THE FEASIBILITY STUDY
ON

THE LOWER NORTHEAST MEDIUM SCALE IRRIGATION PACKAGE PROJECT

IN
THE KINGDOM OF THAILAND

ANNEX

July 1984

JAPAN INTERNATIONAL COOPERATION AGENCY

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A.1. Data Base

Meteorological observation has been operated by the Meteorological Department and Royal Irrigation Department (RID) in this region. The latter authority has distributed a number of observation station over the region mainly to observe rainfall.

The location of observation gauge is shown in Figure A-1-1.

A.1.1 Climatological Data

There exist one syropotic meteorological station at Nakhon Ratchasima. As representing the climate of the Project Basin, climatological data at Nakhon Ratchasima are adopted and is compiled in Table A-1-1.

For this study the reference crop evapotranspiration is computed according to the modified Penman method as recommended by FAO (1977), using the obtained climatological data, and estimated result is shown as follow:

Unit	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
mm/day	3.8	4.4	5.3	5.3	4.5	4.2	4.0	3.7	3.4	3.9	3.9	3.7	-
mm/month	118	123	164	159	140	126	124	115	102	121	117	115	1524

A.1.2. Rainfall

Fourteen Rainfall gauges are located in and near the Sub-Project asins as shown in Figure A-1-1 and Table A-1-2; however, in the hilly and mountan ious regions where the proposed Sub-Project are situated, very few gauges are available.

Thus, it is rather difficult to grasp the areal rainfall of the drainage area of the proposed damsites for the estimation of river discharge.

(1) Annual Rainfall

Annual Rainfall in and near the Project Basins is shown in Table A-1-3. On spatial distribution of rainfall in this region, the annual reinfall is least, about 1000mm, in the Lam Plai Mat and the Nong Lum Puk Sub-Basin and increases to about 1200 - 1400 mm in the Huai Phlu Sub-Basin. In the

southern slope area of the Sam Kamphaeng Range, it remarkably increases about 1500 - 2000 mm.

(2) Monthly Rainfall

The monthly distribution reflects the general characteristics of the climate. On average about 85 percent of the rainfalls in the wet season (May to October) and only 15 percent falls in the dry season and transitional periods.

(3) Daily Rainfall

The frequency analysis of daily reinfall is shown in Table A-1-4.

(4) Hourly Rainfall

Hourly rainfall record with relatively long period is observed in Nang Rong meteorological station.

Based on this data, the following equation is derived from the plot of rainfall depth ratio and rainfall duration using the least square method:

where rt : rainfall intensity for any duration (mm/hr)
R_{24} : maximum one-day rainfall (mm)
t : duration of rainfall (hr)

Since the project area has no rainfall gauging station except the four months observation at the Lam Plai Mat damsite, which was installed just before the field work in study B., the rainfall data at the gauging station related to the project area are collected and arranged to estimate the areal rainfall for the project area.

A.1.3. River Runoff

The river runoff of the project area is also scarece and presents a big seasonal and annual fluctuation due to the particular rainfall pattern and the topographical and geological conditions in the project basin.

Since the basin in the project area consists of a flat topography and is covered with the pervious thick alluvial and terrace deposit, the rainfall at the beginning month of the wet season would be easily absorbed into the ground, which has been dried up during dry seasons of about six months and is not appeared in the river as a runoff.

This fact shows the runoff from May to July is hardly found in the river in spite of the rainfall in the basin.

The runoff appeares in the river from August to October as a form of flood, caused by the high intensity rainfall and the ground conditions satulated by prior rainfall.

Since no runoff observation is made at the damsite of the project area, runoff gauge at the Lam Plai Mat damsite, which has been observed during only three months from August to October, newly installed on August in 1983.

The locations of five runoff gauges are given in Figure A-1-1 and Table A-1-5.

Flood record is collected as shown in Table A-1-7; however it is not available because that recorded discharge is too low and the record length is to short to estimate design flood.

A.1.4 Sediment Transportation

The reservoir sediment data at nearby water storages have been collected.

Reservoir	Drainage Area (sq.km)	Dead Storage (MCM)	Sediment Yield* (cu.m/sq/km/yr.)	Remarks
Lam Nang Rong	453	7.5	165	Existing
Lam Pathia	102	1.2	117	Under Construction
Nam Mun	454	7	154	Study Completed in 1979
Lam Sae	601	7	116	Study Completed in 1979
Lam Ta Khong	1430	20	140	Existing
Average				

Note : *... The useful life of each reservoir has been takne at 100 years.

A.1.5. Water Quality

Water quality in the river runoff was inspected for the irrigation and drinking water at the three places near the damsite of each Sub-Project as shown in Table A-1-8,

No problems are found for the usage on irrigation. However, for the drinking purpose, it will be needed to check in more detail. In this survey, the concentrations of total Iron is in excess of the upper limit of maximum acceptable concentration for drinking water in three basins.

Climatological Data for the Period 1951 - 1980

Station	NAKHON RATCHASIMA	Elevation of station above MSL	187 meters
		Height of barometer above MSL	188 meters
Latitude	14°58' N.	Height of thermometer above ground	1.25 meters
Longitude	102°05' E.	Height of wind vane above ground	11.30 meters
		Height of raingauge	1.00 meters

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Pressure (+1000 or 900 mbs.)													
Mean	13.93	11.85	10.11	08.61	07.09	06.16	06.22	06.24	07.71	10.81	13.14	14.39	09.69
Ext. Max.	28.58	24.58	23.88	21.46	15.78	13.86	14.86	13.36	15.26	19.70	22.98	25.66	26.58
Ext. Min.	03.01	01.78	00.86	98.95	99.34	97.28	97.38	97.26	98.98	01.74	03.68	03.58	97.26
Mean daily range	5.82	6.15	5.94	5.43	4.80	4.32	4.25	4.45	4.65	4.79	4.87	5.34	5.07
Temperature (°C)													
Mean	22.9	25.7	28.1	29.0	28.4	28.1	27.6	27.3	26.5	25.9	24.2	22.5	26.4
Mean Max.	31.0	33.5	35.9	36.5	35.0	34.1	33.4	32.9	31.9	30.8	29.8	29.6	32.9
Mean Min.	16.2	19.3	22.0	23.5	24.0	23.9	23.6	23.4	23.1	22.3	19.5	16.6	21.5
Ext. Max.	37.8	40.6	42.5	42.7	41.4	40.1	40.0	38.1	38.0	35.3	35.3	35.8	12.7
Ext. Min.	4.9	10.6	11.6	15.7	20.7	21.2	21.1	20.5	19.7	16.2	9.1	6.2	4.9
Relative Humidity (%)													
Mean	67.0	65.0	65.0	68.0	76.0	76.0	77.0	78.0	83.0	81.0	76.0	69.0	71.0
Mean Max.	88.0	86.4	86.1	87.2	91.3	91.1	91.4	92.2	95.1	94.2	92.0	90.4	90.5
Mean Min.	43.0	40.9	40.4	43.9	53.4	55.2	56.5	58.6	64.0	63.0	56.2	40.6	52.0
Ext. Min.	22.0	14.0	12.0	19.0	23.0	23.0	35.0	35.0	39.0	31.0	27.0	20.0	12.0
Dew Point (°C)													
Mean	15.8	17.8	19.2	21.8	23.2	23.1	22.0	22.8	23.2	22.2	19.3	16.6	30.6
Evaporation (mm)													
Man Pan	146.4	152.0	193.0	194.4	182.9	173.4	168.9	159.8	132.2	137.2	134.8	140.5	1,915.5
Cloudiness (0 - 8)													
Mean	2.9	3.4	3.8	4.5	5.6	6.3	6.5	6.8	6.5	5.1	3.9	3.2	4.9
Sunshine Duration (hr.)													
Mean	283.0	244.7	248.4	245.3	244.5	207.4	194.7	85.8	166.1	225.0	258.6	277.1	2,780.6
Visibility (km)													
0700 L.S.T.	3.7	3.4	3.6	5.1	8.0	9.6	9.6	9.5	7.7	6.4	5.1	4.1	6.3
Mean	7.5	6.3	6.2	7.6	9.8	10.6	10.6	10.3	9.5	9.7	9.2	8.3	8.8
Wind (Knots)													
Prevailing wind	NE	NE	NE	SW	SW	SW	W	W	W	NE	NE	NE	-
Mean wind speed	2.5	2.6	2.5	2.9	2.8	3.7	3.8	3.5	2.4	2.7	3.2	2.9	-
Max. wind speed	28 ENE	37 E	43 SSW	53 S	46 SE	58 SW	41 W	35 SE	53 S WSW	54 SE	44 NE, E	40 NE	58 SW
Number of days with													
Haze	27.5	26.9	29.1	22.1	0.5	0.9	0.6	1.1	2.3	9.9	17.3	24.2	168.4
Fog	3.2	3.1	2.6	2.9	1.3	0.3	0.3	0.2	1.0	2.3	2.2	2.4	22.0
Hail	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Thunderstorm	0.4	2.0	7.5	13.4	16.9	8.5	8.2	7.5	11.3	7.0	0.6	0.0	63.3
Squall	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7

Remark: 1. Evaporation 1962 - 1980
2. Sunshine duration 1957 - 1969

Table List of Rain Gauge

Code Agency	Station	Location Lat-N	Location Long-E	Elevation M(M.S.L.)	Period of Record	Period of Collected Record	Missing Record
25112	Khon Buri	14°31'10"	102°14'40"	225	1940 to date	1951-'81	'46-51, '62
25530	Lam Sae	14°23'51"	102°15'20"	217.5	1968 to date	1968-'83 1/	'80
(RID.M121)	Soeng Sang	14°18'	102°26.5'	(240)	1983 (July to date)	July-Oct.	
02033	Nang Rong	14°37'40"	102°47'50"	185	1909 to date	1952-'83	'11, '21-22, '25 '27-28, '33-38 '40-41, '45-51
02022	Prakhon Chai	14°36'30"	103°05'10"	(160)	1921 to date	1961-'83	'23, '25-27, '32-33 '40-41, '46, '52
02082	Nikhom Ban Kruat	14°26'00"	103°06'10"	(195)	1962 to date	1962-'83	'71, '74-75, '78
02092	Lahan Sai	14°25'00"	102°51'00"	(216)	1967 to date	1967-'83	'82
(RID)	Lam Nang Rong Dam	14°18'	102°46'	-	1980 to date	1980-'83	
(RID)	Lam Pathia Dam	14°19'	102°57'	-	1982 to date	1982-'83	
(NEA)	Ban Raboh Hu Kwang	13°59.6'	102°25.5'	80	1968 to date	1968-'83	
44191	Huai Samong	14°03'46"	101°55'39"	-	1968 to date	1968-'82 2/	
44181	Lam Phyathan	14°09'30"	101°52'52"	-	1967 to date	1967-'82 2/	
44210	Ta Phraya	14°00'20"	102°48'45"	(70)	1965 to date	1965-'82 2/	'82

Remarks: 1/ Up to Oct. 1983

2/ Monthly basis

Annual Rainfall in and Near the Project Area

Basin/ Location Station	Upper Nam Mun		Lam Plai Mat					Changwat Prachinburi				Lam Chi Noi	
	Khon Buri	Lam Sae	Soeng Sang	Nang Rong	Lam Nang Rong Dam	Lahan Sai	Lam Pathia Dam	Lam Phyathan	Huai Samong	Ban Raboh Hu Kwang	Ta Phraya	Prakhon Chai	Nikhom Bon Kruat
Water Year													
1952	1,116.9	-	-	1,207.6	-	-	-	-	-	-	-	-	-
1953	810.9	-	-	1,093.4	-	-	-	-	-	-	-	1,244.1	-
1954	1,020.8	-	-	1,200.7	-	-	-	-	-	-	-	1,241.4	-
1955	1,264.9	-	-	1,030.6	-	-	-	-	-	-	-	1,426.5	-
1956	1,221.4	-	-	1,355.3	-	-	-	-	-	-	-	1,840.4	-
1957	793.2	-	-	1,330.3	-	-	-	-	-	-	-	1,378.3	-
1958	964.5	-	-	1,155.4	-	-	-	-	-	-	-	1,278.2	-
1959	1,269.4	-	-	1,347.3	-	-	-	-	-	-	-	1,645.0	-
1960	864.9	-	-	1,428.6	-	-	-	-	-	-	-	1,582.9	-
1961	684.3	-	-	1,280.8	-	-	-	-	-	-	-	1,204.4	1,335.8
1962	-	-	-	1,303.3	-	-	-	-	-	-	-	976.5	1,221.9
1963	1,099.3	-	-	1,114.8	-	-	-	-	-	-	-	1,282.0	1,536.7
1964	1,468.4	-	-	1,481.0	-	-	-	-	-	-	-	1,438.8	1,750.6
1965	1,219.6	-	-	1,454.1	-	-	-	-	-	-	1,099.8	1,227.0	1,448.0
1966	1,454.0	-	-	1,575.8	-	1,693.6	-	-	-	-	1,417.4	1,362.5	1,702.1
1967	1,119.6	-	-	1,236.2	-	1,202.4	-	-	-	-	891.2	1,186.6	1,350.6
1968	882.8	948.3	-	954.7	-	1,147.4	-	1,484.4	-	-	932.2	1,223.9	1,390.4
1969	925.7	1,123.8	-	1,213.0	-	1,232.0	-	2,009.5	1,289.0	1,687.4	1,447.7	1,450.8	1,578.0
1970	1,024.9	1,533.0	-	1,171.9	-	1,159.3	-	1,911.7	1,679.2	1,158.5	1,740.0	1,260.9	1,449.1
1971	734.8	1,091.9	-	1,111.9	-	969.6	-	1,827.4	1,720.8	1,837.4	1,175.3	1,429.5	-
1972	890.3	863.7	-	1,672.1	-	1,288.3	-	2,432.2	1,912.9	1,507.5	1,173.3	1,645.1	-
1973	1,159.5	918.4	-	1,181.9	-	1,336.4	-	1,659.8	1,575.4	1,210.2	1,022.1	1,173.4	-
1974	1,096.1	1,146.8	-	1,181.5	-	1,092.7	-	1,901.2	1,526.8	1,660.2	1,113.8	1,091.2	-
1975	1,203.6	1,134.3	-	1,071.8	-	1,219.3	-	-	1,649.9	1,476.5	973.6	1,148.8	1,361.9
1976	1,019.3	1,127.8	-	1,222.7	-	1,134.7	-	2,259.2	2,083.4	1,676.2	746.4	1,467.4	1,086.5
1977	859.4	1,202.4	-	1,298.1	-	874.5	-	2,065.1	1,360.4	1,261.8	696.3	1,102.7	1,308.6
1978	686.3	1,004.2	-	1,394.1	-	1,198.5	-	2,079.5	1,722.5	1,428.1	1,116.8	1,828.1	-
1979	759.6	618.0	-	1,027.8	-	985.1	-	1,686.7	1,356.9	1,235.3	679.6	1,664.7	1,131.3
1980	868.4	1,171.8	-	1,386.6	-	1,851.8	-	2,202.5	1,993.0	1,580.9	1,042.1	1,920.3	1,698.1
1981	812.6	730.8	-	1,058.1	1,010.5	-	-	2,200.3	1,806.0	1,332.0	880.6	1,156.9	1,031.9
1982	848.6	831.2	-	946.8	1,074.1	935.5	1,070.6	2,128.8	1,506.3	1,419.2	-	-	1,351.1
1983	/1(929.6)	/1(1,219.9)	/2(839.4)	/1(1,627.3)	/1(1,204.0)	/1(1,403.6)	/1(1,280.7)	-	-	/1(1,567.8)	-	/1(1,662.5)	/1(1,833.2)
Average upto '82	1,004.8	1,029.8	-	1,241.6	1,042.3	1,207.6	1,070.6	1,989.2	1,655.9	1,462.2	1,067.5	1,375.1	1,396.0

Notes: /1 Rainfall from Apr. to Oct. /2 Rainfall from Jul. to Oct.

Frequency of Maximum One-Day Rainfall

Return Period (Years)	Lam Sae 1/	Lahan Sai 2/
2	75	77
5	100	112
10	115	136
20	131	159
25	136	166
50	151	188
100	166	210
200	181	231
250	186	238
500	201	260
1000	215	282

Notes: 1/ Numbers of years = 14 (1968 - '81)

2/ Numbers of years = 15 (1967 - '81)

Table A-1-5

List of Runoff Gauge

Gauge Code	River	Location Lat.-N	Location Long.-E	D.A (sq.km)	Type of Gauge	Period of Record	Period of Collected Record	Rating Operation
1. Upper Nam Mun Basin								
M81A	Lam Sae	14° 22' 22"	102° 15' 40"	442	F 1/	1970-up-to-date	1970-80, '83	1970-'82
2. Lam Plai Mat Basin								
M121	Lam Plai Mat	14° 03'	102° 26'	485	V	Aug.'83-up-to-date	Up-to Oct. '83	1983
M82	Lam Plai Mat	14° 37' 59"	102° 43' 13"	1581	V	1969-'71	1969-'71	1969-'71
M86	Lam Sai Yong	14° 39' 48"	102° 38' 42"	280	V	1969-'71	1969-'71	1969-'71
3. Lam Chi Noi Basin								
M93	Huai Seo	14° 28' 24"	103° 06' 30"	329	V	1978-up-to-date	1978-Oct. '83	1978-'82

Note: 1/ Vertical staff gauge and float gauge.

Annual Runoff and Runoff Depth at Runoff Gauge

Station	M81A	M121	M82	M86	M93
D.A (sq.km)	442	485	1,581	280	329
1. Annual Runoff (MCM)					
Water Year					
1969	-	-	123	31	-
1970	100	-	148	22	-
1971	143	-	96	14	-
1972	311	-	-	-	-
1973	110	-	-	-	-
1974	172	-	-	-	-
1975	260	-	-	-	-
1976	223	-	-	-	-
1977	122	-	-	-	-
1978	216	-	-	-	54
1979	114	-	-	-	13
1980	189	-	-	-	111
1981	-	-	-	-	11
1982	-	-	-	-	62
1983	(213) 1/	(63) 2/	-	-	(105) 1/
Average 3/	178	-	122	22	50
2. Annual Runoff Depth (mm)					
Water Year					
1969	-	-	78	111	-
1970	226	-	94	79	-
1971	323	-	61	51	-
1972	704	-	-	-	-
1973	249	-	-	-	-
1974	389	-	-	-	-
1975	588	-	-	-	-
1976	505	-	-	-	-
1977	276	-	-	-	-
1978	488	-	-	-	164
1979	257	-	-	-	40
1980	427	-	-	-	337
1981	-	-	-	-	34
1982	-	-	-	-	187
1983	(482) 1/	(131) 2/	-	-	(320) 1/
Average 3/	403	-	78	80	152

Notes: 1/ Runoff from Apr. to Oct.
2/ Runoff from Jul. to Oct.
3/ Up to 1982

Flood Records at Runoff Gauges

Station	M81A	M121	M82	M86	M93
DA (sq.km)	442	485	1,581	280	329
Peak Discharge (cu.m/s); and (Specific Yield) (cu.m/s/sq.km)					
Water Year					
1969	-	-	54 (0.03)	46 (0.16)	-
1970	37 (0.08)	-	38 (0.02)	12 (0.04)	-
1971	131 (0.30)	-	35 (0.02)	8 (0.03)	-
1972	272 (0.62)	-	-	-	-
1973	89 (0.20)	-	-	-	-
1974	59 (0.13)	-	-	-	-
1975	112 (0.25)	-	-	-	-
1976	61 (0.14)	-	-	-	-
1977	103 (0.23)	-	-	-	-
1978	82 (0.19)	-	-	-	38 (0.12)
1979	74 (0.17)	-	-	-	20 (0.06)
1980	112 (0.25)	-	-	-	58 (0.18)
1981	90 (0.20)	-	-	-	6 (0.02)
1982	-	-	-	-	44 (0.13)
1983	156 (0.35)	160 (0.33)	-	-	84 (0.26)

Water Quality at the Proposed Damsites

Date collected 24-25th June, 1983

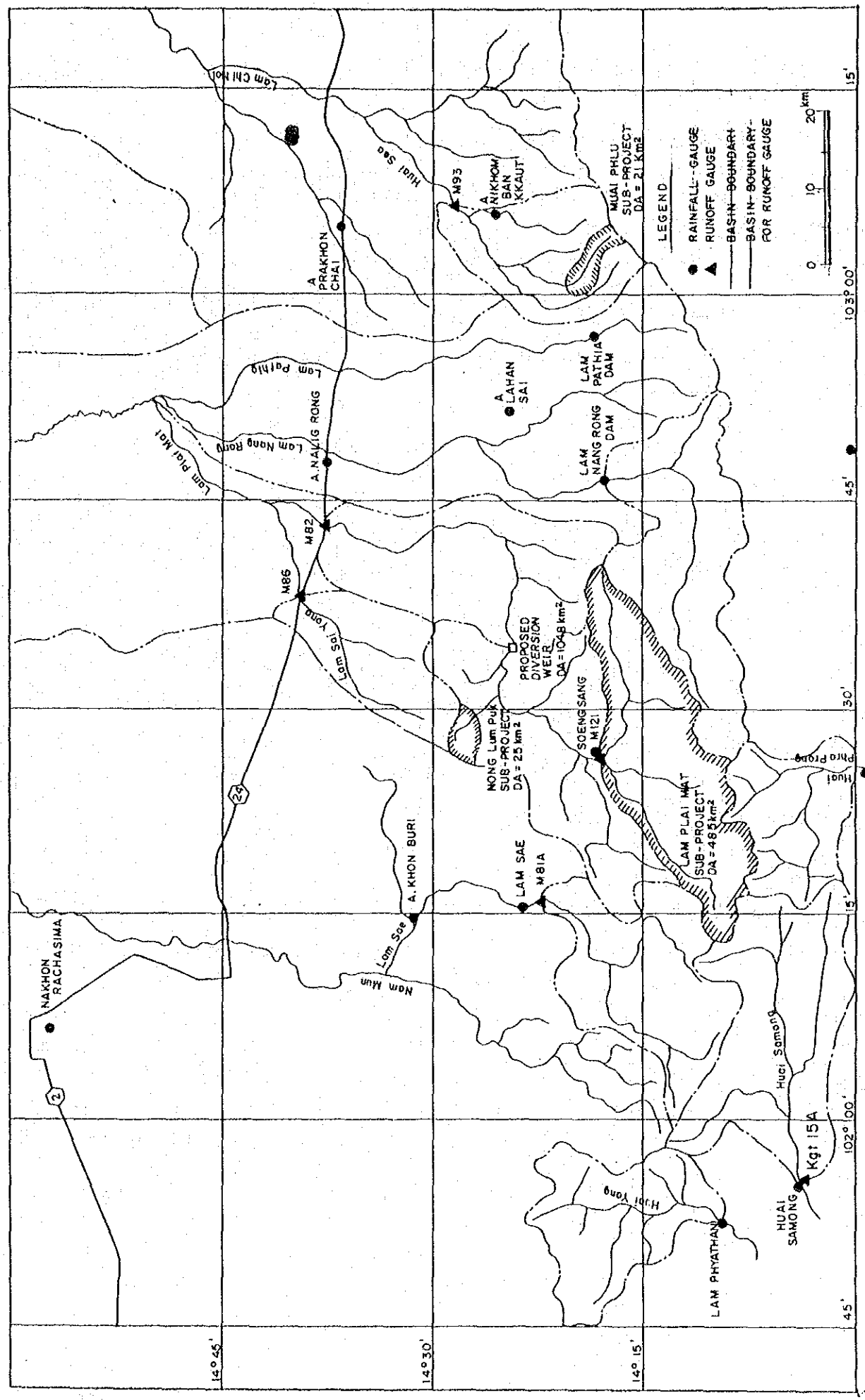
Item		Standard	Lam Plai Mat	Nong Lum Puk	Huai Phlu
P.H		6.5-9.2 1/	6.7	7.3	6.8
EC x 10^6	umho/cm	L.T 250 2/	47	200	120
SiO_2	ppm		5	4	5
B	"	L.T 1 2/	0	0.04	0
Ca^{++}	meq/l(ppm)	(75) 1/	0.15 (3)	0.81 (16)	0.53 (1)
Mg^{++}	"	(50) 1/	0.21 (2)	0.62 (7)	0.44 (5)
Na^{++}	"		0.15 (3)	0.64 (15)	0.21 (5)
K^{+}	"		0.05 (2)	0.15 (6)	0.03 (1)
CO_3^{--}	"		0.0	0.0	0.0
HCO_3^{--}	"		0.25 (15)	1.87 (114)	0.87 (53)
CL^{-}	"	(250) 1/	0.25 (9)	0.18 (6)	0.27 (10)
SO_4^{--}	"	(200) 1/	0.11 (5)	0.13 (6)	0.06 (3)
NO_3^{-}	"		0.01 (0.6)	0.02 (14)	0.01 (0.81)
PO_4^{---}	"		(0.03)	(0.03)	(0.02)
TS	ppm		116	498	167
SSP	%		29	31	18
SAR		L.T 10 2/	0.3	0.8	0.3
RSC	meq/l	L.T 1.25 2/	0	0.44	0
T.Fe	meq/l(ppm)	L.T (0.3) 3/	0.05 (1.0)	0.06	0.11 (2.1)
D.Fe	"		0.04 (0.75)	0.01	0.14 (2.6)

Notes: 1/ Drinking Water Quality Standard of Thailand, Maximum Acceptable.

