CHAPTER I : INTRODUCTION

CHAPTER I. INTRODUCTION

1.1. Background to the Project

In 1967, the farmers of Amphoe Mae Tha, Changwat Lampang presented their petition for redress for grievance from the continuous drought during the previous years which caused much damage to the cultivated land. Furthermore, most of areas in Amphoe Mae Tha, have never been under an irrigation system, and are subject to rainfed system instead. The aspect of the terrain and the deep section of Mae Chang River do not encourage individual farmers to build weirs across the river and the canals along agricultural land as in other parts of the region. Some groups of the farmers would have to group together try and use pumps but the cost of operation and maintenance would be extremely high. Thus agricultural productivity is being held back in comparison to that of the neighboring Mae Wang area where the an irrigation system is provided.

For improvement of the situation in this area, the Royal Irrigation Department (RID) and its regional office has made every possible endeavor to provide an irrigation system since the farmers 1967 petition. As a part of these activities, a development plan of the upper basin of the Mae Wang River was studied and implementation of five project including the Kew Lom Dam and the Mae Chang Dam was recommended.

In 1972, Kew Lom Dam was implemented as a first priority project to provide an irrigation system and irrigation water for Mae Wang area.

Since completion of Kew Lom Dam and the irrigation system, agricultural productivity in the Mae Wang area has significantly improved. This gives a great impact to the implementation of the Mae Chang Dam. In the Mae Wang area, a cropping intensity more than

120 percent has been practiced at present, whereas in the neighboring Mae Chang area, the present cropping intensity is recorded as being below 85 percent.

As the Project is huge in scale and requires a large amount of funds for its implementation, the Government of Thailand requested the Government of Japan to extend technical cooperation for the formulation of the development plan in this Area.

In compliance with the Scope of Works for the Feasibility Study on the Mae Chang Irrigation Project (S/W), the Japan International Cooperation Agency (JICA), the official agency responsible for the implementation of the Japanese Government's technical cooperation programme dispatched a feasibility study team for the first field work beginning on January 30, 1983 and for the second field work beginning on June 5, 1983 for approximately two months, respectively.

1.2. Objectives of the Study

The objectives of the Study are as follows:

(1) to formulate an irrigation project and to testify to the technical and economic feasibility of the Project, and

(2) to transfer technology to Thai counterparts personnel in the course of the Study.

1.3. History of the Study

In accordance with the agreement concluded between the Thai and Japanese delegations in July 1982, the Government of Japan dispatched the Preliminary Survey Team for a feasibility study on the Mae Chang Irrigation Project from October 20 to November 6, 1982 through JICA. The Preliminary Survey Team headed by Mr. Minoru MINE conducted discussions with officials RID and a field survey. As a result of the discussions, the S/W was prepared and approved.

According to the S/W and the Plan of Operation for the Study, the activities of the Study Team are divided into five parts; the preparatory home work, the first field work, the first home office work, the second field work, and the home office work. The field work is performed in Thailand while home work and home office work are performed in Japan.

The first field work covered the field reconnaissance and survey of the study area in the dry season involved collection of data and information on the Project and the investigation and preliminary study of alternative dam sites, while the second field work aimed to make field investigation and survey in the wet season and to discuss the alternative development plans with Thai officials concerned and to select a proposed development plan.

This feasibility study report has been compiled according to the results of surveys and studies conducted in the field and in Japan, and numerous discussion meetings were held among the Thai officials, the supervisory group and the study team. The names of the member of the supervisory group, the Thai counterparts personnel assigned to the Project and the study team are listed as follows:

Supervisory Committee Members

1.	Chairman Mr. Mamoru YOSHIMURA	Director, Land Improvement Engineering Center, Hokuriku Regional Administration Office, Ministry of Agriculture, Forestry and Fisheries (MAFF)
2.	Member (Irrigation & Drainage) Mr. Mitsuhiro GOTO	Director, Irrigation & Drainage Div. Kinki Regional Administration Office, MAFF
3.	Member (Dam Engineering) Mr. Nariaki TAMURA	Irrigation Engr., Land Development Div, Agricultural Structure Improvement Bureau, MAFF

