1	11.9	25.8	12.1	8
9	62.6	17.9	28.2	32.0	12.6	21.4	12.6	13.1	12.4	18.9	29.1	25.2	9
10	52.8	22.1	28.5	44.0	42.4	38.6	19.5	7.8	13.7	34.0	18.7	23.7	10
11	66.8	10.9	35.5	22.0	9.0	15.5	17.1	10.2	15.8	17.3	17.2	22.8	11
12	29.4	16.3	36.3	17.4	14.0	35.0	24.4	47.1	40.2	17.4	13.3	20.5	12
13	18.3	13.3	23.9	25.4	14.4	45.0	78.6	23.4	5.1	7.6	8.9	42.5	13
14	9.6	53.0	22.5	52 8	6.0	31.6	34.5	9.8	5.9	12.1	12.0	11.3	14
15	13.9	86.3	31.7	24.5	8.9	27.9	23.4	9.2	11.2	63.9	12.2	12.4	15
16	13.9	117.3	12.6	28.4	11.1	42.5	6.1	13.2	10.6	28.8	11.0	26.3	16
17	36.1	74.3	22.7	42.9	17.6	44.8	11.8	11.6	29.0	32.7	12.7	29.6	17
18	40.6	77.6	23.1	33.2	28.5	28.1	25.7	12.1	96.7	48.1	31.2	36.0	18
19	60.6	39.4	46.7	62.6	31.0	33.0	41.5	11.1	34.1	37.9	17.9	24.4	19
20	90.2	80.5	36.2	34.2	26.3	30.6	49.8	13.1	20.3	24.6	20.3	17.6	20
21	61.7	56.3	14.3	28.5	36.3	27.5	68.9	24.9	5.3	29.4	31.4	51.6	21
22	42.0	20.7	24.9	22.1	6.5	27.3	50.1	17.3	4.7	27.5	83.3	31.2	22
23	50.7	13.5	107.8	32.4	26.9	10.2	59.7	10.2	23.8	23.0	62.2	62.5	23
24	45.3	10.2	113.2	35.8	19.6	17.3	61.7	14.7	11.3	45.7	23.5	53.1	24
25	58.7	26.4	50.5	7.6	29.3	15.6	45.4	27.7	15.4	57.8	37.7	16.1	25
26	50.8	20.4	33.3	39.1	34.1	27.1	48.9	23.6	26.9	51.8	48.5	18.5	26
27	112.9	18.9	27.4	19.5	23.6	21.7	50.7	70.9	21.0	32.9	33.0	14.0	27
28	49.5	24.6	35.7	22.8	33.8	26.0	42 6	8.6	12.7	18.6	84.8	9.2	28
29	22.6		81.8	25.6	26.2	12.9	29.2	5.0	14.6	17.1	54.0	13.0	29
30	29.1		40.7	29.3	23.6	18.3	22.5	5.5	37.2	14.0	51.8	7.3	30
31	24.1		16.6		13.8		34.1	5.1		14.8		57.6	31
TOTAL	1,389.3	1,312.0	1,268.3	969.4	640.8	762.8	981.1	670.8	651.3	818.7	992.0	944.1	

Annual Total ( )

Table A5-8 (2)

Daily Wind Movement

STATION Khon Kaen

RIVER, IN THE BASIN OF

ELEVATION

UNIT

Nam Phrom, Thailand

YEAR 1963

DATE	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	DATE
1	14.3	29.7	61.2	19.5	25.6	16.1	69.9	10.7	14.0	7.8	21.0	36.4	1
2	10.1	24.4	25.6	20.8	18.5	31.8	50.6	16.2	10.6	25.7	22.8	41.1	2
3	26.9	24.9	15.7	16.1	17.7	54.3	51.8	8.0	5.9	52.0	23.1	18.2	3
4	19.3	53.7	13.2	33.7	68.2	80.9	49.8	9.9	12.0	46.5	28.7	59.6	4
5	19.7	44.4	13.5	18.7	17.3	77.8	39.7	15.5	11.2	18.7	16.5	39.0	5
6	20.0	26.2	23.0	20.9	25.0	66.5	24.3	10.9	30.8	17.7	24.4	18.4	6
7	16.1	29.9	33.2	22.1	30.0	40.9	59.6	17.4	9.2	47.8	14.8	19.0	7
8	51.2	17.1	44.2	88.8	17.2	12.9	62.5	46.1	12.6	24.0	17.7	8.3	8
9	40.2	33.6	39.6	102.1	25.3	42.0	28.0	40.8	54.2	21.9	16.4	17.6	9
10	46.7	44.6	12.5	80.1	13.8	22.3	36.0	51.9	65.1	16.4	15 4	10.9	10
11	33.6	43.6	22.3	52.2	25.9	27.8	24.3	41.5	49.2	13.7	27.4	30.5	11
12	49.4	42.0	29.7	29.1	21.9	16.8	59.6	29.1	49.0	23.2	19.7	64.6	12
13	41.8	33.8	30.0	26.2	21.7	15.3	52.4	9.4	27.3	12.6	18.4	34.3	13
14	52.9	18.2	48.9	31.8	26.6	33.9	40.3	15.7	25.3	24.3	14.9	18.4	14
15	45.5	15.5	34.9	45.3	15.7	37.9	28.7	10.9	25.7	20.7	13.2	14.8	15
16	41.6	31.0	48.0	61.5	13.1	69.1	39.5	19.7	30.5	25.1	19.8	12.1	16
17	35.7	23.1	54.4	18.1	51.8	25.4	45.0	25.6	22.4	34.8	11.6	11.5	17
18	43.1	30.7	31.2	47.9	29.7	21.6	68.5	27.7	23.4	57.1	17.9	23.3	18
19	37.5	31.0	20.9	37.0	20.0	40.9	69.2	21.6	26.9	21.2	9.2	44.7	19
20	19.8	24.5	39.8	29.4	28.6	34.1	55.6	13.4	17.3	54.0	12.8	42.5	20
21	18.5	35.0	40.9	44.1	11.4	31.6	33.3	6.1	11.3	58.1	21.2	34.8	21
22	45.7	69.4	8.6	34.6	29.4	27.7	35.2	6.4	7.3	46.8	12.1	29.8	22
23	46.0	64.6	14.1	21.8	17.8	21.5	48.8	14.5	4.7	32.1	17.3	18.8	23
24	50.8	47.4	32.6	15.0	17.8	26.3	80.3	14.8	66.3	25.2	25.3	12.2	24
25	65.7	35.4	14.2	33.9	37.9	37.5	69.6	18.3	58.8	30.1	12.8	11.0	25
26	91.1	43.0	22.1	31.1	14.4	18.3	76.7	6.9	15.1	47.2	17.7	11.8	26
27	82.1	118.5	22.3	18.8	15.9	19.2	46.6	10.8	39.6	59.3	20.2	21.7	27
28	52.2	71.5	34.0	36.2	22.0	7.2	9.9	15.3	32.7	13.4	39.7	46.3	28
29	39.3		67.9	26.7	17.5	17.2	26.7	27.4	18.7	7.0	33.8	27.0	29
30	27.6		43.6	23.1	9.5	40.5	2.7	12.6	10.1	15.4	22.2	20.2	30
31	77.9		18.0		17.1		14.8	8.7		25.6		13.1	31
TOTAL	1,262 3	1,106.7	960.1	1,086.6	724.3	1,015.3	1,399.4	583.8	787.2	925.4	588.0	81.2	

Annual Total ( )

Table A5-8 (3)
Daily Wind Movement

STATION Khon Kaen

RIVER, IN THE BASIN OF

ELEVATION

UNIT

Nam Phrom, Thailand

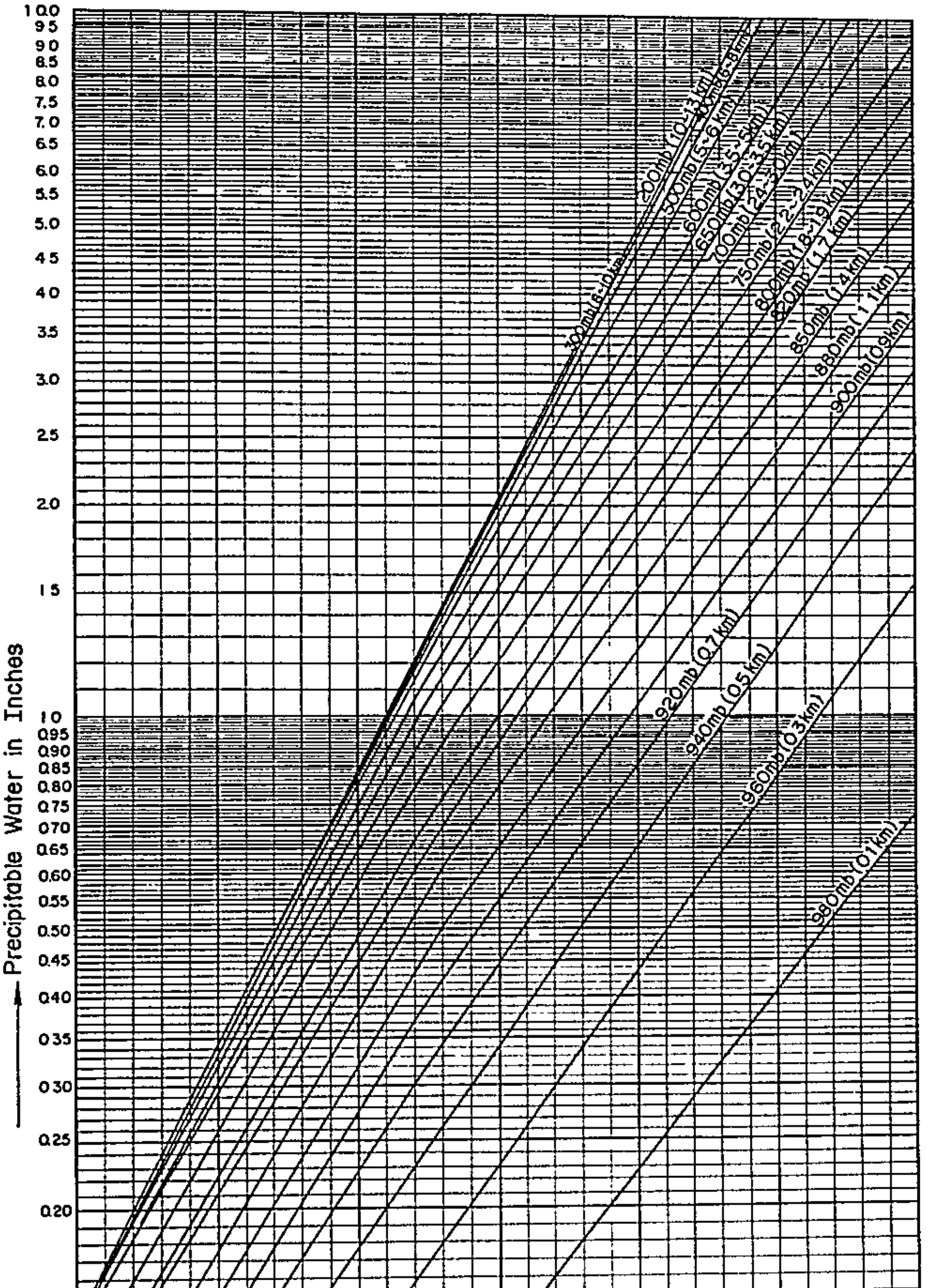
YEAR 1964

DATE	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	DATE
1	12.7	20.6	18.4	36.4	35.0	28.1	32.6	18.1	9.5	11.6	62.0	11.8	1
2	26.3	35.6	14.7	23.5	16.5	27.8	79.4	17.3	17.5	22.2	45.5	22.6	2
3	36.8	66.6	15.5	30.4	26.1	40.8	72.3	49.4	20.3	18.1	31.3	76.0	3
4	32.2	34.8	14.5	43.6	28.2	33.7	21.8	23.5	11.8	8.5	14.7	84.7	4
5	33.6	19.8	19.5	28.5	42.1	53.5	3.8	11.9	16.3	10.4	51.3	27.4	5
6	24.1	22.1	16.9	23.1	30.4	26.4	9.7	13.7	15.4	12.0	26.0	45.8	6
7	14.3	21.1	23.0	27.2	28.8	39.5	8.9	13.6	15.1	12.3	25.2	26.7	7
8	14.4	15.5	39.7	31.4	24.7	29.5	19.1	33.4	20.2	13.2	15.1	14.1	8
9	18.8	15.5	19.9	23.6	20.1	27.3	13.6	66.9	21.1	32.7	30.1	16.4	9
10	16.8	20.1	56.2	17.3	12.9	27.8	11.0	54 4	15.9	24.1	37.2	18.6	10
11	15.3	67.9	80.0	55.2	31.8	36.7	36.8	32.5	15.9	15.4	34.5	16.9	11
12	14.0	84.1	61.1	32.2	45.5	19.4	8.1	33.7	24.5	4.8	41.3	20.2	12
13	11.0	76.1	77.9	23.7	28.7	32.3	17.9	27.6	26.9	5.8	44.1	43.8	13
14	14.4	26.2	76.6	24.8	39.1	26.4	26.5	37.3	16.0	10.1	43.2	57.1	14
15	13.3	28.3	27.3	23.4	21.0	19.1	24 1	28.1	32.0	5.2	33.0	56.1	15
16	14.3	25.8	19.7	24.9	13.5	35.2	37.5	56.1	14.1	13.2	18.7	54.6	16
17	13.8	36.4	17.2	50.9	13.7	40.5	38.5	42.9	14.7	8.2	21.1	101.1	17
18	39.4	26.5	22.2	30.0	16.1	23.6	20.4	35.0	18.0	10.5	14.2	35.3	18
19	62.9	25.5	27.7	13.7	22.6	7.6	15.2	44.0	14.1	13.3	58.9	25.1	19
20	18.2	53.6	13.4	26.1	12.3	9.8	27.2	39.2	18.0	12.2	27.7	54.8	20
21	11.9	42.6	24.0	21.0	31.0	14.3	22.9	34.6	26.7	11.8	52.5	18.7	21
22	23.0	29.6	19.6	41.8	18.5	22.6	26.9	41.6	58.1	18.5	44.0	11.0	22
23	19.2	61.6	38.4	18.1	25.7	21.5	15.1	33.9	37.5	11.2	26.4	12.0	23
24	31.0	78.0	64.5	30.9	20.9	15.1	10.4	43.5	26.6	14.3	28.5	12.5	24
25	39.0	108.4	56.4	12.7	36.7	22.8	6.0	20.5	12.0	13.5	19.8	30.9	25
26	21.2	95.4	56.8	20.4	72.6	29.2	39.6	16.5	11.4	42.0	11.3	39.3	26
27	21.3	66.7	32.3	27.0	19.6	36.1	21.2	12.0	15.8	36.0	20.3	59.6	27
28	31.1	29.6	27.6	36.8	24.3	36.5	23.9	36.5	13.6	18.1	11.9	29.4	28
29	23.0	18.4	27.6	27.9	21.5	34.8	24.4	22.7	34.6	48.3	2.7	19.0	29
30	31.6		37.3	17.1	24.9	37.8	31.6	15.2	37.7	42.9	9.8	19.9	30
31	39.8		31.0		15.0		50.2	12.1		34.5		48.8	31
TOTAL	738.7	1,252.4	1,076.9	843.6	819.8	855.7	796.6	967.7	631.3	554.9	898.7	1,110.2	

Annual Total (   )

Fig. A5 – 1 Diagram of Precipitable Water

Depths of Precipitable Water in A Column of Air of
Given Height Above 1000mb as A Function of Dewpoint,
Assuming Saturation and Pseudoadiabatic Lapse Rate



B. GEOLOGY AND MATERIALS

APPENDIX B GEOLOGY AND MATERIALS

(GEOLOGY)

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Table A6 - 1 Results of Water Pressure Test

No. of Hole	Test Section			Water Pressure (kg/sq. cm)	Water Loss (l/min.)	Lugeon Unit (l/min./m/ 10kg/sq. cm)
	From(m)	To (m)	Length(m)			
D - 1	4.5	7.5	3.0	1.5	7.4	16.4
				3.0	4.2	4.7
	9.0	12.0	3.0	1.5	7.4	16.4
				3.0	22.0	24.4
				4.5	28.0	20.7
	13.5	16.5	3.0	1.5	4.6	10.2
				3.0	8.4	9.3
				4.5	8.4	6.2
	18.0	21.0	3.0	1.5	4.8	10.6
				3.0	8.6	9.6
				5.0	14.2	9.5
	22.5	25.5	3.0	1.5	39.2	87.1
				3.0	54.8	60.9
				4.5	58.6	43.4
	27.2	30.2	3.0	1.5	28.0	62.2
				3.0	68.0	75.6
				3.5	70.0	66.7
D - 2	4.0	7.0	3.0	1.5	16.4	36.4
				3.0	24.4	27.1
				4.5	31.2	23.1
	8.5	11.5	3.0	1.5	6.6	14.7
				3.0	10.2	11.3
	13.2	16.2	3.0	1.5	1.0	2.2
				3.0	2.2	2.4
				4.5	2.8	2.1
	17.7	20.7	3.0	1.5	3.6	8.0
				3.0	2.4	2.7
				5.0	3.6	2.4
	22.4	25.4	3.0	1.5	11.0	24.4
				3.0	21.0	23.3
				4.5	32.6	24.1
	27.0	30.0	3.0	1.5	0.8	1.8
				3.0	3.0	3.3
				4.5	4.6	3.4
D - 3	5.0	8.0	3.0	1.5	1.8	4.0
				3.0	5.2	5.8
	9.2	12.2	3.0	1.5	4.0	8.9
				3.0	5.2	5.8
				4.0	6.8	5.7
	13.6	16.6	3.0	1.5	7.4	16.4
				3.0	11.6	12.9
				4.5	16.4	12.1
	18.3	21.3	3.0	1.5	2.2	4.9
				3.0	3.4	3.8
				4.5	4.6	3.4
	22.9	25.9	3.0	1.5	9.8	21.8
				3.0	12.6	14.0
				4.5	16.0	11.9
	25.9	30.05	4.15	1.5	2.2	4.9
				3.0	3.2	2.6
				4.5	4.6	2.5

Note. LUGEON UNIT is calculated by converting the test result into the value under the water pressure of 10 kg per sq. cm, assuming that the water loss is approximately proportional to the water pressure. A hydrostatic head is neglected in calculation.

