KINGDOM OF THAILAND

FEASIBILITY STUDY ON LAM TA KHONG PUMPED STORAGE DEVELOPMENT PROJECT

FINAL REPORT

SUMMARY

NOVEMBER, 1991

JAPAN INTERNATIONAL COOPERATION AGENCY

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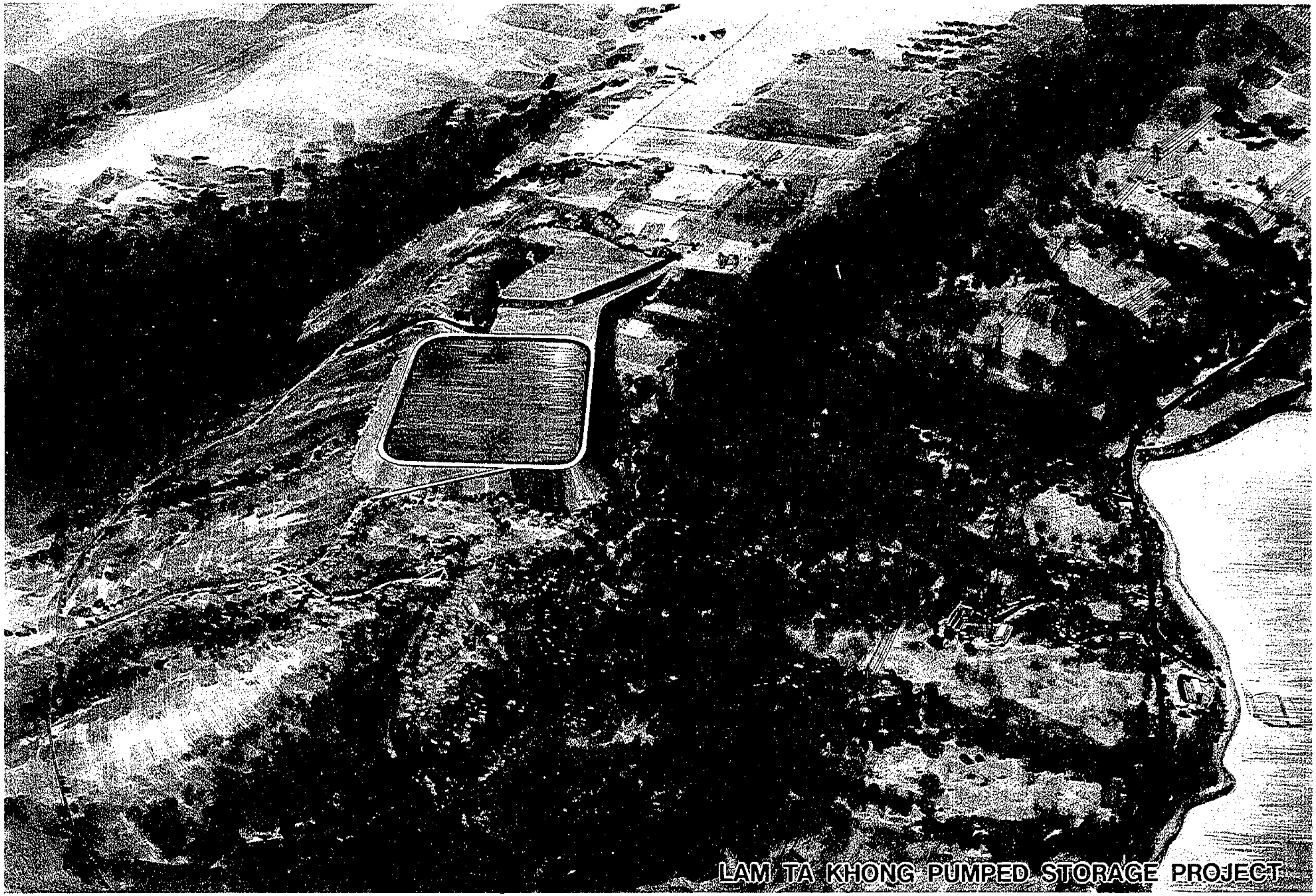
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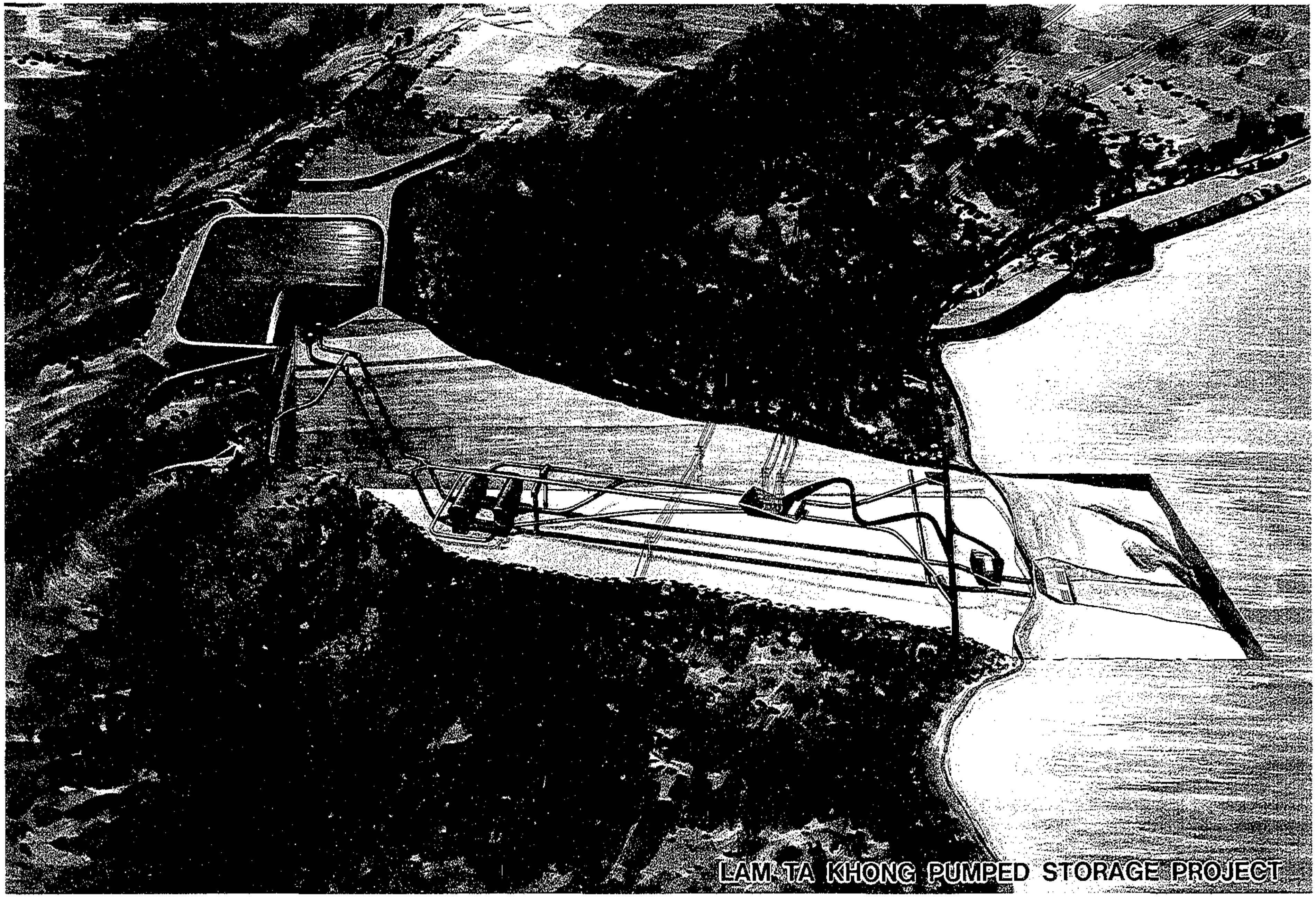
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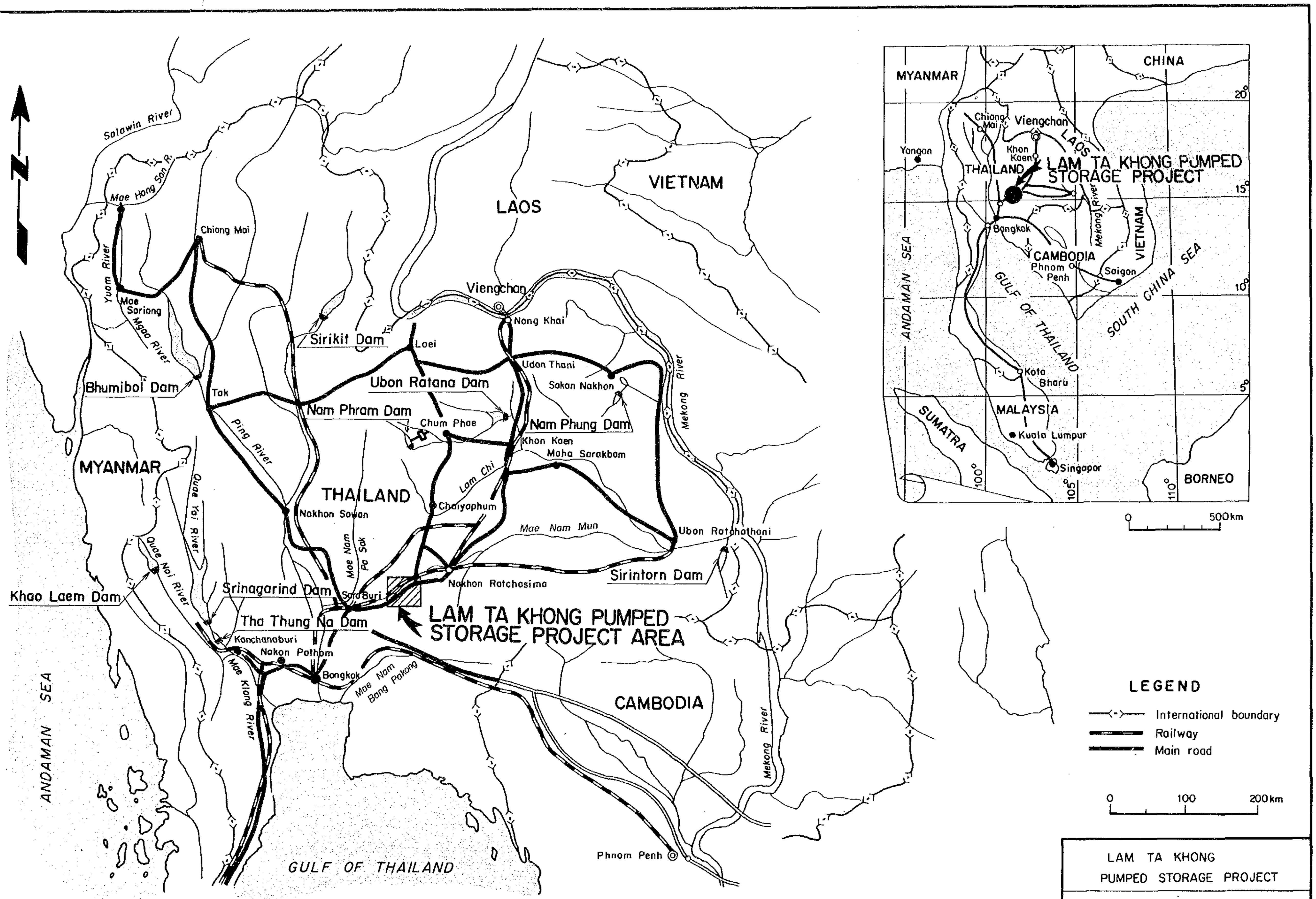
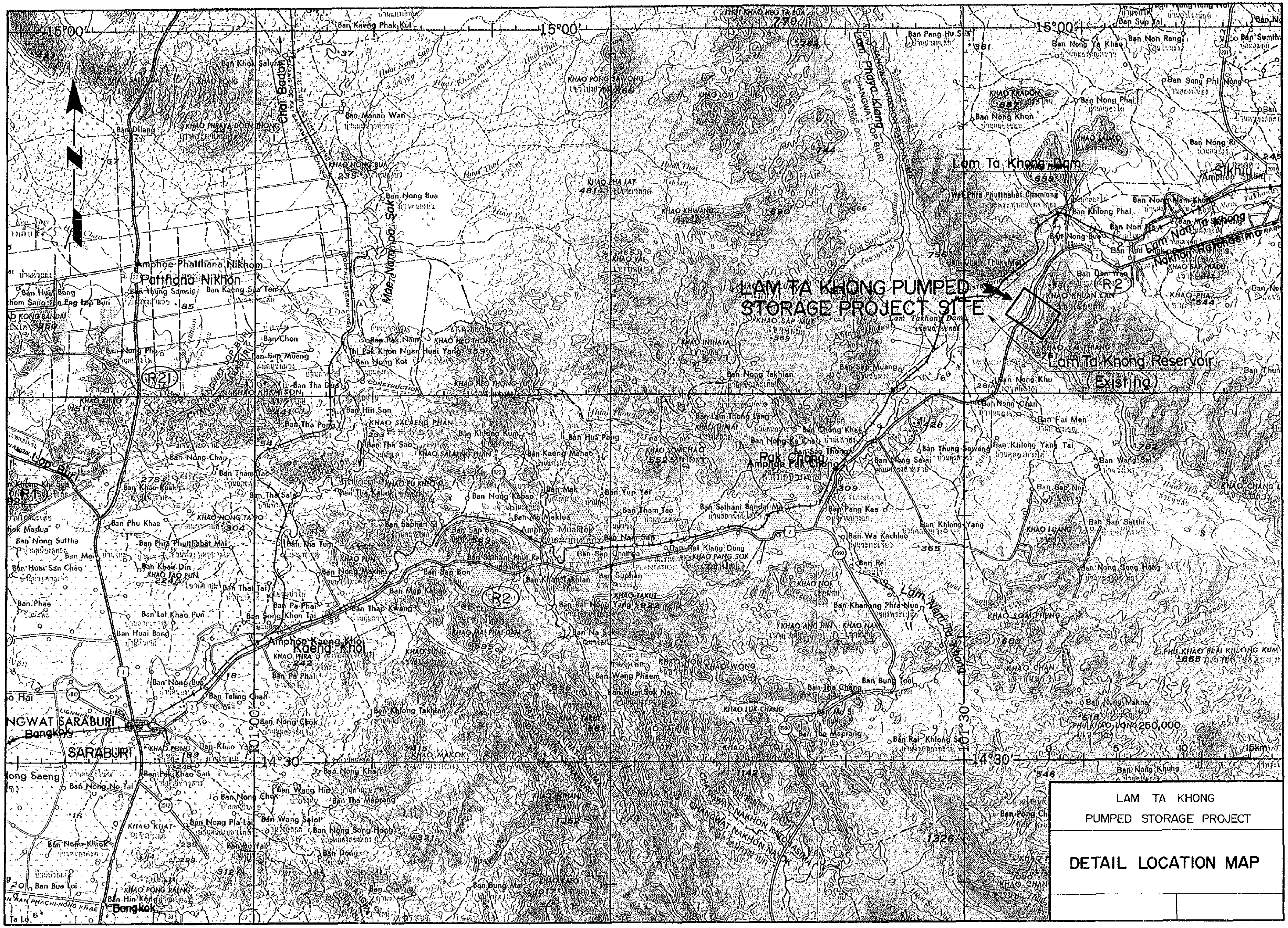