4.	Member (Agronomy & Soil) Mr. Kaichiro SUZUKI	Deputy Director, Project Planning Div., Hokuriku Regional Administration Office, MAFF
5.	Member (Agri-economy) Mr. Mamoru OHBA	Deputy Director, Project Planning Div., Tohoku Regional Administration Office, MAFF
6.	Member (Project Evaluation) Mr. Kazuyasu KAMATA	Deputy Manager, 2nd, Technical Appraisal Div., Economic Research and Technical Appraisal Dept., The Overseas Economic Cooperation Fund (OECF)
7.	Coordinator (First Field Survey) Mr. Teruhisa TAJIRI	Official, Technical Affairs Div., Agricultural, Forestry & Fisheries Planning & Survey Dept., JICA
8.	Coordinator (Second Field Survey) Mr. Harumi KASHIMA	Official, Development Planning Div., Agricultural, Forestry & Fisheries Planning & Survey Dept., Japan International Cooperation Agency (JICA)

Counterparts Personnel Assigned to the Project

1. Dr. Boonyok Vadhanaphuti, Director, Project Planning Division (PPD), RID
2. Mr. Taweechai Mackaman, Chief, Large Scale Project F/S Br., PPD
3. Mr. Kitla Thepalaglekha, Asst. Chief, Large Scale Project F/S Br., PPD
4. Miss Supha Sing-Intra, Chief Economic Br., PPD
5. Mr. Osot Charnvej, Agronomist, O & M Div.
6. Mr. Pasnee Kanchanakhon, Economist, Economic Br., PPD
7. Mr. Apichai Wathanayomnaporn, Agronomist, O & M Div.
8. Mr. Dhanaphong Sridhavat, Geologist, Soil & Geology Div.
9. Mr. Pipop Chupaisert, Geologist, Soil & Geology Div.
10. Mr. Anuchit Changvitayakam, Counterpart, PPD
11. Mr. Norraard Sri Saeng, Counterpart, PPD
12. Mr. Preacha Sukklam, Counterpart, PPD
13. Mr. Youth Kingkate, Director, Region II (Before May, 1983)
14. Mr. Pratin Watang-Gool, Director, Region II (After June, 1983)
15. Mr. Somtob Kaewyen, Deputy Director, Region II
16. Mr. Kanchit Likitdecharote, Counterpart, Region II
17. Mr. Kithisak Hengsadeekul, Counterpart, Region II
18. Mr. Sutasana Wachiraporn, Asst., Law & Land Sec., Region II
19. Mr. Banchong Vadhanaphong, Chief Mechanical Eng., Region II
20. Mr. Thawat Tantitheravit, Project Engr., Region II
21. Mr. Suvachat Vorralittanon, Agronomy Sec., Region II

Study Team Members Assigned to the Project in Thailand

1.	Team Leader Mr. Yoshio ARAI	January 30 to March 27, 1983 June 5 to August 10, 1983 November 15 to 22, 1983
2.	Irrigation & Drainage Mr. Fumimichi OBU	January 30 to March 27, 1983 June 5 to August 10, 1983
3.	Meteorology & Hydrology Mr. Ryosuke SAKANASHI	January 30 to March 27, 1983 June 12 to July 11, 1983
4.	Geology & Dam Foundation Mr. Tsunemi KIMURA	February 11 to March 27, 1983 June 12 to August 2, 1983
5.	Dam & Embankment Materials Mr. Munehisa MURAYAMA	January 30 to March 27, 1983 June 5 to August 10, 1983
6.	Soil & Land Use Mr. Kazuo NAKABAYASHI	January 30 to March 27, 1983
7.	Dam Appurtenances Mr. Osamu SUZUKI	February 11 to March 27, 1983 June 12 to August 1, 1983
8.	Canal & Canal Structures Mr. Sueo MORI	February 11 to March 27, 1983 June 5 to August 10, 1983
9.	Agronomy Mr. Hirokazu KORIKI	February 11 to March 27, 1983 June 12 to July 11, 1983
10.	Agro-economy & Organization Mr. Keizo YAMADA	February 11 to March 27, 1983 June 12 to August 2, 1983
11.	Social Environment & Resettlement Mr. Kenichi HAYASHI	February 11 to March 27, 1983 June 12 to July 11, 1983
12.	Construction Planning & Cost Mr. Yoshiteru TSUNODA	June 12 to August 2, 1983

CHAPTER II : ECONOMIC AND SECTORAL BACKGROUND

CHAPTER II. ECONOMIC AND SECTORAL BACKGROUND

2.1. National Level

2.1.1. General

Thailand's national territory extends over 514,000 square kilometers of which approximately 33 percent is agricultural land.