2/ Acceptable upper value for irrigation with most crops and most soils by U.S. Salinity Laboratory.

3/ Drinking Water Quality Standard of World Health Organization (WHO)

Location Map of Rainfall and Runoff Gauge



A.2. General Relation, Rainfall-Runoff and Areal Rainfall for Sub-Basin.

A.2.1. General Relation, Rainfall-Runoff

In order to grasp the correlation between the rainfall and runoff yield and confirm the scarece runoff in the Lam Plai Mat basin, the gauging station at M121 for runoff observation was newly established.

The observation method and the rating curve of discharge in the Lam Plai Mat gauging station has been checked and reviewed carefully by the study team hydrologist.

Areal rainfall has been produced by Tliessen method as shown in Figure A-2-1.

Annual runoff coefficients with areal rainfall at 4 runoff gauges as shown Table A-2-1 and are summarized as follows:

Station	DA (sq.km)	Average Annual Rainfall (mm)	Average Annual Runoff (mm)	Average Annual Runoff Coef. (%)	Observed Period of Runoff
M81A	442	1233	178	32.7	1970 - '80
M82	1581	1252	122	6.2	1969 - '71
M86	280	1058	22	7.6	1969 - '71
M93	329	1253	50	12.1	1978 - '82

It should be noted that the runoff coeficients at M81A are surprisingly high as compared with 1233 mm of the average annual rainfall and also with the runoff coefficients in other gauges.

The observed runoff data at M121 are shown in Table A-2-2, with adjoining basin's data. On comparing these observated runoff, same tendency as described above and low runoff coefficient at the damsite of the Lam Plai Mat are confirmed.

A.2.2. Areal Rainfall over the drainage area at each Damsite

Areal Rainfall with a long term for Sub-Basin has been estimated to study water resources availability on daily basis.

(1) Lam Plai Mat and Nong Lum Puk Damsites

The areal daily rainfall for a long term to estimate the long period runoff at the Lam Plai Mat damsite is developed based on the correlation between the areal rainfall which is produced by Thiessen method for the duration from July to October, 1983 and the spot rainfall in and near the project basin.

The correlation equation is as follows:

1952 - 1968, $Y = 1.073X1$

1968 - 1982, $Y = 0.600X2 + 0.227X3$

where, Y = Lam Plai Mat, $X1$ = Khon Buri

$X2$ = Lam Sae, $X3$ = Ban Raboh Hu Kwang

Since the daily rainfall data are not observed in X2 and X3 station, before 1968, the data of X1 is adopted for a pariod of 1952 to 1968.

The estimated monthly rainfall by daily basis for the Lam Plai Mat is summarized in Table A-2-3.

This rainfall data are also used for the runoff estimation of the Nong Lum Puk Project, which is located in the same basin.

(2) Huai Phlu Damsite

The areal rainfall with long term for the Huai Phlu damsite in the Huai Seo basin is estimated based on the correlation between rainfall at Lam Pathia Dam and at the other two stations.

The correlation equation is as follows.

1952 - 1960 $Y = 1.049X1$

1961 - 1981 $Y = 0.41X2 + 0.59X3$

Y = Huai Phlu

X1 = Nang Rong

X2 = Lam Pathia Dam

X3 = Nikom Ban Kruat

There are some missing data in the observed rainfall, for which correlation analysis between the nearby gauge has been made. The correlation factors are not always satisfactory.

The monthly rainfall estimated on the daily basis is summarized in Table A-2-3.

(3) Tendency and Frequency of Long-Term Areal Rinfall

These long-term areal rainfalls are analysed to determine whether any consistent trends over the period of 30 years are evident.

The 7 and 13-year moving averages of the annual rainfall have been plotted in Figure A-2-2. The graphs show no consistent trend with time.

Frequency analysis has revealed that water year 1979 was considerable dry year during past 30 years as shown in Table A-2-4.

Areal Rainfall and Annual Runoff Coefficient at Runoff Gauge

Station	M81A	M121	M82	M86	M93
DA (sq.km)	442	485	1,581	280	329
1. Areal Rainfall (mm)					
Water Year					
1969	- 1/	-	1,256.6 2/	1,098.6 3/	-
1970	1,586.1	-	1,318.1	1,115.1	-
1971	1,239.9	-	1,181.2	961.2	-
1972	1,141.3	-	-	-	-
1973	1,070.5	-	-	-	-
1974	1,264.1	-	-	-	-
1975	1,231.2	-	-	-	-
1976	1,353.9	-	-	-	-
1977	1,300.6	-	-	-	- 4/
1978	1,194.4	-	-	-	1,255.1
1979	810.2	-	-	-	1,009.6
1980	1,371.3	-	-	-	1,797.2
1981	-	-	-	-	966.6
1982	-	-	-	-	1,236.2
Average	1,233.0	-	1,252.0	1,058.3	1,252.9
2. Annual Runoff Coefficient (%)					
Water Year					
1969	-	-	6.2	10.1	-
1970	14.2	-	7.1	7.1	-
1971	26.1	-	5.2	5.3	-
1972	61.7	-	-	-	-
1973	23.3	-	-	-	-
1974	30.8	-	-	-	-
1975	47.8	-	-	-	-
1976	37.3	-	-	-	-
1977	21.2	-	-	-	-
1978	40.9	-	-	-	13.1
1979	31.7	-	-	-	4.0
1980	31.1	-	-	-	18.8
1981	-	-	-	-	3.5
1982	-	-	-	-	15.1
Average	32.7	-	6.2	7.6	12.1

Notes: 1/ Areal rainfall = Lam Sae (0.78) + Huai Samong (0.13) + Lam Phyathan (0.09)

2/ Areal rainfall = Nang Rong (0.15) + Lahan Sai (0.27) + B. Raboh Hu Kwang (0.16) + Lam Sae (0.42)

3/ Areal rainfall = Khon Buri (0.40) + Nang Rong (0.60)

4/ Areal rainfall = Lam Pathia (0.41) + Nikhom Ban Kruat (0.59)

Areal Rainfall and Runoff for the Basins in and near Project Area

Basin	D.A.	Item	Aug.(1983) 1	Aug.(1983) 2	Aug.(1983) 3	Sep. 1	Sep. 2	Sep. 3	Oct. 1	Oct. 2	Oct. 3	Total (Aug. to Oct.)	Runoff Coefficient
	(sq.km)		(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(%)
Lam Sae	442	Areal Rainfall	140	106	43	144	29	206	151	136	13	968	50
(M81A)		Runoff	24	34	49	28	22	38	74	165	48	482	
Lam Plai Mat	485	Areal Rainfall	82	61	30	89	58	139	88	166	29	742	18
(M121)		Runoff	2	2	6	8	8	12	20	79	31	131	
Nang Rong Dam	450	Areal Rainfall	133	125	26	47	142	118	103	198	21	907	36
		Runoff 3/	19	4	8	36	16	17	46	153	25	324	
Huai Seo	329	Areal Rainfall	121	91	18	93	131	158	134	123	28	896	32
(M93)		Runoff	9	20	23	6	18	18	40	129	24	287	

1/ 1, 2, 3 : Early, Middle and End of each month.

2/ Thissen Weight

Lam Sae : Lam Sae (0.75) + M121 (0.03) + Huai Samong (0.14) + Lam Phyathan (0.08)
Lam Plai Mat : M121 (0.84) + Nang Rong Dam (0.07) + Ban Raboh Hu Kuang (0.06) + Lam Sae (0.03)
Nang Rong Dam : Nang Rong Dam (0.72) + M121 (0.24) + Ban Raboh Hu Kwang (0.02) + Ta Phraya (0.02)
Huai Seo : Lam Pathia (0.41) + Nikhom Ban Kruat (0.59)

3/ Runoff was estimated on the basis of observed mean daily reservoir stage.

Rainfall Over the Drainage Area at the Proposed Damsites

Table A-2-3

(A) Lam Plai Mat and Nong Lum Puk

1952 - Jun. 1968 Areal Rainfall = 1.073 x Khon Buri

Jul. 1968 - 1981 Areal Rainfall = 0.600 x Lam Sae + 0.227 x Ban Raboh Kwang

MONTHLY RAINFALL IN MILLIMETER

WATER YEAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	ANNUAL
1952	107.3	199.7	180.5	56.9	84.9	75.3	318.0	0.0	0.0	0.0	105.8	70.5	1198.9
1953	137.5	139.0	192.5	230.8	70.4	34.6	34.1	0.0	0.0	0.0	0.0	31.4	870.3
1954	71.1	233.3	51.9	164.2	161.4	259.1	88.7	0.0	0.0	0.0	23.4	42.2	1095.3
1955	117.6	238.7	145.5	82.3	118.3	293.8	107.7	214.9	0.0	0.0	17.9	20.2	1356.9
1956	39.0	59.7	98.1	265.1	150.9	202.2	302.7	29.0	0.0	0.0	1.6	162.2	1310.5
1957	10.5	162.2	45.5	136.9	130.4	181.2	154.2	23.6	0.0	6.4	0.0	0.0	850.9
1958	90.2	29.5	11.8	248.8	160.1	330.8	141.2	0.0	0.0	0.0	9.7	12.9	1035.0
1959	80.5	48.9	103.5	188.6	119.9	549.4	242.0	8.6	0.0	0.0	0.0	20.8	1362.2
1960	68.3	186.2	110.4	37.1	57.9	95.0	260.5	71.3	0.0	0.0	6.4	34.5	927.6
1961	0.0	84.7	104.7	47.4	75.4	170.6	197.7	0.0	0.0	0.0	0.0	51.4	733.9
1962	122.6	112.5	3.2	104.1	43.6	285.7	115.4	0.0	0.0	0.0	0.0	65.5	852.6
1963	115.4	223.2	93.7	38.0	185.4	246.8	153.2	68.0	0.0	0.0	6.2	49.4	1179.3
1964	186.1	334.9	36.2	262.8	131.8	229.8	216.4	26.0	0.0	0.0	47.2	120.2	1591.4
1965	135.2	234.3	72.8	80.1	211.5	378.7	155.2	26.5	0.0	0.0	12.0	2.4	1308.7
1966	158.2	407.6	83.3	88.4	247.8	428.2	109.3	19.8	17.6	0.0	0.0	0.0	1560.2
1967	116.7	186.1	153.1	114.0	128.4	306.7	94.5	27.2	0.0	0.0	0.0	70.9	1199.6
1968	104.4	66.5	116.8	122.5	87.9	176.3	35.3	112.5	0.0	4.3	9.9	93.9	930.3
1969	111.1	90.3	111.2	74.7	138.2	342.7	127.0	8.6	0.0	0.0	.2	53.6	1057.6
1970	102.4	250.5	165.9	115.5	148.2	149.3	145.2	9.3	55.5	13.4	10.0	17.3	1182.5
1971	74.1	89.8	182.4	86.7	133.2	232.0	132.0	4.1	5.9	0.0	32.7	104.7	1059.6
1972	96.0	38.1	103.6	34.3	53.4	252.4	143.8	98.2	1.3	0.0	16.3	22.6	860.0
1973	28.8	79.6	56.5	54.9	97.2	243.1	132.6	21.5	0.0	14.8	28.2	68.6	825.8
1974	98.9	108.1	96.0	99.8	90.1	146.0	197.9	75.7	.3	16.9	25.2	110.1	1065.0
1975	22.2	156.6	103.6	146.9	85.6	200.5	117.7	19.9	3.9	0.0	19.3	139.2	1015.4
1976	66.5	97.2	90.2	120.4	154.8	174.6	288.8	25.3	0.0	3.3	2.9	33.2	1057.2
1977	60.3	205.3	47.9	93.1	135.2	196.4	133.2	30.8	0.0	16.1	18.6	70.3	1007.2
1978	33.8	199.7	83.1	241.7	77.3	208.0	58.8	8.8	.4	0.0	3.8	13.0	926.4
1979	15.4	122.8	81.4	89.3	67.5	169.7	45.0	.9	0.0	0.0	37.7	21.4	651.1
1980	36.9	145.2	293.2	138.1	119.8	77.0	191.7	3.3	1.1	0.0	27.6	87.7	1121.6
1981	52.2	53.5	82.4	63.3	76.9	172.4	82.0	103.2	0.0	0.0	3.8	45.1	740.8
AVERAGE	82.0	152.9	102.8	120.9	118.1	226.9	150.7	34.6	2.9	2.5	15.7	54.5	1064.5

(B) Huai Phlu

1952 - 1960 Areal Rainfall = 1.049 x Nang Rong

1961 - 1981 Areal Rainfall = 0.41 x Lam Pathia + 0.59 x Nikhom Ban Kruat

MONTHLY RAINFALL IN MILLIMETER

WATER YEAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	ANNUAL
1952	29.5	173.9	115.7	82.5	139.7	144.2	345.1	0.0	0.0	12.6	205.7	7.6	1266.5
1953	78.6	147.3	113.0	235.6	105.6	270.1	143.5	31.5	0.0	22.1	0.0	0.0	1147.3
1954	121.2	127.5	97.2	220.5	215.0	348.1	122.0	0.0	0.0	0.0	0.0	18.9	1259.4
1955	0.0	33.6	309.7	98.9	163.2	321.0	16.5	23.3	0.0	0.0	80.4	35.0	1081.6
1956	177.0	120.6	150.0	270.4	127.8	192.1	256.3	0.0	0.0	0.0	0.0	128.2	1422.4
1957	104.8	19.4	94.7	211.1	87.8	385.0	471.4	21.3	0.0	0.0	0.0	0.0	1395.5
1958	0.0	109.4	130.9	193.3	306.9	309.2	162.0	0.0	0.0	0.0	0.0	0.0	1211.7
1959	19.6	133.9	154.6	195.3	84.0	470.2	314.9	0.0	0.0	0.0	0.0	40.4	1412.9
1960	39.0	158.7	110.7	93.6	233.4	316.2	442.5	50.6	0.0	2.8	0.0	50.9	1498.4
1961	138.0	160.5	142.0	155.9	173.5	266.4	167.0	32.0	0.0	0.0	0.0	16.0	1251.3
1962	67.8	142.2	98.2	233.1	124.0	326.7	129.8	0.0	0.0	0.0	2.4	19.9	1144.1
1963	105.3	197.7	194.2	101.1	195.1	316.4	130.5	167.1	0.0	0.0	6.8	26.7	1439.9
1964	53.2	407.3	197.1	184.5	200.2	214.8	126.3	69.4	0.0	0.0	64.4	121.7	1638.9
1965	75.3	171.9	96.8	188.5	293.5	431.6	60.8	24.8	0.0	0.0	12.6	0.0	1355.8
1966	147.2	401.3	117.8	217.1	222.8	268.5	238.9	37.0	17.0	12.7	51.3	0.0	1731.7
1967	101.8	216.2	137.7	122.3	151.5	383.5	107.0	54.8	0.0	18.1	7.9	12.1	1312.9
1968	77.1	174.4	214.0	186.5	123.8	376.6	67.8	3.6	0.0	2.1	9.0	82.5	1312.4
1969	90.2	187.0	156.4	308.5	160.8	447.6	95.6	15.4	0.0	1.0	6.0	13.3	1459.8
1970	124.7	127.5	284.1	135.9	221.8	229.7	190.9	.9	27.4	16.5	0.0	3.5	1352.9
1971	68.0	146.6	223.5	77.9	187.8	247.0	94.3	0.0	0.0	0.0	34.3	26.3	1065.7
1972	112.5	72.0	467.5	36.3	86.9	397.0	141.8	41.8	0.0	0.0	21.3	35.3	1412.4
1973	45.9	152.1	204.6	114.6	256.8	258.1	184.7	34.7	0.0	7.7	41.6	55.4	1336.2
1974	26.5	56.9	85.0	211.1	150.8	267.4	183.5	70.8	0.0	38.7	63.2	47.0	1200.9
1975	53.7	132.8	228.9	207.5	175.5	164.1	147.4	69.9	0.0	0.0	1.6	45.1	1326.5
1976	77.7	124.3	102.7	134.5	107.1	273.1	274.3	27.8	.7	0.0	0.0	6.0	1128.2
1977	44.8	140.0	129.8	71.8	225.3	255.2	67.3	49.5	0.0	0.0	10.7	42.8	1147.2
1978	78.9	269.7	128.4	231.2	153.8	331.1	50.6	11.4	0.0	0.0	0.0	0.0	1255.1
1979	108.4	117.7	163.3	131.8	77.0	321.8	41.4	0.0	0.0	0.0	70.1	0.0	1031.5
1980	39.8	229.7	404.0	154.7	211.1	422.3	272.8	29.8	0.0	0.0	7.1	25.9	1797.2
1981	115.0	140.2	43.4	89.5	83.1	202.8	155.1	73.0	0.0	0.0	47.4	17.1	966.6
AVERAGE	77.7	159.7	169.9	164.8	171.2	305.1	172.4	31.3	1.5	4.5	24.7	29.3	1312.1

Order and Probable Year of Annual Rainfall (1)

Lam Plai Mat & Nong Lum Puk Sub-Basin

Water Year	Annual Rainfall (mm)	Order of Large	Order of Small	Probability of Exceedance (yrs)	Probability of Non-Exceedance (yrs)	Annual Rainfall in Order of Small		
							Annual Rainfall (mm)	Occurred Water Year
1952	1,198.9	8	23	4	-	1)	651.1	1979
53	870.3	23	8	-	5	2)	733.9	61
54	1,095.3	12	19	3	-	3)	740.8	81
55	1,356.9	4	27	8	-	4)	825.8	73
56	1,310.5	5	26	6	-	5)	850.9	57
57	850.9	26	5	-	5	6)	852.6	62
58	1,035.0	17	14	2	2	7)	860.0	72
59	1,362.2	3	28	8	-	8)	870.3	53
60	927.6	21	10	-	3	9)	926.4	78
1961	733.9	29	2	-	17	10)	927.6	1960
62	852.6	25	6	-	5	11)	930.3	68
63	1,179.3	10	21	3	-	12)	1,007.2	77
64	1,591.4	1	30	23	-	13)	1,015.4	75
65	1,308.7	6	25	6	-	14)	1,035.0	58
66	1,560.2	2	29	20	-	15)	1,057.2	76
67	1,199.6	7	24	4	-	16)	1,057.6	69
68	930.3	20	11	-	3	17)	1,059.6	71
69	1,057.6	15	16	2	-	18)	1,065.0	74
70	1,182.5	9	22	4	-	19)	1,095.3	54
1971	1,059.6	14	17	2	-	20)	1,121.6	1980
72	860.0	24	7	-	5	21)	1,179.3	63
73	825.8	27	4	-	7	22)	1,182.5	70
74	1,065.0	13	18	2	-	23)	1,198.9	52
75	1,015.4	18	13	-	2	24)	1,199.6	67
76	1,057.2	16	15	2	-	25)	1,308.7	65
77	1,007.2	19	12	-	2	26)	1,310.5	56
78	926.4	22	9	-	3	27)	1,356.9	55
79	651.1	30	1	-	90	28)	1,362.2	59
80	1,121.6	11	20	3	-	29)	1,560.2	66
1981	740.8	28	3	-	16	30)	1,591.4	1964
Mean	1,064.5							

Order and Probable Year of Annual Rainfall (2)