Fig. A6-1 GEOLOGIC LOG OF DRILL HOLE

NAM CHERN PROJECT, DAM SITE HOLE NO. D-1 (SHEET 1 OF 2)

LOCATION LEFT BANK
ELEVATION 770.00 m
COORDINATE
ANGLE FROM HORIZONTAL 90°
BEARING OF ANGLE HOLE
DEPTH OF HOLE 30.20 m
DEPTH OF OVERBURDEN 3.00 m
LENGTH OF ROCK DRILLING 27.20 m
TOTAL LENGTH OF CORE 26.58 m
CORE RECOVERY 98.00 %
COMMENCED 25-FEB-'67
COMPLETED 27-FEB-'67
DRILLED BY CHAI (UECC)
LOGGED BY

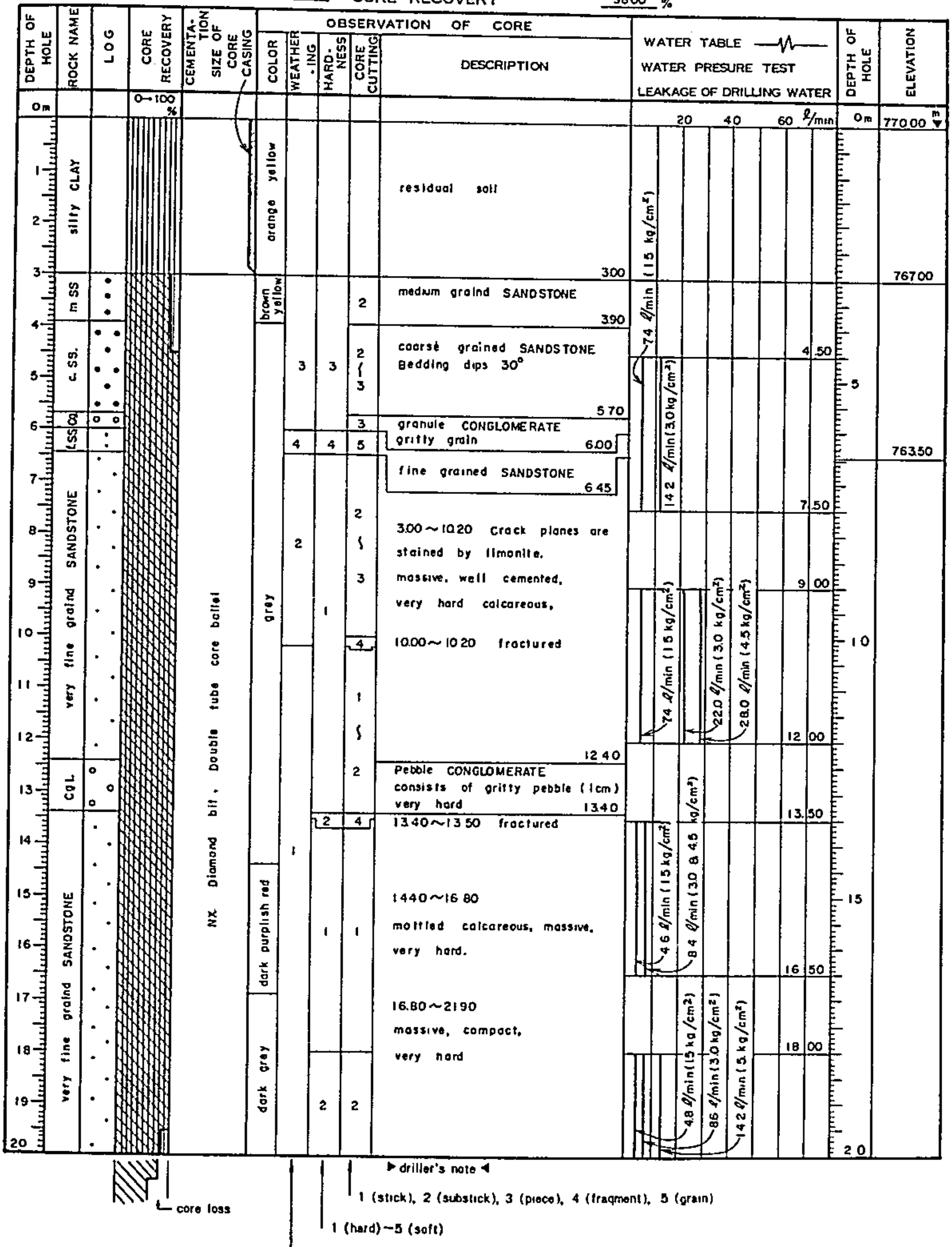

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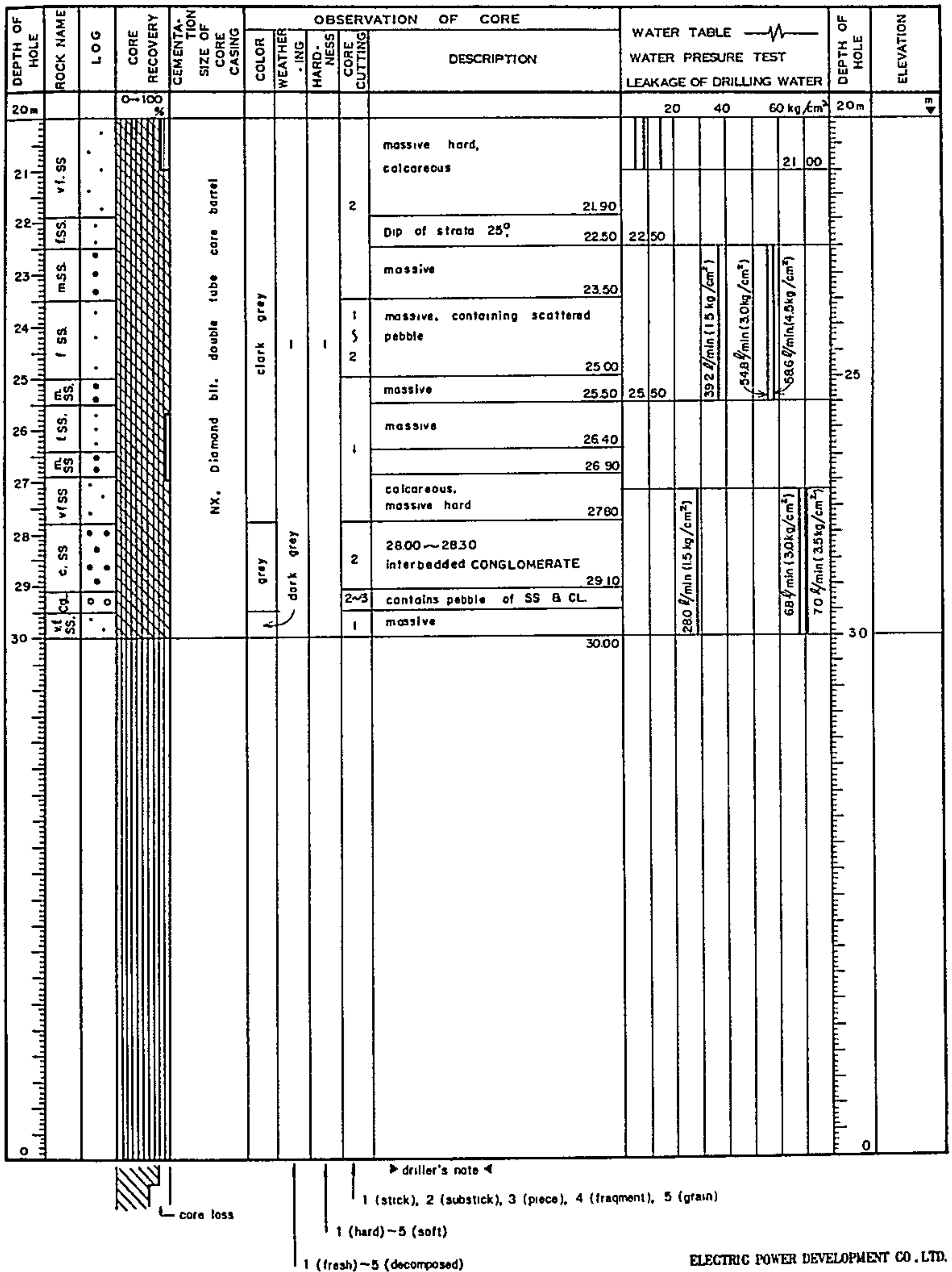
Fig. A6 – 2 GEOLOGIC LOG OF DRILL HOLE

NAM CHERN PROJECT, DAM SITE HOLE NO. D – 1 (SHEET 2 OF 2)

LOCATION	LEFT BANK	DEPTH OF HOLE	30 20 m	COMMENCED	25 –FEB –'67
ELEVATION	770.00 m	DEPTH OF OVERBUPDEN	3 00 m	COMPLETED	27 –FEB. –'67
COORDINATE		LENGTH OF ROCK DRILLING	27 20 m	DRILLED BY	CHAI (UECC)
ANGLE FROM HORIZONTAL	90°	TOTAL LENGTH OF CORE	26.58 m	LOGGED BY	
BEARING OF ANGLE HOLE		CORE RECOVERY	98.00 %		



DESCRIPTION	
massive hard, calcareous	21.90
Dip of strata 25°	22.50
massive	23.50
massive, containing scattered pebble	25.00
massive	25.50
massive	26.40
	26 90
calcareous, massive hard	27.80
28.00 ~ 28.30 interbedded CONGLOMERATE	29.10
contains pebble of SS & CL.	
massive	30.00

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Fig. A6-3 GEOLOGIC LOG OF DRILL HOLE

NAM CHERN PROJECT, DAM SITE HOLE NO. D-2 (SHEET 1 OF 2)

LOCATION RIVER BED
ELEVATION 740 86 m
COORDINATE
ANGLE FROM HORIZONTAL 90 °
BEARING OF ANGLE HOLE

DEPTH OF HOLE 30.20 m
DEPTH OF OVERBURDEN 0 m
LENGTH OF ROCK DRILLING 30 20 m
TOTAL LENGTH OF CORE 30 20 m
CORE RECOVERY 100 %