According to current estimates the total population was about 47.488 million persons in 1981 (see Table 2.1-1, Appendix). The economically active population (labor force, 15 - 64 years of age including unemployed) was 23.810 million persons or 49 percent of the total population, and of this total those employed in the agricultural sector accounted for 16.770 million or 70.4 percent of the total labor force (see Table 2.1-2, Appendix).

2.1.2. Economic Conditions

The Gross Domestic Product (GDP) of Thailand in 1981 rose by 7.6 percent to reach 315,100 million baht at constant 1972 prices, this was an improvement over the 5.8 percent rate of growth recorded in 1980. The main reason for such a higher rate of growth was the sharp increase in agricultural production which in turn lead to the expansion of agro-industries. Furthermore, related industries such as fertilizer, machinery, transportation, etc. also expanded in direct response to the requirements of the agricultural sector.

Agriculture and manufacturing remained the predominant sectors in 1981 having fairly high growth rates of 4.7 and 8.0 percent, respectively, compared with 1.9 and 4.8 percent in 1980.

Production of agricultural goods in 1981 increased by approximately 7.5 percent and crop production in particular, rose sharply due to good weather conditions and the high crop prices of the preceding year.

Table 2.1-3, Appendix, shows the contribution of agriculture to the national economy during the ten year period from 1972 to 1981. Although agriculture's share of GDP has been gradually decreasing year by year total output continues to increase and it still remains the number one contributor to the economy of Thailand.

2.1.3. Development Plan

The present or Fifth National Economic and Social Development Plan (1982 - 1986) has a total of six main objectives which can be briefly stated as follows.

1) Restoration of the country's economic and financial position;

2) Adjustment of the economic structure and the raising of the economic efficiency;

3) Development of social structure and distribution of social services;

4) Poverty alluviation in backward areas;

5) Coordination of economic development activities with national security management;

6) Reformation of the national development administration.

Under the second objective stated above the Fifth Plan has set down goals for restructuring key productive sectors and increasing economic efficiency in several areas, especially in agriculture and the use of natural resources to bear greater yields than in the past.

The Fifth Plan emphasizes the development of a domestic production plan in line with exports and domestic consumption; the encouragement of the private sector to invest in and develop agriculturally advanced areas, including the improvement of land use, water and forest resources to provide maximum returns.

The agriculture sector is targeted to expand by 4.5 percent in real terms (see Table 2.1-4, Appendix) as compared to 3.5 percent actual growth during the Fourth Plan (1977 - 1981). This expansion must occur mainly through an increase in yields in order to preserve existing forest and water resources. It will be necessary to improve the production process and efficiency in the utilization of land, water and forest resources in the northeast and the upper north in particular, since land and water resources are limited and are in a very depressed state at present. The fact that these two areas are economically trailing the rest of the country in income distribution and proportion of rural poor (see Table 2.1-5 and 2.1-6, Appendix) is another reason for their urgent improvement through agricultural development.

Special emphasis will be placed on the productivity increase in paddy rice since it is the most important crop. Especially in the case of paddy rice, development of water resources are a basic factor for the raising of productivity. Therefore, the Fifth Plan calls for the improvement or expansion of irrigated agriculture throughout the country. The Research and Development Budget 1978 - 1980 (see Table 2.1-7, Appendix) shows the great weight and importance placed by the Government on the agriculture and irrigation sector.

2.2. Provincial Level

According to data collected from the National Economic and Social Development Board (NESDB) the Gross Regional Product of the Northern Region at current market prices was 92,235 million baht in 1980. Of this total 40,534 million baht or 43.9 percent was contributed by the agricultural sector (see Table 2.2-1 and 2.2-2, Appendix).