Huai Phlu Sub-Basin

Water Year	Annual Rainfall (mm)	Order of Large	Order of Small	Probability of Exceedance (yrs)	Probability of Non-Exceedance (yrs)	Annual Rainfall in Order of Small:	Annual Rainfall (mm)	Occurred Water Year
1952	1,266.5	17	14	-	2	1)	966.6	1981
53	1,147.3	23	8	-	5	2)	1,031.5	79
54	1,259.4	18	13	-	2	3)	1,065.7	71
55	1,081.6	27	4	-	10	4)	1,081.6	55
56	1,422.4	7	24	4	-	5)	1,128.2	76
57	1,395.5	10	21	3	-	6)	1,144.1	62
58	1,211.7	21	10	-	3	7)	1,147.2	77
59	1,412.9	8	23	-	-	8)	1,147.3	53
60	1,498.4	4	27	-	-	9)	1,200.9	74
1961	1,251.3	20	11	-	2	10)	1,211.7	1958
62	1,144.1	25	6	-	5	11)	1,251.3	61
63	1,438.9	6	25	4	-	12)	1,255.1	78
64	1,638.9	3	28	12	-	13)	1,259.4	54
65	1,355.8	11	20	3	-	14)	1,266.5	52
66	1,731.7	2	29	20	-	15)	1,312.4	68
67	1,312.9	15	16	2	-	16)	1,312.9	67
68	1,312.4	16	15	2	-	17)	1,326.5	75
69	1,459.8	5	26	5	-	18)	1,336.2	73
70	1,352.9	12	19	3	-	19)	1,352.9	70
1971	1,065.7	28	3	-	12	20)	1,355.8	1965
72	1,412.4	9	22	4	-	21)	1,395.5	57
73	1,336.2	13	18	3	-	22)	1,412.4	72
74	1,200.9	22	9	-	3	23)	1,412.9	59
75	1,326.5	14	17	2	-	24)	1,422.4	56
76	1,128.2	26	5	-	6	25)	1,438.9	63
77	1,147.2	24	7	-	5	26)	1,459.8	69
78	1,255.1	19	12	-	2	27)	1,498.4	60
79	1,031.5	29	2	-	23	28)	1,638.9	64
80	1,797.2	1	30	28	-	29)	1,731.7	66
1981	966.6	30	1	-	250	30)	1,797.2	80
Mean	1,312.1							

Thiessen Polygon over The Basin

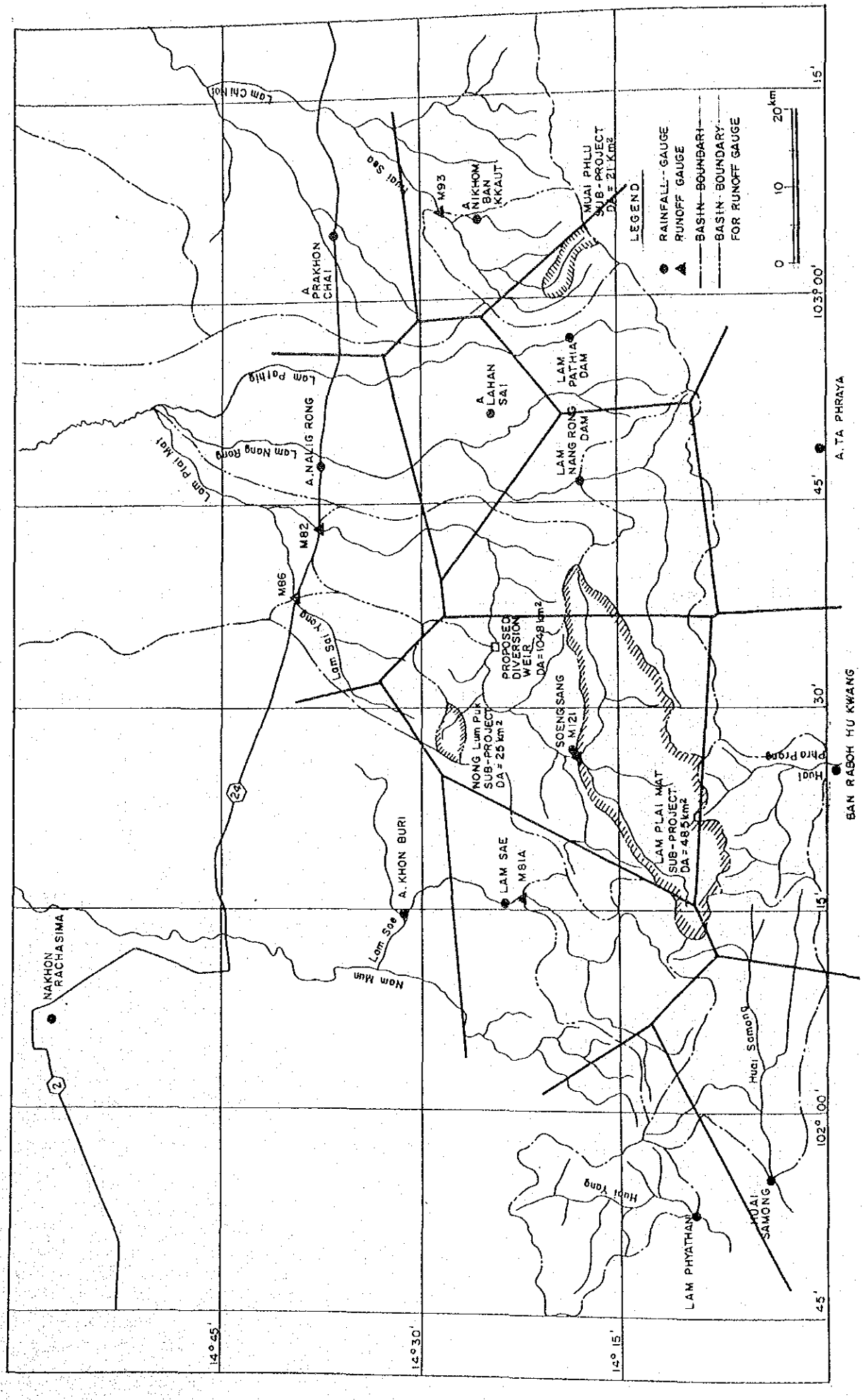
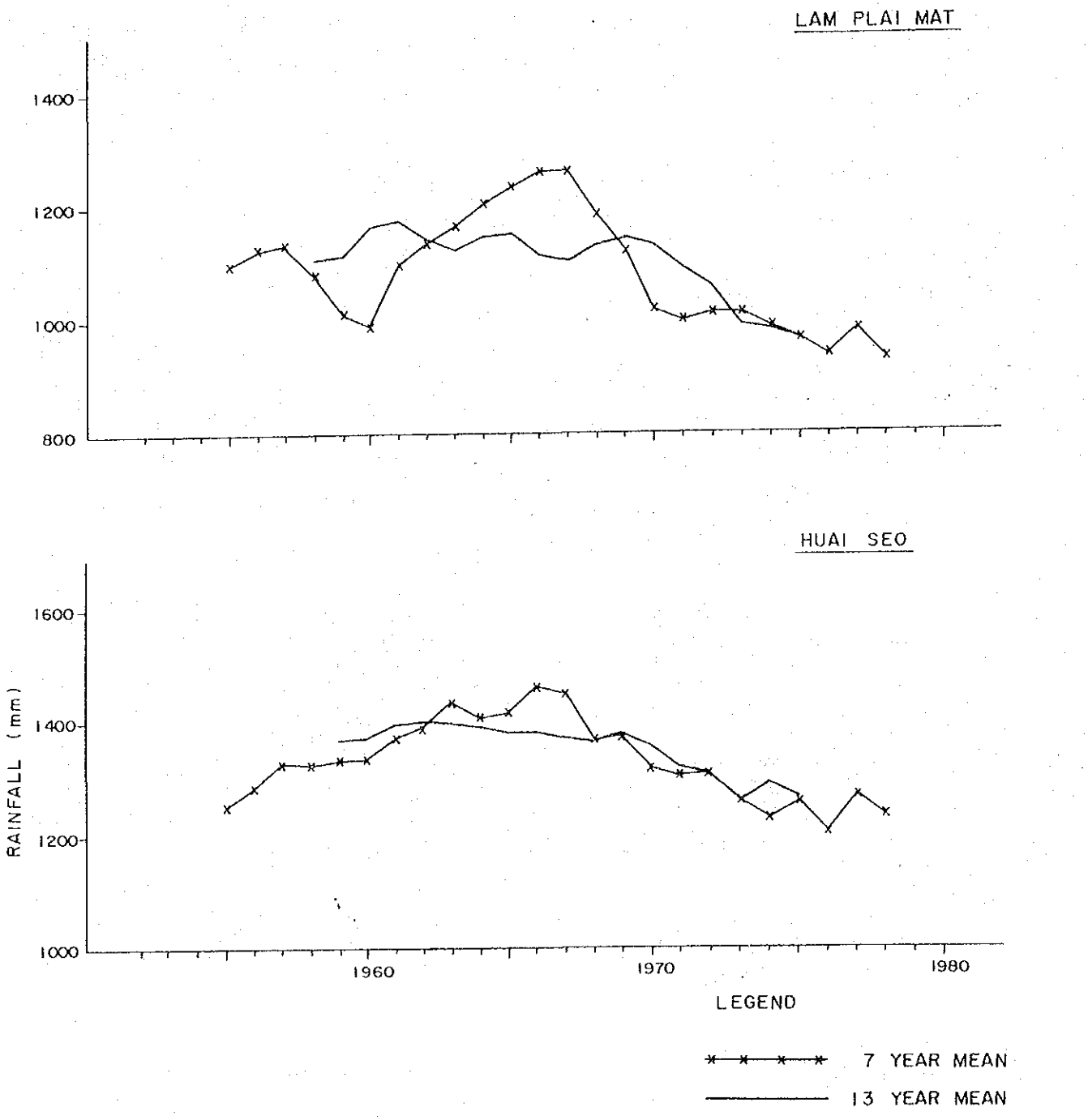


FIGURE RAINFALL ; LONG TERM MEANS



A.3. Runoff Analysis

A.3.1 Runoff Model at Proposed Damsite

To clear the water resources at each damsite of Sub-basin, runoff model has been made, since no runoff gauge exists at damsite except one of Lam Plai Mat Sub-basin of which runoff data have the record length only 3 months.

Under this critical situation, the reunoff at the proposed three damsites has been estimated by establishing a proper runoff model and then applying it a basin-wide areal rainfall. In this study, 10-days runoff based on daily rainfall has been made.

For the development of runoff model, runoff gauge is selected to each Sub-Basin considering the similarity of location and basin characteristics such as vegetation, topography and geology, and record length of observed runoff. Adopted runoff gauges are shown as follows:

Sub-Project and DA	Adopted Runoff Model	Adopted Runoff Gauge and DA	Period of Observed Data
Lam Plai Mat (DA=485 sq.km)	Multiple Regression	M121 (DA=485 sq.km)	Aub. to Oct. 1983
Nong Lum Puk (DA=25 sq.km)	Tank Model of RID.	M86 (DA=280 sq.km)	1969 to 1971
Huai Phlu (DA=21 sq.km)	Tank Model of RID	M93 (DA=329 sq.km)	1978 to Oct. 1983

The runoff model at the damsite of each Sub-basin has been discrived as follows.

(1) Runoff Model of the Lam Plai Mat.

The runoff model at this damsite has been developed by multiple regression method using daily rainfall and runoff data at M121 of the Lam Plai Mat, since the no paddy field exists in its drainage area.

Multiple regression runoff model can be expressed by generalized impulsive response function including the terms up to second order.

$$Q(t) = ho + Q_1(t) + Q_2(t) + \varepsilon(t) \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \text{①}$$

here,

$Q(t)$	:	observed runoff on t day	(mm/day)
ho	:	regression coefficient	
$Q_1(t)$	:	estimated linear runoff on t day	(mm/day)
$Q_2(t)$	:	estimated non-linear runoff on t day	(mm/day)
$\varepsilon(t)$	:	error between observed and estimated runoff.	(mm/day)

where

$$Q_1(t) = \sum_{i=1}^{n} A_i \cdot R(t-(i-1))$$

n	:	time lag on linear runoff	
A_i	:	linear partial negression coefficient	(days)
$R(t-(i-1))$	:	rainfall on $(i-1)$ days before from t day	(mm)

$$Q_2(t) = \sum_{i=1}^{n} \sum_{j=1}^{m} B_{ij} \, R(t-(-1)) \cdot R(t-(j-1))$$

m	:	time lag on non-linear runoff
B_{ij}	:	non-linear partial regression coefficient

These unknown variables (ho, A_i and B_{ij}) can be computed by applying the least squares method to equation ① , thus, using obtained coefficient of variable and time series of rainfall, runoff can be estimated from following equation ②.

$$Q'(t) = ho + Q_1(t) + Q_2(t) \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \text{②}$$

where

$Q'(t)$	:	estimated runoff	(mm/day)

The values of n and m depend on the basin characteristics are adopted 30 and 8 respectively, through several simulations.

Estimated daily discharge is shown by hydrograph in Figure A-3-1.

(2) Runoff Model of the Nong Lum Puk and Huai Phlu

The drainage areas of the selected runoff gauges to the Nong Lum Puk and the Huai Phlu for the development of runoff model include paddy field area, while the drainage areas at the damsites of both projects have no paddy field. Since multiple regression runoff method can not explain the influence by paddy field, tank model method which has the structure to eliminate the effect of the paddy field, has been applied.

As a result of many trials, the coefficients of tank's slits are decided as shown in Figure A-3-2 to the Lam Sai Yong having paddy field 17 percent of it's basin area and in Figure A-3-3 to the Huai Seo having 10.3 percent. These tank model consists of two row tanks and first one indicates the runoff structure of mountainous area, the other one of paddy field area.

To eliminate an effect of the paddy field upon the downstream runoff, secondary row's tanks have been taken off. In this mannar, runoff at the damsites of both basins can be estimated.

In this achievement, areal rainfall has been produced by Thiessen method using daily rainfall. Adopted rainfall gauges are also shown in Figure A-3-1 and Figure A-3-2.

Estimated daily discharges are shown in Figure A-3-4 and A-3-5.

(3) Evaluation of Runoff Model

As shown in Table A-3-5, the difference in average during observation period is not so much on estimation and observation though it is much more in daily and monthly basis. It comes from the insufficient information on rainfall.

A.3.2. Runoff at the Proposed Damsite

Based on the runoff models generated in proceding paragaph, estimated long-term monthly runoff (1952 to 1981) at each damsite on daily basis is compiled in Table A-3-1 and summarized in Table A-3-2.

Annual runoff coefficients are ranging from 1 to 32 percent and 16 percent in average as shown in Table A-3-4 and relations between annual rainfall and runoff are also illustrated in Figire A-3-6.

Frequency analysis study on runoff has revealed that water year 1979 and 1981 were considerable dry year during past 30 years.

A.3.3 Runoff at the Proposed diversion weir site

The Lam Plai Mat Sub-Project includes the construction plan of a diversion weir at Pa Kham in middle reachs of the upper Lam Plai Mat.

The drainage basin of 1048 sq.km at Pa Kham diversion site consist of proposed two dam basins (510 sq.km), remaining mountainous basin (212 sq.km) and plane basin (326 sq.km). The runoff estimation of these remaining basin has been achieved from the result of water balance at M82 under assamption which estimated runoff at the damsite of the Lam Plai Mat can be applied to the runoff estimation of mountainous basin as follows:

Water Year	Runoff at M82 (1581 sq.km)		Used Water 1/ for Existing Paddy (19670 ho)		Runoff from Mountainous Basin (745 sq.km)		Runoff from Plane Basin (836 sq.km)		Ratio
	(MCM)	(mm)	(MCM)	(mm)	(MCM)	(mm)	(MCM)	(mm)	(%)
	(1)	(2)	(3)	(4)	(5)	(6)	(1)+(3)-(5)	(7)	(7)/(6)
1969	123.8	78	50	254	121	163	52.8	63	39
70	145.4	92	33	168	108	146	70.4	84	57
71	98.2	62	41	208	83	112	56.2	67	60
Average	122.5	77	41	210	104	140	59.8	71	53

1/ Obtained from water requirement.

Thus, at Pa Kham diversion site, runoff from the above remaining mountainous and plane basins has been expected at 100 and 50 percent of the damsite runoff respectively.

Runoff Depth at the Proposed Damsites

(A) Lam Plai Mat (DA = 485 sq.km)

Year 1952 - 1981

Year	Apr. (mm)	May. (mm)	Jun. (mm)	Jul. (mm)	Aug (mm)	Sep. (mm)	Oct. (mm)	Nov. (mm)	Dec. (mm)	Jan. (mm)	Feb. (mm)	Mar. (mm)	Total (mm)
1952	0.6	50.1	29.7	2.1	0.3	0.3	102.5	13.7	0.3	0.3	3.5	2.5	205.9
1953	25.4	3.5	48.6	23.8	15.9	1.5	0.3	0.3	0.3	0.3	0.3	0.3	120.5
1954	0.6	27.7	6.7	35.9	16.2	21.5	29.2	0.3	0.3	0.3	0.3	0.3	139.3
1955	5.8	66.1	17.2	7.0	2.3	56.1	15.2	38.8	0.3	0.3	0.3	0.3	209.7
1956	0.3	0.3	0.7	90.0	11.9	25.9	61.0	1.4	0.3	0.3	0.3	39.5	231.9
1957	0.3	40.0	0.3	3.5	25.6	48.5	25.3	0.3	0.3	0.3	0.3	0.3	145.0
1958	4.3	0.3	0.3	58.9	2.9	122.9	43.4	0.3	0.3	0.3	0.3	0.3	234.5
1959	3.0	1.2	12.7	24.3	11.7	149.7	220.2	0.3	0.3	0.3	0.3	0.3	424.3
1960	1.2	31.1	0.6	4.1	0.3	2.8	65.8	3.9	0.3	0.3	0.3	0.3	111.0
1961	0.3	11.4	0.9	6.0	1.3	33.3	54.5	0.3	0.3	0.3	0.3	0.3	109.2
1962	20.7	17.2	0.3	13.3	0.3	67.7	12.4	0.3	0.3	0.3	0.3	0.7	133.8
1963	15.5	49.9	17.2	0.3	15.8	31.6	63.7	26.6	0.3	0.3	0.3	0.3	221.8
1964	11.7	47.5	9.8	49.3	11.0	39.2	66.9	3.6	0.3	0.3	0.3	34.1	274.0
1965	7.3	36.2	6.5	3.2	22.4	85.9	38.0	1.8	0.3	0.3	0.3	0.3	202.5
1966	5.1	97.2	46.2	0.5	55.3	84.6	25.9	0.3	0.3	0.3	0.3	0.3	316.3
1967	2.1	51.9	13.8	6.5	15.9	75.6	29.4	0.3	0.3	0.3	0.3	0.6	197.0
1968	5.5	1.4	9.3	1.2	9.7	17.3	2.6	1.6	0.3	0.3	0.3	4.3	53.8
1969	8.7	7.5	3.3	4.6	1.8	118.6	17.2	0.3	0.3	0.3	0.3	0.3	163.2
1970	3.5	47.5	38.1	2.8	30.5	4.9	15.6	1.9	0.3	0.3	0.3	0.3	146.0
1971	0.3	1.2	20.5	1.5	9.3	47.1	15.0	2.9	0.3	0.3	0.8	11.9	111.1
1972	10.0	0.6	3.2	0.3	0.3	43.1	19.9	3.4	0.3	0.3	0.3	0.3	82.0
1973	0.3	0.3	0.6	0.3	2.2	44.4	30.7	0.3	0.3	0.3	0.3	0.6	80.6
1974	1.8	5.0	0.7	0.8	12.7	16.4	43.1	4.8	0.3	0.3	0.3	0.9	87.1
1975	0.3	12.0	4.7	8.2	0.4	48.3	18.9	0.3	0.3	0.3	0.3	2.7	96.7
1976	4.3	2.6	1.0	4.4	9.2	24.5	77.4	24.8	0.3	0.3	0.3	0.3	149.4
1977	1.5	28.6	2.2	1.9	6.5	23.6	12.2	0.4	0.3	0.3	0.3	2.2	80.0
1978	0.3	21.3	2.1	73.6	0.6	37.5	15.8	0.3	0.3	0.3	0.3	0.3	152.7
1979	0.3	6.1	0.4	7.0	0.3	8.8	11.6	0.3	0.3	0.3	0.3	0.3	36.0
1980	0.3	15.7	123.6	31.6	7.2	0.4	33.4	0.3	0.3	0.3	0.3	20.0	233.4
1981	0.3	0.8	0.5	1.0	0.5	22.2	6.1	5.2	0.3	0.3	0.3	0.3	37.8
Ave.	4.7	22.7	14.1	15.6	10.0	43.5	39.1	4.6	0.3	0.3	0.4	4.2	159.6

Runoff Depth at the Proposed Damsites

(B) Nong Lum Puk (DA = 25 sq.km)

Year 1952 - 1981

Year	Apr. (mm)	May. (mm)	Jun. (mm)	Jul. (mm)	Aug (mm)	Sep. (mm)	Oct. (mm)	Nov. (mm)	Dec. (mm)	Jan. (mm)	Feb. (mm)	Mar. (mm)	Total (mm)
1952	0.0	35.7	27.0	0.7	0.1	1.3	95.9	7.7	0.3	0.0	2.8	0.1	171.6
1953	7.2	20.8	53.2	46.4	15.6	4.5	1.9	0.1	0.0	0.0	0.0	0.0	149.7
1954	0.0	30.0	2.6	12.8	22.0	45.5	58.8	0.4	0.1	0.0	0.0	0.0	172.2
1955	0.0	44.9	8.3	12.0	19.5	84.7	32.2	85.0	0.7	0.4	1.5	0.0	289.2
1956	0.0	0.0	0.0	64.8	25.7	47.2	102.0	8.3	0.6	0.4	0.1	38.7	287.8
1957	0.0	21.6	2.8	9.5	29.6	54.9	42.2	3.8	0.2	0.0	0.0	0.0	164.6
1958	0.1	0.0	0.0	52.0	22.0	91.5	58.8	0.4	0.1	0.0	0.0	0.0	224.9
1959	0.0	0.0	0.0	21.7	17.6	117.0	260.1	1.1	0.6	0.3	0.0	0.0	418.4
1960	0.0	22.7	7.4	5.6	0.0	0.0	101.4	13.6	0.7	0.0	0.0	0.0	151.4
1961	0.0	0.0	0.0	0.0	0.0	15.1	50.1	0.2	0.0	0.0	0.0	0.0	65.4
1962	4.0	5.5	0.0	0.3	0.0	77.5	20.7	0.1	0.0	0.0	0.0	0.0	108.1
1963	3.8	23.5	12.7	0.0	10.0	43.4	62.4	20.9	0.4	0.1	0.0	0.0	177.2
1964	11.9	92.7	3.7	64.3	18.7	52.9	85.6	6.0	0.8	0.6	3.6	33.7	374.5
1965	28.6	49.2	6.1	7.5	54.4	148.9	49.6	7.1	0.9	0.6	0.5	0.1	353.5
1966	26.8	133.1	34.6	11.3	66.4	191.1	32.8	2.8	2.8	0.8	0.4	0.3	503.2
1967	22.6	59.3	29.6	25.8	25.1	78.1	37.5	4.9	0.6	0.3	0.0	0.0	283.8
1968	3.1	0.0	12.6	3.8	10.2	34.1	3.6	15.8	0.2	0.0	0.0	0.0	83.4
1969	0.0	0.2	0.0	0.1	3.6	114.7	28.7	2.4	0.4	0.2	0.0	0.0	150.3
1970	0.0	28.0	32.4	8.2	27.0	17.3	30.9	3.3	6.7	0.6	0.4	0.0	154.8
1971	0.0	0.0	8.0	0.5	10.7	49.5	31.6	7.6	0.5	0.0	0.0	0.3	108.7
1972	3.5	0.0	0.0	0.0	0.0	34.2	24.7	13.6	0.3	0.0	0.0	0.0	76.3
1973	0.0	0.0	0.0	0.0	0.0	23.6	37.4	1.0	0.0	0.0	0.0	0.0	62.0
1974	0.0	0.0	0.0	0.0	0.8	15.1	36.4	14.6	0.3	0.0	0.0	0.0	67.2
1975	0.0	0.9	3.2	19.8	3.3	38.7	25.1	1.6	0.2	0.0	0.0	0.0	92.8
1976	0.2	0.0	0.0	1.7	10.5	35.8	62.3	30.7	0.5	0.3	0.0	0.0	142.0
1977	0.0	15.4	1.9	0.0	7.3	32.0	36.4	7.9	1.6	0.0	0.0	0.0	102.5
1978	0.0	16.5	1.5	54.1	5.8	42.6	16.6	0.6	0.0	0.0	0.0	0.0	137.7
1979	0.0	0.2	0.0	0.0	0.0	3.3	5.8	0.0	0.0	0.0	0.0	0.0	9.3
1980	0.0	0.3	62.0	14.7	13.2	4.4	40.0	0.8	0.1	0.0	0.0	1.0	136.5
1981	0.0	0.0	0.0	0.0	0.0	6.4	4.9	10.2	0.0	0.0	0.0	0.0	21.5
Ave.	3.7	20.0	10.3	14.6	14.0	50.2	49.2	9.1	0.7	0.2	0.3	2.5	174.7