COMMENCED 14 –MAR– 67
COMPLETED 15 – MAR–'67
DRILLED BY CHAI (UECC)
LOGGED BY

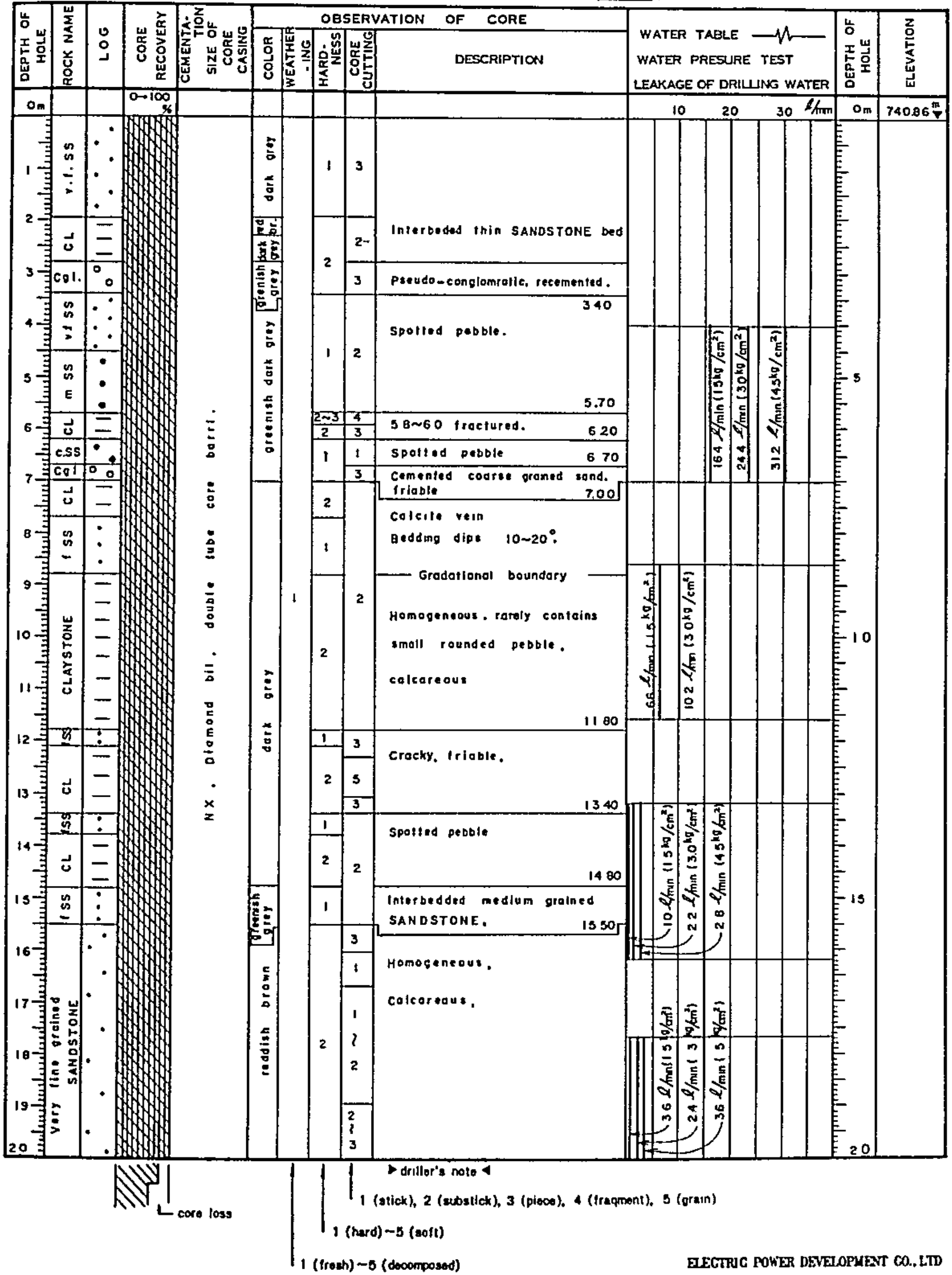

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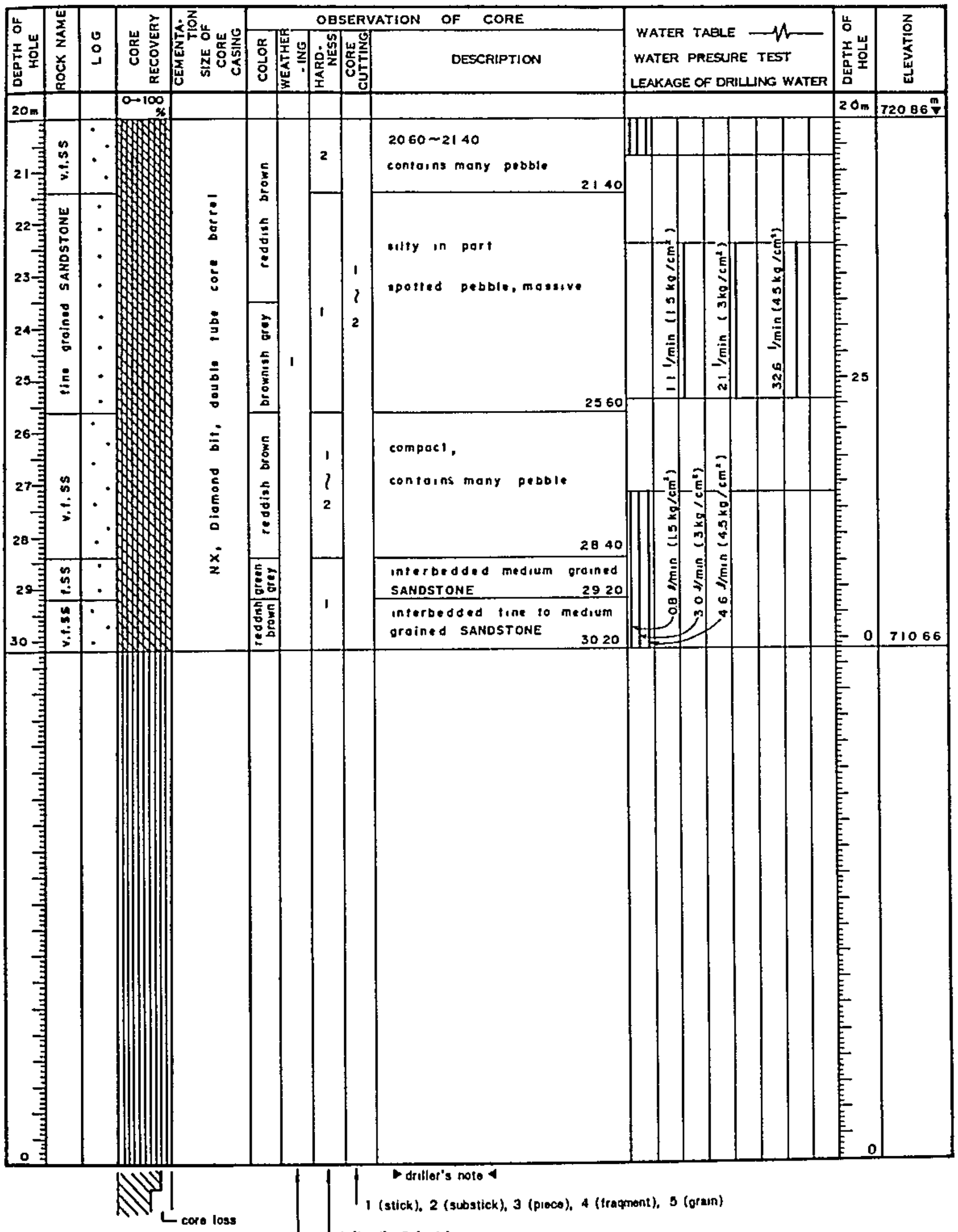
Fig A6-4 GEOLOGIC LOG OF DRILL HOLE

NAM CHERN PROJECT, DAM SITE HOLE NO. D-2 (SHEET 2 OF 2)

LOCATION RIVER BED
ELEVATION ______ m
COORDINATE ______
ANGLE FROM HORIZONTAL 90 °
BEARING OF ANGLE HOLE ______

DEPTH OF HOLE 30 20 m
DEPTH OF OVERBURDEN 0 m
LENGTH OF ROCK DRILLING 30 20 m
TOTAL LENGTH OF CORE 30 20 m
CORE RECOVERY 100 %

COMMENCED 14 –MAR–'67
COMPLETED 15 –MAR–'67
DRILLED BY CHAI (UECC)
LOGGED BY ______



DEPTH OF HOLE	ROCK NAME	LOG	CORE RECOVERY	CEMENTATION SIZE OF CORE CASING	COLOR	WEATHERING	HARDNESS	CORE CUTTING	DESCRIPTION	WATER TABLE / WATER PRESURE TEST / LEAKAGE OF DRILLING WATER	DEPTH OF HOLE	ELEVATION
20m			0→100 %								20m	720 86 m ▼
21	v.f.SS			NX, Diamond bit, double tube core barrel	reddish brown	1	2	1 ~ 2	20 60 ~ 21 40 contains many pebble 21 40			
22–25	fine grained SANDSTONE				reddish brown brownish grey		1		silty in part spotted pebble, massive 25 60	1 1 l/min (1 5 kg/cm²) 2 1 l/min (3kg/cm²) 32 6 l/min (4 5 kg/cm²)	25	
26–28	v.f.SS				reddish brown		1 ~ 2		compact, contains many pebble 28 40	0 8 l/min (1.5 kg/cm²) 3 0 l/min (3kg/cm²) 4 6 l/min (4.5kg/cm²)		
29	f.SS				green grey		1		interbedded medium grained SANDSTONE 29 20			
30	v.f.SS				reddish brown				interbedded fine to medium grained SANDSTONE 30 20		0	710 66
0											0	

core loss

▶ driller's note ◀

1 (stick), 2 (substick), 3 (piece), 4 (fragment), 5 (grain)

1 (hard)~5 (soft)

1 (fresh)~5 (decomposed)

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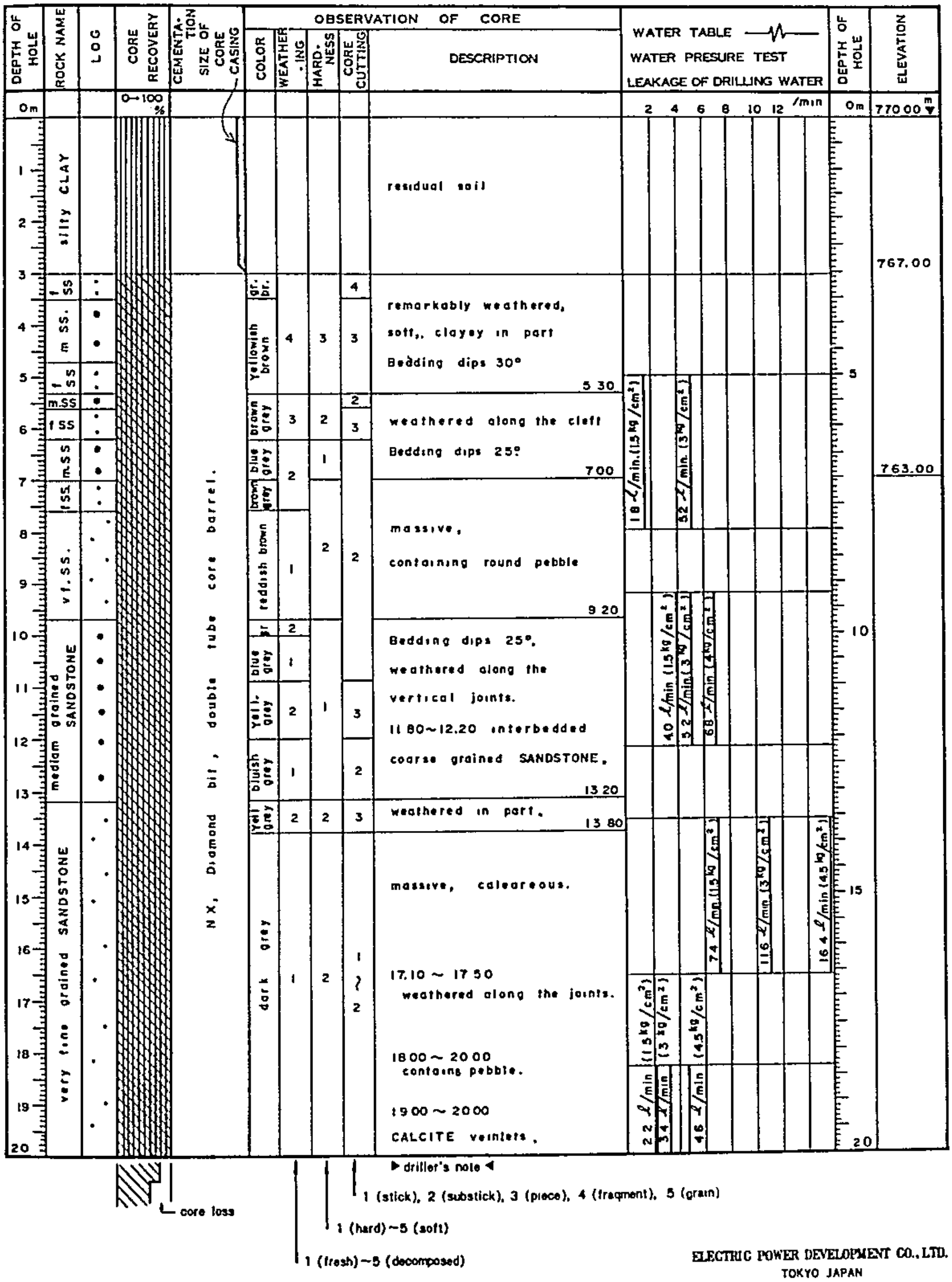
Fig. A6-5 GEOLOGIC LOG OF DRILL HOLE

NAM CHERN PROJECT. DAM SITE HOLE NO. D-3 (SHEET 1 OF 2)

LOCATION RIGHT BANK
ELEVATION 770 00 m
COORDINATE
ANGLE FROM HORIZONTAL 90°
BEARING OF ANGLE HOLE

DEPTH OF HOLE 30 05 m
DEPTH OF OVERBURDEN 3 00 m
LENGTH OF ROCK DRILLING 27.05 m
TOTAL LENGTH OF CORE 27.05 m
CORE RECOVERY 100 %

COMMENCED 18 - MAR - '67
COMPLETED 19 - MAR - '67
DRILLED BY CHAI (UECC)
LOGGED BY



residual soil

remarkably weathered,
soft,, clayey in part
Bedding dips 30°
5 30

weathered along the cleft
Bedding dips 25°
7 00

massive,
containing round pebble
9 20

Bedding dips 25°,
weathered along the vertical joints.
11 80 ~ 12.20 interbedded coarse grained SANDSTONE,
13 20

weathered in part,
13 80

massive, calcareous.

17.10 ~ 17 50
weathered along the joints.

18 00 ~ 20 00
contains pebble.

19 00 ~ 20 00
CALCITE veinlets,

▶ driller's note ◀

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Fig A6-6 GEOLOGIC LOG OF DRILL HOLE

NAM CHERN PROJECT, DAM SITE HOLE NO. D-3 (SHEET 2 OF 2)

LOCATION	RIGHT BANK	DEPTH OF HOLE	30 05 m	COMMENCED	18 – MAR – '67
ELEVATION	770 00 m	DEPTH OF OVERBURDEN	3 00 m	COMPLETED	19 – MAR – '67
COORDINATE		LENGTH OF ROCK DRILLING	27 05 m	DRILLED BY	CHAI (UECC)
ANGLE FROM HORIZONTAL	90°	TOTAL LENGTH OF CORE	2705 m	LOGGED BY	
BEARING OF ANGLE HOLE		CORE RECOVERY	100 %		

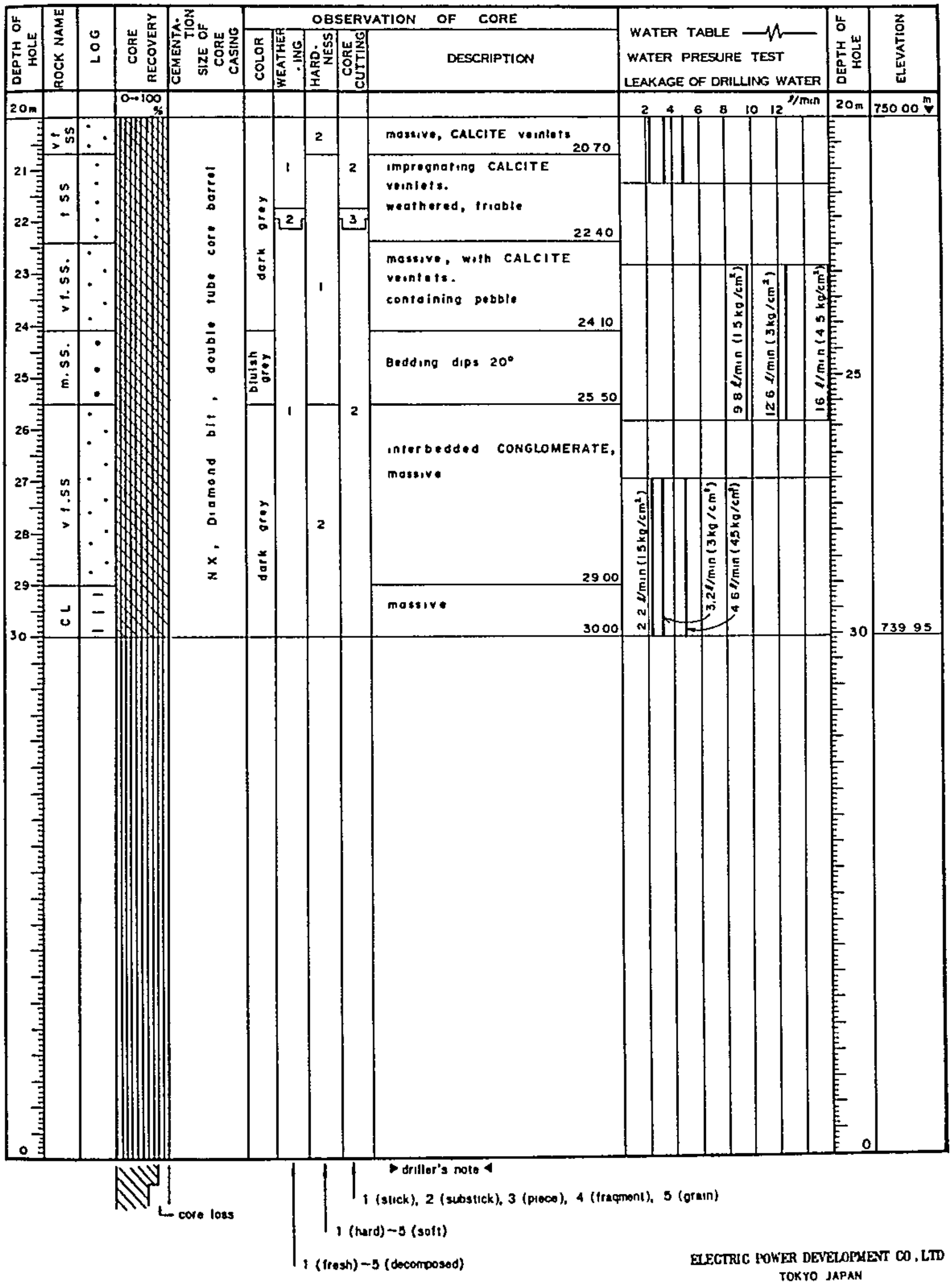

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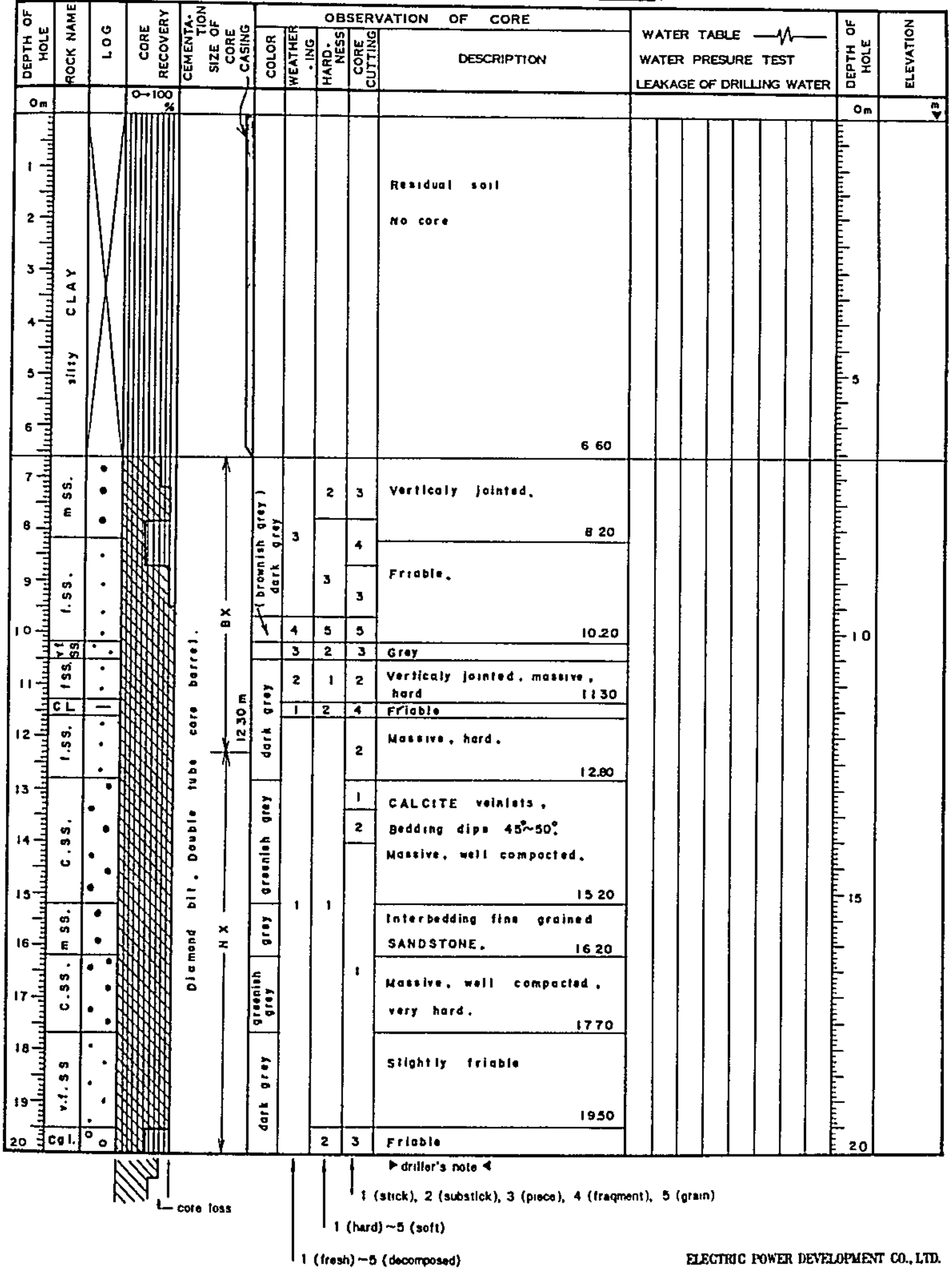
Fig. A6-7 GEOLOGIC LOG OF DRILL HOLE