Table 2.2-3, Appendix shows that per capita GRP in the Northern Region is next to last in the country being only greater than that of the Northeastern Region. Moreover, it is the only region whose per capita GRP has fallen recently as can be seen in the figures for 1979 and 1980.

In 1980, of the 17 provinces in the Northern Region Lampang Province ranked seventh in Gross Provincial Product (GPP). However, it ranked number 11 in agricultural production and number 12 in per capita GRP. Statistics on agricultural production (see Table 2.2-2, Appendix) for the period 1976 to 1980 show that while output of livestock, fisheries, and forestry products has been increasing steadily crop production has been quite erratic and in 1980 was still below 1976 levels.

CHAPTER III: THE PROJECT AREA

CHAPTER III. THE PROJECT AREA

3.1. Location and General Features

3.1.1. Geographical Location and Road System

The Project Area is located in Changwat Lampang about 630 km north of Bangkok, and lies between 18°05' to 18°15'N and 99°20' to 99°35'E.

National highways No.1 and No.11 with asphalt concrete or double surface treatment pass through the eastern and western part of the Area and are well maintained under the Department of Highways. Within the Area exist provincial and village roads paved with double surface treatment or gravel, and with the exception of some village raods, cause no difficulties for transportation even during the rainy season.

Farm roads for transporting agricultural input materials and products are not provided in the fields throughout all of entire Area.

3.1.2. Population and Living Conditions

1) Population

According to vital statistics data received from the Lampang Provincial Public Health Office, the population in Lampang Province increased from 655,932 persons in 1979 to 665,400 persons in 1981 resulting in an annual average rate of population growth of 1.17 percent. This is already considerably lower than the target growth rate of 1.5 percent to be reached by the end of the Fifth Economic and Social Development Plan in 1986.

Data collected from the Lampang Commercial Office which includes migration into and out of the province shows a much lower annual average rate of population growth of 0.60 percent during the same 1979 to 1981 period. From this data it can be concluded that the number of people migrating out of the province is greater than the number migrating in.

Vital Statistics, Lampang

Year	Population	Births	Deaths	Annual Growth Rate (per cent)
1979	655,932	12,037	4,120	1.21
1980	659,234	11,901	4,143	1.18
1981	665,400	11,548	4,186	1.11

Source: Lampang Provincial Public Health Office

Population Statistics including Migration in and out Province

Year	Population	Increase	Annual Growth Rate (Per cent)
1979	653,932	1,404	0.21
1980	659,433	5,501	0.84
1981	664,496	5,062	0.76

Source: Provincial Commercial Office Annual Report 1981

The Project Area includes parts of two districts in Lampang Province, namely Amphoe Mae Tha and Amphoe Ko Kha. The area covered by the study in Amphoe Mae Tha is more extensive than that in Amphoe Ko Kha. Populations in the two districts in 1981 were Amphoe Mae Tha 63,729 persons and Amphoe Ko Kha 59,522 persons.

2) Living Conditions

The Royal Irrigation Department's Economic Branch conducted a Socio-Economic Survey in the study area during the crop year 1980/81. Results of the survey show that the average family size is five persons, the number of males being slightly greater than the number of females. The average age of the head of the household is 47 years. Approximately 71 percent of the sample population are of working age (15 to 60 years old). The education levels of the household heads are as follows; 15.6 percent have no education, 21.25 percent completed less than Prathom 4 and 61.25 percent completed Prathom 4. The majority of the household heads (84.4%) were born in their present village of residence while the remainder (15.6%) migrated from outside villages but from within Lampang Province for reasons of marriage.

Although the Province has a total of seven District Hospitals (10 beds each) none of them are located within the Project Area. Therefore, villagers in the Project Area mostly depend upon the provincial level health services located in Lampang City. Health treatment facilities located in the Project Area are the Sub-District Health Center which is mainly for minor illnesses and the distribution of birth-control devices and the Midwifery Center. The number of Sub-District Health Centers in Amphoe Mae Tha is 10 and Amphoe Ko Kha 9, and the number of Midwifery Centers in Amphoe Mae Tha is 1 and in Amphoe Ko Kha 0.