Runoff Depth at the Proposed Damsites

(C) Huai Phlu (DA = 21 sq.km)

Year 1952 - 1981

Year	Apr. (mm)	May. (mm)	Jun. (mm)	Jul. (mm)	Aug (mm)	Sep. (mm)	Oct. (mm)	Nov. (mm)	Dec. (mm)	Jan. (mm)	Feb. (mm)	Mar. (mm)	Total (mm)
1952	0.0	11.4	1.8	1.7	8.2	15.3	96.4	8.3	0.4	0.2	20.7	20.6	185.0
1953	0.0	6.7	4.8	25.9	13.1	34.8	30.0	3.6	0.5	0.7	0.2	0.0	120.3
1954	0.0	0.9	5.1	25.8	29.8	85.5	43.9	1.0	0.7	0.5	0.3	0.1	193.6
1955	0.0	0.0	17.2	23.5	25.8	60.7	12.2	0.7	0.4	0.1	3.6	0.2	144.4
1956	5.4	8.6	5.1	60.5	13.1	32.0	65.0	1.5	0.7	0.5	0.2	16.2	208.8
1957	17.2	0.1	0.5	46.3	6.9	88.5	226.6	6.3	1.0	0.7	0.5	0.3	394.9
1958	0.1	5.6	7.5	37.7	67.4	69.2	42.2	1.6	0.8	0.6	0.4	0.2	233.3
1959	0.0	0.7	5.7	32.2	8.3	71.1	248.1	3.6	0.8	0.6	0.4	2.9	374.4
1960	0.1	13.3	9.3	3.4	35.3	57.3	232.8	4.4	1.1	0.7	0.5	0.9	359.1
1961	14.3	12.8	10.3	15.1	9.0	42.3	32.5	2.2	0.9	0.7	0.5	0.4	141.0
1962	2.9	0.9	22.1	33.1	5.2	66.2	25.4	1.0	0.6	0.4	0.2	0.0	158.0
1963	0.2	13.1	30.6	2.3	14.0	57.5	30.8	35.9	1.1	0.8	0.6	0.9	187.8
1964	1.9	92.2	27.8	35.6	13.7	39.0	26.8	9.2	1.3	1.1	3.2	7.5	259.3
1965	19.7	14.3	12.3	36.8	44.4	170.9	26.0	2.4	1.6	1.4	1.2	1.0	332.0
1966	10.7	106.1	12.9	28.7	24.5	78.0	26.6	14.0	2.4	2.2	5.2	3.4	314.7
1967	10.6	29.3	17.9	5.8	15.3	60.0	61.9	4.6	2.2	2.5	1.8	1.7	213.6
1968	2.0	12.1	40.3	23.2	8.6	113.4	9.9	2.2	2.0	1.8	1.5	7.2	224.2
1969	6.8	22.2	11.9	60.8	15.6	138.1	19.8	3.4	2.3	2.1	1.7	1.7	286.4
1970	15.1	14.7	34.2	18.3	40.6	30.8	26.4	7.9	3.1	2.5	1.8	1.8	197.2
1971	2.2	12.0	39.4	5.8	27.3	41.1	14.5	2.5	1.9	1.7	2.2	1.7	152.3
1972	6.9	4.4	166.7	7.4	2.9	128.3	38.7	3.1	1.8	1.6	1.6	2.1	365.5
1973	1.6	6.2	33.1	6.5	27.9	58.4	48.6	3.6	1.8	1.6	3.2	2.3	194.8
1974	1.1	2.0	4.5	17.6	18.6	42.4	41.5	10.2	1.5	4.1	6.9	2.5	152.9
1975	1.6	5.0	20.7	85.3	14.7	26.7	13.0	12.6	1.7	1.5	1.2	2.0	186.0
1976	3.3	13.5	3.5	6.9	2.7	41.1	44.1	15.2	1.4	1.2	0.9	0.8	134.6
1977	1.1	9.0	6.5	1.1	62.7	49.0	10.2	5.9	2.5	0.8	0.6	1.6	151.0
1978	1.2	53.8	10.3	36.2	11.0	46.2	31.1	1.4	1.0	0.8	0.5	0.4	193.9
1979	5.1	7.1	11.8	12.8	2.5	60.5	34.1	1.0	0.3	0.1	0.0	0.0	135.3
1980	0.0	7.7	73.9	21.5	16.9	102.2	73.5	7.6	1.6	1.3	1.1	1.1	308.4
1981	7.5	7.6	1.6	3.4	6.1	20.8	21.2	5.2	0.9	0.7	4.3	1.3	80.6
Ave.	4.6	16.4	21.6	24.0	19.7	64.2	55.1	6.1	1.3	1.2	2.2	2.8	219.4

Summary of Runoff for each Sub-Project.

Description	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total
1. Lam Plai Mat													
Monthly Average Runoff (MCM)	2.3	11.0	6.8	7.6	4.9	21.1	19.0	2.2	0.1	0.1	0.2	2.0	77.4
Monthly Average Runoff Depth (mm)	4.7	22.7	14.1	15.6	10.0	43.5	39.1	4.6	0.3	0.3	0.4	4.2	159.6
Annual Runoff Coefficient (%)													15.0
2. Nong Lum Puk													
Monthly Average Runoff (MCM)	0.08	0.50	0.26	0.37	0.35	1.26	1.23	0.23	0.02	0.01	0.01	0.06	4.37
Monthly Average Runoff Depth (mm)	3.0	20.0	10.3	14.6	14.0	50.2	49.2	9.1	0.7	0.2	0.3	2.5	174.7
Annual Runoff Coefficient (%)													17.3
3. Huai Phlu													
Monthly Average Runoff (MCM)	0.10	0.34	0.45	0.50	0.41	1.35	1.16	0.13	0.03	0.03	0.05	0.06	4.61
Monthly Average Runoff Depth (mm)	4.6	16.4	21.6	24.0	19.7	64.2	55.1	6.1	1.3	1.2	2.2	2.8	219.4
Annual Runoff Coefficient (%)													16.7

Order and Probable Year of Annual Runoff (1)

at Lam Plai Mat Damsite

Water Year	Annual Runoff (MCM)	Order of Small	Probability of Non-Exceedance (yrs.)	Annual Runoff in Order of Small: Annual Runoff (MCM)	Annual Runoff in Order of Small: Occurred Water Year
1952	99.866	22	-	1) 17.465	1979
53	58.384	12	3	2) 18.338	81
54	67.623	14	2	3) 26.107	68
55	101.767	23	-	4) 38.746	77
56	112.515	25	-	5) 39.120	73
57	70.383	15	-	6) 39.818	72
58	113.781	27	-	7) 42.229	74
59	205.780	30	-	8) 46.948	75
60	53.849	10	3	9) 53.015	61
1961	53.015	9	3	10) 53.849	1960
62	64.859	13	2	11) 53.917	71
63	107.548	24	-	12) 58.384	53
64	132.982	28	-	13) 64.859	62
65	98.232	21	-	14) 67.623	54
66	153.459	29	-	15) 70.383	57
67	95.520	20	-	16) 70.849	70
68	26.107	3	17	17) 72.454	76
69	79.152	19	-	18) 74.084	78
70	70.849	16	-	19) 79.152	69
1971	53.917	11	3	20) 95.520	1967
72	39.818	6	5	21) 98.232	65
73	39.120	5	5	22) 99.866	52
74	42.229	7	5	23) 101.767	55
75	46.948	8	5	24) 107.548	63
76	72.454	17	-	25) 112.515	56
77	38.746	4	5	26) 113.281	80
78	74.084	18	-	27) 113.781	58
79	17.465	1	150	28) 132.982	64
80	113.281	26	-	29) 153.459	66
1981	18.338	2	100	30) 205.780	1959
Mean	77.402				

Order and Probable Year of Annual Runoff (2)

at Nong Lum Puk Damsite

Water Year	Annual Runoff (MCM)	Order of Small	Probability of Non-Exceedance (Yrs)		Annual Runoff in Order of Small: Annual Runoff (MCM)	Annual Runoff in Order of Small: Occurred Water Year
1952	4.289	20	-	1)	0.233	1979
53	3.742	15	2	2)	0.537	81
54	4.304	21	-	3)	1.548	73
55	7.232	26	-	4)	1.634	61
56	7.196	25	-	5)	1.680	74
57	4.116	19	-	6)	1.909	72
58	5.624	23	-	7)	2.088	68
59	10.462	29	-	8)	2.322	75
60	3.786	17	2	9)	2.561	77
1961	1.634	4	6	10)	2.700	1962
62	2.700	10	3	11)	2.717	71
63	4.431	22	-	12)	3.412	80
64	9.362	28	-	13)	3.444	78
65	8.842	27	-	14)	3.551	76
66	12.582	30	-	15)	3.742	53
67	7.098	24	-	16)	3.759	69
68	2.088	7	4	17)	3.786	60
69	3.759	16	2	18)	3.873	70
70	3.873	18	-	19)	4.116	57
1971	2.717	11	3	20)	4.289	1952
72	1.909	6	5	21)	4.304	54
73	1.548	3	6	22)	4.431	63
74	1.680	5	6	23)	5.624	58
75	2.322	8	3	24)	7.098	67
76	3.551	14	2	25)	7.196	56
77	2.561	9	3	26)	7.232	55
78	3.444	13	2	27)	8.842	65
79	0.233	1	190	28)	9.362	64
80	3.412	12	2	29)	10.462	59
1981	0.537	2	35	30)	12.582	1960
Mean	4.368					

Order and Probable Year of Annual Runoff (3)

at Huai Phlu Damsite

Water year	Annual Runoff (MCM)	Order of Small	Probability of Non-Exceedance (yrs)		Annual Runoff in Order of Small: Annual Runoff (MCM)	Annual Runoff in Order of Small: Occurred Water Year
1952	3.888	11	3	1)	1.693	1981
53	2.527	2	9	2)	2.527	53
54	4.063	14	2	3)	2.826	76
55	3.033	6	5	4)	2.841	79
56	4.385	18	2	5)	2.960	61
57	8.292	30	-	6)	3.033	55
58	4.901	21	-	7)	3.170	77
59	7.861	29	-	8)	3.200	71
60	7.541	27	-	9)	3.210	74
1961	2.960	5	5	10)	3.320	1962
62	3.320	10	4	11)	3.888	52
63	3.941	13	3	12)	3.904	75
64	5.447	22	-	31)	3.941	63
65	6.973	26	-	14)	4.063	54
66	6.606	25	-	15)	4.072	78
67	4.484	19	-	16)	4.089	73
68	4.710	20	-	17)	4.142	70
69	6.017	23	-	18)	4.385	56
70	4.142	17	2	19)	4.484	67
1971	3.200	8	4	20)	4.710	1968
72	7.674	28	-	21)	4.901	58
73	4.089	16	2	22)	5.447	64
73	3.210	9	4	23)	6.017	69
75	3.904	12	3	24)	6.476	80
76	2.826	3	6	25)	6.606	66
77	3.170	7	4	26)	6.973	65
78	4.072	15	2	27)	7.541	60
79	2.841	4	6	28)	7.674	72
80	6.476	24	-	29)	7.861	59
1981	1.693	1	75	30)	8.292	1957
Mean	4.608					

Table A-3-4

Estimated Annual Runoff and Runoff Coefficient at the Proposed Damsites

Water Year	Annual Rainfall	Lam Plai Mat		Nong Lum Puk		Huai Phlu		
		Annual Runoff	Annual Runoff Coef.	Annual Runoff	Annual Runoff Coef.	Annual Rainfall	Annual Runoff	Annual Runoff Coef.
		(mm)	(%)	(mm)	(%)	(mm)	(mm)	(%)
1952	1,198.9	205.9	17.2	171.6	15.0	1,266.5	185.2	14.6
53	870.3	120.4	13.8	149.7	17.2	1,147.3	120.3	10.5
54	1,095.3	139.4	12.7	172.2	15.7	1,259.4	193.5	15.4
55	1,356.9	209.8	15.5	289.3	21.3	1,081.6	144.4	13.4
56	1,310.5	232.0	17.7	287.9	22.0	1,422.4	208.8	14.7
57	850.9	145.1	17.1	164.6	19.3	1,395.5	394.9	28.3
58	1,035.0	234.6	22.7	225.0	21.7	1,211.7	233.4	19.1
59	1,362.2	424.3	31.1	418.5	30.7	1,412.9	374.3	26.5
60	927.6	111.0	12.0	151.5	16.3	1,498.4	359.1	24.0
1961	733.9	109.3	14.9	65.4	8.9	1,251.3	141.0	11.3
62	852.6	133.7	15.7	108.0	12.7	1,144.1	158.1	13.8
63	1,179.3	221.7	18.8	177.2	15.0	1,438.9	187.7	13.0
64	1,591.4	274.2	17.2	374.5	23.5	1,638.9	259.4	15.8
65	1,308.7	202.5	15.5	353.7	27.0	1,355.8	332.1	24.5
66	1,560.2	316.4	20.3	503.3	32.2	1,731.7	314.6	18.2
67	1,199.6	196.9	16.4	283.9	23.7	1,312.9	213.5	16.3
68	930.3	53.8	5.8	83.5	9.0	1,312.4	224.2	17.1
69	1,057.6	163.2	15.4	150.3	14.2	1,459.8	286.5	19.6
70	1,182.5	146.1	12.4	154.9	13.1	1,352.9	197.3	14.6
1971	1,059.6	111.2	10.5	108.7	10.3	1,065.7	152.4	14.3
72	860.0	82.1	9.5	76.3	8.9	1,412.4	365.4	25.9
73	825.8	80.7	9.8	61.9	7.5	1,336.2	194.7	14.6
74	1,065.0	87.1	8.2	67.2	6.3	1,200.9	152.8	12.7
75	1,015.4	96.8	9.5	92.9	9.1	1,326.5	185.9	14.0
76	1,057.2	149.4	14.1	142.0	13.4	1,128.2	134.6	11.9
77	1,007.2	79.9	7.9	102.5	10.2	1,147.2	151.0	13.2
78	926.4	152.8	16.5	137.7	14.9	1,255.1	193.9	15.4
79	651.1	36.0	5.5	9.3	1.4	1,031.5	135.3	13.1
80	1,121.6	233.6	20.8	136.5	12.2	1,797.2	308.4	17.2
1981	740.8	37.8	5.1	21.5	2.9	966.6	80.6	8.3
Average	1,064.5	159.6	15.0	174.7	16.4	1,312.1	219.4	16.7

Summary of Error Evaluation of Runoff Model

(Unit: mm)

Description	Water Year 1983 Aug.	Sep.	Oct.	Total
Lam Plai Mat				
Estimated Runoff (Qe)	9.5	34.7	128.5	172.7
Observed Runoff (Q)	10.4	28.1	130.5	169.0
Error (Qe/Q)	0.91	1.23	0.98	1.02

	Water Year 1969	1970	1971	Average
Nong Lum Puk				
Estimated Runoff (Qe)	122	63	57	80.7
Observed Runoff (Q)	111	79	51	80.3
Erro (Qe/Q)	1.10	0.80	1.12	1.00

	Water Year 1978	1979	1980	1981	1982	1983	Average
Huai Phlu							
Estimated Runoff (Qe)	156	77	304	34	165	331	177.8
Observed Runoff (Q)	167	40	336	34	187	320	180.7
Erro (Qe/Q)	0.93	0.93	0.90	1.00	0.88	1.03	0.98