LAM TA KHONG
PUMPED STORAGE PROJECT

KEY AND LOCATION MAP



LAM TA KHONG

PUMPED STORAGE PROJECT

DETAIL LOCATION MAP

Photo-1 Upper Reservoir Site (View from West)

Photo-2 Tailrace Site

Photo-3 Route of Waterway (View from Upper Reservoir)

Photo-4 Route of Waterway (View from Tailrace Site)

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UNITS AND GLOSSARIES

(1) Units

mm	:	Millimeter
cm	:	Centimeter
m	:	Meter
km	:	Kilometer
cm^2	:	Square centimeter
m^2	:	Square meter
km^2	:	Square kilometer
m^3	:	Cubic meter
MCM	:	Million cubic meter (for development planning)
kg	:	Kilogram
t	:	Metric ton
m^3/s	:	Cubic meter per second
kW	:	Kilowatt
kWh	:	Kilowatt hour
MW	:	Megawatt
GWh	:	Gigawatt hour
kV	:	Kilovolt
kVA	:	Kilovolt-Ampere
MVA	:	Megavolt-Ampere
MCM	:	Thousands of circular mils (for transmission line)
rpm	:	Revolutions per minutes
Hz	:	Hertz (cycles per second)
El.	:	Elevation
°C	:	Degree in centigrade
mb	:	Millibar
%	:	Percentage
Lu	:	Lugeon value (rate of water loss from a drillhole)
ℓ	:	Liter
1 MW	:	1,000 kW
1 GWh	:	1,000,000 kWh
1 barrel	:	159 ℓ
1 rai	:	1,600 m^2
gal	:	cm/sec^2 (acceleration of earthquake motion)
kine	:	cm/sec

(2) Glossaries

(i) Terms

NHWL	:	Normal High Water Level
LWL	:	Low Water Level
TWL	:	Tail Water Level
US$	:	U.S. dollar
฿	:	Baht
M฿	:	Million Baht
hrs	:	Hours
yr	:	Year
ea.	:	Each
Max.	:	Maximum
Min.	:	Minimum
cct	:	Circuit
a.c.	:	Alternative current
ACSR	:	Aluminum Conductor Steel Reinforced
ASTM	:	American Standard for Testing and Materials
CA	:	Catchment Area
FY	:	Fiscal Year
GDP	:	Gross Domestic Product
M_B	:	Body Wave Magnitude
M_S	:	Surface Wave Magnitude
IRR	:	Internal Rate of Return
EDR	:	Equalizing Discount Rate
PAX	:	Private Automatic Exchanger
PMF	:	Probable Maximum Flood
PMP	:	Probable Maximum Precipitation
UHF	:	Ultra High Frequency
VHF	:	Very High Frequency
B-C	:	Net Present Value of Surplus Benefit
B/C	:	Benefit Cost Ratio

(ii) Agencies

AIT	:	Asian Institute of Technology
EGAT	:	Electricity Generating Authority of Thailand
EPDC	:	Electric Power Development Co., Ltd.
JICA	:	Japan International Cooperation Agency
Lao PDR	:	Lao People Democratic Republic
MEA	:	Metropolitan Electricity Authority
NEA	:	National Energy Administration
NEPO	:	National Energy Policy Office
NESDB	:	National Economic and Social Development Board
NIDA	:	National Institute of Development Administration
OPEC	:	Organization of Petroleum Exporting Countries
PEA	:	Provincial Electricity Authority
RID	:	Royal Irrigation Department
TDRI	:	Thailand Development Research Institute
IBRD	:	International Bank for Reconstruction and Development

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1. INTRODUCTION

This report concerns the feasibility study of the Lam Ta Khong Pumped Storage Development Project. The feasibility study has been conducted from 1990 to 1991 by the Japan International Cooperation Agency (JICA) under a technical cooperation program of the Government of Japan.

(1) Background of the Project

Thailand's economic growth rate in 1989 was marked at 11%, being prominent among Asian developing nations. Particularly, the growth of its industrial sector was significant.

The installed capacity of electric power generating facilities in Thailand was 8,314 MW in 1989. Composition of power sources consisted of 2,271 MW in hydro plants (27.3%) and 6,043 MW in thermal plants (72.7%).

The rates of average annual increase of EGAT's power and energy generation for the five years from 1986 to 1990 were 12.9% and 13.2% respectively. The rates increased in 1990 by 13.8% and 18.5% respectively. The rates of increase of future demand will decrease gradually to be 7.6% and 8.3% in 1995, and 6.2% and 7.2% in 2000. After 1995, the annual increase of demand is considered to be about 900 MW and about 6,100 GWh respectively. Therefore, new power plants having a capacity of 900 MW should be implemented every year.

The Thai Government has a policy of utilizing indigenous energy sources such as natural gas, lignite, hydropower, etc., while suppressing the increase of oil importation as much as possible.

Under such circumstances, keen attention has been focussed recently on the Lam Ta Khong Pumped Storage Project which is close to Bangkok metropolitan area, the biggest demand area of electricity in Thailand.

In order to cope with the high growth of electricity demand, especially peak demand, a feasibility study on the Lam Ta Khong Pumped Storage Project was requested to the Japanese Government by the Thai Government in 1988.

(2) Outline of the Project

The Lam Ta Khong Pumped Storage Project is to be carried out on the Lam Ta Khong River, a tributary of the Mun River of the Mekong River system, 200 km northeast of the capital Bangkok.

The project features are shown on the table "General Project Description on Lam Ta Khong Pumped Storage Project".

(3) Provision of Equipments

To promote the study of the Project the following equipments were provided to the EGAT, and the EGAT carried out the investigation works listed below.

Equipments Provided and Investigation Works

Equipments	Investigation Works
FRP Boat (MODEL W-198F) and Accessories . Depth Recorder (MODEL RS-61S)	Sounding survey in the Lam Ta Khong reservoir
Rotary Boring Machine (MODEL YBM-3JES) and Accessories	Drilling at upper pondage, waterway and powerhouse site

(4) Technology Transfer to the Counterparts

The technology transfer to the counterparts from the EGAT was done during the study period as follows:

- Counterpart Mr. Prakit Pooviboonsuk
  (December 2, 1990 - February 7, 1991)

  Mr. Pote Angwatanapanich
  (October 7, 1991 - December 4, 1991: Scheduled)

  Mr. Suvit Kritdum
  (October 7, 1991 - December 4, 1991: Scheduled)

- Schedule
  . Technology transfer and discussions on the feasibility-grade design of the Project

  . Inspections at factories of turbines and generators

  . Inspections at pumped storage power stations under construction or in operation

Table 1-1 General Project Description of Lam Ta Khong Pumped Storage Project (1/4)

	Project Name		Lam Ta Khong Pumped Storage	
			Upper Reservoir	Lower Reservoir
1.	LOCATION			Lam Ta Khong River Tributary of Mun River
			District, Pak Chong Sikhiu	District, Pak Chong Sikhiu
			Province: Nakhon Ratchashima	Province: Nakhon Ratchashima
2.	PURPOSE		Power Generation	Multi purpose (Existing)
3.	HYDROLOGY			
	Catchment Area	km^2	0.4	1,430
	Period of Runoff Analysis	yrs.	-	28
	Average Annual Inflow	MCM	-	261
	Design Flood	m^3/sec	-	2,130
4.	RESERVOIR			
	Normal High Water Level (NHWL)	m.MSL.	660.0	277.0
	Low Water Level	m.MSL.	620.0	261.0
	Total Storage Capacity	MCM	10.3	310
	Effective Storage Capacity	MCM	9.9	290
	Surface Area at NHWL	km^2	0.3	44
5.	DAM			
	Type		Rockfill Dam with Asphalt Facing	Homogeneous Earth-fill Dam
	Dam Height	m	60	40.3
	Crest Elevation	m.MSL.	662.50	282.3
	Crest Length	m	2,210	527
	Dam Volume	10^3 m^3	6,190	853
	Upstream Face Slope	-	1 : 2.5	1 : 3.0 - 5.0
	Downstream Face Slope	-	1 : 2.5	1 : 2.5

General Project Description of Lam Ta Khong Pumped Storage Project (2/4)

	Project Name		Lam Ta Khong Pumped Storage	
6.	INTAKE			
	Type		Morning-glory	
	Size	m	$(18.0 - 5.8)^D \times 51$	
	Number	set	2	
7.	PENSTOCK			
	Type	-	Inclined Shaft Embedded Steel	
	Number	-	2 - 4	
	Inner Diameter	m	5.8 - 2.6	
	Length	m	690	
8.	TAILRACE TUNNEL			
	Type	-	Concrete Lined Pressure Type	
	Number	-	4 - 2	
	Inner Diameter	m	4.90 - 6.60	
	Length	m	1,470	
9.	SURGE CHAMBER			
	Type	-	Chamber Surge Tank	
	Number	-	2	
	Dimension			
	- Main Body	m	Inside 8.90	Height 107.0
	- Chamber	m	Inside 10.00 x 10.00	Length 35.0
10.	OUTLET			
	Type	-	4 Continuous Box Culvert	
	Number	-	2	
	Size	m	Width 6.6 - 30.0	
		m	Height 6.6 - 10.0	
		m	Length 55.0	