The main sources of domestic water supply in the Project Area are shallow wells, deep wells, surface water and rain water collected and stored in tanks. In the villages, people take drinking water from shallow wells or use collected rain water. Water from deep wells is mainly used for washing and bathing.

The domestic water supply for municipal areas in Lampang Province is under the jurisdiction of the Public Water Works

Authority Region 9 which covers the four Pronvinces of Lampang, Nan, Phayao and Phrae. Rural water supply projects are carried out by the Public Health Office or Tambon Rural Development Committees with full technical support provided by the Public Water Works Authority. Present rural water supply stations in Lampang Province are;

Station Name	Capacity (cm/hr)	Water Source
So - Prab Health Center	20	Mae Nam Wang
Chae Hom	20	"
Soem Ngam	30	"
Ngao	30	Mae Nam Ngao
Ban Chua Um Long	-	Natural Canal
Ban Lampang Luang	30	Deep Well (pump)
Ban Pha Pung	-	Natural Canal
Ban Mae Tha	20	Reservoir
Ban Mae Chiang Rai Lum	10	Mae Nam Wang
Ban Tha Haen	10	Deep Well (pump)
Hang Chat Health Center	20	"
Mae Tha Health Center	30	"

Source: Public Water Works Authority Region 9 Office Lampang

Data on electrification show that approximately 36 percent of all households in Lampang Province are supplied with electricity. However, only densely populated areas near main roads are supplied with electricity whereas villages in remote areas still remain without.

3.2. Physical Conditions

3.2.1. Topography and River

(1) Topography

The Project Area stretches over the lower river valley of the Mae Chang located in Changwat Lampang in the North of Thailand.

The elevation of the Area is from 210 to 260 m above mean sea level (AMSL) and slopes gently from east to west at a rate of 1/200.

This area can be divided into the three sub-areas of i) Mae Chang Right Bank ii) Sop Chang and iii) Mae Wa sub-areas.

2) Rivers

The river Mae Chang is one of the major tributaries of the Mae Wang and is the source of water for this Project.

As illustrated in Fig.3.2-1, the Mae Chang rises from the moutains with an elevation of 500 to 800 m AMSL situated in the north-east of the Project Area. After joining Mae Moh, the stream water flows down from dam site A to C, joins with Mae Tha near dam site D and flows into Mae Wang at Ban Sop Chang at a point four kilometers from Amphoe Ko Kha to the south. The total drainage area of the Mae Chang is estimated at about 1,360 square kilometers up to the above mentioned confluence.

3.2.2. Meteorology and Hydrology

1) Climate

Although cold wind currents sometimes blow in winter, the climate of Thailand has a generally tropical character. Except for the top of mountains which experience frost-fall, the temperature seldom goes down below zero in the lowland areas. The upper stream area of Mae Chang is situated in the region of comparatively lesser rainfall.

Climatic seasons of the region are influenced by two different monsoons. One is the north-east monsoon which begins in November and ends in the middle of March and the other is the south-west

monsoon which lasts from the middle of May to September. The period between both monsoons is called the transitional period.

Two seasons are defined by the annual distribution of rainfall into the rainy season and the dry season. The former occurs in the period from May to October and the latter from November to April. Most rainfall is concentrated in the rainy season.

Typhoons sometimes enter the North of Thailand from the east. They are weakened however, by having to pass through the mountainous areas of Laos and Cambodia before reaching this region.

i) Meteorological Observation

The Meteorological Department and RID are in charge of the meteorological observation in this region. The major facilities of the former are in Chiang Mai and Lampang. The latter authority has distributed a number of observation stations throughout the region and chiefly observes rainfall and temperature, evaporation and wind if required. Table 3.2-1 and Fig. 3.2-1 show the names and the locations of the stations, and Table 3.2-2 shows the climatic data of Lampang representing the climate of the Project Area and surrounding area.

ii) Evaporation

According to the results of the RID's W-15 station and the Lampang Meteorological Department, the monthly evaporation in the Project Area was measured as follows:

FIG. 3.2-1 RIVER BASIN & STATION MAP

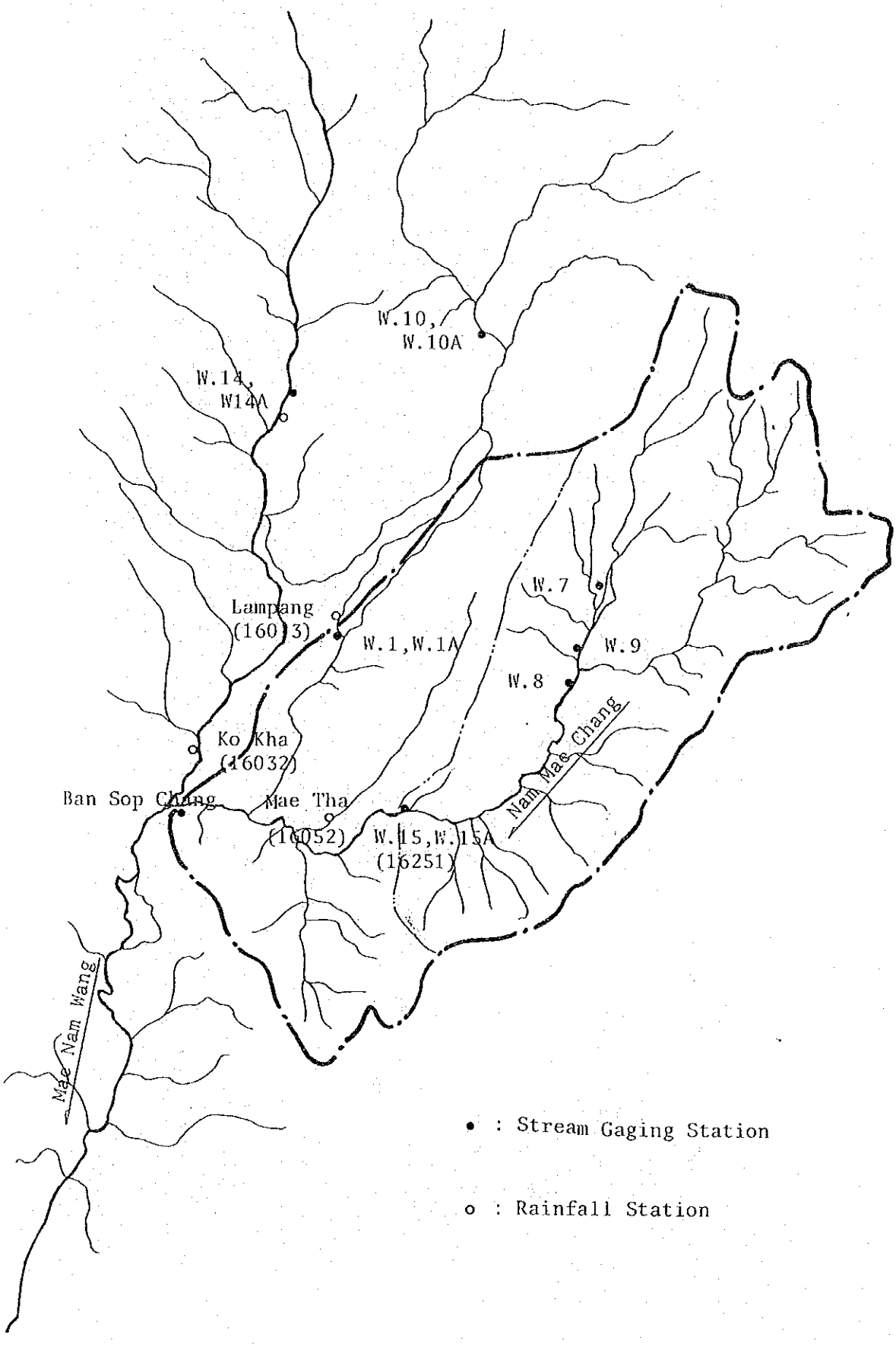


Table 3.2-1. Observation Period of Meteorological Observatories

Station	Temperature	Dew Point and Relative Humidity	Evaporation	Cloudiness	Wind	Rainfall	Sunshine Hours	Agent
A. Muang, Lampang (16013)	1951-81	1951-81	1975-81	1951-81	1951-81	1951-81	-	MO
A. Mae Tha, Lampang (19052)	-	-	-	-	-	1952-81	-	RID
Mae Chang, T. Ma Khrua (W-15)(16251)	1971-81	1971-81	1971-81	-	1971-81	1971-81		RID
A. Ko Kha, Lampang (16032)	-	-	-	-	-	1952-81		RID