FIGURE : TANK MODEL OF LAM SAI YONG

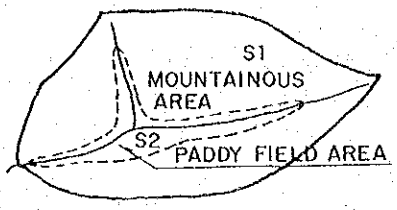
STREAM : LAM SAI YONG

STATION : M.86

DRAINAGE AREA : 280 km²

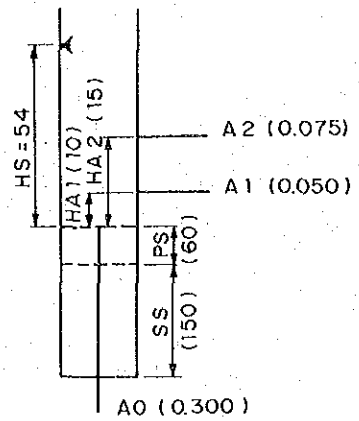
RAINFALL : STATION & WEIGHT

KHON BURI	0.4
NANG RONG	0.6

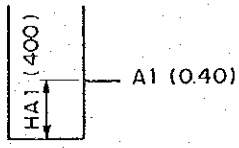


S1 : S2 = 0.83 : 0.17

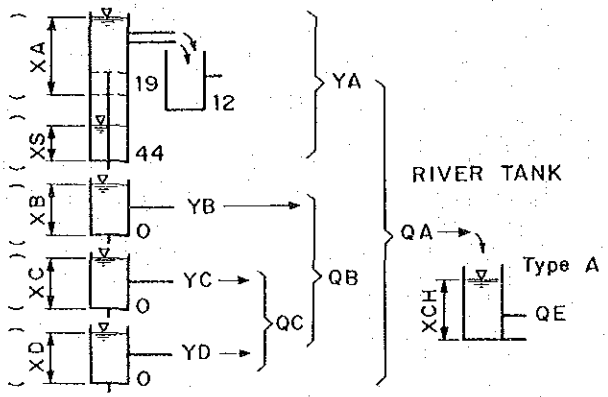
MOUNTAINOUS AREA MODEL

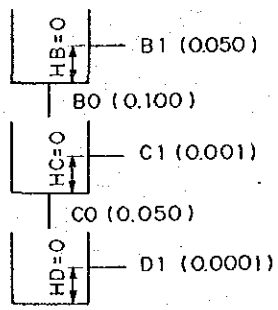


PADDY FIELD AREA MODEL

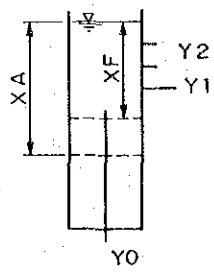


FLOW CHART OF RUNOFF

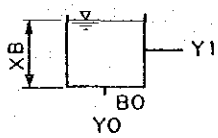




SUB B

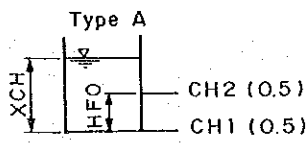


SUB C



RIVER TANK

SUB D



SUB A

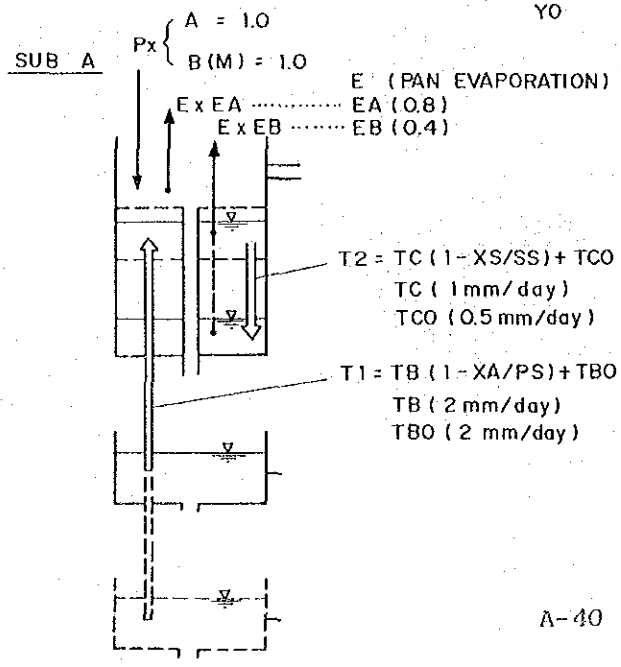


FIGURE : TANK MODEL OF HUAI SEO

STREAM : HUAI SEO

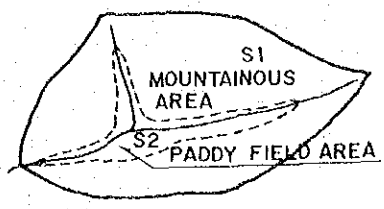
STATION : M.93

DRAINAGE AREA : 329 km²

RAINFALL : STATION & WEIGHT

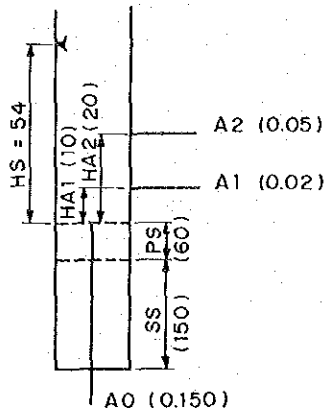
LAM PATHIA DAM 0.41

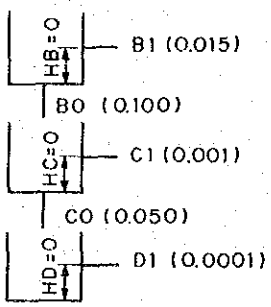
NIKOM BAN KRUAT 0.59



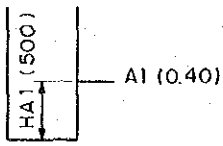
S1 : S2 = 0.897 : 0.103

MOUNTAINOUS AREA MODEL

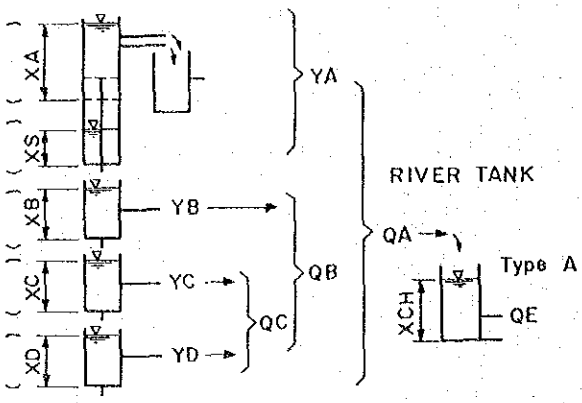




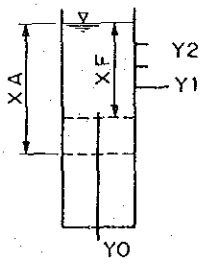
PADDY FIELD AREA MODEL



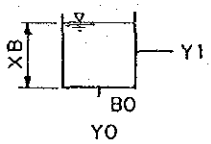
FLOW CHART OF RUNOFF



SUB B

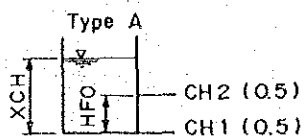


SUB C



RIVER TANK

SUB D



SUB A

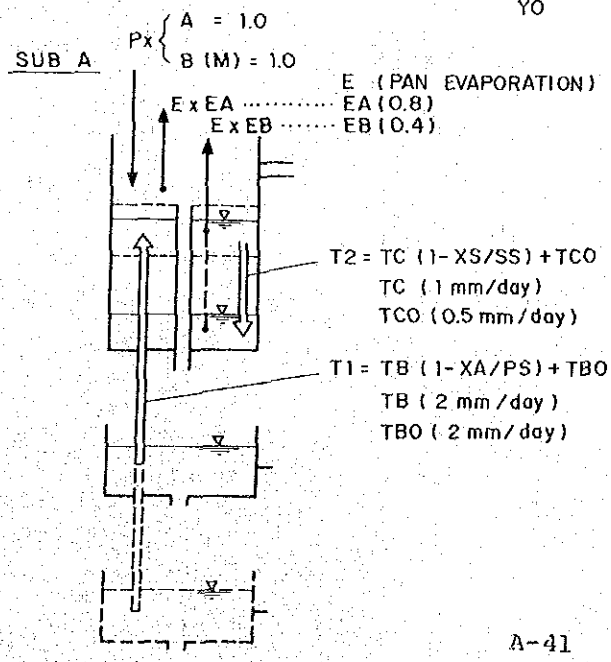
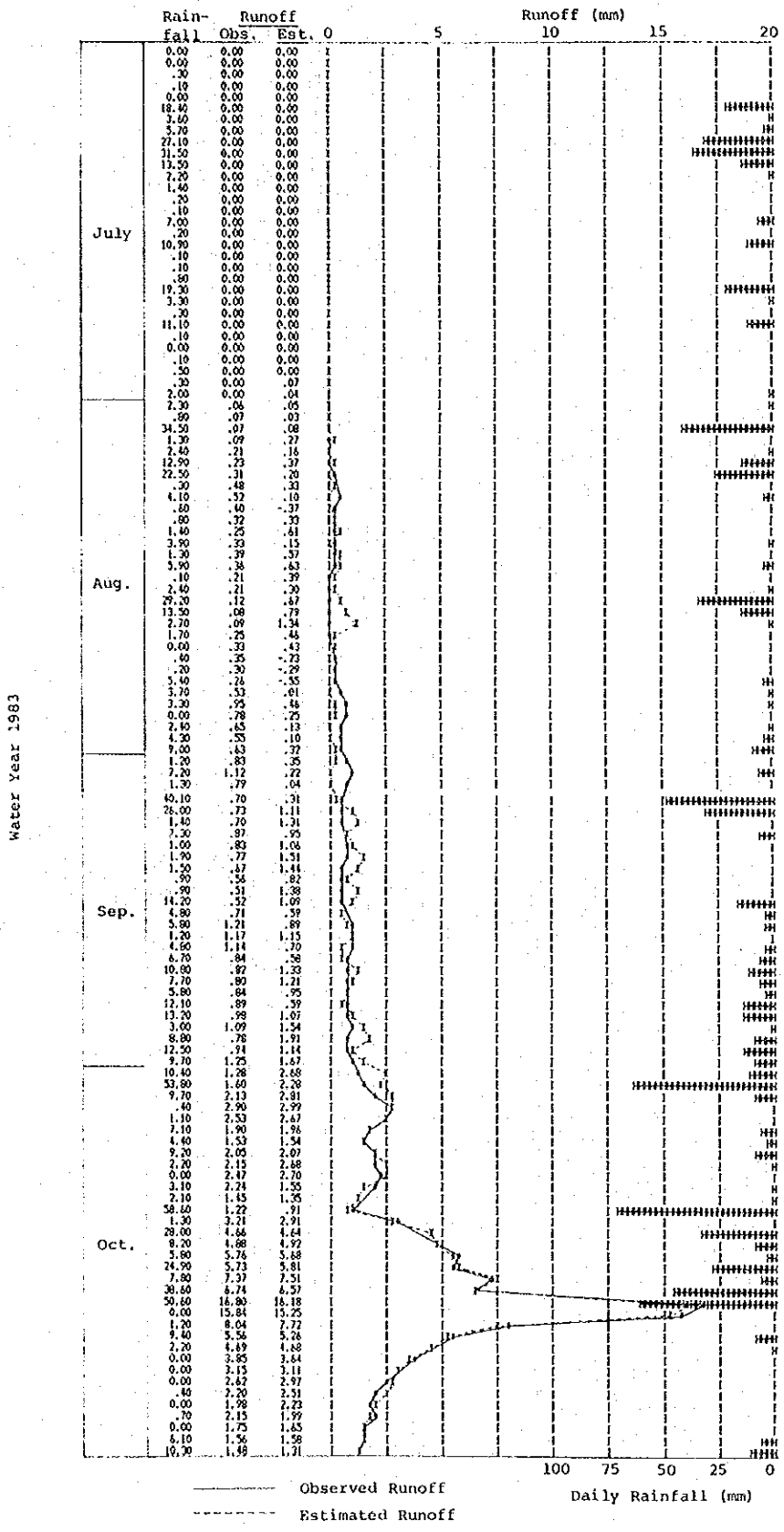
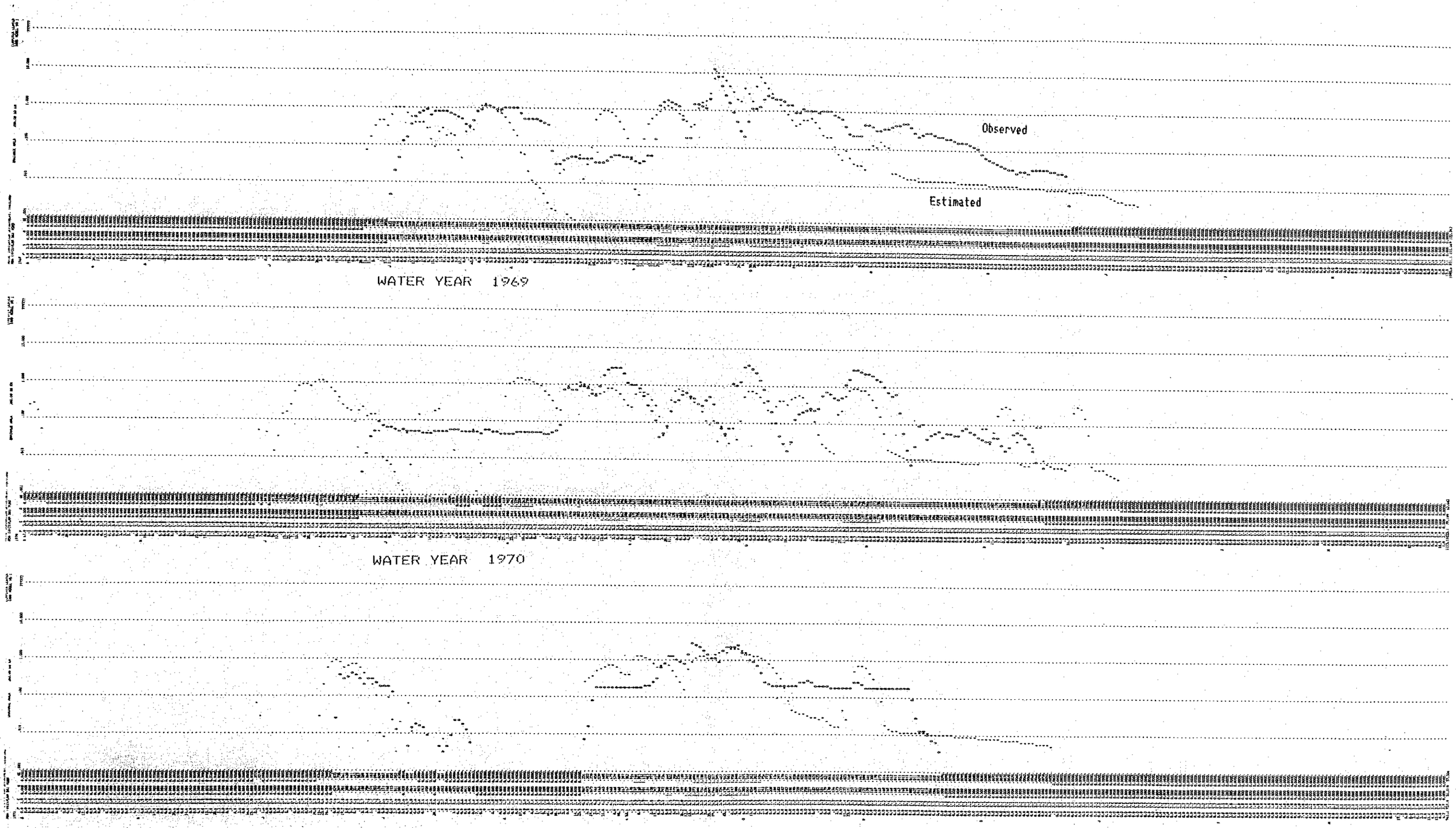
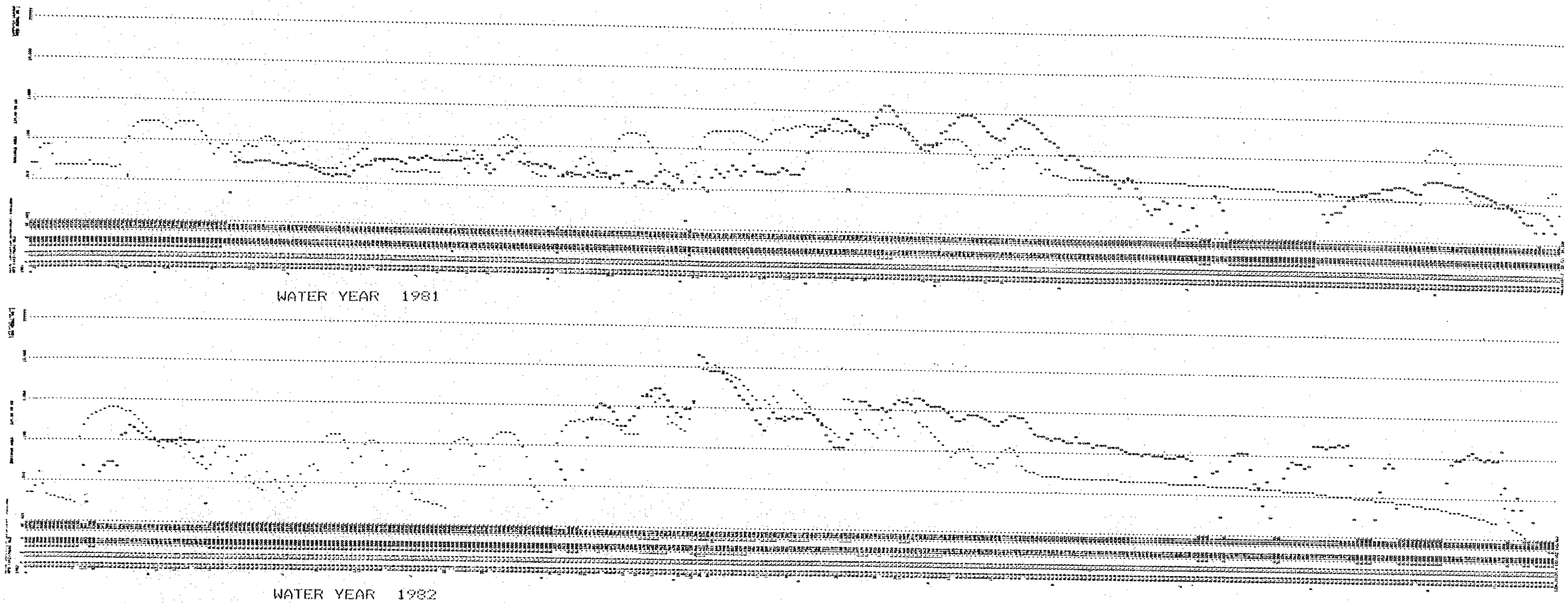


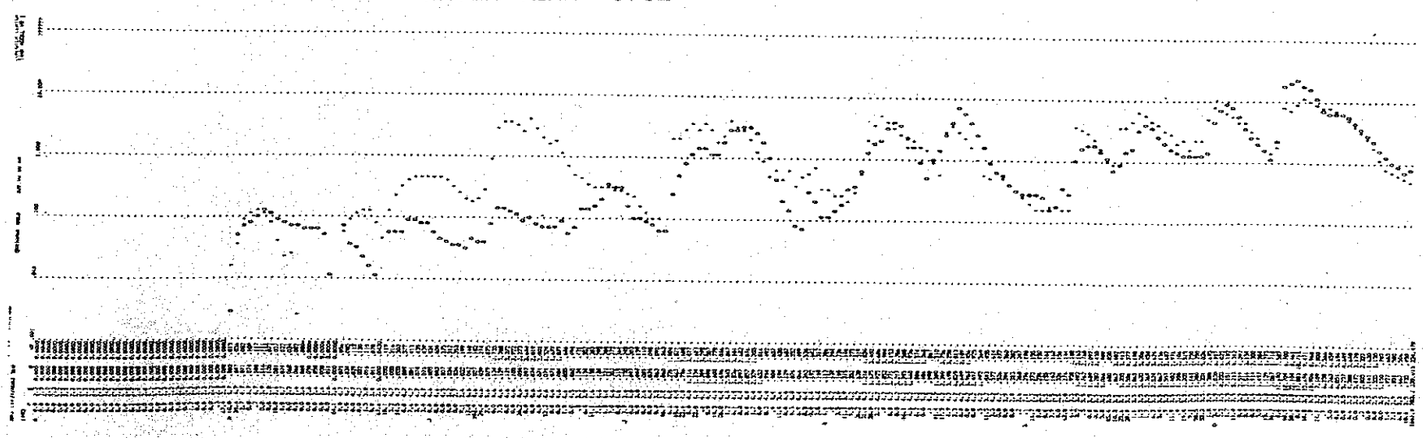
Figure Output of Multiple Regression Runoff Model for Lam Plai Mat



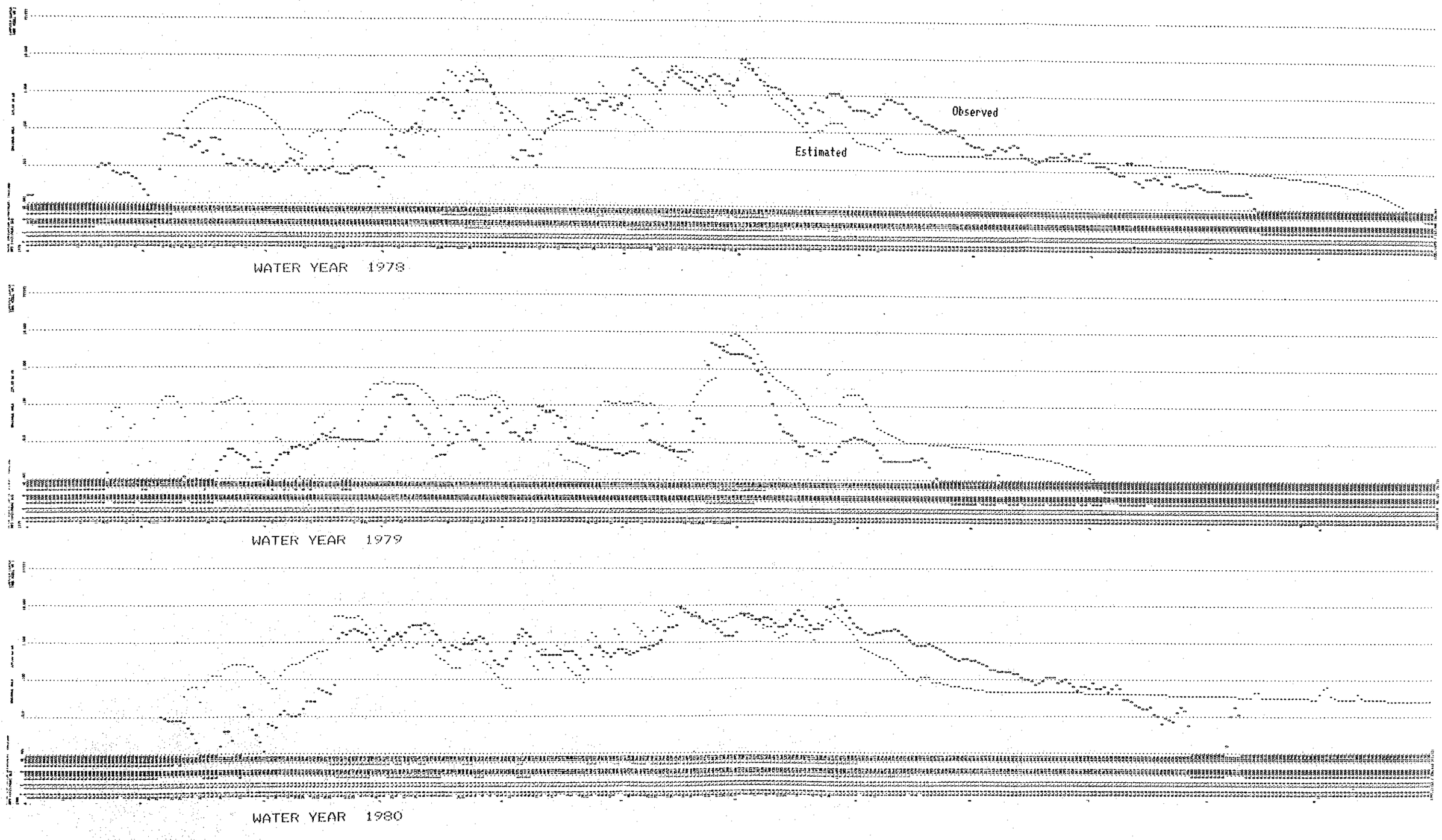


OUTPUT OF TANK MODEL FOR LAM SAI YONG





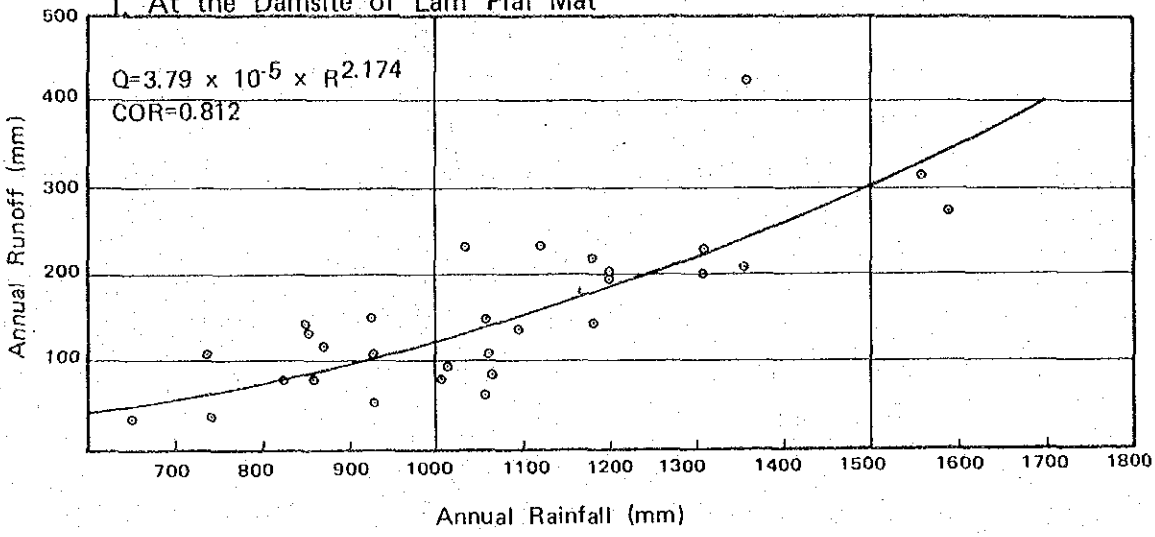
OUTPUT OF TANK MODEL FOR HUAI SEO



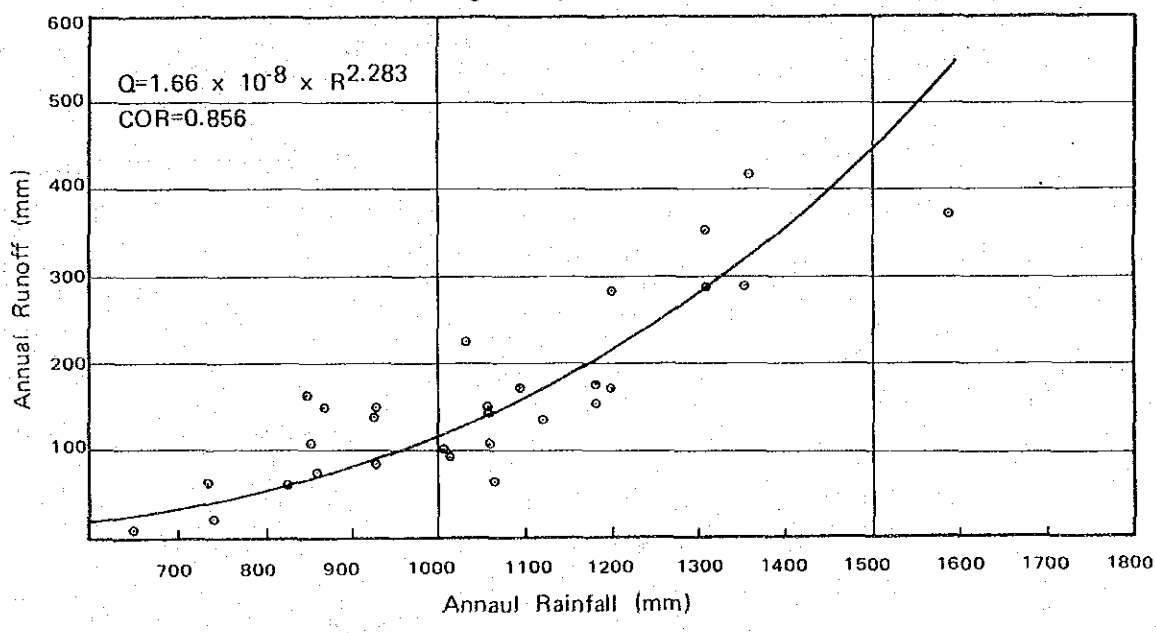
OUTPUT OF TANK MODEL FOR HUAI SEO
(continued)