General Project Description of Lam Ta Khong Pumped Storage Project (3/4)

	Project Name		Lam Ta Khong Pumped Storage
11.	POWER HOUSE		
	Type	-	Underground type
	Size (Width x Length x Height)	m	22 x 117 x 45.7
	Draft Gate		
	- Type	-	Bonnet Type Gate
	- Number	set	4
	Tailrace Gate		
	- Type		Roller Gate
	- Number		2
12.	TURBINE/PUMP		
	(Turbine)		
	Type		Vertical Shaft Francis type reversible pump turbine
	Number of Units	unit	4
	Max. Gross Head	m	401
	Rated Intake Water Level	m.MSL.	653
	Rated Tail Water Level	m.MSL.	276
	Gross Head	m	377
	Normal Effective Head	m	357
	Max. Power Discharge	m^3/sec	82.5
	Rated Output	MW	255
	Revolving Speed	rpm	375
	(Pump)		
	Max. Pump Head	m	409
	Max. Pump Input	MW	277
	Max. Pump Discharge	m^3/sec	71.4
	Revolving Speed	rpm	375
13.	GENERATOR/MOTOR		
	Type		3-phase AC Synchronous Generator-Motor
	Number of Units	unit	4
	Rated Output	MVA	278
	Voltage	kV	16.5
	Power Factor	-	Generator 0.9 (Lag) Motor 0.98 (Lead)
	Frequency	Hz	50
	Revolving Speed	rpm	375

General Project Description of Lam Ta Khong Pumped Storage Project (4/4)

	Project Name		Lam Ta Khong Pumped Storage	
14.	MAIN TRANSFORMER			
	Number of Units	unit	4	
	Type	-	Special 3-phase in door forced oil water cooled type with on load tap changer	
	Capacity	MVA	290	
	Voltage	kV	230/16.5	
15.	SWITCHYARD			
	Type	-	SF_6 Gas Insulated Switchgear Type	
	Nominal Voltage	kV	230	
	Number of Circuits	cct	8	
16.	TRANSMISSION LINE			
	Connection	-	To Saraburi 2 - Nakon Rachasima 2 Existing 230 kV Line	To Thalan 3
	Nominal Voltage	kV	230	230
	Number of Circuits	cct	2	2
	Length	km	15	95
17.	POWER GENERATION			
	Max. Power Discharge	m^3/sec	340 (4 units)	
	Normal Effective Head	m	357	
	Installed Capacity	MW	1,000	
	Annual Operating hours	hrs	800	
	Generating Capability of Continuous Operation	hrs	8	
18.	PROJECT COST	M฿ (MUS$)	16,674 (641)	
19.	ECONOMIC COST	M฿ (MUS$)	11,254 (433)	
20.	ECONOMICS			
	B - C	M฿	1,504	
	B / C	-	1.16	
	EDR	%	17.4	
21.	CONSTRUCTION PERIOD	yrs.	5	
22.	COMMISSIONING		1997	

2. CONCLUSIONS AND RECOMMENDATIONS

The Lam Ta Khong Pumped Storage Project is situated on the Lam Ta Khong River, a tributary of the Mun River of the Mekong River system, 200 km northeast of the capital, Bangkok. This Feasibility Study reveals that the project is feasible from technical, environmental and economic points of view. An outline of the conclusions and recommendations are given below.

Conclusions

(1) Electric power demand in Thailand recorded an annual growth rate of 14 percent in 1990 as a result of rapid industrialization. It is predicted that demand will grow at an annual rate of approximately 16 percent in 1991 and 7 percent in 1997. The peak power demand in 1990 of 7,094 MW is estimated to become about 13,000 ~ 14,000 MW in 1997. Therefore, there will be a necessity to construct new facilities of approximately 900 MW every year.

(2) At present, only a few power source exist to meet the rapid increase of peak power demand. In order to supply reliable electric power in the future corresponding to the rapid industrialization of Thailand, it is necessary to develop hydroelectric power plants capable of coping with the peak load. The Lam Ta Khong project is extremely promising as a power source to cope with the above-mentioned increase in demand and as a power source to supply peak loads of Thailand.

(3) The optimum scale of development of the Lam Ta Khong pumped storage power plant is 1,000 MW having the capability of 8 hours' continuous operation (storage capacity of upper reservoir). It is desirable to commence operation of the project at the earliest, and it is considered that this is in the year 1997. In the case that the development of the project is divided into two stages and that the unit 3 and 4 (250 MW x 2 units) are installed later than 1997, it is recommended that the units 3 and 4 shall be installed by the year of 2002 from an economic point of view.

(4) The power system stability poses a limitation of plant operation. The 1,000 MW generation will be possible in 1997, however, pumping at off-peak time will have to be restricted to 500 MW at most from the stand point of the power system stability.

(5) In addition to the function of power supply capability the Lam Ta Khong power plant will provide the following benefits to EGAT's system. The project will have quick load following characteristics corresponding to load fluctuation, regulating the system frequency and voltage, reserve capacity in case of failure of other power plants, and reducing the frequency of start-and-stop of thermal power plants thereby enabling high efficiency operation of thermal power plants.

(6) Civil structures including surface membrane fill dam for upper reservoir, underground powerhouse, penstock and tailrace tunnel were designed taking into consideration topography, geology, availability of construction materials, earthquakes and environmental aspect.

Bedrock of the upper reservoir, the waterway and the underground powerhouse is composed of sedimentary rock of Mesozoic era, and remarkable faults or other problems were not found judging from the results of in situ rock tests. There are no technical problems which would influence the realization of this project.

(7) The project area is located in an environmental area where development is restricted by the Thai government. Construction of structures on the surface are prohibited in a part of the area. In order to evade the restricted area, underground structures are adopted in this project.

There are no people living in the project area, so there will be no resettlement problem.

Since the project is designed considering the environment, it is feasible from an environmental point of view.

(8) The estimated project cost including import duty, interest during construction and escalation up to 1997 is 16,674 million Baht (US$641 million).

(9) The present value of surplus benefit (B - C), benefit-cost ratio (B/C), and equalizing discount rate (EDR) of the project obtained from economic comparison of the Lam Ta Khong power plant and an alternative thermal plant are 1,504 million Baht, 1.16 and 17.4 percent, respectively. These values indicate that the development of the project is economically feasible.

Recommendations

(1) It is necessary to proceed to the stage of definite study as soon as possible in order that the project is completed and commissioned as scheduled in the year 1997.

(2) The following additional investigations and studies are recommended:

- Exploratory adit should be excavated as soon as possible in order to design the powerhouse and study its construction method. In situ rock tests should be carried out in order to understand the physical properties of the bedrock.

- Along with the definite study of the project development, it is necessary to study reinforcing the power system in future, especially to study installing facilities to supply reactive power for the purpose of holding voltage of 230 kV bus at each substation at the appropriate level. It is particularly important to hold the voltages at Saraburi 2 and Nakhon Ratchasima 2 substations during Lam Ta Khong's pumping.

- In order that the power sources in the northern area can be developed on schedule and the Lam Ta Khong power station and other power stations can be properly operated without limitations it is necessary to reinforce the power system in and after the end of 1990's when power system stability at pumping hours will become critical. The power system reinforcement should be studied including the possibility of pumping by three or four units of the Lam Ta Khong power station.

3. LOAD FORECAST

3.1 Result of Load Forecast

Power demand forecast by the JICA Team are shown in Table 3-1 and Table 3-2. Future values on these tables were forecasted based on such data of Thailand as actual energy consumption, past GDP, GDP and population in future predicted by the Thai government agencies.

(1) Energy Consumption

The JICA Team forecasted that the energy consumption would increase at the average growth rate of 13.01% from about 31,500 GWh in 1989 to about 39,400 GWh in 1991, 9.52% from 1992 to 1996 and 7.36% from 1997 to 2001, and in 2000 it will be about 82,800 GWh, which is about 2.6 times as much as that in 1989.

Energy consumption per capita in 2000 is predicted to be 1286 kWh, which is about 2.26 times as much as 568 kWh at the present time.

(2) Energy Demand and Maximum Power Demand

The energy demand at generating end is predicted to increase at an average rate of about 8.93% per year from the current about 36,500 GWh to about 97,000 GWh in 2000.

The annual load factor at generating end is predicted to decrease gradually in future from current 68% to 63.3% in 2000.

The maximum power demand at generating end is predicted to grow at a rate of 9.42% per year on average and to be about 17,400 MW in 2000.

(3) Comparison between the Load Forecasts Made by the JICA Team and Thai Organization

Load forecast formulated by Thai organization is shown in table 3-3. The difference between the above two is exceedingly small in the energy demand at generating end, although the JICA forecast is a little bit lower than the High Case forecast by the Thai organization. They can be regarded as almost the same.

As for the maximum power demand, each forecast predicts that it will grow almost in the same way until 1995 or 1996, but after that the values predicted by the JICA Team surpass those predicted by the Thai organization due to the different prediction for the future annual load factors.

Table 3-1 POWER DEMAND FORECAST IN THILAND

Year	Generating End							Sending End			Transmission & Distribution Losses		Energy Consumption
	Energy	KWH Station Losses		Maximum Power	KW Station Losses		Load Factor	Energy	Maximum Power	Load Factor			
	(GWH)	(GWH)	(%)	(MW)	(MW)	(%)	(%)	(GWH)	(MW)	(%)	(GWH)	(%)	(GWH)
1980	14,753.73	590.45	4.00	2,417.40	87.0	3.60	69.7	14,163.28	2330.4	69.4	1,156.31	8.2	13,006.97
1981	15,959.97	612.29	3.84	2,588.70	89.4	3.45	70.4	15,347.68	2499.3	70.1	1,455.16	9.5	13,892.52
1982	16,881.95	602.49	3.57	2,838.00	91.2	3.21	67.9	16,279.46	2746.8	67.7	1,507.29	9.3	14,772.17
1983	19,066.30	659.05	3.46	3,204.30	99.7	3.11	67.9	18,407.25	3104.6	67.7	1,951.28	10.6	16,455.97
1984	21,066.44	830.10	3.94	3,547.30	125.8	3.55	67.8	20,236.34	3421.5	67.5	2,196.89	10.9	18,039.45
1985	23,356.57	1,022.81	4.38	3,878.40	152.9	3.94	68.7	22,333.76	3725.5	68.4	2,519.57	11.3	19,814.19
1986	24,779.53	1,010.03	4.08	4,180.90	153.4	3.67	67.7	23,769.50	4027.5	67.4	2,755.66	11.6	21,013.84
1987	28,193.16	1,154.68	4.10	4,733.90	174.5	3.69	68.0	27,038.48	4559.4	67.7	2,867.63	10.6	24,170.85
1988	31,996.00	1,265.89	3.96	5,444.00	193.8	3.56	67.1	30,730.11	5250.2	66.8	3,165.26	10.3	27,564.85
1989	36,457.09	1,532.22	4.20	6,232.70	235.8	3.78	66.8	34,924.87	5996.9	66.5	3,429.77	9.8	31,495.10
1990	41,256	1,735	4.20	7,074	268	3.78	66.6	39,522	6,806	66.3	4,190	10.2	35,332
1991	45,961	1,954	4.25	7,916	303	3.83	66.3	44,007	7,613	66.0	4,576	10.4	39,431
1992	50,953	2,189	4.30	8,815	341	3.87	66.0	48,764	8,474	65.7	5,116	10.5	43,648
1993	56,132	2,438	4.34	9,754	381	3.91	65.7	53,694	9,373	65.4	5,699	10.6	47,995
1994	61,476	2,698	4.39	10,731	424	3.95	65.4	58,778	10,307	65.1	6,240	10.6	52,538
1995	66,987	2,971	4.43	11,746	469	3.99	65.1	64,017	11,277	64.8	6,781	10.6	57,236
1996	72,699	3,257	4.48	12,805	516	4.03	64.8	69,441	12,289	64.5	7,307	10.5	62,134
1997	78,189	3,539	4.53	13,835	564	4.07	64.5	74,650	13,271	64.2	7,775	10.4	66,875
1998	84,118	3,846	4.57	14,952	615	4.12	64.2	80,272	14,337	63.9	8,346	10.4	71,926
1999	90,392	4,175	4.62	16,141	671	4.16	63.9	86,217	15,470	63.6	8,972	10.4	77,245
2000	97,012	4,525	4.66	17,404	731	4.20	63.6	92,487	16,673	63.3	9,679	10.5	82,808
2001	103,921	4,896	4.71	18,730	794	4.24	63.3	99,025	17,936	63.0	10,390	10.5	88,635
2002	110,571	5,260	4.76	19,940	854	4.28	63.3	105,312	19,087	63.0	11,059	10.5	94,253
2003	117,549	5,646	4.80	21,199	916	4.32	63.3	111,903	20,282	63.0	11,752	10.5	100,151
2004	124,933	6,058	4.85	22,530	983	4.36	63.3	118,875	21,547	63.0	12,471	10.5	106,404
2005	132,760	6,499	4.89	23,942	1055	4.41	63.3	126,261	22,887	63.0	13,230	10.5	113,031
2006	141,061	6,970	4.94	25,439	1131	4.45	63.3	134,091	24,308	63.0	14,036	10.5	120,055