Note: MD: Meteorogical Department,
RID: Royal Irrigation Department

Table 3.2-2. Major Climatic Elements at Lampang

Month	Temperature			Mean Relative Humidity	Mean Dew Point	Mean Evapo-ration	Cloudi-ness	Wind		Sunshine Hours
	Max. Mean (°C)	Mean (°C)	Min. Mean (°C)	(%)	(°C)	(mm)	(octas)	Mean Speed (Knots)	Prevailing Direction	(hrs/day)
Jan.	30.1	21.3	13.6	72.0	15.2	82.3	2.6	1.9	S	
Feb.	33.2	23.9	15.1	64.0	15.4	107.0	2.2	2.3	S	
Mar.	35.9	27.4	18.7	58.0	16.9	153.7	2.3	2.8	S	
Apr.	37.3	29.7	22.4	59.0	19.7	197.8	3.4	3.4	S	
May	34.9	28.8	23.8	72.0	22.7	157.6	5.4	3.1	S	
Jun.	33.0	28.0	24.0	77.0	23.4	146.3	6.4	3.3	S	- No observation -
Jul.	32.3	27.6	23.8	78.0	23.2	129.7	6.8	3.5	SW	
Aug.	31.8	27.1	23.5	82.0	23.6	117.9	6.9	2.8	S	
Sep.	31.6	26.6	23.0	85.0	23.7	110.8	6.3	2.0	S	
Oct.	31.2	25.9	21.7	84.0	22.7	98.7	5.1	1.6	NE	
Nov.	30.5	24.0	18.4	80.0	19.8	87.9	3.8	1.5	NE	
Dec.	29.4	21.4	14.8	76.0	16.5	98.0	3.3	1.7	NE	
Average	32.6	26.0	20.2	74.0	20.2	1,469.7 1/	4.5	2.5	-	

Data Source: Climatological Data of Thailand 30-year Period (1951-1980), Meteorological Department

Note: 1/ Annual Mean Eraporation (mm)

Average Monthly Evaporation
(Period: 1952 - 1981) (Unit: mm)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.
W-15	75.2	92.1	124.3	142.5	119.6	100.2	93.9
Lampang	82.3	107.0	153.7	197.8	157.6	146.3	129.7

Aug.	Sep.	Oct.	Nov.	Dec.	Total
39.8	87.0	76.9	70.0	70.4	1,142.3
117.9	110.8	98.7	87.9	80.0	1,469.7

(2) Hydrology

Rainfall and river runoff as irrigation water sources for the Project and, are described along with flooding for the Project Area as follows.

i) Rainfall

Rainfall is observed at 12 stations located throughout the Changwat Lampang. The data are reasonably observed.

a) Annual Rainfall

The annual average rainfall in the neighbouring area including the Project Area ranges from 900 to 1,140 mm as shown in Table 3.2-3 from this table, 1,090 mm, measured at a central place of Amphoe Mae Tha in the Project Area, is employed as the annual rainfall to be used for water resource calculation.

b) Monthly Rainfall

The monthly distribution of annual rainfall is illustrated in the following table and, about 90 percent of the rainfall falls intensively for the six months from May to october.

Average Monthly Rainfall: A. Mae Tha

(Period: 1952 to 1981) (Unit: mm)

Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
65.7	159.2	140.0	123.8	193.6	222.2	114.7	22.0	4.7

Jan.	Feb.	Mar.	Total
7.4	10.2	20.5	1,090.3

The monthly rainfall records at Amphoe Mae Tha during 1952 to 1981 are shown in Table 3.2-3, Appendix 3.2-1.

c) Daily Rainfall

The maximum daily rainfall occurs between July and October, and especially frequently in August and September. Data relative to Amphoe Mae Tha are shown in Table 3.2-2, Appendix 3.2-1.