Annual Rainfall and Runoff at Dam Site (1952 - 1981)

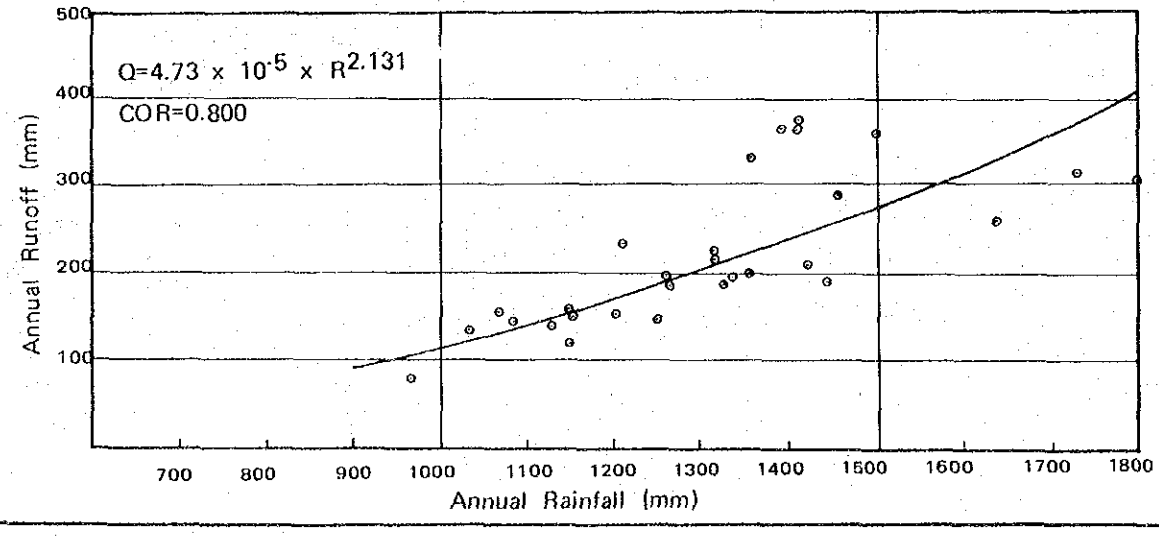
1. At the Damsite of Lam Plai Mat



2. At the Damsite of Nong Lumphuk



3. At the Damsite of Huai Phlu



A.4. Flood Analysis

A.4.1. Desing Flood and Design Rainfall frequency.

According to the criteria decided by Project Planning Division RID, the frequency of design flood in Medium Project is adopted in accordance with the types of structures as follows:

	Frequency (yrs.)
Storage Dam	500
Diversion Weir	50

As a reference of studies, floods of 2, 5, 10, 20, 25, 50, 100, 200, 250 500 and 1,000 years are to be estimated.

A.4.2. Design Flood

As decribed in Section A.1.3, observed flood records at near by runoff gauges could not available because their values are too low and the recorded length too short to estimate the design flood. Thus, it has been made by analytical method using rainfall record.

(1) Design Flood at the Proposed Damsite

(a) Unit Hydrograph

Synthesis hydrograph developed by Snyder would be applied for the estimation of probable flood.

Unit hydrograph is obtainable by,

$$Qp = 0.275\ Cp \cdot A/Tp$$

where,

Qp : Peak discharge of unit hydrograph (Cu.m/s/mm)

Cp : Snyder's coefficient (Cp = 0.56 to 0.69)

A : Drainage area (sq.km)

Tp : Time lag from midpoint of effective rainfall duration t_r to the peak of a unit hydrograph

$$Tp = 0.75\ Ct \cdot (L \cdot Lc)^{0.3}$$

here,

Ct : Snyder's time coefficient (Ct = 1.8 to 2.2)

L : River length from the concerning point to the upstream limit of the drainage area (km)

LC : River length from the concerning point a point on the river nearest the centroid of the drainage area (km)

Tb = 2A/3.6

where,

Tb : Runoff duration of unit hydrograph

A : Drainage area (sq.km)

Qp : Peak discharge of unit hydrograph

Basin characteristics at the proposed damsite is shown below.

Proposed Damsite	Drainage Area (sq.km)	River Length L (km)	River Length LC (km)	Hight Difference H (m)	Slope
Lam Plai Mat	485	36	18	464	1/77
Nong Lum Puk	25	12	4	57	1/158
Huai Phlu	21	12	5	82	1/130

Then, the dimension of unit hydrographs are shown in Table A-4-1.

(b) Probable rainfall

As representing desin rainfall gauge, Lam Sae for the Lam Plai Mat and the Nong Lum Puk Sub-Projects, and Lahan Sai for the Huai Phlu Sub-Project are selected.

The design rainfall are as follows:

Adapted Maximum One-day Rainfall (mm)
(Gumbel's method)

Sub-Project	Return Period (yrs.)							
	5	10	20	25	50	100	200	500
Lam Plai Mat & Nong Lum Puk	100	115	131	136	151	166	181	201
Huai Phlu	112	136	159	166	188	210	231	260

(c) Rainfall Intensity and Effective Rainfall

Rainfall Intensity is computed by the following equation described in Section A.1.2.

$$rt = 0.6368 \cdot R24 \cdot t^{-0.858}$$

where, rt : Rainfall intensity for any duration (m/hr)
R24 : Maximum one-day rainfall (mm)
t : duration of rainfall (hr)

As effective rainfall, rainfall during the time of flood concentration is deemed to be effective. Effective peak rainfall is arranged to be occured at 80 percent of flood concentration time as shown in Table A-4-2.

(d) Design flood at the Proposed Damsite

Design flood hydrograph with the return period of 500 years is derived from the previously obtained unit hydrograph and effective rainfall as shown in Table A-4-2.

The other probable floods are obtained by rational formula with the peak runoff coefficient of design flood.

Peak and specific discharge of each probability are shown in Table A-4-4.

(e) Cross-Check by Envelope Curve.

The estimated peak discharge and yield in the precending paragraph are cross-checked by the envelope curve for peak specific yield developed by Hydrology Division, RID as shown in Figure A-4-1. The estimated specific yield is compared with the one on the envelope curve and two value are almost close.

Thus, the estimated peak discharge are fully testfied to be technical reasonable.

(2) Design Flood at the Proposed Weir Site

The estimation procedure of design flood is almost same except the estimation method of flood concentration time.

The concentration time at the weir site with the drainage area of 1,048 sq.km is estimated as follows:

$$Tc = T_1 + T_2$$

Tc : Flood concentration time

T_1 : Flood concentration time at the damsite of the Lam Plai Mat ; 11.5 hrs.

T_2 : Flood concentration time from the damsite to the weir site.

T_2 is estimated by Manning' equation as follows:

$$T_2 = L/V = 12.3 \quad \text{(hr)}$$

Where,

L : River length from the damsite to the weir site, 31 km

V : Average velocity in a case with probable flood of 50 years return period at the damsite, 0.70 m/s

$$V = 1/n \cdot R^{2/3} \cdot I^{1/2}$$

Where,

n : ruffness coefficient, 0.10

R : Hydraulic radius, 3.65 m

I : Slope of river, 1/1170

Thus, obtained flood concentration time (Tc) is about 24 hours.

In the same manner as that described for flood estimation of the damsite, design flood at the weir site is derived.

The dimension of unit hydrograph, hydrograph and peak discharge are shown in Table A-4-1, Table A-4-3, and Table A-4-4.

Dimension of Unit Hydrograph

Interesting Points	Damsite			Pa Kham Diversion Weir Site
	Lam Plai Mat	Nong Lum Puk	Huai Phlu	
- Drainage Area: A (sq.km)	485	25	21	1,048
- River Length from Origin: L (km)	36	12	12	67
- River Length from Center of Basin: Lc (km)	18	4	5	-
- Snyder's Time Coefficient: Ct	2.0	2.0	2.0	-
- Time Lag: Tp (hr)	10.5	4.8	5.1	22.0
- Unit Time: tr (hr)	2.0	1.0	1.0	4.0
- Concentration Time: Tc (hr)	11.5	5.5	5.5	24.0
- Snyder's Discharge Coefficient: Cp	0.63	0.63	0.63	0.56
- Peak Discharge of Unit Hydrograph: qp (cu.m/s/mm)	8.003	0.902	0.713	7.336
- Runoff Duration: Tb (hr)	33.7	15.0	16.4	79.0

Flood Estimation at the Proposed Damsites for 1/500 Years by Unit Hydrograph

Lam Plai Mat				Nong Lum Puk				Huai Phlu			
Time (hr)	Unit Hydrograph (cu.m/s/mm)	Effective Rainfall (mm)	Direct Runoff (cu.m/s)	Time (hr)	Unit Hydrograph (cu.m/s/mm)	Effective Rainfall (mm)	Direct Runoff (cu.m/s)	Time (hr)	Unit Hydrograph (cu.m/s/mm)	Effective Rainfall (mm)	Direct Runoff (cu.m/s)
2	1.392	3.6	5.0	1	0.164	2.2	0.4	1	0.130	2.8	0.4
4	2.784	5.5	17.7	2	0.328	5.1	1.6	2	0.259	6.5	1.6
6	4.175	6.9	39.9	3	0.492	6.2	3.8	3	0.389	8.1	3.8
8	5.567	9.3	75.2	4	0.656	8.4	7.4	4	0.519	10.8	7.5
10	6.959	141.2	306.9	5	0.820	128.0	31.9	5	0.648	165.6	32.7
12	7.829	14.6	557.1	6	0.854	13.2	58.4	6	0.683	17.1	59.6
14	7.109		798.6	7	0.759		83.9	7	0.618		85.9
16	6.389		1,027.9	8	0.664		108.0	8	0.553		110.7
18	5.669		1,241.3	9	0.569		130.1	9	0.488		133.5
20	4.949		1,366.2	10	0.474		134.6	10	0.423		139.7
22	4.229		1,259.1	11	0.379		120.8	11	0.358		127.7
24	3.509		1,128.7	12	0.284		105.3	12	0.293		114.0
26	2.789		998.3	13	0.189		89.8	13	0.228		100.3
28	2.069		867.9	14	0.094		74.3	14	0.163		86.6
30	1.349		737.5	15	0.000		58.8	15	0.098		72.9
32	0.629		607.1	16			43.5	16	0.033		59.2
34	0.000		477.0	17			28.7	17			45.5
36			349.7	18			14.5	18			32.2
38			226.5	19			1.2	19			19.4
40			108.5					20			7.1
42			9.2					21			0.6

Flood Estimation at the Proposed Weir Site for 1/50 yrs. by Unit Hydrograph

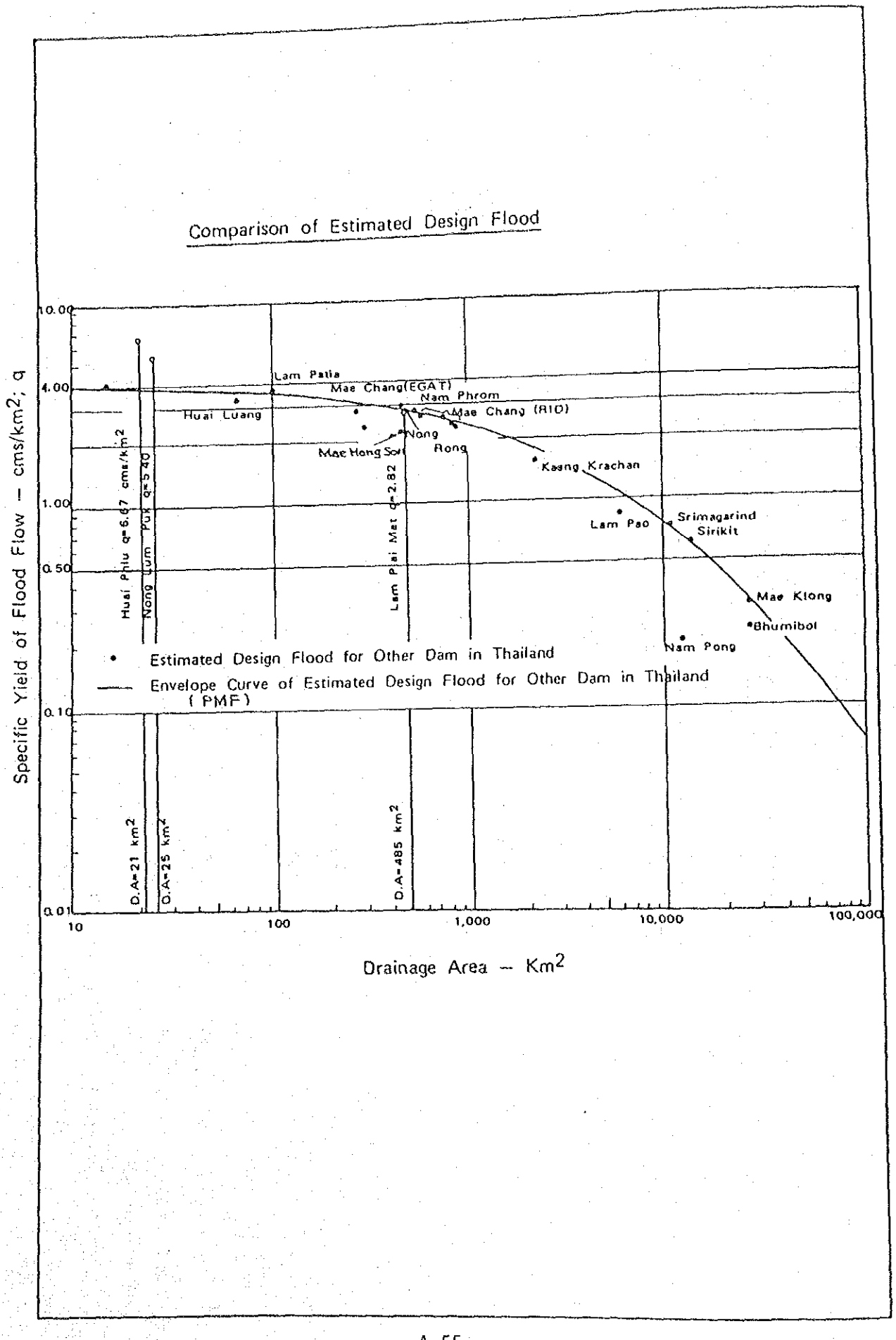
Time (hr)	Unit Hydrograph (cu.m/s/mm)	Effective Rainfall (mm)	Direct Runoff (cu.m/s/mm)
4	1.223	3.9	4.8
8	2.445	4.6	15.2
12	3.668	5.7	32.5
16	4.891	7.6	59.2
20	6.113	117.1	229.0
24	7.336	12.1	413.6
28	6.802		591.4
32	6.269		761.1
36	5.735		920.7
40	5.202		1,067.1
44	4.668		1,007.7
48	4.135		927.2
52	3.601		846.6
56	3.068		766.1
60	2.534		685.5
64	2.601		607.3
68	1.467		527.2
72	0.934		447.3
76	0.400		367.8
80			353.6
84			212.6
88			130.2
92			58.1
96			4.8

Estimated Peak Discharge by Unit Hydrograph

Return Period (year)	Damsite: Lam Plai Mat (DA = 485 sq.km)				Damsite: Nong Lum Puk (DA = 25 sq.km)				Damsite: Huai Phlu (DA = 21 sq.km)				Pa Kham Diversion Weir Site (DA = 1048 sq.km)			
	R24 1/ (mm/day)	r_t 2/ (mm/hr)	Qp (cms)	qp (cms/sq.km)	R24 1/ (mm/day)	r_t (mm/hr)	Qp (cms)	qp (cms/sq.km)	R24 1/ (mm/day)	r_t (mm/hr)	Qp (cms)	qp (cms/sq.km)	R24 1/ (mm/day)	r_t (mm/hr)	Qp (cms)	qp (cms/sq.km)
2	75	5.9	512	1.06	75	11.1	51	2.04	77	11.4	42	2.00	75	3.1	525	0.50
5	100	7.8	677	1.40	100	14.7	67	2.68	112	16.5	60	2.86	100	4.2	712	0.68
10	115	9.0	781	1.61	115	17.0	77	3.08	136	20.1	73	3.48	115	4.8	813	0.78
20	131	10.3	894	1.84	131	19.3	88	3.52	159	23.5	86	4.10	131	5.5	932	0.89
25	136	10.7	928	1.91	136	20.1	92	3.68	166	24.5	89	4.24	136	5.7	966	0.92
50	151	11.8	1,024	2.11	151	22.3	102	4.08	188	27.7	101	4.81	151	6.3	1,067	1.02
100	166	13.0	1,128	2.33	166	24.5	112	4.48	210	31.0	113	5.38	166	6.9	1,169	1.11
200	181	14.2	1,232	2.54	181	26.7	122	4.88	231	34.1	125	5.95	181	7.5	1,271	1.21
250	186	14.6	1,267	2.61	186	27.4	125	5.00	238	35.1	128	6.10	186	7.7	1,305	1.25
500	201	15.7	1,366	2.82	201	29.6	135	5.40	260	38.3	140	6.67	201	8.4	1,423	1.36
1000	215	16.8	1,458	3.01	215	31.7	144	5.76	282	41.6	152	7.24	215	9.0	1,525	1.46

Notes: 1/, 2/ : Probable maximum one-day rainfall at Lam Sae and Lahan Sai rainfall stations.

3/ : Average rainfall intensity during the concentration time (t hrs.) of flood.


Comparison of Estimated Design Flood
Specific Yield of Flood Flow — cms/km2; q
Drainage Area — Km2
10.00
4.00
1.00
0.50
0.10
0.01
10
100
1,000
10,000
100,000
Huai Phlu q=6.67 cms./km2
Nong Lum Puk q=5.40
Lam Plai Mat q=2.82
D.A=21 km2
D.A=25 km2
D.A=485 km2
Lam Patia
Mae Chang(EGAT)
Nam Phrom
Mae Chang (RID)
Huai Luang
Nong
Mae Hong Son
Rong
Kaeng Krachan
Lam Pao
Srimagarind
Sirikit
Mae Klong
Bhumibol
Nam Pong
Estimated Design Flood for Other Dam in Thailand
Envelope Curve of Estimated Design Flood for Other Dam in Thailand
(PMF)

A.5 Designed Sediment Transportation

Based on the collected data, the sediment yield of 150 cu.m per sq.km per year has been taken up for three Sub-Projects, and the low water level of an effective reservoir capacity has been set up through provision of the sediment storage for 100 years.

ANNEX B TOPOGRAPHY AND GEOLOGY

ANNEX B. TOPOGRAPHY AND GEOLOGY

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ANNEX B. TOPOGRAPHY AND GEOLOGY

B.1. Topography and Geology of the Project Area

B.1.1. Topography

The Project Area is located on the southern part of Korat Plateau.

The altitude of the Plateau ranges from 150 m to 250 m above mean sea level (msl) and the Project area is bounded on the south by cuesta ridges of the San Kamphaen Range, ranging from 300 to 800 msl. Two-river systems are developed in the Project area. One is the Lam Plai Mat river running from Mt. Khao Yai (849 m) in the San Khampaen Range. The other is the Lam Chi Noi river flowing from cuesta ridges of the same range on the border or Kampuchea.

Two major tributaries of the Lam Plai Mat, the Lam Nang Rong and the Lam Pathia flow from cuesta ridge in a direction parallel to the main stream on the east.

The upper part of the Lam Plai Mat flows 40 km northeastward to amphoe Soeng Saeng, then turns eastward for 20 km to amphoe Pra Kham and finally it flows northward to the lower part of the Lam Plai Mat. The Lam Nang Rong and Lam Pathia join 25 km north of amphoe Nang Rong. The Nong Lum Puk, one of the minor tributaries of the Lam Plai Mat, joins 2 km east of amphoe Soeng Sang.

The Upper part of the Lam Chi Noi consists of four tributaries, Huai Taria, Huai Lae Ngao, Huai Seo and Huai Takaek being located from east to west. The Huai Phlu, one of the minor tributaries, is located in the upper part of the Huai Seo. Four major tributaries meet one another in the middle Lam Chi Noi basin and it flows to the northward to join the Mae Nam Mun.

River beds are comparatively broad on the upper Lam Plai Mat and Lam Chi Noi. Hilly mountains form on the both banks of the river with several ten meters in height which suit to be good abutment of an earth fill dam. General gradient of river course is estimated 1 to 1,000 on the main stream.

In the middle part of the Lam Plai Mat, flood floor extends its width several hundred meters and frequently meanders on the main stream. Undulated hills on both banks of river rise only slightly, therefore, it is difficult to find suitable dam abutment along the main stream. Topographic conditions on the middle part of the Lam Chi Noi are almost the same as the Lam Plai Mat, but height of the hills is lower than that because of geologic conditions.

The lower part of the Lam Plai Mat and Lam Chi Noi flows on the broad alluvial plain with a gradient of more than 1 to 3,000. Slope of the undulated hill increases so slightly that it is hardly discriminated from the alluvial river bed.