NAM CHERN PROJECT, RIGHT BANK RIDGE OF RESERVOIR HOLE NO. R-1 (SHEET 1 OF 1)

LOCATION ____
ELEVATION ____ m
COORDINATE ____
ANGLE FROM HORIZONTAL 90 °
BEARING OF ANGLE HOLE ____

DEPTH OF HOLE 20.00 m
DEPTH OF OVERBURDEN 6 60 m
LENGTH OF ROCK DRILLING 13.40 m
TOTAL LENGTH OF CORE 12 28 m
CORE RECOVERY 91 5 %

COMMENCED 23 – MAR – '67
COMPLETED 25 – MAR – '67
DRILLED BY TONG CLANG
LOGGED BY ____



ROCK NAME	COLOR	WEATHER-ING	HARD-NESS	CORE CUTTING	DESCRIPTION
silty CLAY					Residual soil No core 6 60
m SS.	brownish grey dark grey	3	2	3 4	Vertically jointed. 8 20
f.SS.		3 4	3 5	3 5	Friable. 10.20
vf SS		3	2	3	Grey
fSS.	dark grey	2	1	2	Vertically jointed, massive, hard 11 30
CL		1	2	4	Friable
f.SS.	dark grey	1	1	2	Massive, hard. 12.80
C.SS.	greenish grey			1 2	CALCITE veinlets, Bedding dips 45°~50°. Massive, well compacted. 15 20
m SS.	grey				Interbedding fine grained SANDSTONE. 16 20
C.SS.	greenish grey			1	Massive, well compacted, very hard. 17 70
v.f.SS	dark grey				Slightly friable 19 50
Cgl.			2	3	Friable

▶ driller's note ◀

1 (stick), 2 (substick), 3 (piece), 4 (fragment), 5 (grain)

1 (hard) ~ 5 (soft)

1 (fresh) ~ 5 (decomposed)

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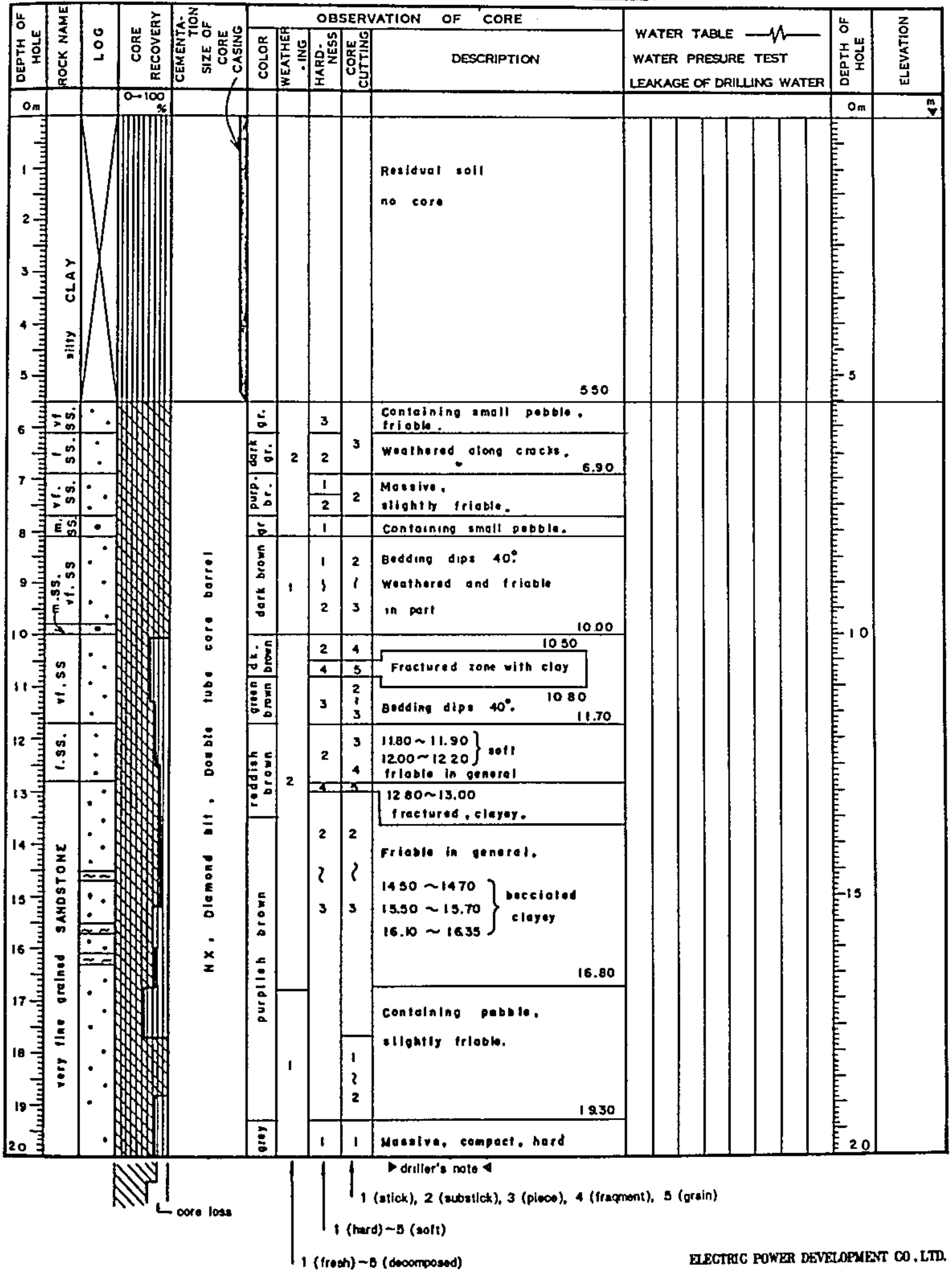
Fig. A6-8 GEOLOGIC LOG OF DRILL HOLE

NAM CHERN PROJECT. RIGHT BANK RIDGE OF RESERVOIR HOLE NO. R-2 (SHEET 1 OF 1)

LOCATION ______ DEPTH OF HOLE 20.00 m COMMENCED 26 -MAR-'67
ELEVATION ______ m DEPTH OF OVERBURDEN 5.50 m COMPLETED 27 -MAR -'67
COORDINATE ______ LENGTH OF ROCK DRILLING 14.50 m DRILLED BY TONG CLANG
ANGLE FROM HORIZONTAL 90 ° TOTAL LENGTH OF CORE 11.82 m LOGGED BY ______
BEARING OF ANGLE HOLE ______ CORE RECOVERY 81.5 %



ROCK NAME	COLOR	WEATHERING	HARDNESS	CORE CUTTING	DESCRIPTION
silty CLAY					Residual soil no core 5.50
vf SS.	gr.	2	3	3	Containing small pebble, friable.
f SS.	dark gr.		2		Weathered along cracks. 6.90
vf. SS.	purp. br.		1 2	2	Massive, slightly friable.
m. SS.	gr.		1		Containing small pebble.
vf. SS m.SS.	dark brown	1	1 ~ 2	2 ~ 3	Bedding dips 40°. Weathered and friable in part 10.00
vf. SS	dk. brown	2	2 4	4 5	10.50 Fractured zone with clay 10.80
	green brown		3	2 ~ 3	Bedding dips 40°. 11.70
f. SS.	reddish brown		2	3 4	11.80 ~ 11.90 } soft 12.00 ~ 12.20 } friable in general
very fine grained SANDSTONE			4	5	12.80 ~ 13.00 fractured, clayey.
	purplish brown		2 ~ 3	2 ~ 3	Friable in general. 14.50 ~ 14.70 } becciated clayey 15.50 ~ 15.70 } 16.10 ~ 16.35 } 16.80
		1		1 ~ 2	Containing pebble, slightly friable. 19.30
	grey		1	1	Massive, compact, hard

▶ driller's note ◀

1 (stick), 2 (substick), 3 (piece), 4 (fragment), 5 (grain)

1 (hard) ~ 5 (soft)

1 (fresh) ~ 5 (decomposed)

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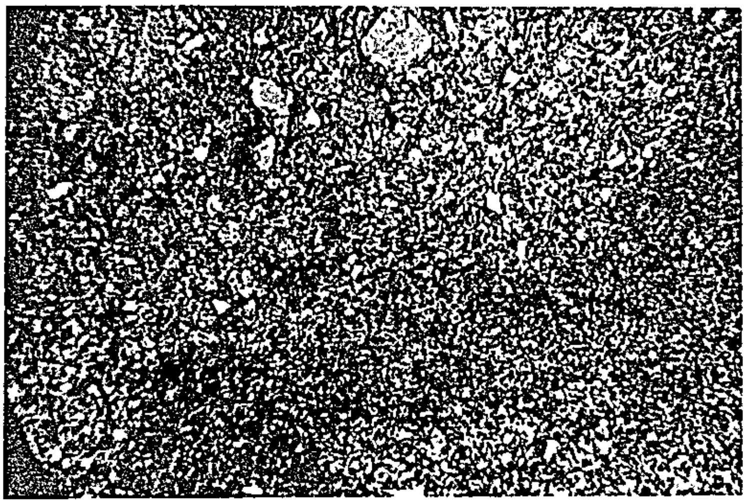
Fig. A6-9 Microphotographs of Rock Section.

No. 1



Calcareous very
fine grained

SANDSTONE

Core of Drill Hole D-1
at the depth of 17.25 m.

Open nicols
x 98.

Grain size is not uniform in general. Finer grains of under 0.01 mm in size mainly consists of calcite. Coarser grains of 0.02 - 0.05 mm in size predsminate quàrty and plagioclase. Microcrystals of chlorite are recognizable.

No. 2

Calcareous very
fine grained

SANDSTONE

Core of Drill Hole D-1
at the depth of 15.10 m.

Open nicols
x 98.

Consists of unsorted grains of calcite, quartz and plagioclase, finer than 0.1 mm in size; impregnating magnetite and containing tourmaline.

Fig. A6-10 Microphotographs of Rock Section.

No. 3

Calcareous fine grained

SANDSTONE

River bed,
at the dam axis.

Open nicols
x 98.

Angular grains (under 0.1 mm) of quartz, calcite, plagioclase, chlorite and magnetite are cemented with clayey minerals.

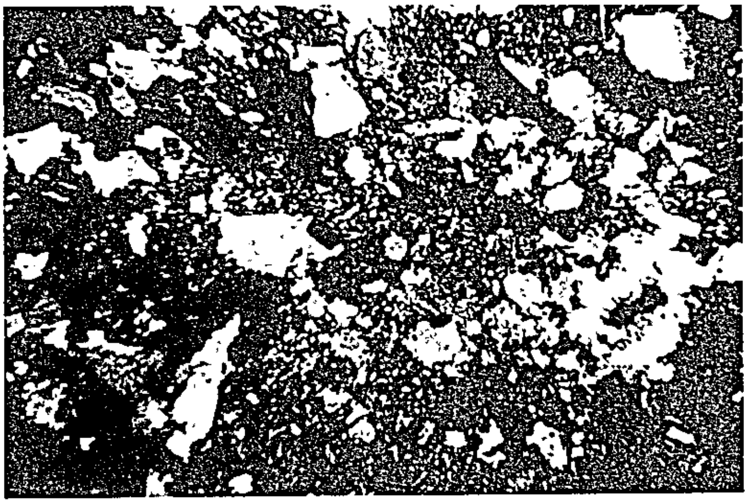
No. 4

Medium grained

SANDSTONE

River bed, 400 m
downstream
from dam axis.

Crossed nicols
x 38.



Mainly consists of anguler grains (0.2 - 0.3 mm) of quartz, calcite, plagioclase and fragments of trachytic rock and felsitic rock.
matrix is composed of fine grains of chlorite, quartz and clayey minerals, containing magnetite and ilmenite.

Table A6-2 Summary of Soil Test Results

Sample No	Depth (m)	(1) Natural Water Content (%)	Classification		Specific Gravity	Atterberg Limits			Gradation			Compaction (2)		Permeability (3)		Shear					
			Revised PR System	Unified System		LL	PL	PI	-4.8 mm (%)	-75 μ (%)	-5 μ (%)	Optimum Water Content (%)	Maximum Dry Density (t/m³)	Water Content (%)	Coefficient of Permeability (cm/sec)	Direct			Triaxial		
																Water Content (%)	Cohesion (kg/cm²)	Coefficient of Internal Friction	Water Content (%)	Cohesion (kg/cm²)	Coefficient of Internal Friction
P 3A	10	18.1	A − 4 (8)	ML	265	329	240	89	985	775	350	153	1824	160	15×10^{-6}	15.5	042	0570	145	161	0510
P 3B	19	22.2	A-7-6(13)	ML	265	470	283	187	920	780	520										
P14A	12	226	A-7-6(13)	ML	–	469	278	191	–	–	–	180	1783	–	–	–	–	–	–	–	–
P14B	26	20.1	A − 6 (8)	ML	–	389	280	109	–	–	–										
P16A	05	298	A-7-5(18)	MH	265	620	377	243	967	878	550	186	1729	221	38×10^{-7}	186	053	0422	182	201	0437
P16B	21	244	A-7-6(12)	ML	267	462	287	175	950	928	415										
P18A	07	257	A-7-5(15)	MH	–	566	367	199	–	–	–	176	1764	–	–	–	–	–	–	–	–
P18B	2.1	255	A − 4 (8)	CL	271	54.7	251	96	998	890	26.5										
P 12	09	–	A-2-4(0)	SM	–	–	–	–	959	312	–	–	–	–	–	–	–	–	–	–	–
P 21	02 ~ 29	–	A − 4 (2)	SM	–	–	–	–	100 0	460	390	–	–	–	–	–	–	–	–	–	–

NOTE (1) Samples picked up at the site were sent to Bangkok kept in plastic sacks and tested in Chulalongkorn University

(2) Samples were dried by oven before the test Consequently, test results are considered to give smaller values for maximum water content and larger values for maximum dry density than their respective values which shall be obtained from samples in natural condition

(3) Coefficient of permeability was computed by utilizing consolidation test

(Others) Sample A picked up from the upper part of the pit and sample B picked up from the lower part of the pit were mixed for compaction permeability and shear tests

Table A6-3 Summary of Rock Test Results

Sample No.	Rock Name	Specific Gravity	Water Absorption (%)	Abrasion (Los Angeles) (%)
A 1	Sandstone	2.691	0.87	19 9
Q 2	Sandstone	2 655	1.58	24.8
Q 3	Sandstone	2 697	0.89	21.1

Notes :

1. Locality of sampling

   Sample A 1 was taken from an outcrop.

   Samples Q 2 and Q 3 were taken from drill cores.

   The localities of sampling are shown in Fig. 6-2

2. Abrasion test

   The number of revolutions of Los Angeles machine was 500.