Table 3-2 FORECAST OF ENERGY CONSUMPTION IN THAILAND

Year	Energy Consumption *1		GDP in 1972 Price *2		Energy Consumption Per GDP		Population *2	kWh Per Capita	
	GWh	Growth Rate	M Baht	Growth Rate	Wh/Baht	Growth Rate	Thousand	kWh	Growth Rate
1980	13,006.97	(%)	299,472	(%)	43.4	(%)	46,961	277.0	(%)
1981	13,892.52	6.8	318,440	6.3	43.6	0.4	47,875	290.2	4.8
1982	14,772.17	6.3	331,379	4.1	44.6	2.2	48,847	302.4	4.2
1983	16,455.97	11.4	355,411	7.3	46.3	3.9	49,515	332.3	9.9
1984	18,039.45	9.6	380,739	7.1	47.4	2.3	50,583	356.6	7.3
1985	19,814.19	9.8	394,113	3.5	50.3	6.1	51,796	382.5	7.3
1986	21,013.84	6.1	411,813	4.5	51.0	1.5	52,969	396.7	3.7
1987	24,170.85	15.0	446,361	8.4	54.2	6.1	53,973	447.8	12.9
1988	27,564.85	14.0	495,378	11.0	55.6	2.8	54,961	501.5	12.0
1989	31,495.10	14.3	542,706	9.6	58.0	4.3	55,448	568.0	13.3
1990	35,332	12.2	589,370	8.6	59.9	3.3	56,340	627.1	10.4
1991	39,431	11.6	637,964	8.2	61.8	3.1	57,199	689.4	9.9
1992	43,648	10.7	686,300	7.6	63.6	2.9	58,041	752.0	9.1
1993	47,995	10.0	734,802	7.1	65.3	2.7	58,876	815.2	8.4
1994	52,538	9.5	783,975	6.7	67.0	2.6	59,693	880.1	8.0
1995	57,236	8.9	834,063	6.4	68.6	2.4	60,508	945.9	7.5
1996	62,134	8.6	885,081	6.1	70.2	2.3	61,311	1013.4	7.1
1997	66,875	7.6	932,103	5.3	71.7	2.2	62,100	1076.9	6.3
1998	71,926	7.6	981,893	5.3	73.3	2.1	62,879	1143.9	6.2
1999	77,245	7.4	1,033,820	5.3	74.7	2.0	63,640	1213.8	6.1
2000	82,808	7.2	1,087,614	5.2	76.1	1.9	64,390	1286.0	6.0
2001	88,635	7.0	1,143,570	5.1	77.5	1.8	65,182	1359.8	5.7
2002	94,253	6.3	1,195,714	4.6	78.8	1.7	66,012	1427.8	5.0
2003	100,151	6.3	1,249,304	4.5	80.2	1.7	66,803	1499.2	5.0
2004	106,404	6.2	1,305,113	4.5	81.5	1.7	67,594	1574.2	5.0
2005	113,031	6.2	1,363,229	4.5	82.9	1.7	68,385	1652.9	5.0
2006	120,055	6.2	1,423,742	4.4	84.3	1.7	69,176	1735.5	5.0

Note : *1. The values for the year of 1990 onward were predicted by the JICA Team.
*2. The values for the year of 1990 onward were predicted by the Office of National Economic and Social Development Board, and National Energy Policy Office in Thailand.

Table 3-3 Load Forecast by Thai Organization
(High Case)

Fiscal Year	Peak Generation			Energy Generation			Load Factor
	MW	Increase		GWh	Increase		
		MW	%		GWh	%	%
			Actual				
1979	2,255.00	154.40	7.35	13,964.55	1,592.88	12.88	70.69
1980	2,417.40	162.40	7.20	14,753.73	789.18	5.65	69.67
1981	2,588.70	171.30	7.09	15,959.97	1,206.24	8.18	70.38
1982	2,838.00	249.30	9.63	16,881.95	921.98	5.78	67.91
1983	3,204.30	366.30	12.91	19,066.30	2,184.35	12.94	67.92
1984	3,547.30	343.00	10.70	21,066.44	2,000.00	10.49	67.79
1985	3,878.40	331.10	9.33	23,356.57	2,290.13	10.87	68.75
1986	4,180.90	302.50	7.80	24,779.53	1,422.96	6.09	67.66
1987	4,733.90	553.00	13.23	28,193.16	3,413.63	13.78	67.99
1988	5,444.00	710.10	15.00	31,996.00	3,812.84	13.49	67.09
1989	6,232.70	788.70	14.49	36,457.09	4,461.09	13.94	66.59
Average Growth 1980-1989	–	397.77	10.70	–	2,249.25	10.07	–
			Forecast				
1990	7,168.00	935.30	15.00	42,203.00	5,745.91	15.76	67.21
1991	8,028.00	860.00	12.00	48,013.00	5,810.00	13.77	68.27
1992	8,911.00	883.00	11.00	53,760.00	5,747.00	11.97	68.87
1993	9,802.00	891.00	10.00	59,470.00	5,710.00	10.62	69.26
1994	10,689.00	887.00	9.47	65,113.00	5,643.00	9.92	69.54
1995	11,498.00	809.00	7.57	70,505.00	5,392.00	8.28	70.00
1996	12,335.00	837.00	7.28	76,113.00	5,608.00	7.95	70.44
1997	13,190.00	855.00	6.93	81,674.00	5,561.00	7.31	70.69
1998	14,093.00	903.00	6.85	87,931.00	6,257.00	7.66	71.23
1999	15,009.00	916.00	6.50	94,167.00	6,236.00	7.09	71.62
2000	15,946.00	937.00	6.24	100,951.00	6,784.00	7.20	72.27
2001	16,916.00	970.00	6.04	108,041.00	7,090.00	7.02	72.91
2002	17,842.00	926.00	5.47	114,096.00	6,055.00	5.60	73.00
2003	18,777.00	935.00	5.24	120,075.00	5,979.00	5.24	73.00
2004	19,681.00	904.00	4.81	125,856.00	5,781.00	4.81	73.00
2005	20,593.00	912.00	4.63	131,688.00	5,832.00	4.63	73.00
2006	21,499.00	906.00	4.40	137,482.00	5,794.00	4.40	73.00
Average Growth							
1987-1991	–	769.42	13.94	–	4,646.69	14.14	–
1992-1996	–	861.40	8.97	–	5,620.00	9.65	–
1997-2001	–	916.20	6.52	–	6,385.60	7.26	–
2002-2006	–	916.60	4.91	–	5,960.20	4.94	–

4. POWER DEVELOPMENT PLAN

4.1 Power Development Plan of EGAT

The power supply capability of EGAT as of September, 1990 is as follows:

	Installed (MW)	Dependable (MW)
Hydro	2249.2	1908.9
Thermal	4306.5	4220.4
Combined	1176.6	1153.0
Gas Turbine	238.0	202.3
Total	7970.3	7484.6

The main part of EGAT's power development plan is occupied by the development of thermal power which comprises combined cycle, lignite fired and coal fired thermal power plants.

There are some development plans of hydro power and pumped storage, but the ratio of their total capacity to the entire development capacity by 2006 is only 6.5 percent or so.

Total developed capacity added to the above by 2006 is 19,934 MW, but some of old gas turbines and thermal power plants are planned to be retired, so the total capacity in 2006 is supposed to be 24,974.2 MW.

Table 4-1 shows the power development plan in Thailand (EGAT's PDP 90-03).

4.2 Balance of Power Supply and Demand

Reserve margin was estimated by combining the load forecast by the JICA Team with the power development plan of EGAT.

It is noted that the estimated reserve margin is 18 percent in 1993 but it becomes smaller yearly to nearly zero in 2004.

A power system must have operating reserve or extra generating capacity available to cope with emergencies such as unexpected interruption of plant operation, decrease in output power due to shortage of water or unforeseen increase of power demand.

The appropriate amount of operating reserve must be studied in conjunction with power supply reliability.

If Japan's reliability target, LOLE 0.3 days per month, is applied to Thailand, reserve margin of at least 15 to 16 percent would be required, which means about 800 MW must be added to the capacity developed in 1997 to 1998 based on the present power development plan.

4.3 Significance of Lam Ta Khong Project

A hydro power plant has a swift responsive performance for the requirement of power generation. It takes charge of the peak portion of load curve and is used as spinning reserve where the power can be called upon very rapidly following any unexpected loss of generating capacity.

However, future development of hydro power in Thailand will be greatly hampered by the lack of sites to be economically developed and troubles on environmental concerns. As a result, the ratio of power supply taking charge of peak load and power system frequency control will decrease gradually.

When sites for hydro power development becoming scarce, the development of pumped storage power will become an effectual alternative.

Because of its functional feature like general hydro power plant, a pumped storage power plant is used to secure supply capability to meet power demand as operating reserve and to control the frequency and voltage of the power system. It is also made use of for economical operation of thermal power plants.

In Japan, the appropriate development capacity of pumped storage power is said to be between 15 to 20 percent of increased demand, though it somewhat varies according to a power system.

Taking account of the situation of future hydro power supply, EGAT should develop Lam Ta Khong project as early as possible (in fiscal 1997 as the present power development plan).

EGAT should start to study reinforcement of the power system and development of power sources to secure sufficient supply capability after the end of nineteen-nineties.

In this connection, it is particularly important to study the development of peak load power stations including pumped storage power plants in respect of power system frequency control and economical operation of power system.

Table 4-1 Power Development Plan in Thailand (EGAT's PDP 90-03)