B.1.2. Regional Geology

Three distinctively different sequences of geologic units, the Khorat Group Basalt and the Quaternary Formation, underlie the Project area.

The Khorat Group is a basement of the Plateau, which ranges in age from the Lower Jurassic to the Upper Cretaceous or Lower Tertiary comprising only slightly deformed non-marine sedimentary beds of conglomerate, sandstone, siltstone, claystone and shale. The Khorat Group comprises six formation that is from the Phu Kradung at the base to the Phra Whihan, the Sao Khua, the Phu Pham, the Khok Kruat and the Maha Sarakham Formations.

The Khorat Group generally dip centripetally from the Plateau perimeter, but locally are warped into narrow anticlines and synclines that trend approximately parallel to the neighboring sector of a basin boundary. Stratigraphic dips are low, 10 to 15 degrees or less around Plateau perimeter, decreasing to 5 degrees and less within a few kilometers basinward.

The Phu Kradung Formation underlies the southern slope of the Sam Kamphaen Range at the anticlinal axis. The Phra Wihan Formation lies conformably on the Phu Kradung Formation and it underlies the southern edge of the Plateau forming cuesta ridge. The formation consists of thick to massive bedded well consolidated sandstone with interbedded siltstone and shale. The damsite of Lam Plai Mat is located in this formation.

The Sao Khua Formation lies conformably on the Phra Wihan Formation and consists of interbedded sandstone, siltstone and shale. They are characteristically micaceous and reddish brown. Sandstone in the formation is mainly fine-grained and tight. The damsite of Huai Phlu is located on this formation. THe Phu Phan Formation consists of fine to coarse grained arkosic sandstone and conglomerate. It caps the second line of cuesta ridges inward from the basin perimeter.

The Khok Kruat Formation underlies the middle part of the Lam Plai Mat and Lam Chi Noi basins where the topographic gradient turns gentle. The formation consists of interbedded siltstone, sandstone and shale. It is overlain by the Basalt in several places.

The Maha Sarakham Formation, so called the Salt Formation, underlies the lower part of the basins and consists of reddish-brown to pale red siltstone and sandstone; frequently interbedded rock-salt and gypsum. Basalt was extruded at the Tertiary, overlying the Khorat Group as an erosional remnant. The remnant of Basalt caps a few ridges and low hills on the middle stream of the

Project area. There are large basalt flows south of the highway No.10 in the Lam Plai Mat basin. It lies with both an angular and a moderately pronounced erosional unconformity upon the Sao Khua, Khok Kruat and Maha Sarakham Formations. The damsite of Huai Nong Lum Puk is located on this rock. The Quaternary Formation is composed of thin deposit of terrace, extremely variable thickness of alluvial deposit and slope detritues.

The terrace deposit underlies adjacent to stream valley on the upper part of the Lam Plai Mat. It consists of clay, fine and medium grained sand and small amount of gravel. The alluvial deposit underlies mostly flood floor consisting clay and fine and medium grained sand. It is widely distributed in almost all the area but lateral and vertical extent vary in proportion with its place. It is natural that the lower part of the basin is larger than the upper part.

The slope detritus underlies the flank and slope of undulated hill and it consists of rock fragment, clay and fine and medium grained sand which were derived from the basement. These sequences except the Quaternary Formation are not exposed at the surface on the middle and lower river basins, however few outcrops of Khorat Group are exposed at the hilly mountains on the upper part of the Lam Plai Mat and Lam Chi Noi.

General idea of geologic sequence is shown in Table B-1-1.

Table B-1-1 Stratigraphy of the Project Area

Age			Name of Formation	Lithology	Igneous Rocks
Quarternary	Pleis-Holocene		Alluvial Talus, Slope Detritus Recent River Bed	Alluvial gravel, sand, silt and clay of flood plain and swamp deposits	
	Pleistocene		Terrace deposit	Terrance gravel, sand and silt; local laterite and lateritic soil	
Tertiary			Khorat Group Maha Sarakham	Reddish-brown to pale red silt-stone and sandstone; frequently interbedded rock-salt and gypsum	Basalt Predominantly divine basalt, locally weathered to laterite and lateritic soil
Cretaceous	Lower		Khok Kruat	Grayish-red, reddish-brown and pale red-silt-stone, sand stone and fine calcareous conglomerate	
Jurassic	Upper		Phu Phan	Thick-bedded, cross bedded, brownish gray, pinkish gray and orange sandstone and conglomeratic sand stone; reddish brown siltstone and shale	
			Sao Khua	Calcareous, purplish-brown, purplish-gray and reddish brown siltstone and sandstone	
	Lower		Phara Wihan	Thick-bedded, cross bedded, quartzose and quartzitic white, brown and yellowish-brown sandstone with some purplish-red to reddish-brown siltstone	
			Phu Kradung	Calcareous, micaceous, reddish-brown and purplish-red siltstone isome greenish-gray to yellowish-brown sandstone and basal conglomerate	

After Geological Map of Thailand 1/250,000 "Nakhon Ratchasima" publish by Department of Mineral Resources, 1978.

B.2. Engineering Geology of the Lam Plai Mat Damsite

B.2.1. Location and Topographic Features

The Lam Plai Mat Project area is located in the upper Lam Plai Mat basin and consists of the damsite with a drainage area of 485 sq.km.

The damsite is accessible by an all-weather road which runs from Ban Non Somban, four kilometers north. The damsite is located downstream the confluence of the Huai Sai Kong and the Lam Plai Mat, at an elevation of 235 msl. The site is formed by very gentle topography with the river gradient of 1 to 1,200 and the bank slope of 1 to 10.

The drainage area of the Lam Plai Mat dam is divided into two sub-basins; the Lam Plai Mat and the Huai Sai Kong. The former sub-basin is formed by the steep mountain range with drainage area of 241 sq.km at an elevation of 820 to 235 msl and the latter by the flat valley area with drainage area of 244 sq.km at an elevation of 370 to 235 msl.

Following physiographic characters among both tributaries can be pointed out by the topo-map scaled 1:50,000 and the landsat false-color imageries. Erosional forms on the Lam Plai Mat main basin, west half of the drainage area, is characterized physiographically by well-eroded and widely extended river channel, and outcrops of alluvial deposits on the channel. An erosional forms on the Huai Sai Kong, especially along the river channels is so gentle and moderate in comparison with the west half of the drainage area that it is slightly difficult to judge a direction of flow. Dense forest covers undulated slope and valley, and only a lined sparse and tall trees can be found on an exact location of the channel.

No alluvial deposit could be observed along the channel.

B.2.2. Physiographic and Geologic Features of the Drainage Area

According to the Geological Map "Nakhon Ratchasima" of 1:250,000 in scale, published by DMR, the Phra Wihan, the Sao Khua and the Phu Phan Formations of the Khorat Group, underlie the drainage area of the Lam Plai Mat damsite.

The Phra Wihan Formation, the lowest formation of the area consists of thick-bedded, crossbedded quartzone and quartzitic sandstone with some siltstone and it is exposed in west half of the drainage area. The area, underlain by this formation, covers 338 sq.km or 69 percent of the total area, and it is characterized by steep slope and deep cut valleys with broad channel plains. The Sao Khua Formation consists of siltstone and sandstone, and it underlies in the basin of Huai Sai Kong. Conspicuous ridges which form steep cliff on the southwestern slope are located along the northeastern margin of the Phra Wihan Formation. It is probably formed by conglomeratic sandstone or conglomerate. Siltstone underlies in the upper part of the Huai Sai Kong and it is overlain by thick bedded conglomeratic sandstone of the Phu Phan Formation.

The Phu Phan Formation consists fo thick-bedded sandstone and conglomeratic sandstone, siltstone and shale. It underlies in the northeastern marging of the Huai Sai Kong drainage area. The Formation is characterized by conspicuous ridge with steep cliff on the southern slope of the ridge.

The Khorat Group trends west-northwest and dips north-northeast gently but discernibly. Geological map of the drainage area is shown in Figure B-2-1.

Differences of physiographi and geologic features between the Huai Sai Kong and the Lam Plai Mat sub-basins have influence on the hydrologic aspect. Since the runoff of the Lam Plai Mat damsite presents the low value compared with adjoining basins, the physiographic features of the drainage area is carefully studied.

It is considered that the rainfall in the Huai Sai Kong sub-basin would percolate into the ground and hardly appears as the runoff in the sub-basin, because of its pervious overburden. This consideration is supported by the following field evidences that any alluvial and fluvial deposits could not be recognized around the river channel.

In addition to the above, sandstone underlying the overburden is represented by coarse grained and porous lithologically and would have the retention of groundwater, which stores the rainfall through the overburden in the sub-basin. The groundwater would be easily transpired through dense forest and a part of it would be discharged outside the drainage area as groundwater flow. Coarse sandstone, exposed in the middle part of Huai Sai Kong, plays the most important role for discharge channel outside the drainage area.

It is no wonder that the features described above should take place only in the upper part of Huai Sai Kong. It would not affect the proposed reservoir and damsite because of the location.

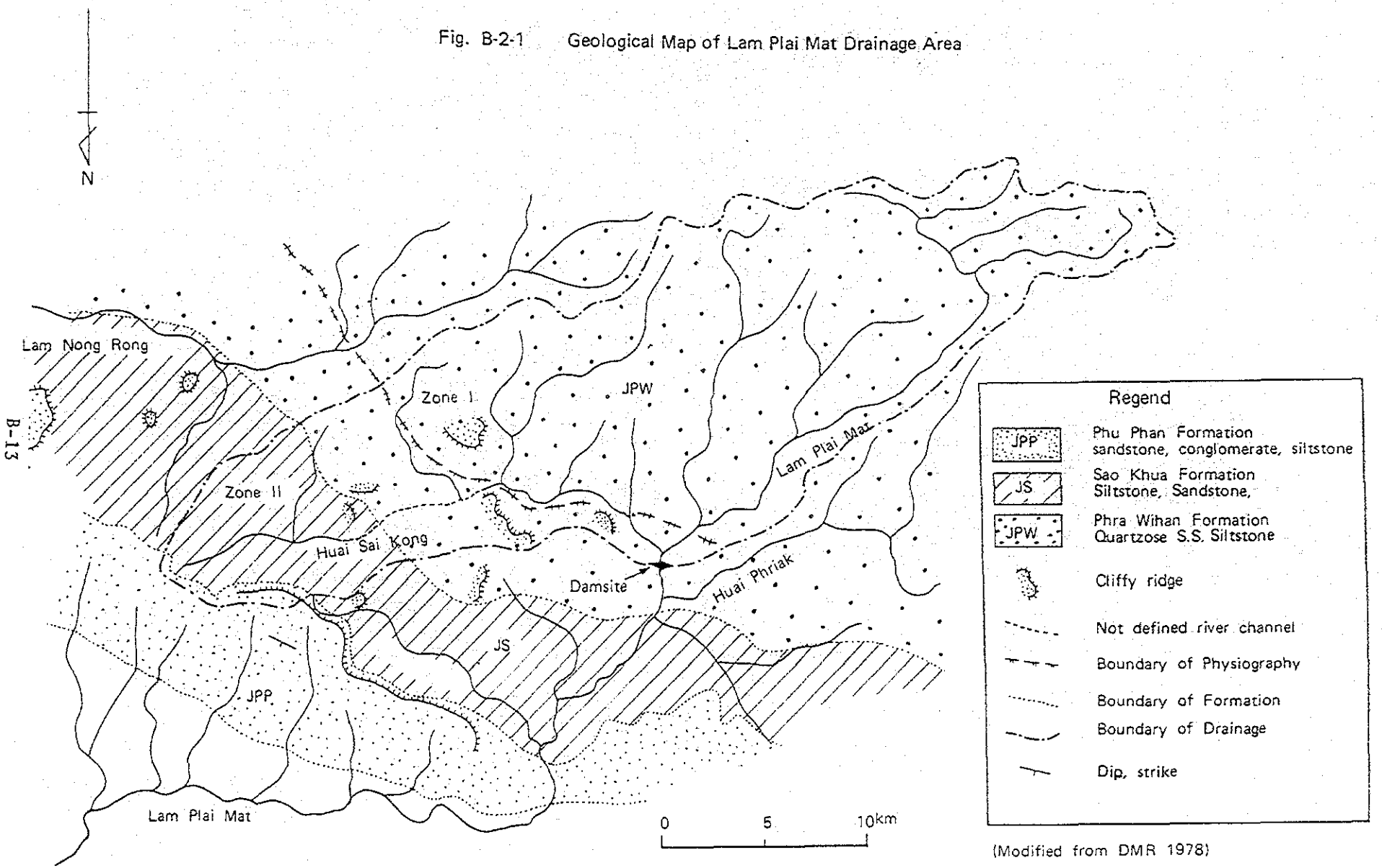
Detail figures of the physiographic features which have been carried out by the aerial photograph inter-pretation are shown in Figure B-2-2.

B.2.3. Foundation Geology

1) Dam Foundation

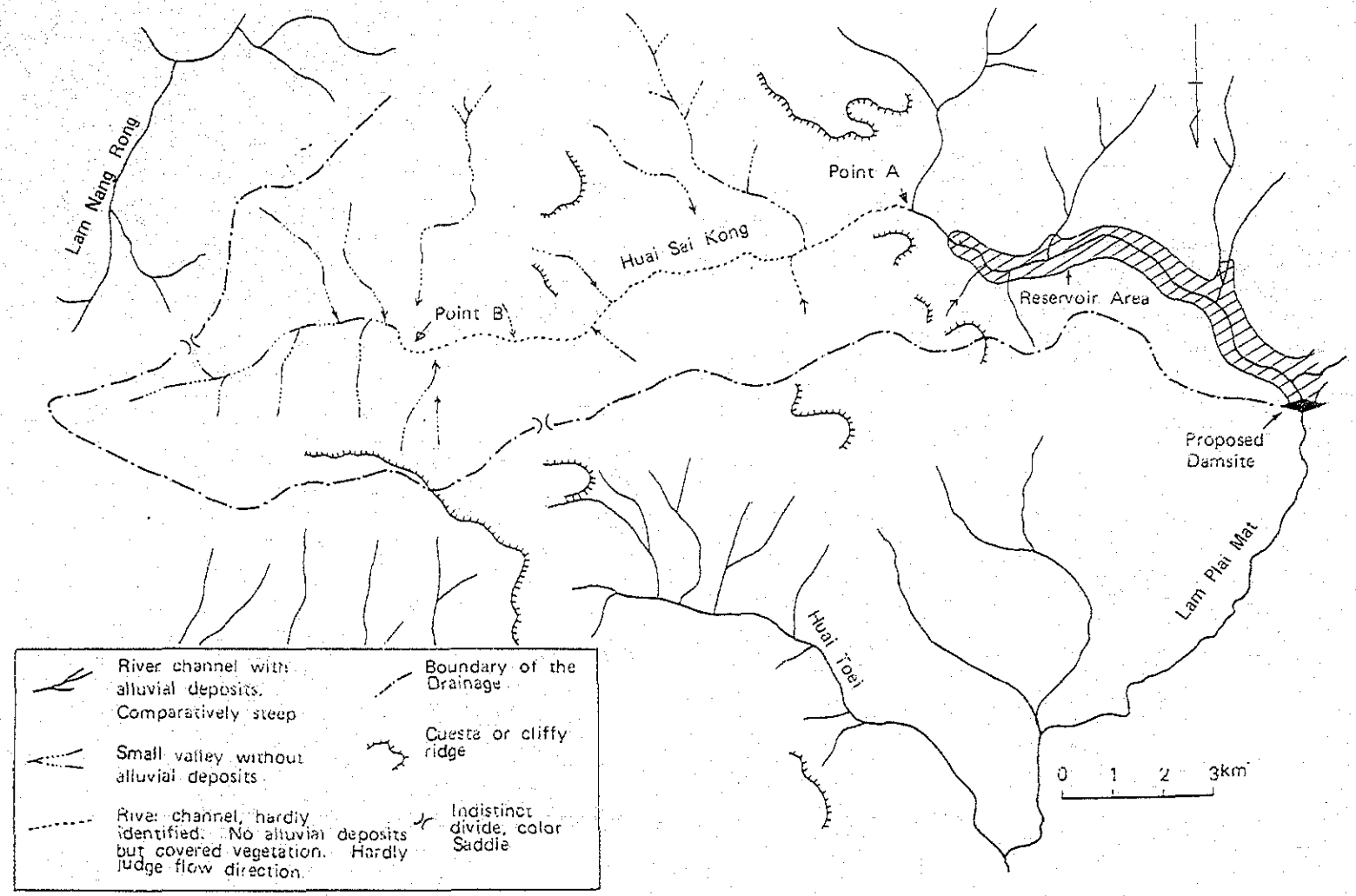
In accordance with the field investigation and the result of 18 core drillings carried out by RID, the damsite is underlain by four different geologic formations, the Slope Detritus, the Alluvial Formation, the Terrace Deposit and the Phra Wihan Formation. Three of them except the Phra Wihan formation are unconsolidated deposit.

Fig. B-2-1 Geological Map of Lam Plai Mat Drainage Area



(Modified from DMR 1978)

Fig. B-2-2 Physiographical Map of Huai Sai Kong Basin



The Slope Detritus is exposed in both sides of dam abutment with gentle slope and consists of 0.5 to 5.5 m of silty sand and gravel. The uppermost part of the right bank is exposed 2.4 to 5.5 m of silty sand and silty gravel, and it forms undulated hill top. The formation originated by disintegration and decomposition in various processes of weathering of underlying sandstone and conglomerate.

Bearing capacity of the formation ranges from 3 to 22 in blows by Standard Penetration Test (SPT), and it averages 13 blows.

Permeability of the formation ranges from 1.3×10^{-3} to 2.3×10^{-4} cm/sec and it averages 8.0×10^{-4} cm/sec. The cut-off trench shall be provided in this formation and all materials at the trench should be excavated up to underlying sandstone due to high permeability.

The Alluvial Formation extends at the center of dam axis with 300 m width and is formed by extraordinary floods. The formation is composed of silty layers in the upper part and sandy layer in the lower part. The maximum thickness of formation is about eighteen meters nearby the river channel. Bearing capacity of the formation presents less than 20 blows in SPT with several exceptions and it averages 11 blows in the upper silty layer and 18 blows in the lower sandy layer.

Permeability in the formation decreases in accordance with their depth. It ranges from 3.8×10^{-3} to 1.2×10^{-4} cm/sec in the upper layer and 4.5 to 8.6×10^{-5} cm/sec in sandy materials of the lower layer.

In general, the deposit consisting of sandy silt with well compacted and low permeability would have a higher value of SPT than the above value. Therefore, it is assumed that the permeability test or SPT had supposedly been carried out incorrectly. The cut

off trench excavation is tentatively designed to reach the rock foundation by removing out all unconsolidated deposit even if it is of low permeability. Lithology and physical character of the deposit should be carefully checked by core drilling with test in the detail design. The cut off trench up to rock foundation should be provided at all the Alluvial Formations.

The Terrace Deposit is found at the flat plain of the left bank to the river bed with a width of 200 m and a thickness of about 10 m. The deposit consists of sandy silt of 4 m thick in the upper layer and of clayey sand and clayey gravel of 4.7 to 0.5 m. Bearing capacity of the upper layer ranges from 8 to 10 blows in SPT and it attains more than 20 blows in the lower layer.

Permeability ranges 5.6×10^{-4} to 4.3×10^{-5} cm/sec in the upper layer and 1.0 to 1.3×10^{-3} cm/sec in the lower layer.

The Terrace Deposit material is also highly permeable and should be excavated for the cut off trench. The Phra Wihan Formation is exposed in both sides of abutment and overlain by the Terrace Deposit and the Alluvial Formation at the center of dam axis.

The formation consists of interbedded mudstone, siltstone, fine to medium grained sandstone, conglomeratic sandstone and conglomerate. The formation trends west-northwest and dips gently northward. Thick mudstone bed underlies the Alluvial Formation at the center of axis and it extends both sides with slightly dipping to the right side, then it turn its lithology into interbedded coarse sandstone and conglomerate at DH-3. It is difficult to judge which is the cause of lithological anomaly, grading or fault. Even it was caused by fault, presumably it is inactive and would pose no threat to dam foundation security. Mudstone is restricted in distribution below 235 msl. Interbedded sandstone and conglomerate

with thin layer of siltstone overlies mudstone and it also extends both abutments. It crops out in the upper part of the left bank in contrast with the right bank where the Slope Detritus overlies it.

The Phra Wihan Formation is well consolidated even at the surface outcrop. The compressive strength of sandstone at 1.7 and 4.3 m in depth presents 303 and 403 kg/sq.cm in the laboratory test. The permeability test shows the value of 1×10^{-3} to 1×10^{-4} cm/sec at the upper part and 1×10^{-4} to 10^{-5} cm/sec at the lower part.

Therefore, the cut off trench is placed on this rock foundation and does not require the excavation except trimming. Geological map of damsite and geologic profile of the dam axis are shown in Figure B-2-3 and Drawings respectively. Summarized data of core drilling are shown in Table B-2-1.

2) Spillway

The overflow section of spillway would be founded on firm consolidated medium to coarse grained sandstone after less than 1 m of the overburden soil is stripped away.

Sandstone would provide satisfactory foundation for the spillway structure. As the beds dip less than 5 degrees northeast, bedding plane slides should not be a serious potential problem in the construction cuts. Foundation geology of the shute is estimated the same as the overflow section until Station 4 (250 mamsl), then the overburden thickens to the downward. Estimated thickness of it at Station 5 (233 mamsl) and 6 (226.3 mamsl) is 1 and 5 m, respectively. (See Drawing)

B.2.4. Construction Materials

1) Riprap

Although quality of sandstone is slightly inferior for the rock materials, riprap material would be obtained from excavated sandstone at the spillway.

The quality of sandstone which was tested by RID laboratory is shown in Table B-2-2. The quarry of sandstone is easily located in the upper part of Lam Plai Mat sub-basin, 3 km southwest of the damsite, when quantitative problem of riprap arises at the detail design.

2) Aggregate

The dense basalt would be suitable for concrete aggregate. It underlies the middle part of Lam Plai Mat basin where few quarries are now under exploited. One of them, the east of Phu Phra Angkham, would provide aggregate of suitable quality for the Project.

B.2.5. Foundation Treatment

The unconsolidated formations including 18 m thick of the Alluvial Formation, should be excavated for the cut off trench. They are suitable for the dam foundation when stripping vegetation and loose surface of about 1 m.