Fig. A6-II Logs of Test Pits (1-2)

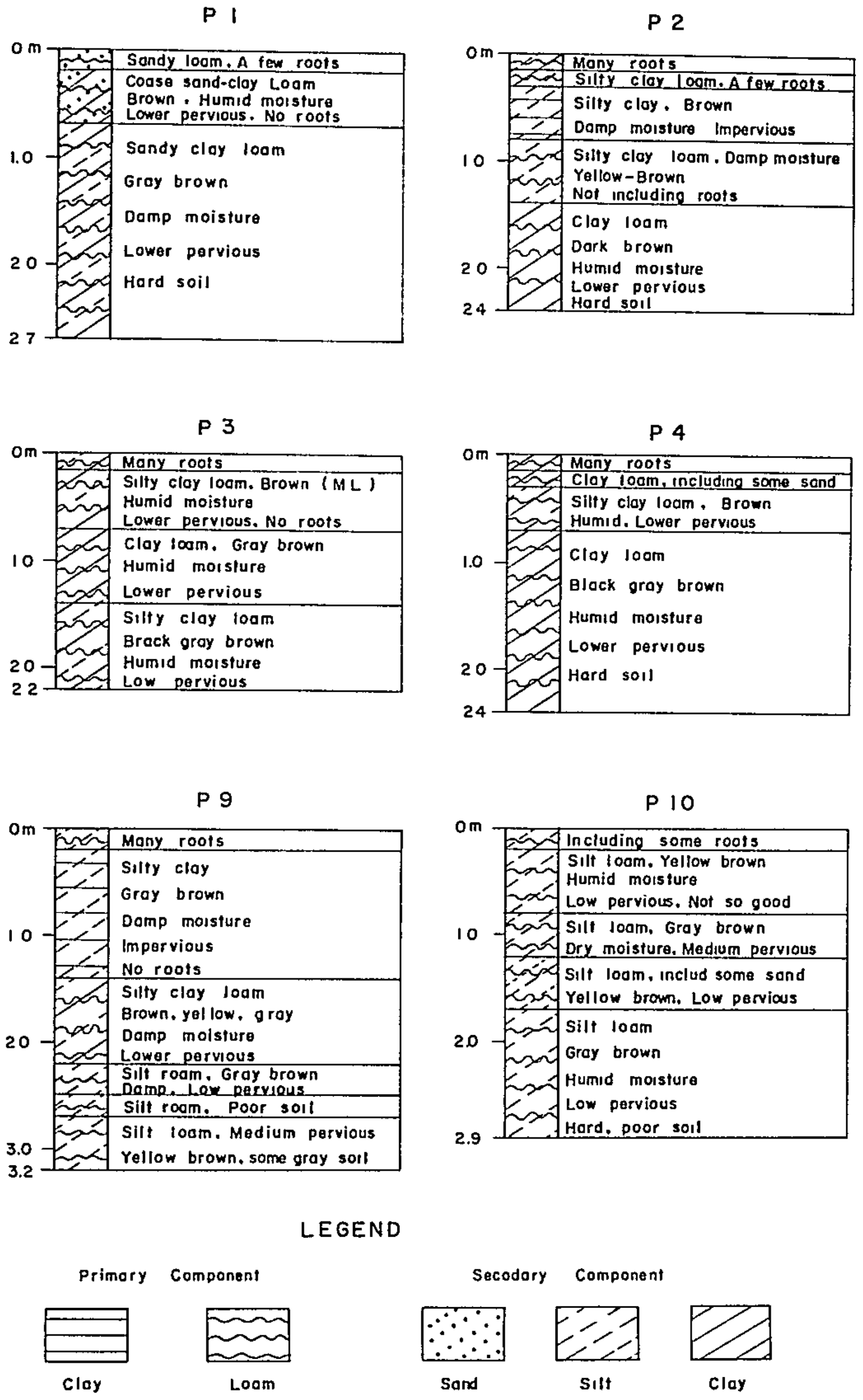
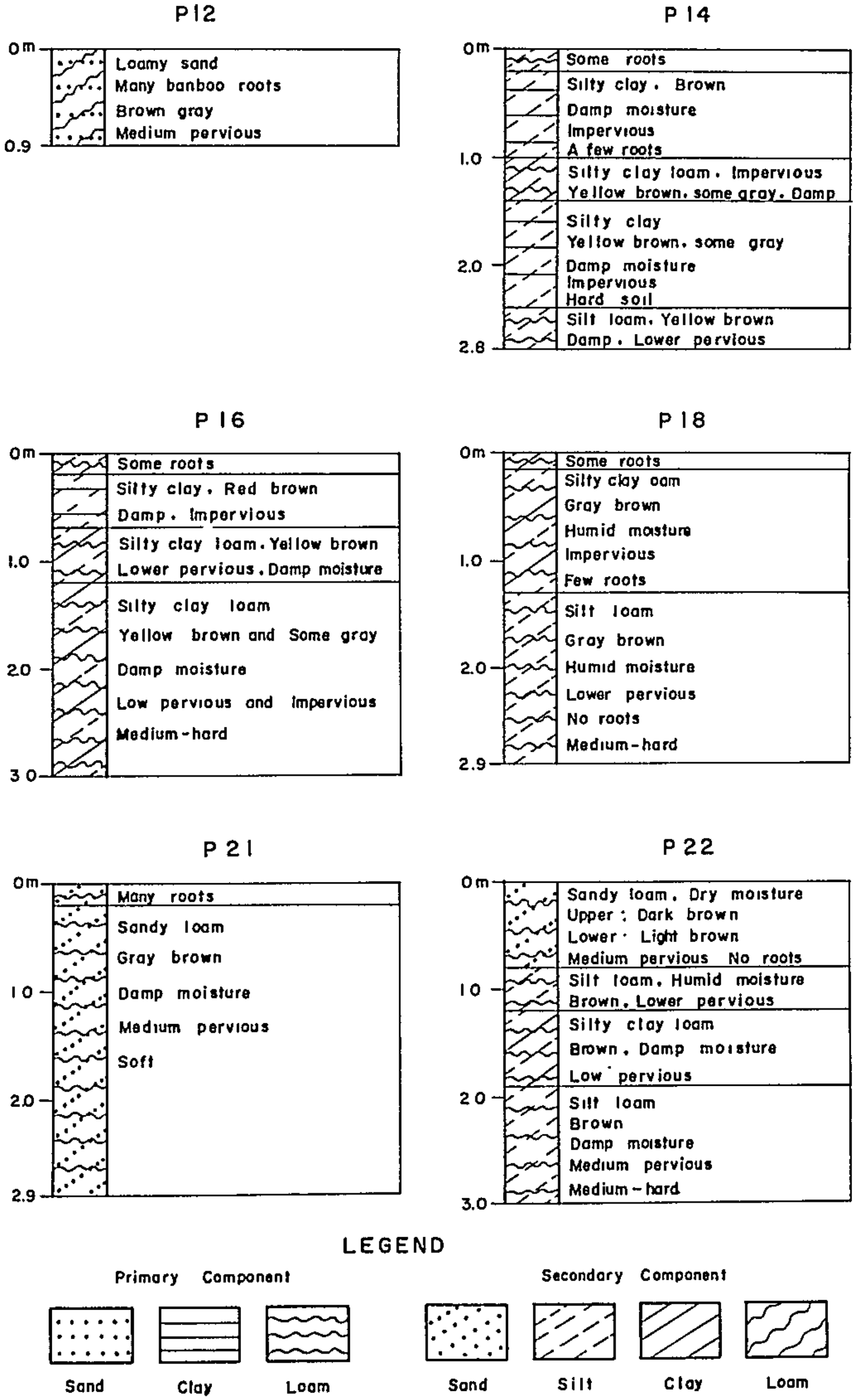


Fig. A6-12 Logs of Test Pits (2-2)



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Fig, A6-13 GEOLOGIC LOG OF DRILL HOLE

NAM CHERN PROJECT, QUARRY AREA-A, HOLE NO. Q-1 (SHEET 1 OF 2)

LOCATION ________

ELEVATION ________ m

COORDINATE ________

ANGLE FROM HORIZONTAL 90°

BEARING OF ANGLE HOLE ________

DEPTH OF HOLE 30 00 m

DEPTH OF OVERBURDEN 3 00 m

LENGTH OF ROCK DRILLING 27 00 m

TOTAL LENGTH OF CORE 26 08 m

CORE RECOVERY 97 %

COMMENCED 10 –MAR–'67

COMPLETED 12 –MAR–'67

DRILLED BY CHAI (UECC)

LOGGED BY ________

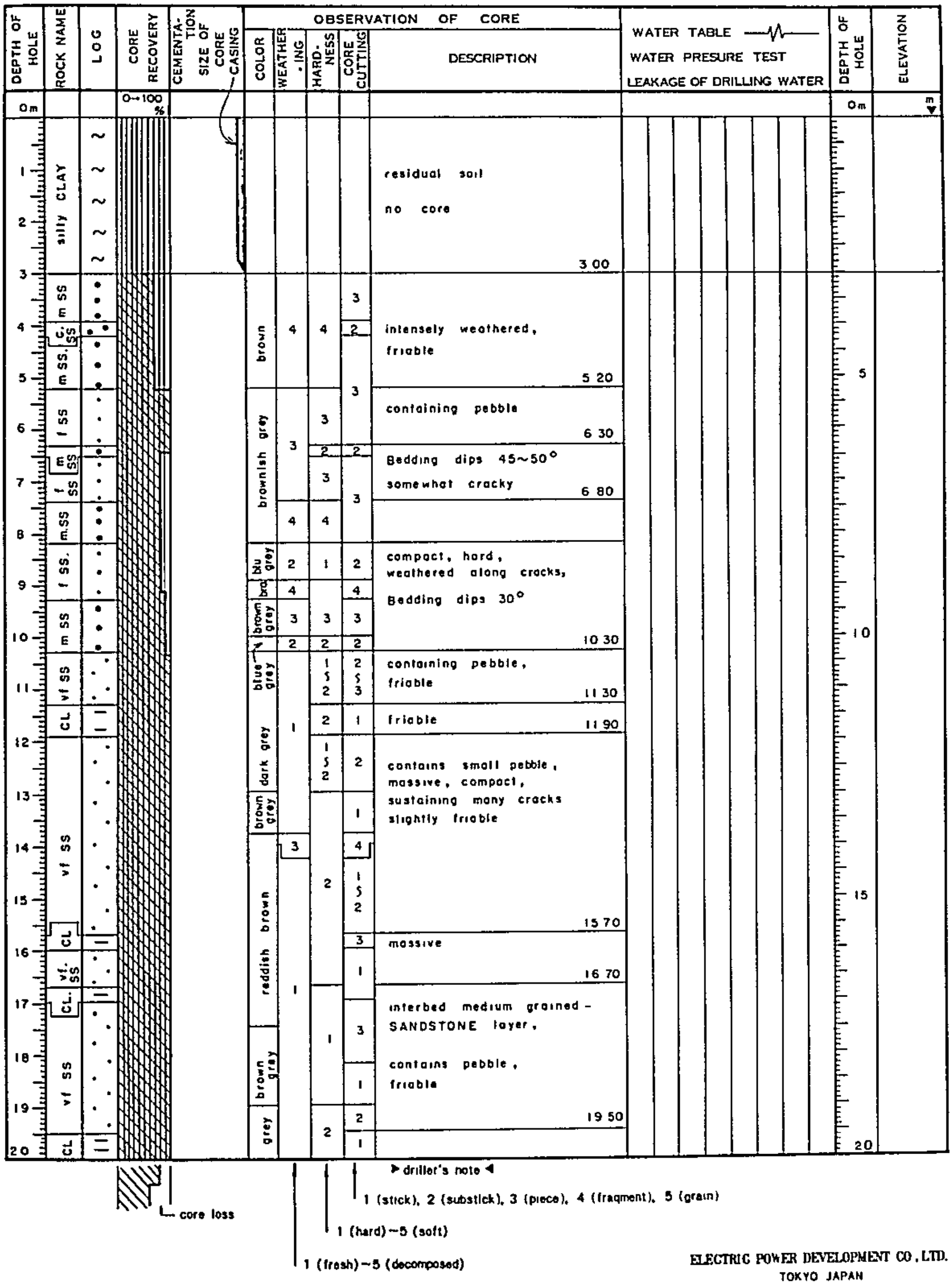

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Fig. A6-14 GEOLOGIC LOG OF DRILL HOLE

NAM CHERN PROJECT, QUARRY AREA-A, HOLE NO. Q-1 (SHEET 2 OF 2)

LOCATION ______
ELEVATION ______ m
COORDINATE ______
ANGLE FROM HORIZONTAL 90°
BEARING OF ANGLE HOLE ______

DEPTH OF HOLE 30.00 m
DEPTH OF OVERBURDEN 3.00 m
LENGTH OF ROCK DRILLING 27.00 m
TOTAL LENGTH OF CORE 26.08 m
CORE RECOVERY 97 %