	Power Plant	Fuel Type	Unit Number	Rating (MW)	Total (MW)	Commissioning Date	
Under Construction	Rayong CC 1 (GT)	Gas	1-2	103	206	November	1990
	Nam Phong CC 1 (GT)	Gas	1-2	121	242	December	1990
	Rayong CC 2 (GT)	Gas	1-2	103	206	December	1990
	Rayong CC 3 (GT)	Gas	1-2	103	206	March	1991
	Srinagarind	Hydro	5	180	180	April	1991
	Bang Pakong CC 3 (ST)	-	1	99	99	March	1991
	Bang Pakong CC 4 (ST)	-	1	99	99	July	1991
	Rayong CC 1 (ST)	-	1	102	102	August	1991
	Rayong CC 2 (ST)	-	1	102	102	September	1991
	Nam Phong CC 1 (ST)	-	1	113	113	November	1991
	Mae Moh	Lignite	10	300	300	November	1991
	Rayong CC 3 (ST)	-	1	102	102	December	1991
	Bang Pakong Thermal	Oil/Gas	3	600	600	March	1992
	Mae Moh	Lignite	11	300	300	May	1992
	Bang Pakong Thermal	Oil/Gas	4	600	600	May	1993
	Pak Mun	Hydro	1-4	34	136	Jun 94 - Nov 94	
	Bhumibol Renovation	Hydro	1	(70)	(70)	June	1992
	Nam Phong CC 2 (GT)	Gas	1-2	121	242	January	1993
	Bhumibol Renovation	Hydro	2	(70)	(70)	January	1993
	Rayong CC 4 (GT)	Gas	1-2	100	200	March	1993
	South Bangkok CC 1 (GT)	Gas	1-2	100	200	April	1993
	Khanom CC1(GT)	Gas	1-2	100	200	December	1993
	Nam Phong CC 2 (ST)	-	1	113	113	January	1994
	Sirikit	Hydro	4	125	125	February	1994
	Rayong CC 4 (ST)	Gas	1	100	100	March	1994
	South Bangkok CC 1 (ST)	-	1	100	100	April	1994
	Khanom CC 2 (GT)	Gas	1-2	100	200	April	1994
	Wang Noi Gas Turbine	Gas	1-2	100	200	November	1994
	Khanom CC 1 (ST)	-	1	100	100	December	1994
	Kaeng Krung	Hydro	1-2	40	80	December	1994
	Bhumibol	Hydro	8	175	175	January	1995
	Wang Noi Gas Turbine	Gas	3-4	100	200	April	1995
	Khanom CC 2 (ST)	-	1	100	100	April	1995
	Mae Moh	Lignite	12	300	300	April	1996
	Ao Phai	Coal	1	700	700	August	1996
	Mae Moh	Lignite	13	300	300	October	1996
	Lam Takhong	Hydro	1-4	150	600	Dec 96 - Jun 97	
	Ao Phai	Coal	2	700	700	April	1997
	Ao Phai	Coal	3	700	700	April	1998
	Mae Taeng	Hydro	1-2	18+8	26	June	1998
	Nam Khek	Hydro	1	50	50	December	1998
	Lampang	Lignite	1	300	300	January	1999
	Mae Lama Luang	Hydro	1-3	80	240	January	1999
	Lampang	Lignite	2	300	300	July	1999
	Nam Ngao	Hydro	1-2	70	140	January	2000
	Lampang	Lignite	3	300	300	January	2000
	Saba Yoi	Lignite	1	300	300	April	2000
	Lampang	Lignite	4	300	300	July	2000
	Saba Yoi	Lignite	2	300	300	October	2000
	Lampang	Lignite	5	450	450	January	2001
	New Gas Turbine	Gas	1-2	100	200	April	2001
	Lampang	Lignite	6	450	450	July	2001
	Ao Phai	Coal	4	700	700	October	2001
	Saba Yoi	Lignite	3	300	300	April	2002
	New Thermal	1/	1	1,000	1,000	October	2002
	New Thermal	1/	2	1,000	1,000	April	2003
	Sin Pun	Lignite	1	75	75	April	2003
	New Gas Turbine	Gas	3-4	100	200	May	2003
	New Thermal	1/	3	1,000	1,000	January	2004
	Sin Pun	Lignite	2	75	75	April	2004
	New Thermal	1/	4	1,000	1,000	January	2005
	New Thermal	1/	5	1,000	1,000	October	2005
	New Thermal	1/	6	1,000	1,000	April	2006

Existing Capacity by September 1990	=	7,970.3	MW
Total Added Capacity (Up to 2006)	=	19,934.0	MW
Plant Retirement	=	2,930.1	MW
Total Capacity by Year 2006	=	24,974.2	MW

Note : 1/ Type of fuel will be determined later on.

5. HYDROLOGY

The Lam Ta Khong River, about 170 kilometers in length, is one of the major tributaries of the Mun River. It flows generally north and eastward passing the city of Nakhon Ratchasima to its confluence with the Mun River at Ban Tha Chang about 20 kilometers east of the city.

The Lam Ta Khong River basin originates in the high mountainous area on the southwest corner of the Khorat Plateau and lies on the northern slopes of the divide between the provinces of Nakhon Nayok and Nakhon Ratchasima.

The rainfall in the project area mainly depends on the Southwest Monsoon and the depression that originates from the South China Sea then passes through Vietnam and moves toward the northeast of Thailand.

The drainage basin of the Lam Ta Khong River lies in the area of less rainfall. This is because the mountain ranges along the western end of the Plateau act as high barriers against the Southwest Monsoon.

The average annual rainfall in the project area is between 900 mm and 1,100 mm. The annual rainfall as low as 500 ~ 600 mm may be expected in dry years, while 1,500 mm in wet years.

About 80% of the annual rainfall occurs during the months of May through October, and maximum monthly rainfall of 200 ~ 250 mm occurs in September.

The annual mean temperature is 26.5°C, and the extreme highest and lowest temperatures are recorded 42.7°C in April and 6.2°C in December.

The annual mean relative humidity is 72.2%, and the monthly mean relative humidity is as high as 94.7% in September and as low as 84.8% in March.

The annual evaporation is 1,879.2 mm, and the maximum is 192.1 mm in April.

The climatological data at the station of Nakhon Ratchasima is tabulated on Table 5-1.

Data on stream flows on the Lam Ta Khong River upstream of the Lam Ta Khong dam are available at five gauging stations. The station M38C near the Lam Ta Khong dam has recorded since 1962, but the flow data since July, 1968 are the outflows from the Lam Ta Khong dam. Locations of rainfall stations and gauging stations are shown in Fig. 5-1.

The monthly reservoir inflows of the Lam Ta Khong dam are tabulated on Table 5-2. The natural annual reservoir inflow is 258.94 MCM (8.21 m^3/sec) on the average, 110.00 MCM in the driest year (1968) and 495.00 MCM in the wettest year (1972).

The reservoir water levels of the Lam Ta Khong dam are illustrated in Fig. 5-2.

Table 5-1 Climatological Data for the Period 1956 - 1985

Station: Nakhon Ratchasima (EL. 187 m)
Lat, 14°58'N, Long, 102°05'E

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Rainfall (mm)													
Mean	4.8	22.7	43.9	68.3	145.2	111.6	132.6	130.4	261.5	154.1	30.0	3.6	1,108.7
Mean rainy days	1.0	2.9	5.6	8.0	13.4	14.1	13.4	16.4	19.7	12.3	4.0	0.9	115.7
Greatest in 24 hr.	71.2	59.7	57.3	91.5	73.8	114.8	104.1	72.3	143.7	136.0	84.3	20.6	143.7
Temperature (°C)													
Mean	23.0	25.9	28.3	29.2	28.5	28.2	27.7	27.4	26.7	26.0	24.4	22.7	26.5
Mean Max.	30.7	33.5	36.0	36.5	35.1	34.1	33.4	33.0	31.9	30.8	29.7	29.5	32.9
Mean Min.	16.3	19.7	22.2	23.8	24.2	24.1	23.7	23.6	23.2	22.4	19.9	16.9	21.7
Ext. Max.	37.8	40.6	42.3	42.7	41.4	40.1	40.0	38.1	38.0	35.3	35.3	35.8	42.7
Ext. Min.	6.7	11.4	11.6	16.9	20.7	21.1	21.1	20.5	19.7	16.2	9.1	6.2	6.2
Relative Humidity (%)													
Mean	65.8	63.6	62.8	66.8	74.4	74.5	75.8	77.0	82.4	80.3	75.3	67.6	72.2
Mean Max.	87.5	85.3	84.8	86.1	90.3	90.0	90.6	91.3	94.7	93.8	91.2	89.1	89.6
Mean Min.	41.7	40.2	38.3	43.4	52.3	54.0	55.7	57.8	63.2	62.0	55.6	47.3	51.0
Ext. Min.	22.0	14.0	12.0	19.0	23.0	23.0	35.0	35.0	41.0	31.0	27.0	20.0	12.0
Evaporation (mm)													
Mean - Pan	140.6	149.7	190.8	192.1	176.1	170.9	168.1	158.2	131.3	135.7	130.0	137.7	1,879.2
Cloudiness (0-10)													
Mean	3.4	4.2	4.6	5.5	7.1	7.9	8.5	8.5	8.1	6.5	4.9	3.9	6.1
Sunshine Duration (hr)													
Mean	283.0	244.5	249.0	245.0	244.5	207.2	194.2	185.4	165.1	225.1	257.8	276.0	2,776.8

Table 5-2 Estimated Inflow At Lam Ta Khong Dam: Unit (MCM)

YEAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	TOTAL
1962	-	-	-	37.00	20.00	73.00	56.00	10.00	5.00	3.00	2.00	3.00	-
1963	3.00	3.00	4.00	17.00	30.00	57.00	87.00	25.00	10.00	7.00	4.00	3.00	250.00
1964	3.00	53.00	19.00	25.00	23.00	50.00	112.00	23.00	9.00	6.00	6.00	6.00	335.00
1965	4.00	9.00	22.00	31.00	6.400	81.00	69.00	20.00	10.00	6.00	5.00	4.00	325.00
1966	5.00	26.00	14.00	22.00	49.00	34.00	19.00	10.00	6.00	4.00	4.00	4.00	197.00
1967	5.00	15.00	15.00	16.00	22.00	22.00	49.00	7.00	4.00	3.00	2.00	3.00	163.00
1968	4.00	24.00	8.00	11.00	12.00	16.00	18.00	5.00	2.00	4.00	2.00	4.00	110.00
1969	2.00	1.00	19.00	38.00	33.00	110.00	38.00	15.00	8.00	7.00	6.00	8.00	285.00
1970	8.00	7.00	14.00	22.00	17.00	36.00	40.00	9.00	9.00	5.00	5.00	4.00	176.00
1971	6.00	14.00	11.00	23.00	15.00	28.00	18.00	6.00	6.00	2.00	7.00	6.00	142.00
1972	5.00	0.0	6.00	17.00	24.00	192.00	168.00	33.00	15.00	13.00	13.00	9.00	495.00
1973	12.00	16.00	11.00	12.00	19.00	70.00	47.00	6.00	6.00	5.00	10.00	16.00	230.00
1974	15.00	18.00	18.00	19.00	22.00	32.00	75.00	46.00	13.00	11.00	10.00	11.00	290.00
1975	8.00	19.00	38.00	39.00	39.00	92.00	107.00	18.00	10.00	10.00	12.00	8.00	400.00
1976	13.00	20.00	24.00	30.00	59.00	82.00	99.00	43.00	15.00	6.00	6.00	10.00	407.00
1977	10.00	16.00	11.00	28.00	22.00	35.00	20.00	7.00	7.00	4.00	5.00	6.00	171.00
1978	14.00	10.00	19.00	35.00	36.00	39.00	57.00	8.00	4.00	5.00	3.00	2.00	232.00
1979	7.00	10.00	9.00	24.00	29.00	61.00	53.00	7.00	6.00	4.00	4.00	3.00	217.00
1980	5.90	5.50	24.80	19.60	18.10	41.90	84.80	17.40	5.70	4.40	3.80	2.00	233.90
1981	11.00	16.10	22.60	27.50	31.80	43.60	33.80	27.20	4.60	0.0	3.00	5.30	226.50
1982	4.40	6.40	8.80	21.70	28.70	70.20	38.90	11.40	4.80	4.20	2.30	0.60	202.40
1983	1.60	4.50	7.50	12.90	46.50	58.90	231.40	30.00	16.00	10.40	14.20	7.20	451.10
1984	11.70	8.20	8.40	24.50	32.10	41.50	83.60	15.80	7.50	8.50	4.20	1.50	247.50
1985	9.20	26.70	30.80	32.30	31.20	45.80	51.00	16.70	6.60	5.90	2.00	4.40	262.60
1986	11.10	24.30	10.20	15.00	14.60	29.90	77.90	11.00	5.60	1.80	3.70	1.80	206.90
1987	7.90	12.80	10.70	8.90	12.20	73.90	44.80	17.00	5.10	5.80	7.10	2.90	209.10
1988	5.50	22.60	16.60	14.30	29.70	87.40	105.80	15.60	9.70	7.50	4.90	7.40	327.00
1989	1.60	20.10	7.70	8.90	9.80	-	-	-	-	-	-	-	-
TOTAL	193.90	408.20	410.10	631.60	789.70	1603.10	1884.00	470.10	210.60	153.50	151.20	143.10	6792.00
NUMBER	27	27	27	28	28	27	27	27	27	27	27	27	28
AVERAGE	7.18	15.12	15.19	22.56	28.20	59.37	69.78	17.41	7.80	5.69	5.60	5.30	261.32
MAX	15.00	53.00	38.00	39.00	64.00	192.00	231.40	46.00	26.00	13.00	14.20	16.00	495.00
MIN	1.60	0.0	4.00	8.90	9.80	16.00	18.00	5.00	2.00	0.0	2.00	0.60	110.00