The foundation of cut off trench, the Phra Wihan Formation, presents comparatively high rate of permeability of 0.01 to 0.001 cm/sec at both sides of the abutment where rock is exposed at the surface. However, it presents 10^{-4} cm/sec at the depth of 10 m from top of the rock. Lugeon map of the Phra Wiham Formation is shown in Figure B-2-4. As easily visualized from the maps, grouting at the upper part of formation is required for prevention of seepage flow. Two kinds of groutings are proposed, the blanket and the curtain grouting.

The curtain grouting is designed by three rows of half of water depth at the river bed section and 5 m depth at both abutments. Each row is designed 1.5 m interval with 3.0 m hole spacing. The final layout of grouting should be designed on the basis of the preliminary grouting test.

As already stated there is inconsistent interrelationship between lithology, bearing capacity and permeability in the lower part of the Alluvial Formation.

Although cut off trench would be provided in all the Alluvial Formations as of present, excavation depth in the formation should be shifted as the results of reinvestigation drilling at the detail design.

Table B-2-1 Data Summary of Core Drilling - Plai Mat Damsite

Hole No.	Site Elv. (mamsl)	Depth Hole (m)	Depth of layers (mbgs)			SPT (N-value)		Permeability (cm/sec)		
			Soil	Heavy weathered bedrock	Bedrock	Soil	Heavy weathered bedrock	Soil	Heavy weathered bedrock	Bedrock
DH-1	267.7	15.3	-	-	0 ∿15.3	-	-	-	-	$2x10^{-2}$∿$2x10^{-5}$
-2	258.8	15.6	0 ∿1.2	-	1.2 ∿15.6	75	-	-	-	$5x10^{-3}$∿$8x10^{-6}$
-3	246.7	19.5	0 ∿4.4		4.4 ∿19.5	8∿15	-	$2x10^{-3}$∿$4x10^{-4}$	-	$4x10^{-3}$∿$3x10^{-5}$
-4	244.8	25.05	0 ∿2.5	-	2.5 ∿25.05	3	-	$1x10^{-2}$∿$3x10^{-3}$	-	$2x10^{-3}$∿$2x10^{-5}$
-5	244.3	24.85	0 ∿9.55	-	9.55∿24.85	3∿40	-	$1x10^{-3}$∿$4x10^{-5}$	-	$2x10^{-4}$∿$2x10^{-5}$
-6	238.8	29.9	0∿15.0	15.0∿17.6	17.6 ∿29.9	5∿50	33∿50	$6x10^{-3}$∿$8x10^{-5}$	$1x10^{-4}$	$3x10^{-5}$∿$1x10^{-5}$
-7	231.4	30.55	0 ∿8.0	8.0∿15.25	15.25∿30.55	3∿22	22∿57	$7x10^{-3}$∿$4x10^{-4}$	$1x10^{-3}$∿$4x10^{-5}$	$2x10^{-4}$∿$4x10^{-6}$
-8	237.7	29.8	0∿17.5	-	17.5 ∿29.8	5∿43	-	$6x10^{-3}$∿$2x10^{-5}$	-	$2x10^{-4}$∿$2x10^{-5}$
-9	237.3	25.2	0 ∿9.3	-	9.3 ∿25.2	4∿20	-	$4x10^{-3}$∿$6x10^{-5}$	-	$2x10^{-4}$∿$6x10^{-6}$
-10	238.7	25.6	0 ∿4.0	-	4.0 ∿25.6	3∿35	-	$1x10^{-2}$∿$2x10^{-5}$	-	$1x10^{-3}$∿$3x10^{-6}$
-11	246.6	19.8	0 ∿0.5	-	0.5 ∿19.8	-	-	-	-	$6x10^{-3}$∿$1x10^{-5}$
-12	253.1	20.3		-	0 ∿20.3	-	-	-	-	$5x10^{-3}$∿$6x10^{-7}$
-13	260.2	15.9	0 ∿0.6	-	0.6∿15.9	-	-	-	-	$6x10^{-4}$∿$2x10^{-5}$
-14	266.1	14.8	0 ∿0.7	-	0.7 ∿14.8	-	-	-	-	$2x10^{-4}$∿$2x10^{-5}$
-15	267.9	15.2	0 ∿2.4	-	2.4 ∿15.2	13∿20	-	$1x10^{-3}$∿$8x10^{-4}$	-	$6x10^{-4}$∿$8x10^{-5}$
-16	269.5	16.3	0 ∿5.5	-	5.5 ∿16.3	11∿33	-	$3x10^{-3}$∿$1x10^{-4}$	-	$4x10^{-4}$∿$2x10^{-5}$
-17	258.9	11.0	0 ∿1.7	-	1.7 ∿11.0	14	-	$2x10^{-3}$	-	$4x10^{-3}$∿$4x10^{-4}$
-18	269.5	16.3	0 ∿5.5	-	5.5 ∿16.3	11 33	-	$4x10^{-4}$∿$2x10^{-5}$	-	$1x10^{-4}$∿$6x10^{-5}$

Fig. B-2-3 GEOLOGICAL MAP OF LAM PLAIMAT DAMSITE

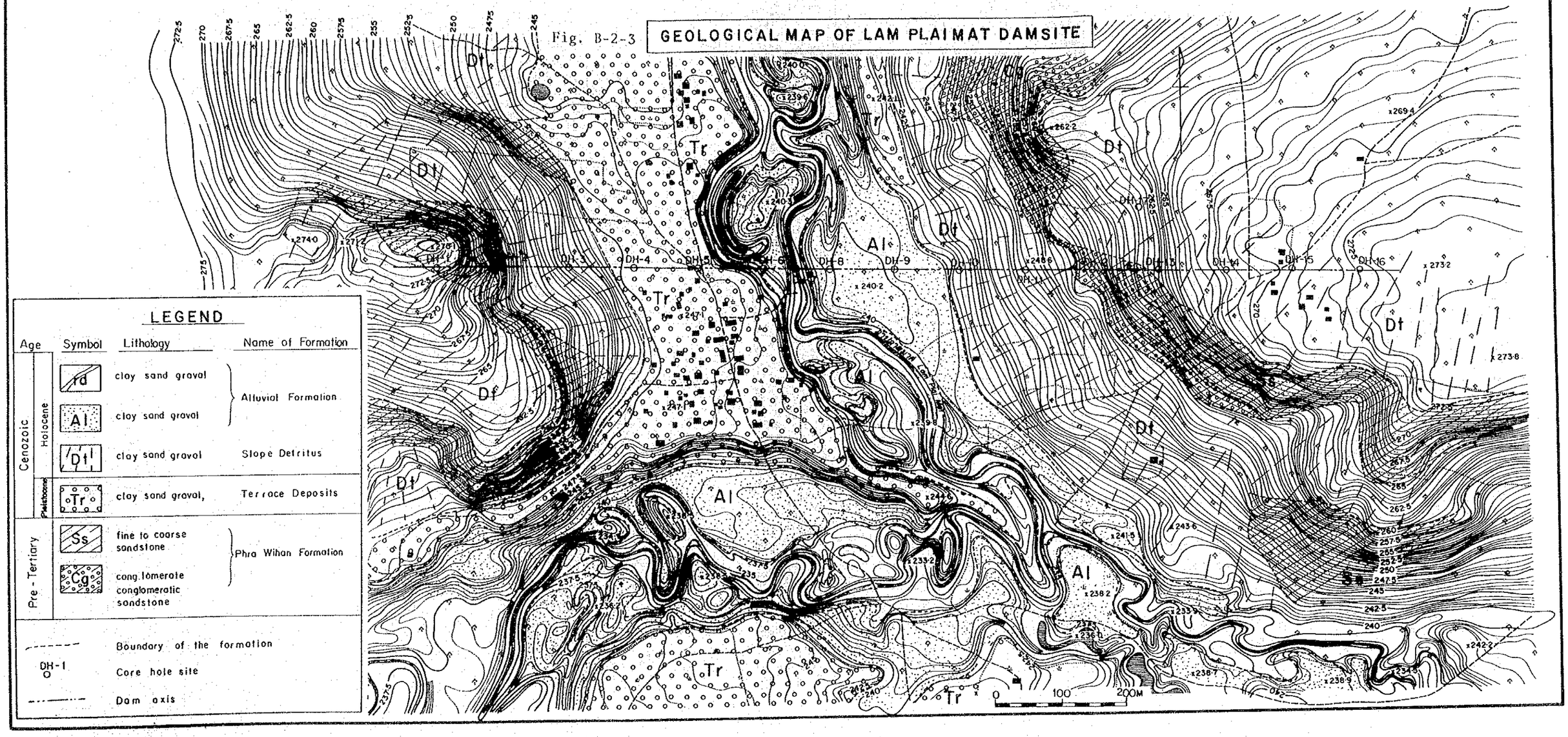


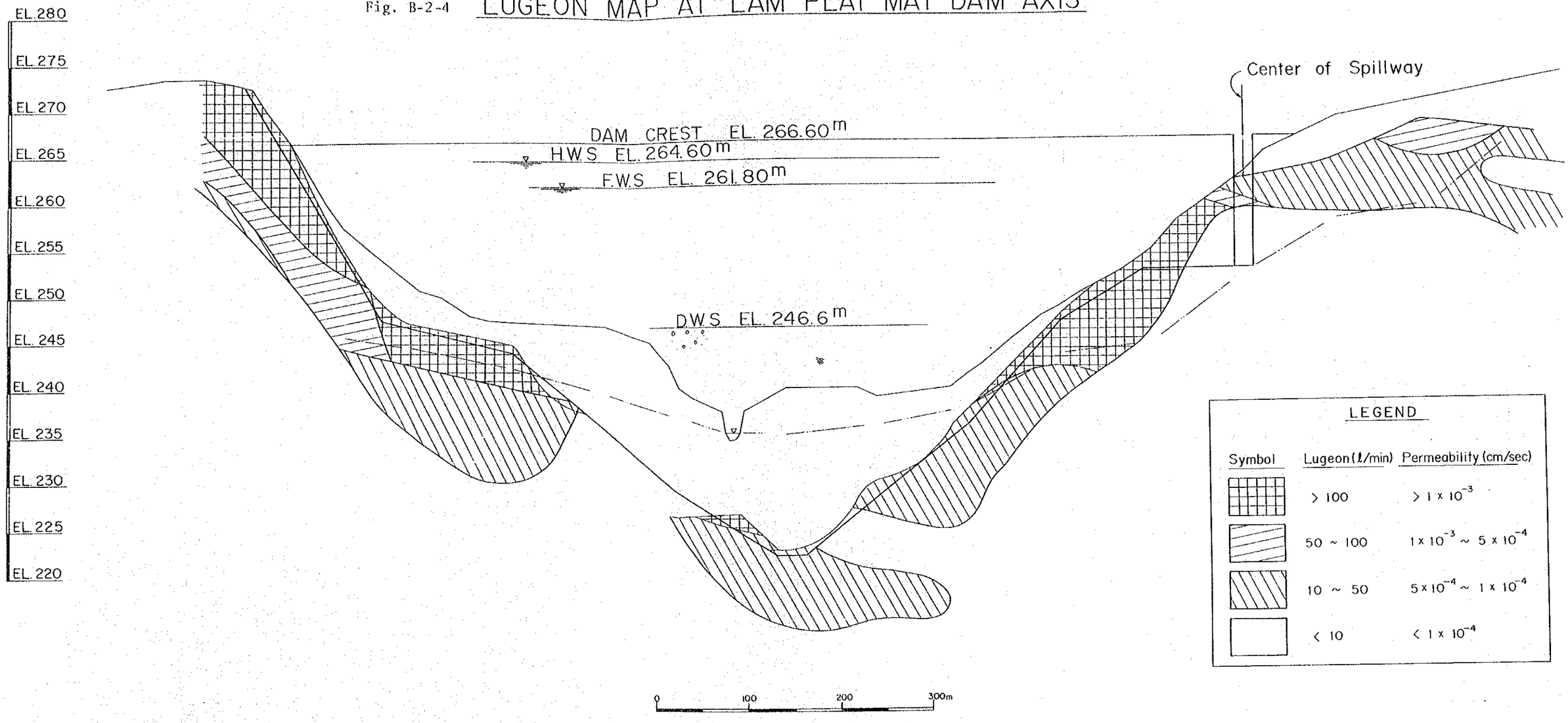
Table B-2-2 Test Results of Rock Core Sample, Lam Plai Mat

Tested by : Concrete and Materials Laboratory
Research and Laboratory Division
Royal Irrigation Department

Date : October 11, 1985

Hole No.	Depth (m)	Lithology	Dimension (cm)		Specific Gravity	Absoprtion (%)	Soundness loss (%)	Compressive Strength (kgf/cm^2)
			Diameter	Length				
DH-17	3.80 - 4.30	fine-medium sandstone	5.42	10.90	2.39	2.02	6.85	303
DH-18	1.70 - 2.55	fine-medium sandstone	4.12	8.37	2.37	3.05	7.92	430

Fig. B-2-4 LUGEON MAP AT LAM PLAI MAT DAM AXIS



B.3. Engineering Bedlogy of Nonb Lum Puk Damsite

B.3.1. Location and Topographic Features

Damsite of Nong Lum Puk is located 5 kilometers northeast of Amphoe Soeng Saeng. Huai Nong Lum Puk is one of the tributary of the Lam Plai Mat where it turns from north to east. The drainage area of site is comparatively small, 25 sq.km and gradient of river course is about 1:350 instead of 1:1,000 at the main stream.

The slope gradient of dam abutment ranges from 1:20 to 1:30 in proportion to its altitude. The damsite is accessible by fair-weather roads. The alluvial flood floor is narrow, less than 200 m.

B.3.2. Foundation Geology

1) Dam Foundation

In accordance with six core drillings and the geological field investigation, the following geological features are revealed;

The dam foundation is underlain by three different formations, the Alluvial Formation, the Slope and Residual Detritus and the Basalt. Tow of them except the Basalt are unconsolidated deposits. The valley slope at the dam axis are underlain by the Slope and Residual Detritus consisting of Clayey gravel, gravelly clay and tuffaceous clay.

The both abutments of dam are formed by the Slope and Residual Detritus which is derived from underlying basalt and tuff. Thickness of it ranges from 2 to 8 m and more than 8 m in the upper part of left bank. The upper part of the right bank is underlain by clayey gravel and it is also in-place residual detritus derived from

Table B-3-1 Data Summary of Core Drilling - Nong Lumpuk Kamsite

Hole No.	Site Elv. (mamsl)	Depth Drilled (m)	Depth to layers (mgbs)			SPT (blows)		Permeability (cm/sec)		Remarks
			Soil	Heavily weathered bedrock	Bedrock*2)	Range	Average	Soil*1)	Bedrock	
DH-1	237.6	20.0	0∿11	11∿17	17∿20	10∿214	70	$<2\times10^{-4}$	9.9×10^{-4}	
2	237.2	13.2	0∿6.9	-	6.9∿13.2	17 ∿94	54	$<6\times10^{-4}$	2.2×10^{-3}∿6.1×10^{-4}	
3	230.7	12.4	0∿4.5	4.5∿6.4	6.4∿12.4	20 ∿37	29	No water loss	2.3×10^{-3}∿1.4×10^{-3}	Tuff underlie 9.1 16.6m
4	224.9	16.6	0∿4.2	4.2∿9.1	9.1∿16.6	19∿107	43	$<7\times10^{-5}$	2.8×10^{-3}	
5	233.3	10.7	0∿4.2	4.2∿6.0	6.0∿10.7	15∿100	47	2×10^{-3}∿1×10^{-4}	2.1×10^{-3}∿9.7×10^{-4}	
6	235.3	15.7	0∿9.2	9.2∿11.2	11.2∿15.7	19∿100	41	$<1.8\times10^{-4}$	1.5×10^{-3}	

*1) Appropriate tests of permeability in the unconsolidated soil were not carried out

*2) Basalt except at DH-4 of 9.1 to 16.6m depth.

underlying basalt. Thickness is about 3 m on an average. Tuffaceous clay is overlain by gravelly clay at both abutments and thickness ranges from 1 to 3 m. It is in-lace detritus derived from underlying tuff. The Alluvial Formation underlies the valley in 170 m width and consists of gravelly clay with a thickness of about 4 m.

The Basalt is formed by interbedded tuff and is overlain by the Slope and Residual Detritus, and the Alluvial formation. Basalt is found at 4 m depth in the river bed and at about 10 m in the right abutment. Basalt ranges from very dense to highly vesicular and it is generally seamy but in part blocky in the upper part of the rock.

Bearing capacity of the unconsolidated deposits overlying the Basalt is more than 20 blows in SPT with partial exception. It is sufficient for the foundation in view of bearing capacity. The unconsolidated deposits overlaying the Basalt presents impervious as listed in Table B-3-1.

Ground surface at the damsite is only stripped with half meter depth. The small cut off trench should be provided in the impervious overburden due to dam height of 12.0 m and the grouting is not required because of underlying impervious foundation.

2) Spillway

The spillway is provided at the right bank of damsite, and designed by non-control overflow type without gate.

The overflow structure of spillway should be founded on the well compacted gravelly clay, because of the Basalt underlies more than 7 m below the surface. The foundation presents permeability of less than 10^{-4} cm/sec and bearing capacity obtained is more than 50 blows in SPT throughout the deposits. Although, it presents slightly loose layers at a depth of more than 4 m, the overburden deposits of the right bank is suitable for the foundation of the overflow weir of spillway.

Geological map of the damsite and geologic profile of the dam axis are shown in Figure B-3-1 and Drawings.

B.3.3. Construction material

1) Riprap and Aggregate

Although basalt is the only riprap material nearby the damsite, it occurs few meters below the surface. It is plentiful and widely underlain over the hilly land, south of the Nong Lum Puk damsite.

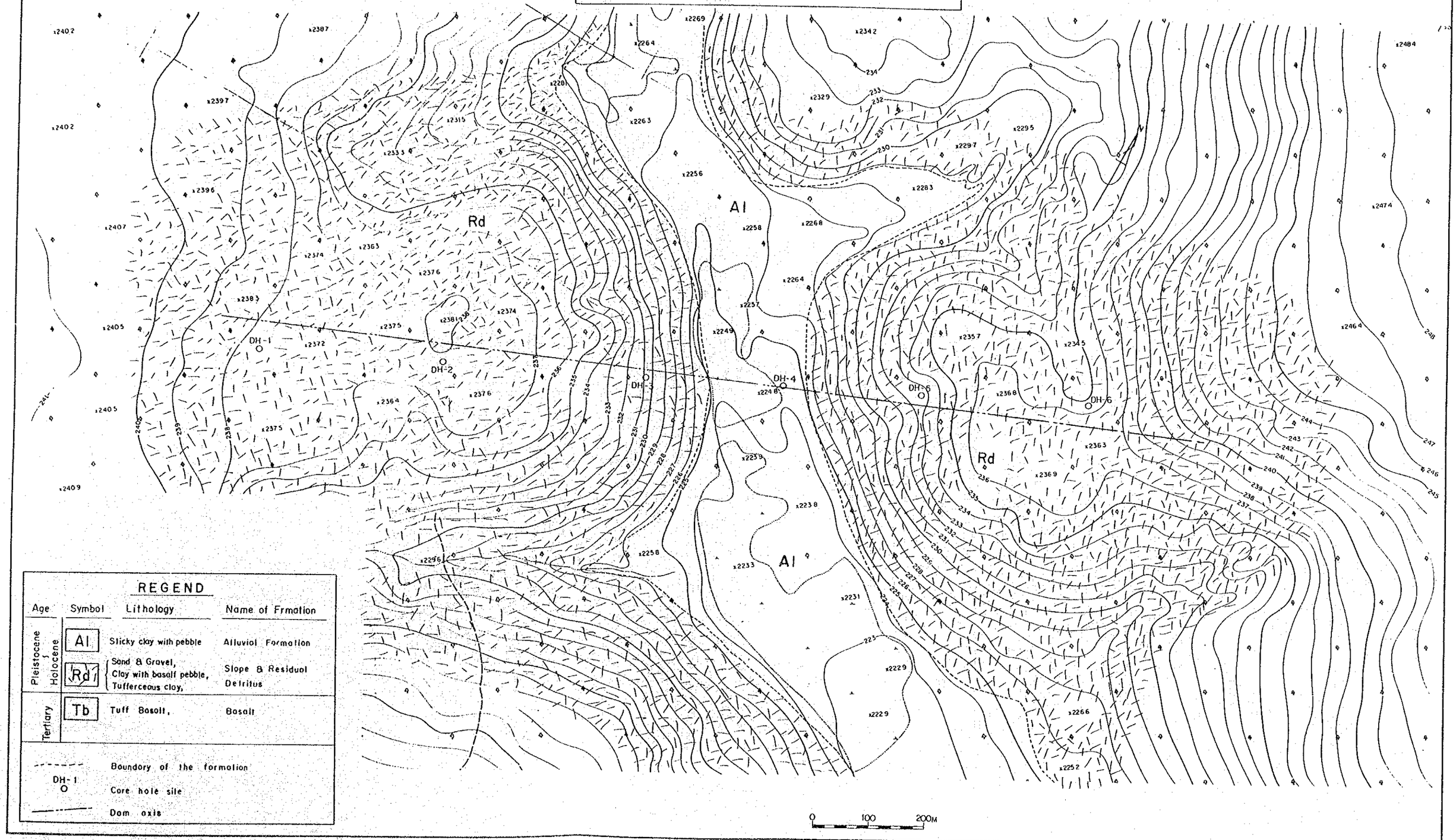
Development of basalt material is of increasing use and value for not only the materials of Nong Lum Puk but of other neighboring Projects. The proposed site for development seems a hill of 241 msl of the right bank. Quality and quantity of basalt to be developed seem almost equal to Ban Non Phet quarry, 10 km east of amphoe Chok Chai.

B.3.4. Foundation Treatment

The foundation surface would require only a minor amount of stripping. A poor ground in the alluvial plain of about 0.5 m thick would have to be stripped for the foundation. Underseepage through the Alluvial Formation and the Slope and Residual Detritus would be a relatively minor problem because of their lithology. Furthermore, underseepage in basalt would be limited by the natural upstream blanket overlying gravelly clay.

Fig. B-3-1

GEOLOGICAL MAP OF NONG LUM PUK DAMSITE



REGEND

Age	Symbol	Lithology	Name of Frmation
Pleistocene ~ Holocene	Al	Slicky clay with pebble	Alluviol Formation
	Rd	Sand & Gravel, Clay with basalt pebble, Tufferceous clay,	Slope & Residuol Detritus
Tertiary	Tb	Tuff Basalt,	Basalt

Boundory of the formation

DH-1 Core hole site

Dam axis

Fig. B-4-1 GEOLOGICAL MAP OF HUAI PHLU DAMSITE