COMMENCED 10-MAR-'67
COMPLETED 12-MAR-'67
DRILLED BY CHAI (UECC)
LOGGED BY ______

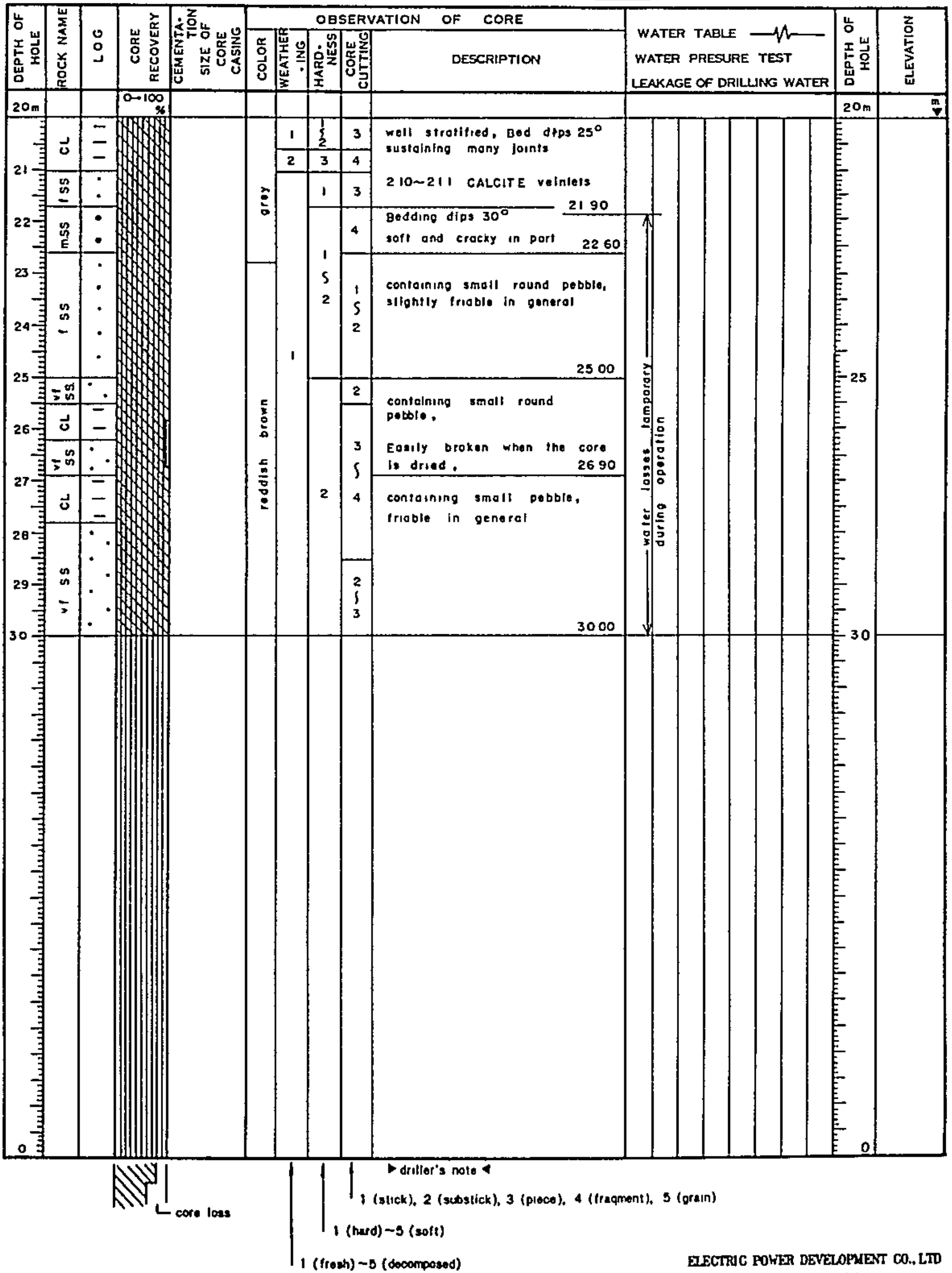

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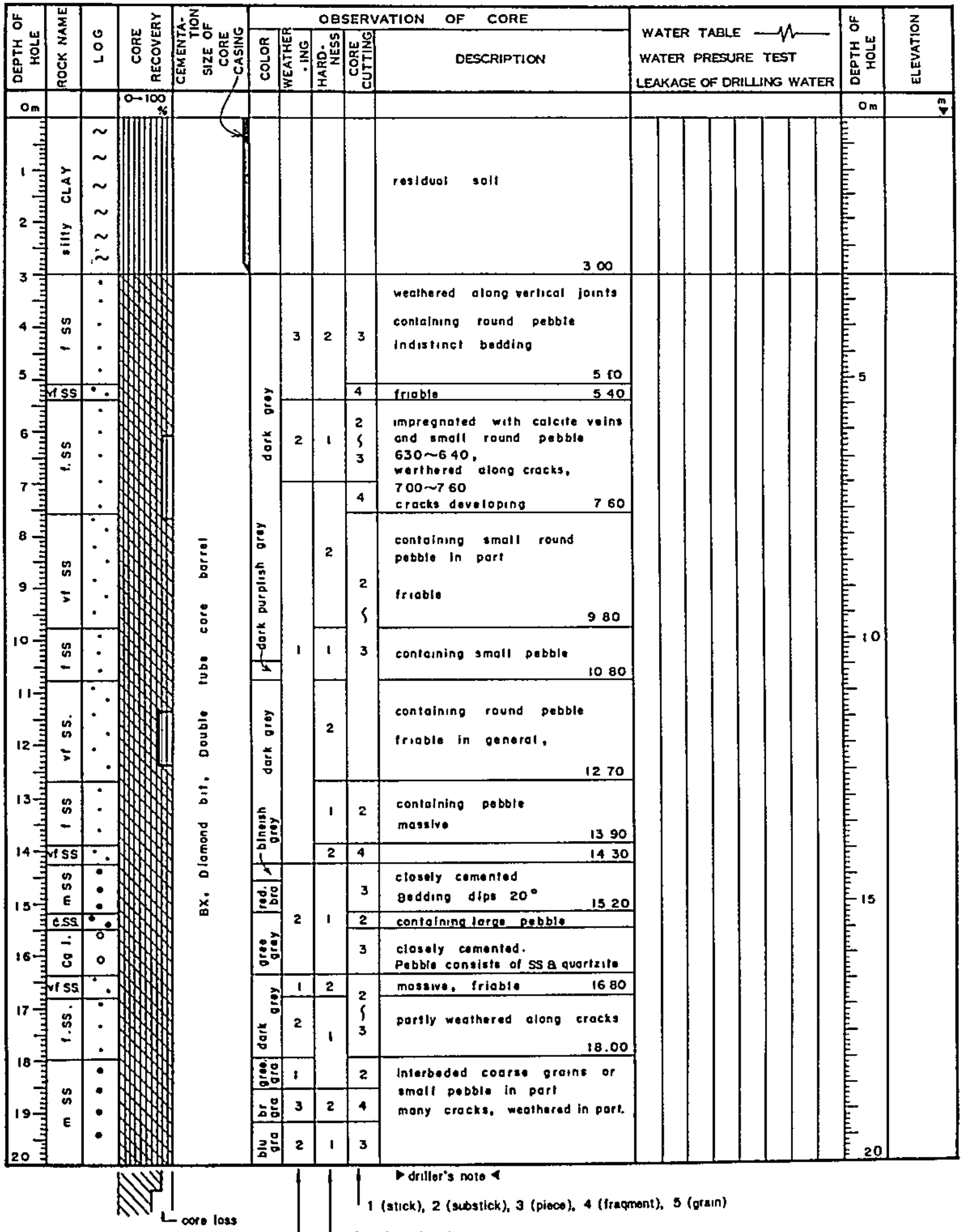
Fig. A6-15 GEOLOGIC LOG OF DRILL HOLE

NAM CHERN PROJECT, QUARRY AREA-C, HOLE NO. Q-2 (SHEET 1 OF 2)

LOCATION		DEPTH OF HOLE	30.05 m	COMMENCED	6 – MAR – '67
ELEVATION	m	DEPTH OF OVERBURDEN	3.00 m	COMPLETED	9 – MAR – '67
COORDINATE		LENGTH OF ROCK DRILLING	27.05 m	DRILLED BY	CHAT (UECC)
ANGLE FROM HORIZONTAL	90°	TOTAL LENGTH OF CORE	26.65 m	LOGGED BY	
BEARING OF ANGLE HOLE		CORE RECOVERY	98.5 %		



ROCK NAME	SIZE OF CORE CASING	COLOR	WEATHERING	HARDNESS	CORE CUTTING	DESCRIPTION
silty CLAY						residual soil 3.00
f SS	BX, Diamond bit, Double tube core barrel	dark grey	3	2	3	weathered along vertical joints containing round pebble indistinct bedding 5.10
vf SS					4	friable 5.40
f. SS			2	1	2 ~ 3	impregnated with calcite veins and small round pebble 630~640, werthered along cracks, 700~760
			1	2	4	cracks developing 7.60
vf SS		dark purplish grey			2 ~ 3	containing small round pebble in part friable 9.80
f SS		dark		1		containing small pebble 10.80
vf SS.		dark grey		2		containing round pebble friable in general, 12.70
f SS		blueish grey		1	2	containing pebble massive 13.90
vf SS				2	4	14.30
m SS		red. bro	2	1	3	closely cemented Bedding dips 20° 15.20
c.SS		gree grey			2	containing large pebble
Cg l.					3	closely cemented. Pebble consists of SS & quartzite
vf SS		dark grey	1	2	2 ~ 3	massive, friable 16.80
f. SS.			2	1		partly weathered along cracks 18.00
m SS		gree. gra	1		2	Interbeded coarse grains or small pebble in part many cracks, weathered in part.
		br gra	3	2	4	
		blu gra	2	1	3	

▶ driller's note ◀

CORE CUTTING: 1 (stick), 2 (substick), 3 (piece), 4 (fragment), 5 (grain)

HARDNESS: 1 (hard) ~ 5 (soft)

WEATHERING: 1 (fresh) ~ 5 (decomposed)

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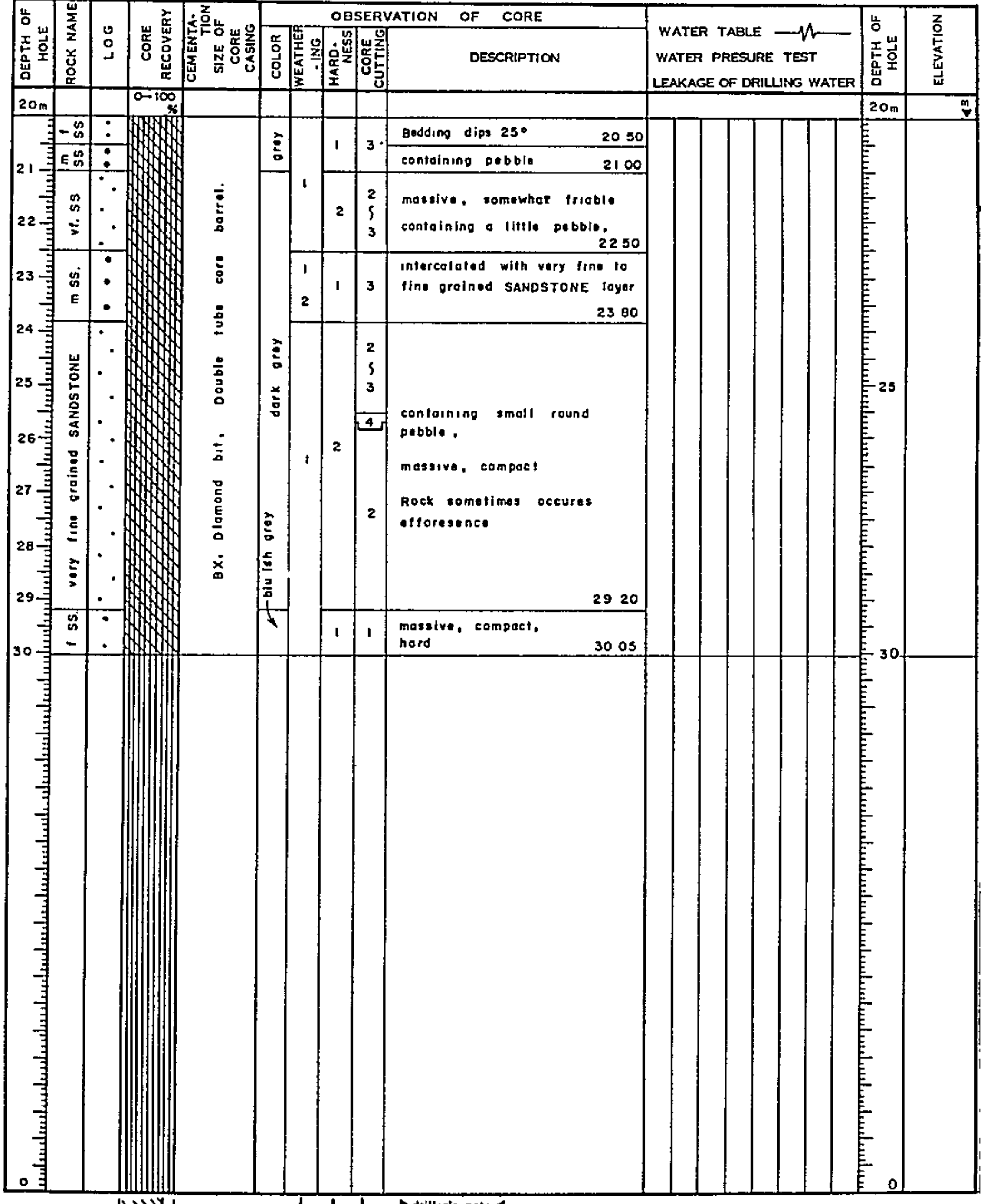
Fig. A6-16 GEOLOGIC LOG OF DRILL HOLE

NAM CHERN PROJECT, QUARRY AREA-C, HOLE NO. Q-2 (SHEET 2 OF 2)

LOCATION ________
ELEVATION ________ m
COORDINATE ________
ANGLE FROM HORIZONTAL 90°
BEARING OF ANGLE HOLE ________

DEPTH OF HOLE 30 05 m
DEPTH OF OVERBURDEN 3 00 m
LENGTH OF ROCK DRILLING 27 05 m
TOTAL LENGTH OF CORE 26 65 m
CORE RECOVERY 98 5 %

COMMENCED 6 – MAR – '67
COMPLETED 9 – MAR – '67
DRILLED BY CHAI (UECC)
LOGGED BY ________



DEPTH OF HOLE	ROCK NAME	LOG	CORE RECOVERY (0→100 %)	CEMENTATION SIZE OF CORE CASING	COLOR	WEATHERING	HARDNESS	CORE CUTTING	DESCRIPTION	WATER TABLE / WATER PRESURE TEST / LEAKAGE OF DRILLING WATER	DEPTH OF HOLE	ELEVATION m
20m	f SS			BX, Diamond bit, Double tube core barrel.	grey	1	1	3	Bedding dips 25° 20 50		20m	
21	m SS								containing pebble 21 00			
22	vf. SS				dark grey		2	2 ∫ 3	massive, somewhat friable containing a little pebble, 22 50			
23	m SS.					1 2	1	3	intercalated with very fine to fine grained SANDSTONE layer 23 80			
24 25 26 27 28 29	very fine grained SANDSTONE				bluish grey	1	2	2 ∫ 3 4 2	containing small round pebble, massive, compact Rock sometimes occures efforesence 29 20		25	
30	f SS.						1	1	massive, compact, hard 30 05		30	
0											0	

core loss

▶ driller's note ◀

1 (stick), 2 (substick), 3 (piece), 4 (fragment), 5 (grain)

1 (hard) ~ 5 (soft)

1 (fresh) ~ 5 (decomposed)

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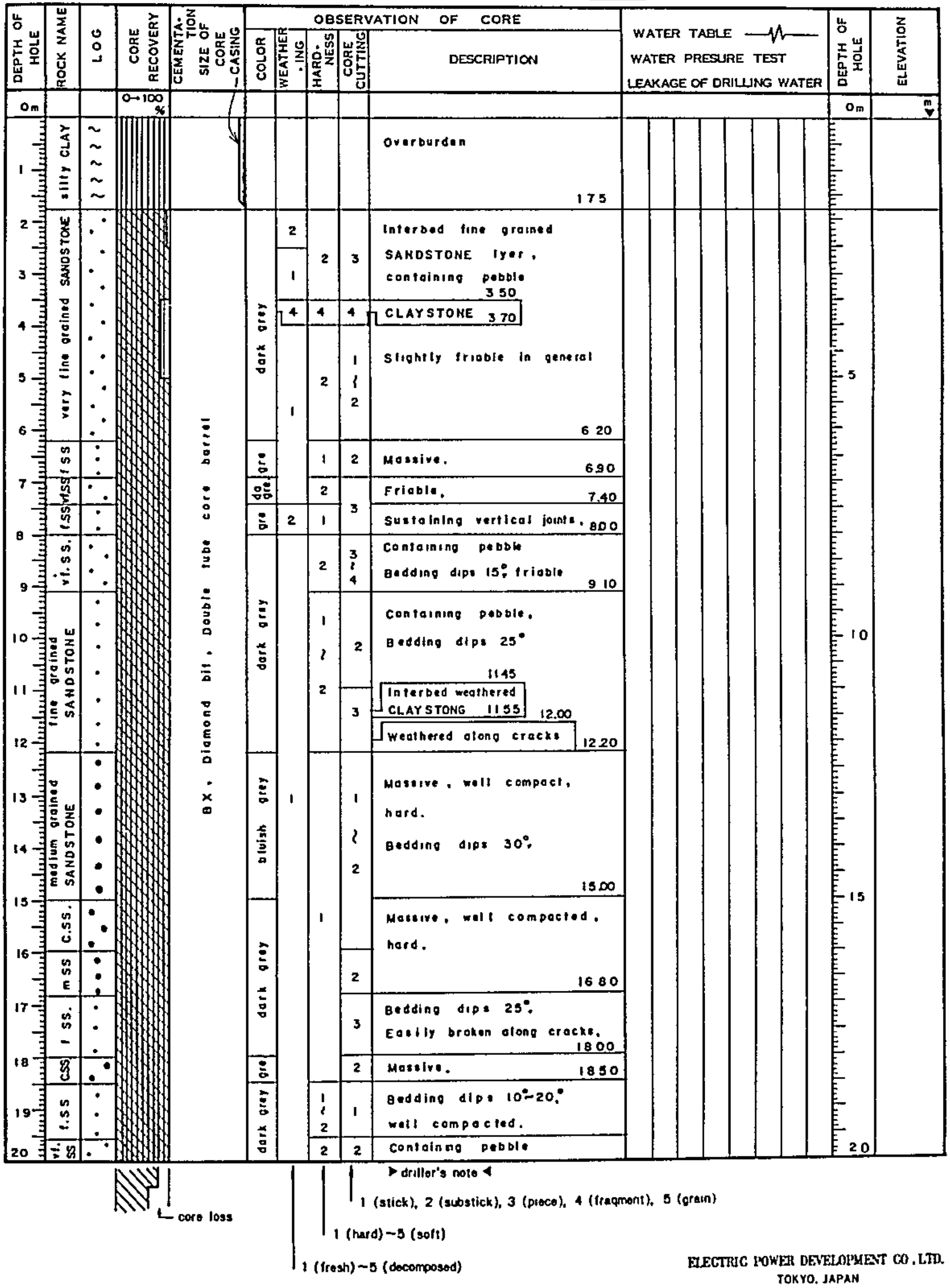
Fig.A6-17 GEOLOGIC LOG OF DRILL HOLE

NAM CHERN PROJECT, QUARRY, AREA-C HOLE NO. Q-3 (SHEET 1 OF 2)

LOCATION ______
ELEVATION ______ m
COORDINATE ______
ANGLE FROM HORIZONTAL 90 °
BEARING OF ANGLE HOLE ______

DEPTH OF HOLE 3006 m
DEPTH OF OVERBURDEN 175 m
LENGTH OF ROCK DRILLING 2831 m
TOTAL LENGTH OF CORE 2796 m
CORE RECOVERY 99 %

COMMENCED 2 -MAR-'67
COMPLETED 5 -MAR-'67
DRILLED BY CHAI (UECC)
LOGGED BY ______



Rock name	Color	Weather-ing	Hard-ness	Core cutting	Description
silty CLAY					Overburden 175
very fine grained SANDSTONE	dark grey	2 1	2	3	Interbed fine grained SANDSTONE lyer, containing pebble 3 50
		4	4	4	CLAYSTONE 3 70
		1	2	1 ~ 2	Slightly friable in general 6 20
f ss	gre		1	2	Massive. 690
vf.SS	da gre		2	3	Friable. 7.40
f.SS	gre	2	1		Sustaining vertical joints. 800
vf.SS.	dark grey		2	3 ~ 4	Containing pebble Bedding dips 15°, friable 9 10
fine grained SANDSTONE	dark grey		1 ~ 2	2	Containing pebble, Bedding dips 25° 1145
				3	Interbed weathered CLAYSTONG 1155 12.00
					Weathered along cracks 12.20
medium grained SANDSTONE	bluish grey	1		1 ~ 2	Massive, well compact, hard. Bedding dips 30°. 15.00
C.SS.	dark grey		1		Massive, well compacted, hard.
m SS				2	16 80
f SS.				3	Bedding dips 25°. Easily broken along cracks. 18 00
CSS	gre			2	Massive. 1850
f.SS	dark grey		1 ~ 2	1	Bedding dips 10°~20°, well compacted.
vf. SS			2	2	Containing pebble