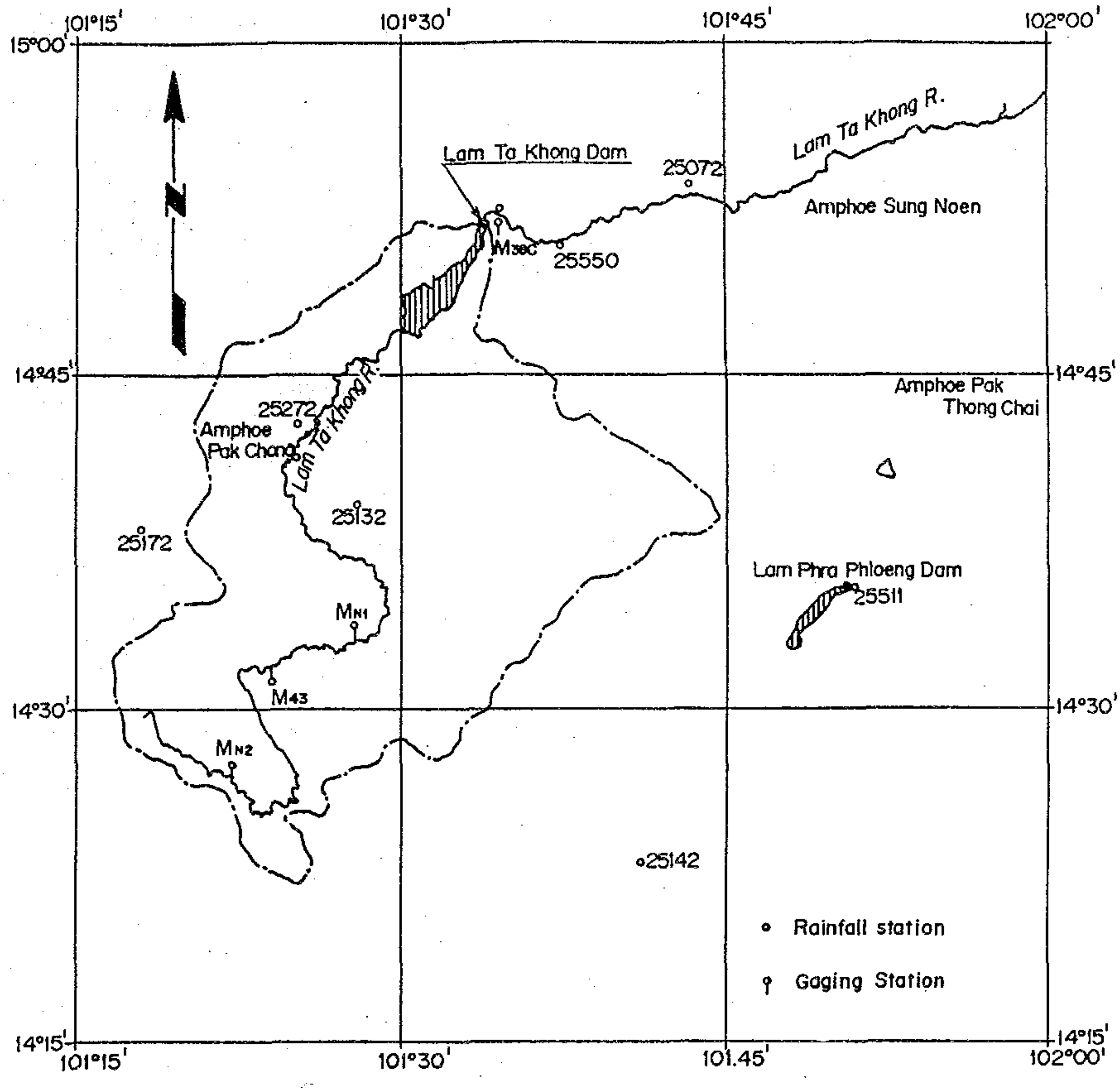


Fig.5-1 Location of Rainfall Station and Gauging Station

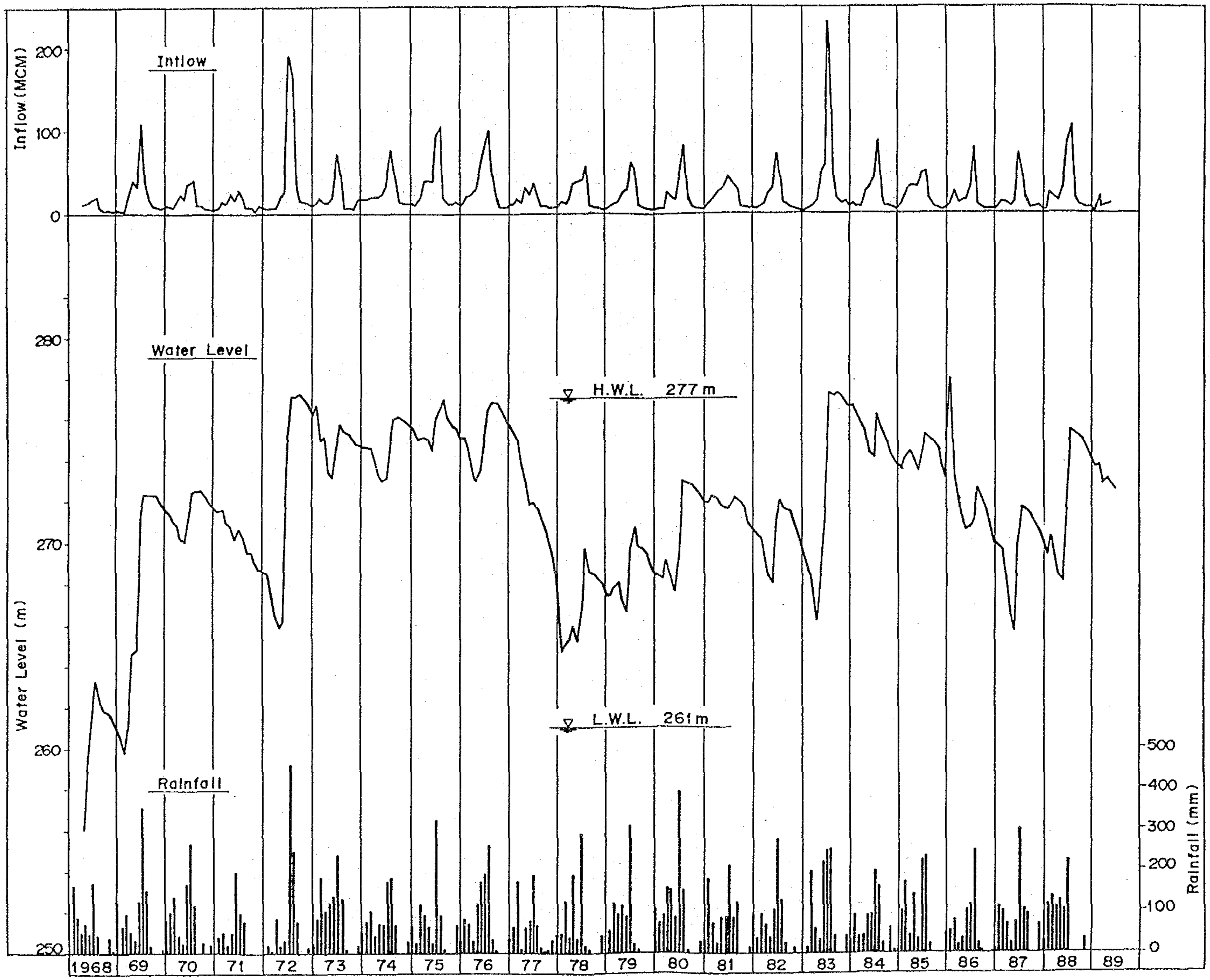


Fig.5-2 Inflow, Water Level and Rainfall of Lam Ta Khong Dam

6. GEOLOGY, CONSTRUCTION MATERIALS AND SEISMICITY

6.1 Geology

(1) Outline of Geology

As shown in DWG. 6-1 and 6-2, the bedrock of the project area is composed of the Phu Kradung formation which consists of siltstone, fine-grained sandstone, and partly conglomerate and the Phra Wihan formation which consists of coarse-grained sandstone, claystone, alternation of fine-grained sandstone and siltstone. In terms of hardness of rock, the sandstones are generally massive and hard while the degree of consolidation of siltstone is slightly low and that of claystone is low. The relations between the layers are conformable and the strikes of the layers are N30° W to N70° and the dips 5° to 10° (average 6°) NE. Residual soil with a thickness of several meters covers the bedrock at the upper reservoir site. Colluvial deposit and Talus deposit which attain 30 m in thickness are distributed in the slope above the waterway tunnel. Outlines of the bedrocks constituting the project sites and the main values of physical properties of each bed are given in Table 6-1.

In this area no fault was found in the outcrop, however, the drilling resulted in small-scaled faults being found. Also, in aerophotographs several lineaments which may indicate the existence of faults could be found.

(2) Engineering Geological Evaluation of Main Structure Sites

(a) Upper Reservoir Site

The foundation rock consists of weathered coarse-grained sandstone and claystone. The former has enough strength and the latter also can be used for the foundation rock of the dam. The residual soil distributed at the ground surface with the thickness under about 5 m is necessary to be removed by excavation since its strength is not enough.

(b) Intake and Headrace Tunnel Site

The bedrock consists of coarse-grained sandstone, alternation of fine-grained sandstone and siltstone. Although the bedrock may be partly weathered and there is a fault shear zone with the apparent width of approximately 4 m, there will be no problem about the construction of the structures.

(c) Penstock and Underground Powerhouse Site

The bedrock consists of alternation of fine-grained sandstone and siltstone, coarse-grained sandstone, siltstone and fine-grained sandstone. It is not weathered and has few faults, so the geologic conditions of the site are mostly good.

Although the conditions of siltstone observed in drill cores look bad due to slaking, the geologic conditions of bedrock are presumably not so bad from the result of drill hole deformation tests. Siltstone is judged to be capable of the construction of tunnel, however, it will be necessary to spray concrete as soon as possible after the excavation in order to prevent the deterioration of bedrock.

Although the fine-grained sandstone distributed in the underground powerhouse site is very stiff, the treatment for spring may be necessary as its permeability is high.

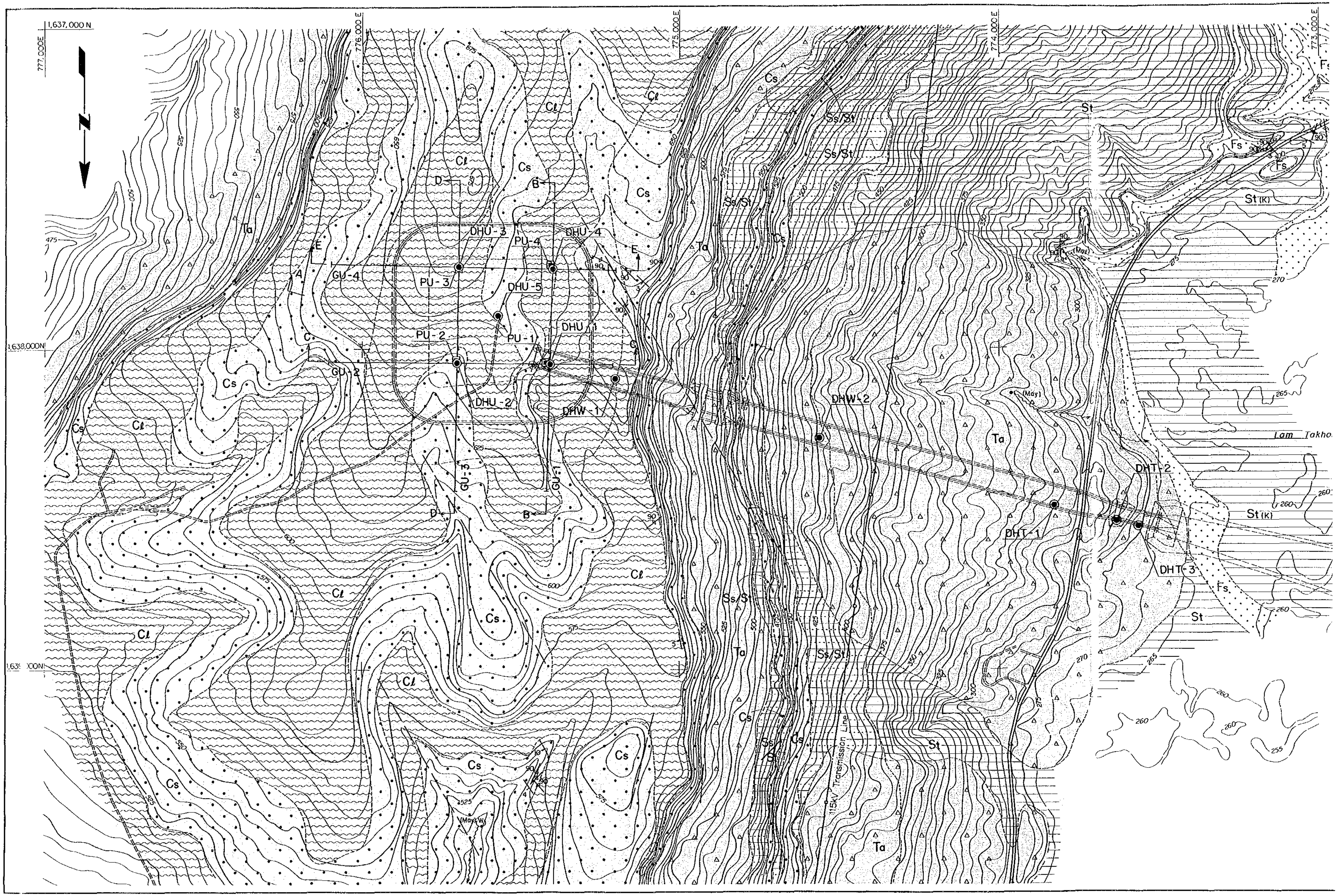
(d) Tailrace Tunnel and Outlet Site

The bedrock is as similar as that of the underground powerhouse site except that it is softened by weathering near the outlet site since the depth from the ground surface is shallow.

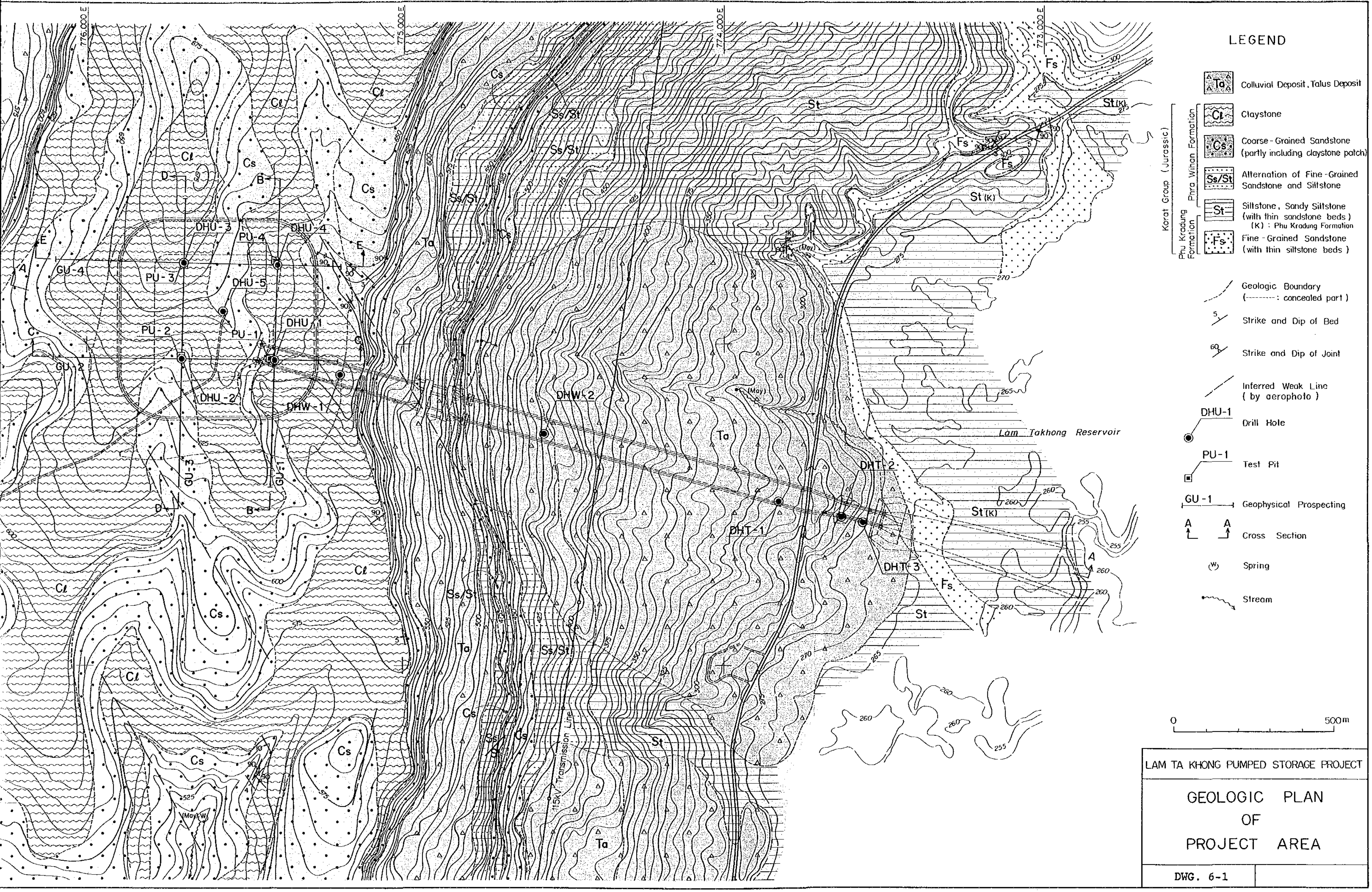
The colluvial and talus deposit of the slope over the tailrace tunnel is highly likely to have been formed by the landslide acted in the past. At present no particular phenomenon indicating current activities can be observed, however, attention should be paid to the point that the excavation for outlet, switchyard and access road in the slope may eventually cause a damage to the stability of the slope.

Table 6-1 Stratigraphy and Properties of Rocks in Project Area

Era	Period	Formation (Geologic Unit)		Lithology	Thickness (m) Unit bed	Thickness (m) Total	Distribution	Compressive Strength (kgf/cm²)	Deformation Modulus (kgf/cm²)	Remarks
CENOZOIC	Quaternary	Colluvial Deposit Talus Deposit		Sandstone fragments and soil material: poorly sorted, including boulders	—	0~30	Slope over waterway	—	—	
		Residual Soil		Lateritic red soil: silty gravel~sandy clay rich in oxides of iron	—	0~ 4	Upper Reservoir	—	—	N-value:50<
MESOZOIC	Jurassic	Phra Wihan Formation	upper part	Claystone: Massive, light-gray, silty	5<, 5-15, 1-3	60<	Upper Reservoir	20-30	—	weathered
				Medium to coarse-grained sandstone: weakly laminated, light-gray, quartzose, partly including claystone patch	25, 30-40		Upper Reservoir, Intake	500-800	10,000-60,000	weathered RQD = 66 %
			middle part	Alternation of sandstone and siltstone: Fine-grained sandstone; light-gray, calcareous, Siltstone and sandy siltstone; Reddish-purple to greenish-gray, calcareous	—	200	Headrace, Penstock	Fine-grained sandstone 500-1,100 Siltstone 200-300	Fine-grained sandstone 50,000-80,000 Siltstone 11,000-25,000	fresh RQD = 75 %
				Medium to coarse-grained sandstone: weakly laminated, light-gray, quartzose	5, 25			700-800	50,000 -300,000<	fresh RQD = 92 %
			lower part	Siltstone and sandy siltstone: Reddish-purple to greenish-gray, calcareous, intercalated light-gray fine-grained calcareous sandstone	—	180	Penstock, Powerhouse	200-300 (sandy part : 500-800)	11,000-25,000	fresh RQD = 79 %
		Phu Kradung Formation		Siltstone and sandy siltstone: Reddish-purple to greenish-gray, calcareous	—	130<	Powerhouse, Tailrace, Outlet	200-300 (sandy part : 500-800)	1,500-25,000	partly weathered RQD = 86 %
				Fine-grained sandstone: light-gray, calcareous, locally intercalated greenish-gray very coarse-grained sandstone and conglomerate	2-20, 20, 10			700-1,100	9,000-80,000	partly weathered RQD = 79 %



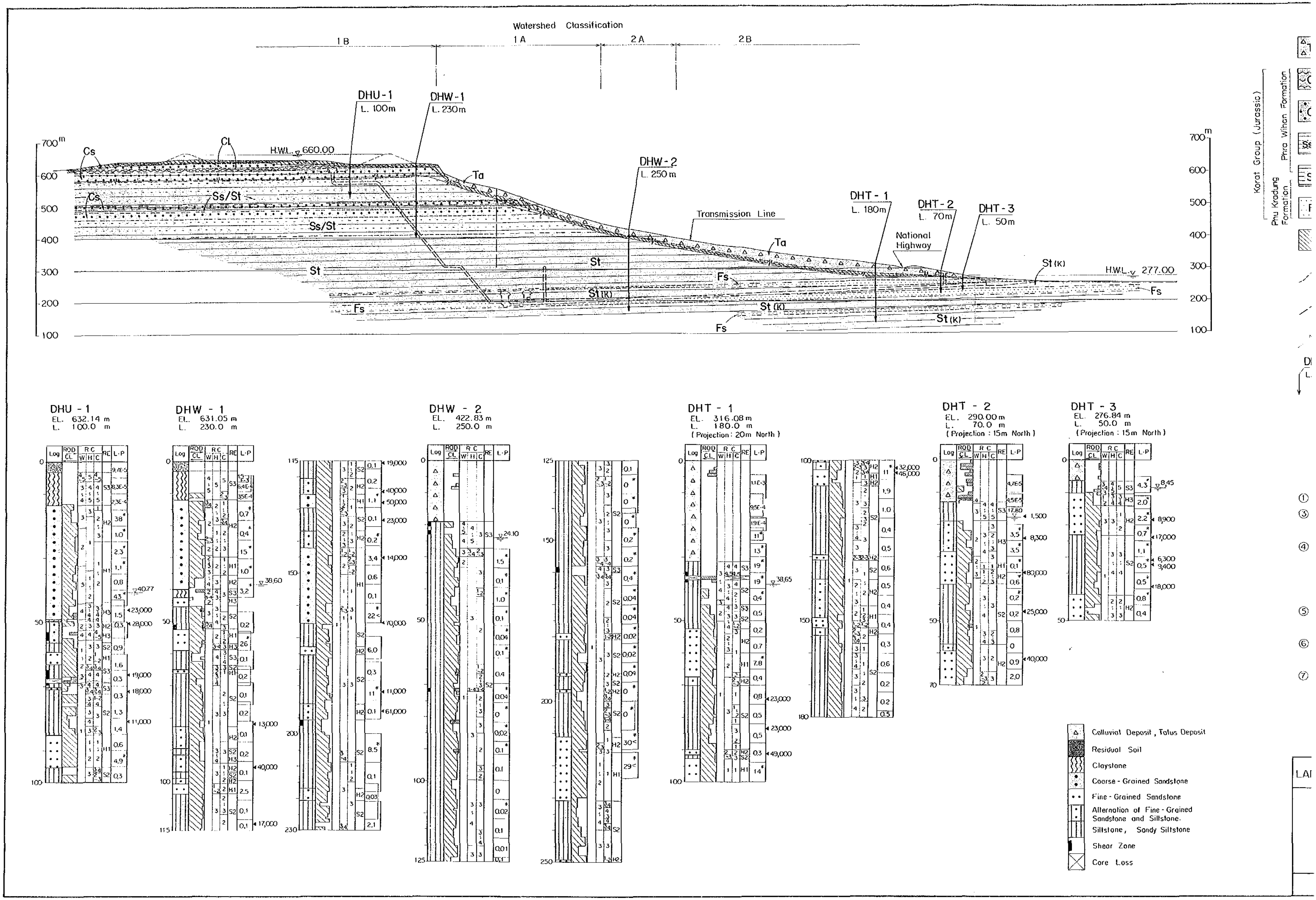
1,637,000 N
777,000E
776,000 E
775,000E
774,000E
773,000E
1,638,000N
N
DHU-3
DHU-4
DHU-5
DHU-1
DHU-2
DHW-1
DHW-2
DHT-1
DHT-2
DHT-3
PU-1
PU-2
PU-3
PU-4
GU-1
GU-2
GU-3
GU-4
Ta
Cs
Cℓ
Ss/St
St
St(K)
Fs
Lam Takho
15kV Transmission Line
(May)