Depth of hole: 0 m – 20 m (scale 5, 10, 15, 20)

▶ driller's note ◀

1 (stick), 2 (substick), 3 (piece), 4 (fragment), 5 (grain)

1 (hard) ~ 5 (soft)

1 (fresh) ~ 5 (decomposed)

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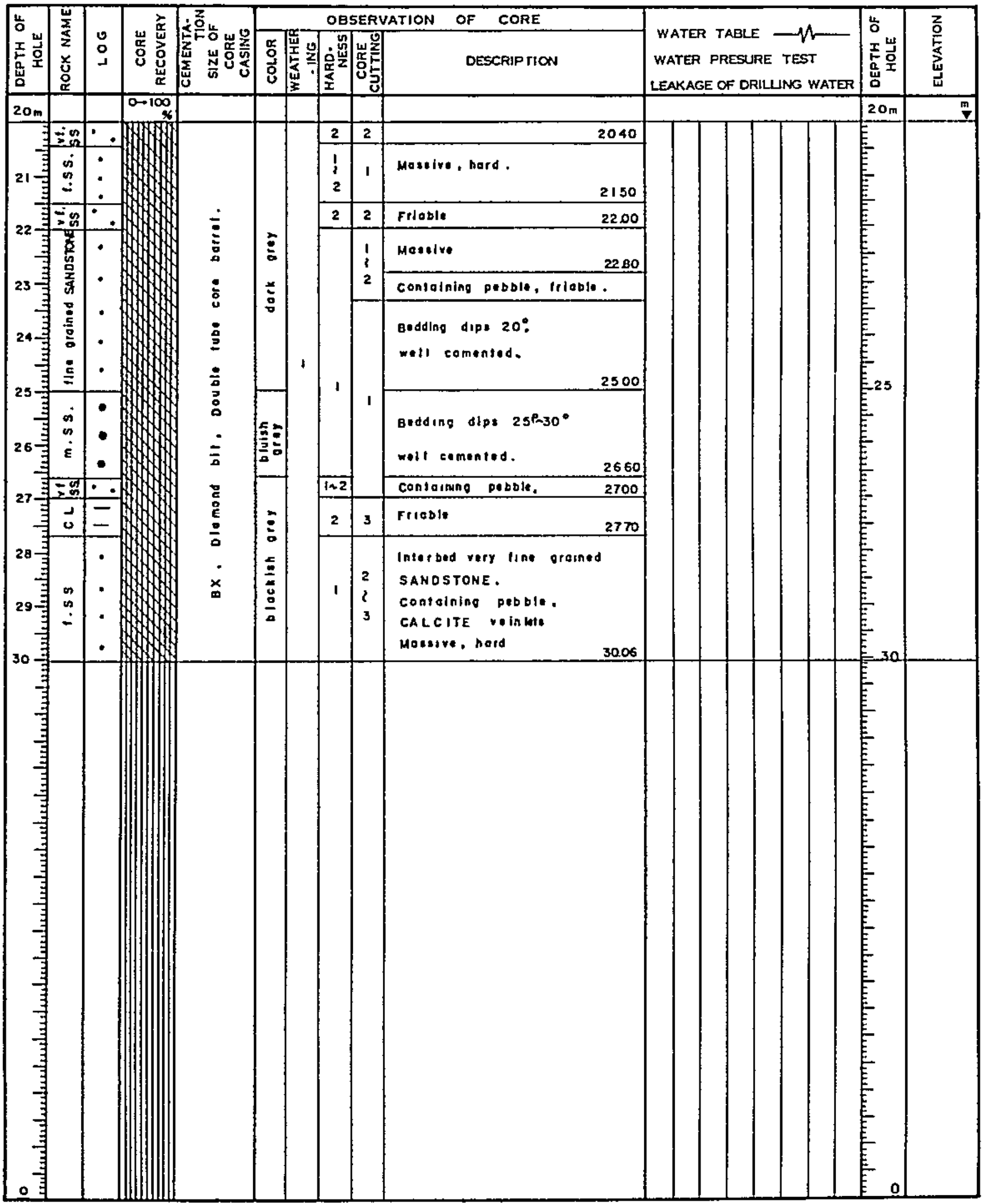
Fig. A6-18 GEOLOGIC LOG OF DRILL HOLE

NAM CHERN PROJECT, QUARRY AREA-C, HOLE NO. Q-3 (SHEET 2 OF 2)

LOCATION ______
ELEVATION ______ m
COORDINATE ______
ANGLE FROM HORIZONTAL 90 °
BEARING OF ANGLE HOLE ______
DEPTH OF HOLE 30.06 m
DEPTH OF OVERBURDEN 1.75 m
LENGTH OF ROCK DRILLING 28.31 m
TOTAL LENGTH OF CORE 27.96 m
CORE RECOVERY 99 %
COMMENCED 2-MAR-'67
COMPLETED 5-MAR-'67
DRILLED BY CHAI (UECC)
LOGGED BY ______



DEPTH OF HOLE	ROCK NAME	CORE RECOVERY	CEMENTATION SIZE OF CORE CASING	COLOR	WEATHERING	HARDNESS	CORE CUTTING	DESCRIPTION
20m		0→100 %						
	vf. SS		BX, Diamond bit, Double tube core barrel.	dark grey	1	2	2	20.40
21	f.s.s.					1~2	1	Massive, hard. 21.50
	vf. SS					2	2	Friable 22.00
22, 23, 24	fine grained SANDSTONE					1	1~2	Massive 22.80
								Containing pebble, friable.
							1	Bedding dips 20°, well cemented. 25.00
25, 26	m.s.s.			bluish grey				Bedding dips 25°~30° well cemented. 26.60
	vf SS			blackish grey		1~2		Containing pebble, 27.00
27	CL					2	3	Friable 27.70
28, 29, 30	f.ss					1	2~3	Interbed very fine grained SANDSTONE. Containing pebble. CALCITE veinlets Massive, hard 30.06

WATER TABLE
WATER PRESURE TEST
LEAKAGE OF DRILLING WATER

DEPTH OF HOLE: 20m, 25, 30, 0
ELEVATION: m

core loss

▶ driller's note ◀
1 (stick), 2 (substick), 3 (piece), 4 (fragment), 5 (grain)
1 (hard) ~ 5 (soft)
1 (fresh) ~ 5 (decomposed)

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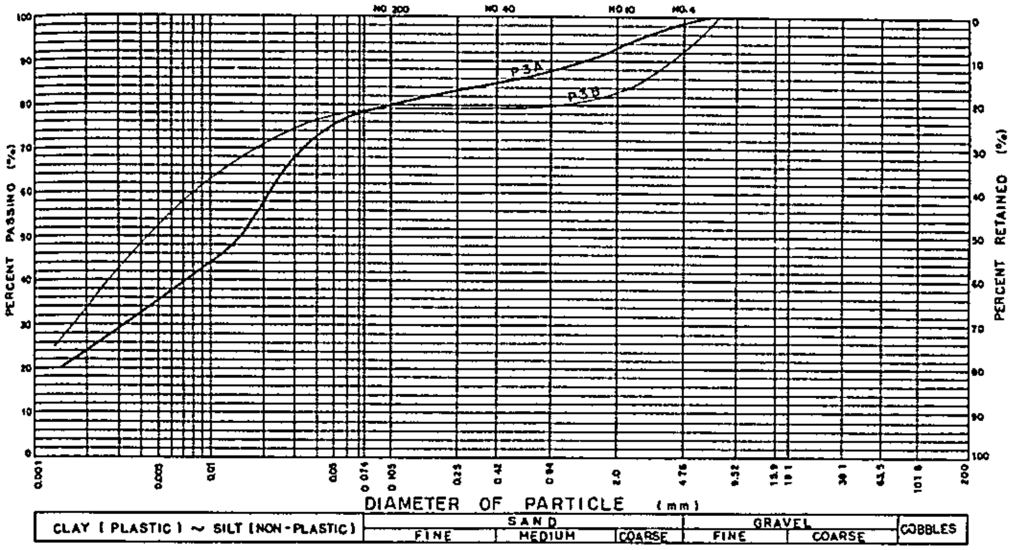
Fig A6-19 Gradation Analysis Curve



SAMPLE NO	P3A	P3B
MAX GRAIN SIZE	8	8
mm (%)		
mm (%)		
4.8 mm (%)	98 5	92 0
0.075 mm (%)	77 5	78 0
D_{60} (mm)	00083	0 022
D_{30} (mm)	00017	00034
D_{10} (mm)	–	–
C_u	–	–
C_c	–	–

$C_u = \frac{D_{60}}{D_{10}}$

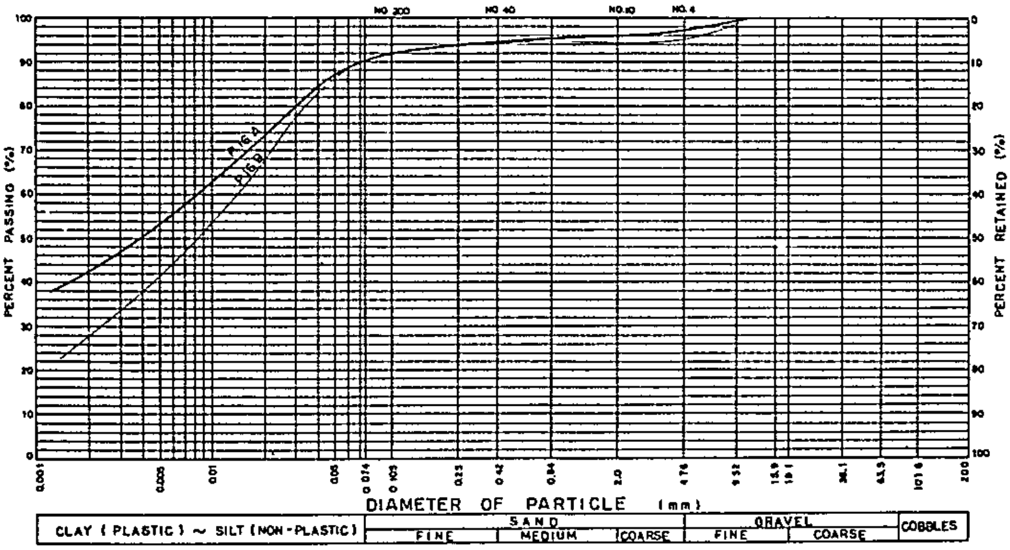
$C_c = \frac{(D_{30})^2}{(D_{60}) \times (D_{10})}$

C_u : COEFFICIENT OF UNIFORMITY

C_c COEFFICIENT OF CURVATURE

SAMPLE NO.	SAMPLE DEPTH (m)	SOIL CLASSIFICATION		SPECIFIC SYSTEM		ATTERBERG LIMITS			
		UNIFIED SYSTEM	REVISED P R SYSTEM	+ mm	− 2 mm	LL	PL	PI	SL
P 3 A	1.0	M L	A-4 (8)		2 65	32 9	24 0	8 9	
P 3 B	1.9	M L	A-7-6 (13)		2 65	47 0	28 3	18 7	

Fig A6-20 Gradation Analysis Curve



SAMPLE NO	P16A	P16B
MAX GRAIN SIZE	10	10
mm (%)		
mm (%)		
4.8 mm (%)	97 0	95 0
0.075 mm (%)	90 0	90 0
D_{60} (mm)	0083	0014
D_{30} (mm)	–	0 0024
D_{10} (mm)	–	–
C_u	–	–
C_c	–	–

$C_u = \frac{D_{60}}{D_{10}}$

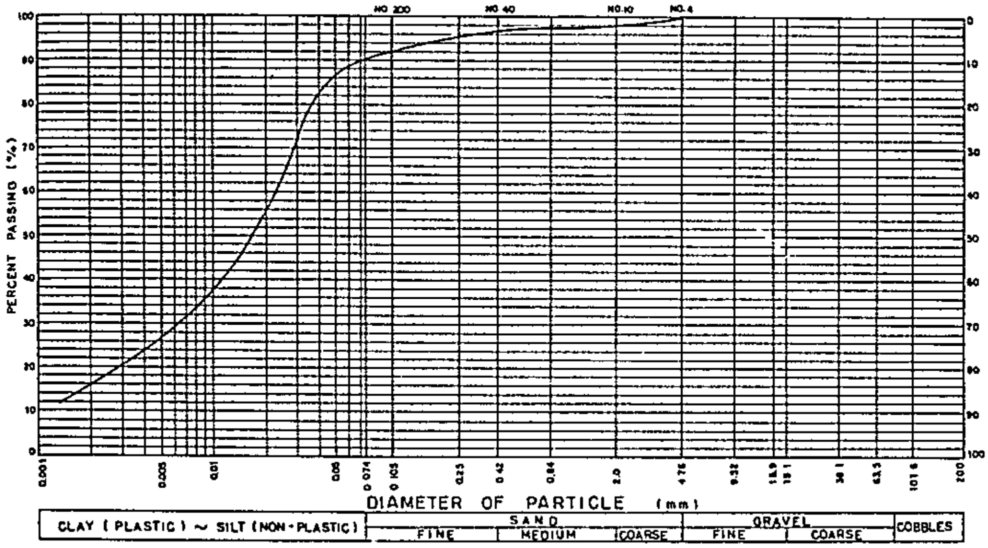
$C_c = \frac{(D_{30})^2}{(D_{60}) \times (D_{10})}$

C_u : COEFFICIENT OF UNIFORMITY

C_c . COEFFICIENT OF CURVATURE

SAMPLE NO.	SAMPLE DEPTH (m)	SOIL CLASSIFICATION		SPECIFIC SYSTEM		ATTERBERG LIMITS			
		UNIFIED SYSTEM	REVISED P R SYSTEM	+ mm	− 2 mm	LL	PL	PI	SL
P 16 A	0 5	MH	A-7-5 (18)		2 65	62 0	37 7	24 3	
P 16 B	2 1	ML	A-7-6 (12)		2 67	46 2	28 7	17 5	

Fig A6-21 Gradation Analysis Curve



SAMPLE NO	P188	
MAX GRAIN SIZE	5	
mm (%)		
mm (%)		
4.8 mm (%)	100 0	
0.075 mm (%)	90 0	
D_{60} (mm)	0 023	
D_{30} (mm)	0 0064	
D_{10} (mm)	–	
C_u	–	
C_c	–	

$$C_u = \frac{D_{60}}{D_{10}}$$

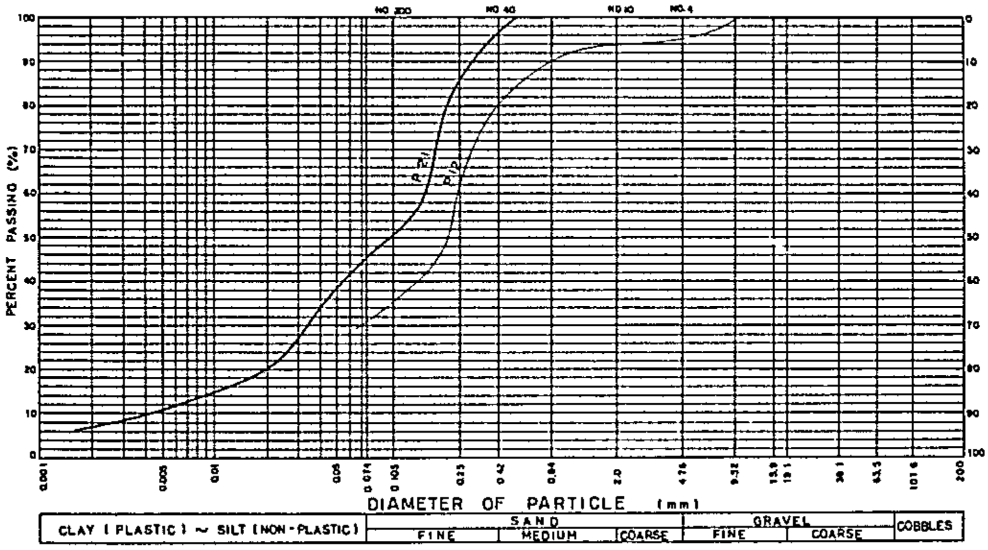
$$C_c = \frac{(D_{30})^2}{(D_{60}) \times (D_{10})}$$

C_u : COEFFICIENT OF UNIFORMITY

C_c : COEFFICIENT OF CURVATURE

SAMPLE NO.	SAMPLE DEPTH (m)	SOIL CLASSIFICATION		SPECIFIC SYSTEM		ATTERBERG LIMITS			
		UNIFIED SYSTEM	REVISED P R SYSTEM	+ mm	– 2 mm	LL	PL	PI	SL
P 18 B	2 1	CL	A – 4 (8)		2 71	34 7	25 1	9 6	

Fig A6-22 Gradation Analysis Curve



SAMPLE NO	P21	P12
MAX GRAIN SIZE	0 5	10
mm (%)		
mm (%)		
4.8 mm (%)	100 0	90 5
0.075 mm (%)	46 0	31 0
D_{60} (mm)	0 15	0 24
D_{30} (mm)	0 033	0 067
D_{10} (mm)	0 0041	–
C_u	36	–
C_c	1 8	–

$$C_u = \frac{D_{60}}{D_{10}}$$

$$C_c = \frac{(D_{30})^2}{(D_{60}) \times (D_{10})}$$

C_u : COEFFICIENT OF UNIFORMITY

C_c COEFFICIENT OF CURVATURE

SAMPLE NO	SAMPLE DEPTH (m)	SOIL CLASSIFICATION		SPECIFIC SYSTEM		ATTERBPRO LIMITS			
		UNIFIED SYSTEM	REVISED P R SYSTEM	+ mm	– mm	LL	PL	PI	SL
P 21	02~29	SM	A-4 (8)						
P 12	09	SM	A-2-4 (0)						

Fig. A6-23 Compaction Curve

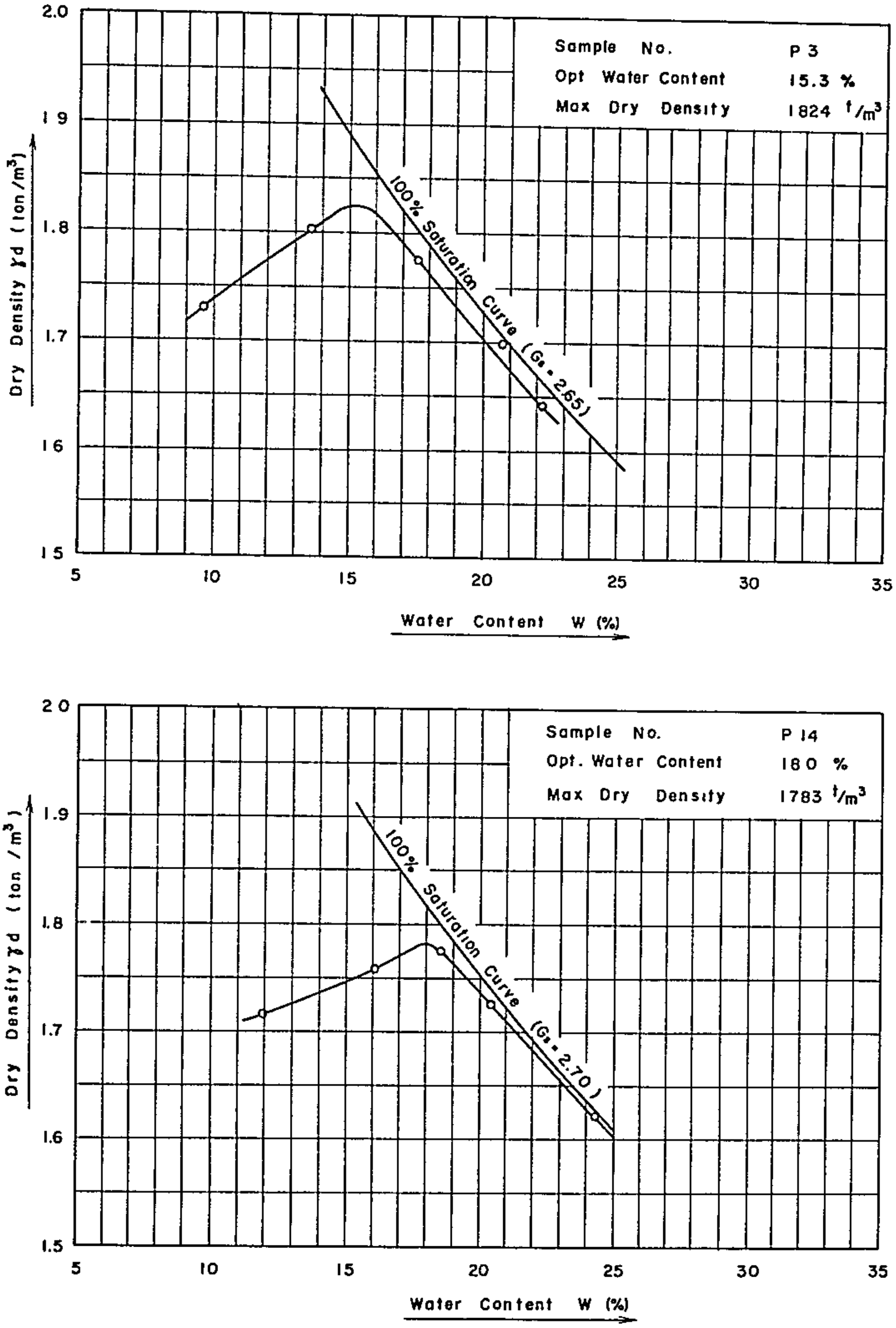


Fig. A6-24 Compaction Curve

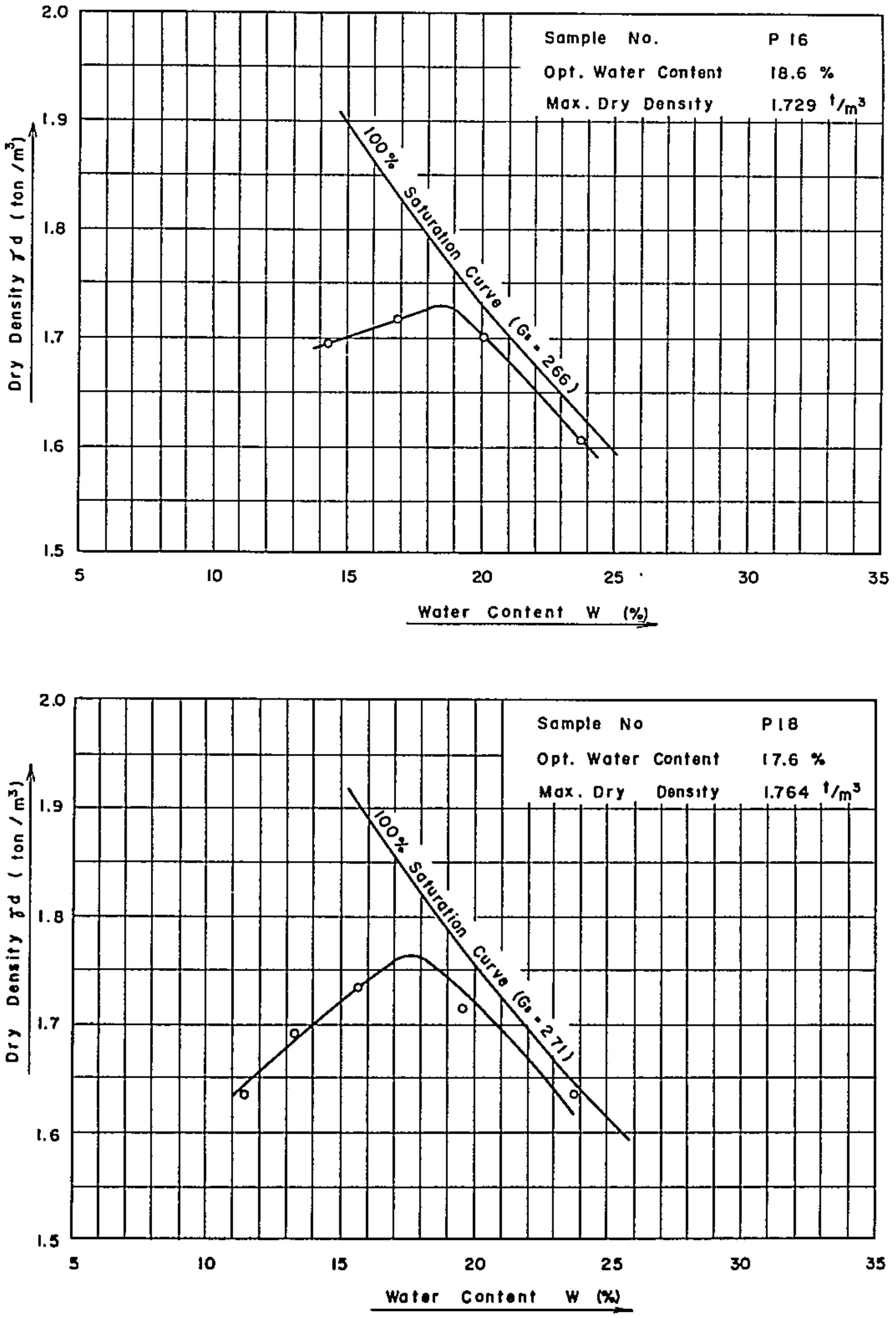
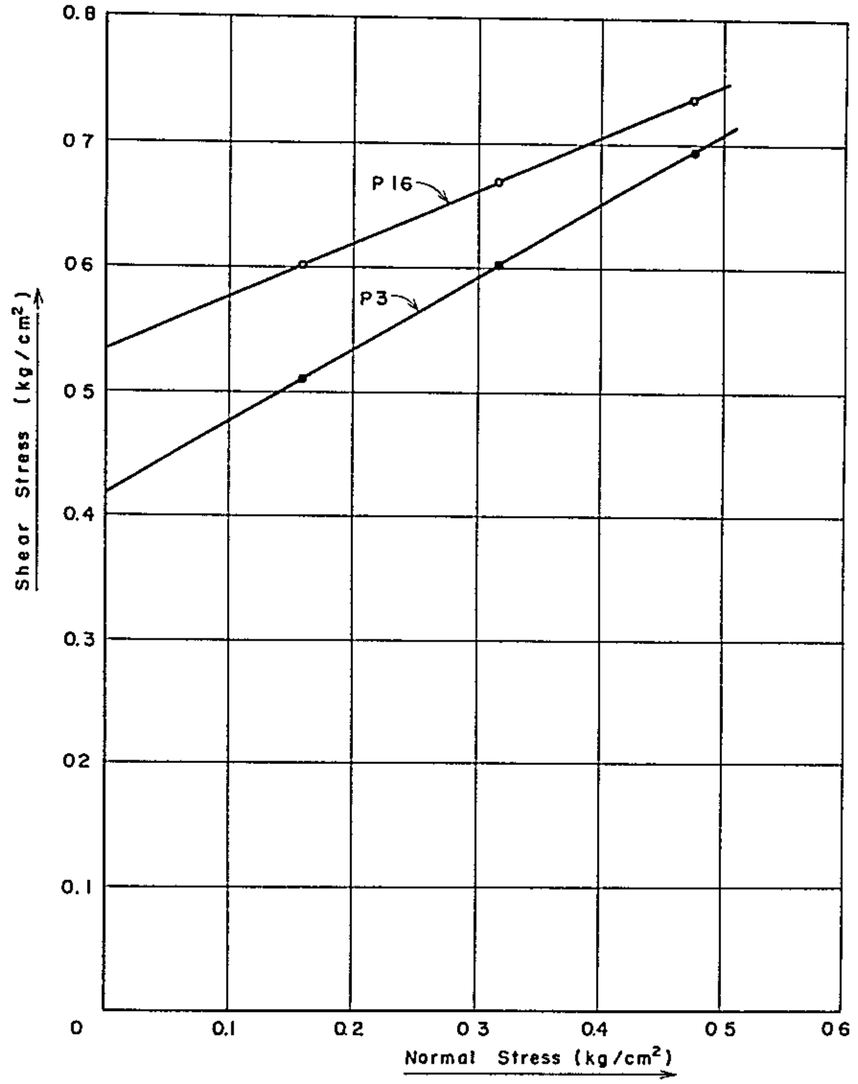


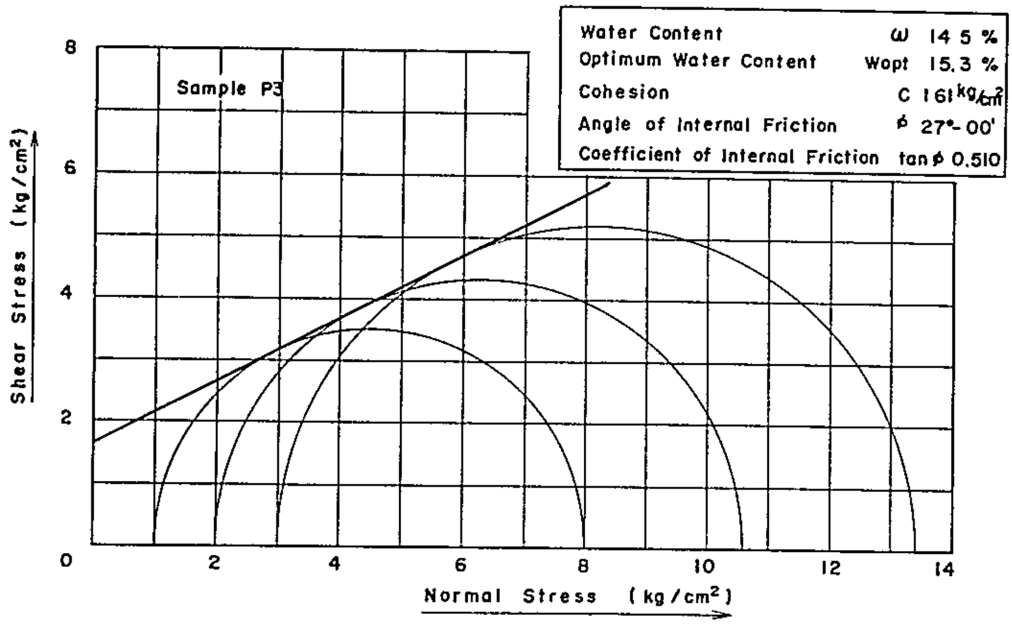
Fig A6-25 Direct Shear Test



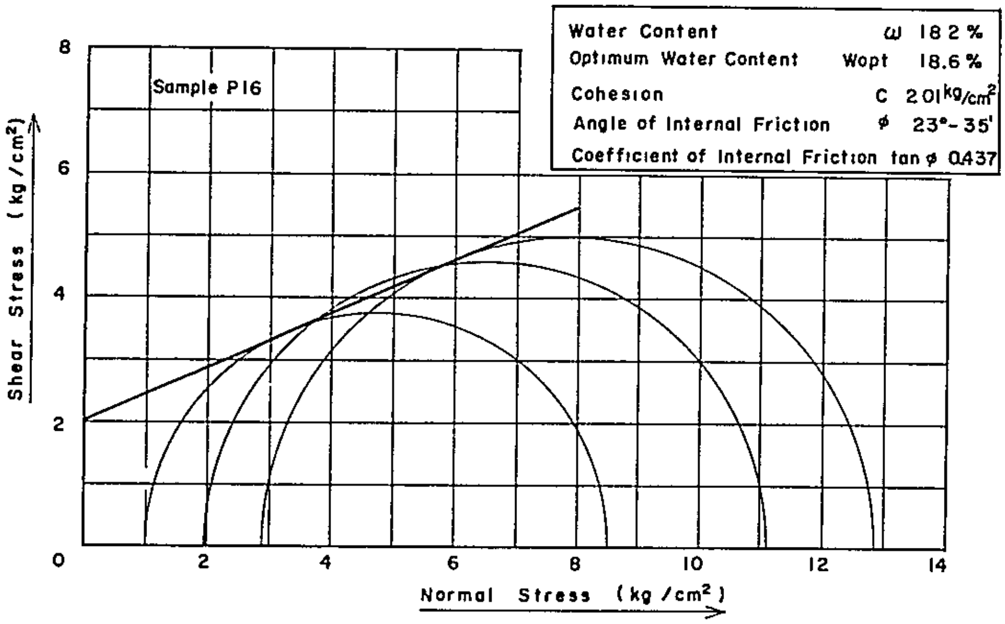
Quick Shear Test

Sample NO.	P 3	P 16
Water Content (%)	15.5	18.6
(Optimum Water Content %)	15.3	18.6
Cohesion C (kg/cm²)	0.42	0.53
Angle of Internal Friction ϕ	29°-40'	22°- 52'
Coefficient of Internal Friction, tan ϕ	0 570	0.422

Fig, A6 - 26 Triaxial Shear Test



Water Content	ω	14 5 %
Optimum Water Content	Wopt	15.3 %
Cohesion	C	$1\,61\ \mathrm{kg/cm^2}$
Angle of Internal Friction	ϕ	27°- 00'
Coefficient of Internal Friction	$\tan\phi$	0.510



Water Content	ω	18 2 %
Optimum Water Content	Wopt	18.6 %
Cohesion	C	$2\,01\ \mathrm{kg/cm^2}$
Angle of Internal Friction	ϕ	23°- 35'
Coefficient of Internal Friction	$\tan\phi$	0.437

Test Procedure :

Undrained Consolidation - Drained Consolidation - Shear