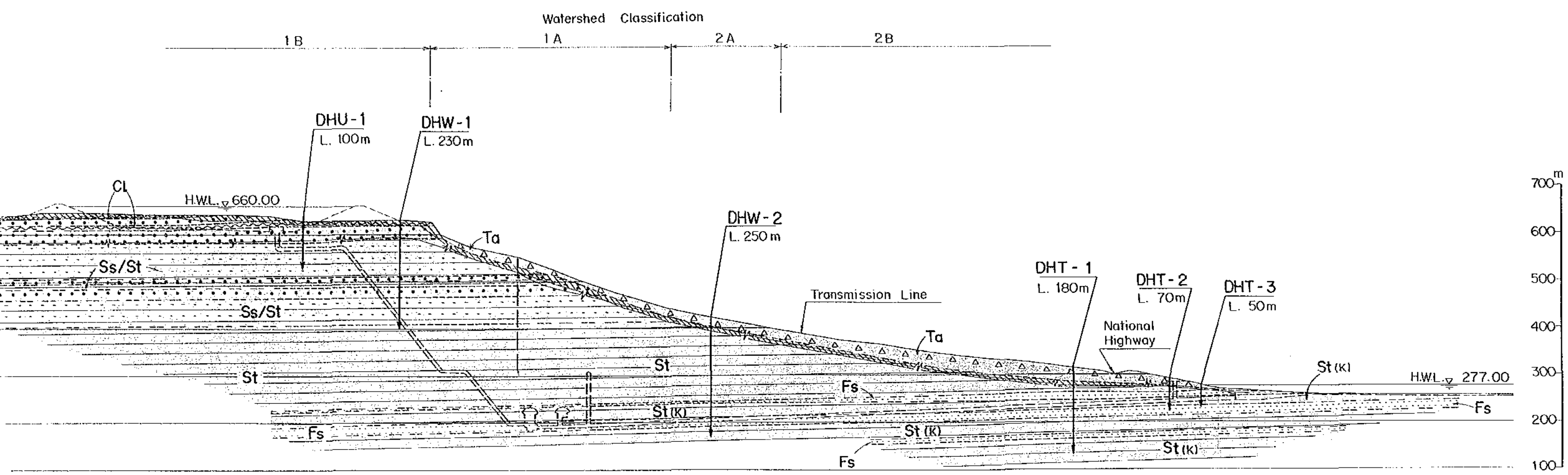
LAM TA KHONG PUMPED STORAGE PROJECT

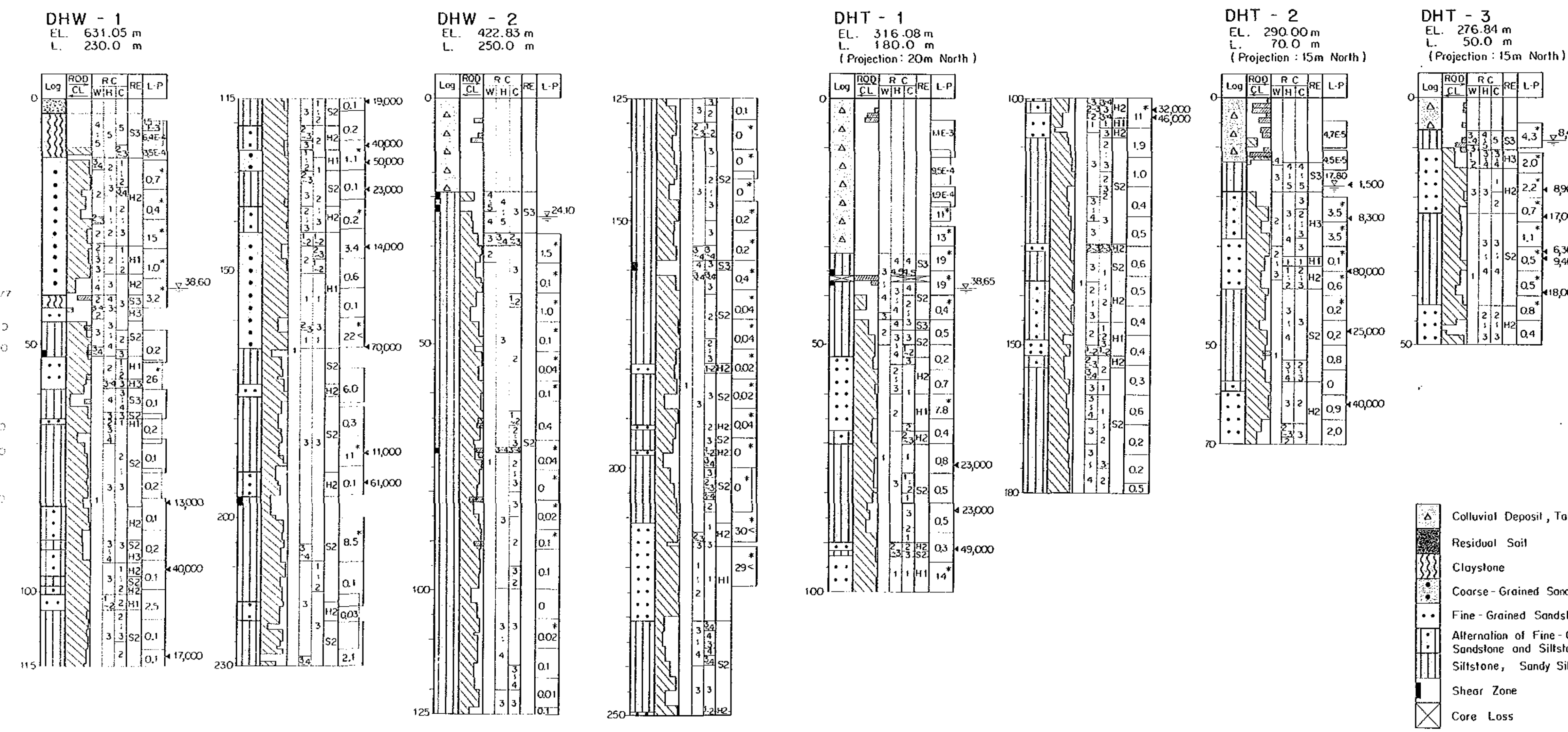
GEOLOGIC PLAN OF PROJECT AREA

DWG. 6-1



Watershed Classification
1 B
1 A
2 A
2 B
DHU-1
L. 100m
DHW-1
L. 230m
DHW-2
L. 250 m
DHT-1
L. 180m
DHT-2
L. 70m
DHT-3
L. 50m
H.W.L. 660.00
H.W.L. 277.00
Transmission Line
National Highway
Cs
CL
Ta
Ss/St
St
St(K)
Fs
Korat Group (Jurassic)
Phra Wihan Formation
Phu Kradung Formation
DHU - 1
EL. 632.14 m
L. 100.0 m
DHW - 1
EL. 631.05 m
L. 230.0 m
DHW - 2
EL. 422.83 m
L. 250.0 m
DHT - 1
EL. 316.08 m
L. 180.0 m
(Projection : 20m North)
DHT - 2
EL. 290.00 m
L. 70.0 m
(Projection : 15m North)
DHT - 3
EL. 276.84 m
L. 50.0 m
(Projection : 15m North)
Log
RQD
CL
R C
W H C
RE
L-P
Colluvial Deposit , Talus Deposit
Residual Soil
Claystone
Coarse - Grained Sandstone
Fine - Grained Sandstone
Alternation of Fine - Grained Sandstone and Siltstone.
Siltstone, Sandy Siltstone
Shear Zone
Core Loss





LEGEND

Korat Group (Jurassic): Phra Wihan Formation; Phu Kradung Formation

- Ta — Colluvial Deposit, Talus Deposit
- Cl — Claystone
- Cs — Coarse-Grained Sandstone (partly including claystone patch)
- Ss/St — Alternation of Fine-Grained Sandstone and Siltstone
- St — Siltstone, Sandy Siltstone (with thin fine-grained sandstone beds) (K): Phu Kradung Formation
- Fs — Fine-Grained Sandstone (with thin siltstone beds)
- Highly Weathered Rock (W ≧ 3‥4)
- Geologic Boundary (-- -- --: inferred)
- Inferred Weak Line (by aerophoto)
- Ground Water Table
- DHU-1 L. 50m — Drill Hole; E.L. : Elevation; L. : Length

① ② ③ ④ ⑤⑥ ⑦

① Depth (m) ② Geologic Column

③ RQD : Rock Quality Designation (%)

CL : Core Loss (%)

④ RC : Rock Classification

W : Weathering, 1 (very fresh) ~ 5 (extremely weathered)

H : Hardness, 1 (very hard) ~ 5 (soft)

C : Joint Interval, 1 (over 30cm) ~ 5 (under 1cm)

⑤ RE : Rock Evaluation

H : Hard Rock, S : Soft Rock, 1 (good) ~ 3 (bad)

⑥ L-P : Lugeon Value (Lu) or Permeability Coefficient (cm/s)

* : Converted Lugeon Value, E-6 : $\times 10^{-6}$

⑦ ▽5.00 : Final Water Level (m)

◂60,000 : Deformation Modulus (kgf/cm^2)

0 100 200 300 400 500 m

- Colluvial Deposit, Talus Deposit
- Residual Soil
- Claystone
- Coarse-Grained Sandstone
- Fine-Grained Sandstone
- Alternation of Fine-Grained Sandstone and Siltstone.
- Siltstone, Sandy Siltstone
- Shear Zone
- Core Loss

LAM TA KHONG PUMPED STORAGE PROJECT

GEOLOGIC PROFILE OF WATERWAY (A-A)

DWG. 6-2

6.2 Construction Materials

(1) Embankment Materials for Upper Dam

As for embankment materials for the upper dam, it will be possible to utilize residual soil, claystone and coarse-grained sandstone obtained by excavation of the upper reservoir. There will be no problem about the utilization of coarse-grained sandstone for the embankment material judging from the results of the drill core test and the concrete aggregate test. According to the material test results, residual soil and claystone are suitable for impervious material, however, it is sufficiently possible to use them for the embankment materials after adequate mixing with coarse-grained sandstone.

(2) Concrete Aggregate

It is hard to collect the river bed gravel in the area around the project site so that it is necessary to collect aggregate at quarries. As quarry sites the following two sites may be proposed: the one is the site where limestone of the Ratburi group is distributed about 12 km to the southwest of Pak Chong (about 30 km to the southwest of the project site) and the other is the site where coarse-grained sandstone is distributed about 1.5 km to the northeast of the upper reservoir.

The limestone of the existing quarry comes up to the standard in ASTM and JIS (Japan Industrial Standards). The rock, however, contains dolomite component which may be noxious for concrete because of alkali-carbonate reaction. Therefore the detailed tests should be carried out hereafter to clarify the suitability.

As for the coarse-grained sandstone, the value of dry density, about 2.35 g/cm^3 is under that of the standard (2.50 g/cm^3) in JIS and the other test results satisfy the standard. As the standard value of density is considered not to be absolute, synthetic examination considering design condition, economics and so forth is necessary for the selection of concrete aggregate.

6.3 Seismicity

Judging from the wide standpoint of view, it can be clearly said that Thailand is an aseismic country except its northern part. Seismic activity of Thailand is remarkably low compared with the adjacent countries, or Myanmar, India, China, Nepal, Japan and so forth. The Lam Ta Khong project site is located in the stable Khorat Plateau which has no fold and the influence of metamorphism. No active fault or no large fault has been reported in and around the site.

On retrieval from the earthquake data files of NOAA (National Oceanic and Atmospheric Administration) with regard to earthquakes in which tremors were felt in the project area, the results obtained were zero times within a radius of 200 km from the Lam Ta Khong upper reservoir site, 8 times within 500 km, and 543 times within 1,000 km.

As is clearly indicated by this, it may be considered that there has been no historical earthquake at this project site from 1959 to 1987 which should be considered in design of the dam and other structures. The maximum acceleration of seismic oscillation was estimated at 20 gal at most at the Lam Ta Khong Upper Reservoir Site, according to the results of earthquake risk evaluated based on earthquakes in history. According to the estimated value, the design seismic intensity at the project site has been adopted 0.05 in consideration of importance of the key structures.

Since the clear location of active faults near the project site have never been reported, the design seismic intensity (0.05) is regarded as appropriate.