The probable annual maximum daily rainfalls at A. Mae Tha was estimated as shown below:

Probable Annual Maximum Daily Rainfall

Station: A. Mae Tha, (unit: mm)
Period: 1952 to 1980

Return Period	1-day	2-day	3-day
2 years	74.2	96.1	109.7
3 "	84.1	106.2	119.2
5 "	95.1	116.5	128.5
10 "	108.6	128.5	138.8
20 "	121.5	139.0	147.6
30 "	128.9	144.8	152.3
50 "	138.0	151.7	157.9
100 "	150.5	160.7	164.9

Table 3.2-3 Annual Rainfall

(Unit: mm)

Water Year	Lampang (16013)	A. Mae Tha (16052)	W - 15 (16151)	A. Ko Kha (16032)
1952	814.5	867.9	-	-
1953	-	1225.8	-	-
1954	904.9	1063.0	-	1582.8
1955	1057.2	1009.8	-	1300.4
1956	1036.9	1103.3	-	-
1957	854.2	1118.5	-	731.5
1958	770.3	956.2	-	766.0
1959	1276.8	1448.4	-	1224.5
1960	1164.2	1128.0	-	1251.2
1961	1189.0	952.0	-	1148.7
1962	937.4	1050.1	-	1054.7
1963	1023.4	1083.6	-	-
1964	1101.5	1324.7	-	1082.5
1965	883.9	899.5	-	874.7
1966	1101.9	945.0	-	912.2
1967	909.6	1039.5	-	1044.8
1968	941.4	1173.7	-	849.6
1969	1122.4	1284.1	-	1164.1
1970	1477.8	1215.8	-	1258.5
1971	1332.2	1122.9	1140.7	1172.5
1972	1125.8	1025.8	1126.4	1160.6
1973	1205.8	1321.7	1325.0	1106.2
1974	1462.7	1127.7	1334.1	1528.7
1975	1390.6	1322.6	833.3	1286.8
1976	795.5	940.7	334.4	988.2
1977	1238.7	1146.5	816.8	1157.5
1978	927.6	887.6	1096.9	1050.1
1979	702.4	810.1	788.9	843.7
1980	895.8	980.6	768.5	1046.8
1981	1036.0	1133.9	1339.9	1167.7
1982	927.4	792.6	809.3	746.3
Average	1056.9	1090.3	991.4	1138.6

Data Source: Hydrology Section, RID

Table 3.2-4 Monthly Rainfall

Station : A. MAE THA, LAMPANG (16052)

(Unit : mm)

Year	Apr.	May	Jun.	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Annual
1952	62.3	80.6	79.6	150.6	186.6	127.8	80.2	12.9	0	29.7	57.6	0	867.9
1953	37.7	140.8	263.0	154.0	216.3	251.8	142.4	9.3	10.5	0	0	0	1225.8
1954	10.1	222.7	110.0	64.5	174.8	145.8	198.4	0	9.4	0	53.5	74.0	1063.0
1955	37.2	82.6	270.3	86.7	191.7	246.6	33.5	27.6	0	0	18.5	15.3	1009.8
1956	97.8	177.5	120.6	167.2	212.7	213.6	81.2	12.6	0.5	0	12.8	6.8	1103.3
1957	111.1	121.6	138.8	154.9	124.3	325.5	120.7	0	0	21.6	0	0	1118.5
1958	89.9	96.5	208.8	58.9	223.7	160.1	85.5	12.7	0	0	0	20.1	956.2
1959	91.4	363.5	267.1	190.8	176.9	257.2	74.3	0	0	15.4	0	11.8	1448.4
1960	10.3	199.5	150.5	139.0	186.2	233.5	115.0	42.7	10.2	0	1.3	39.8	1128.0
1961	103.5	180.8	102.2	46.6	195.9	120.6	190.2	2.9	4.7	4.6	0	0	952.0
1962	9.7	74.7	80.9	127.5	161.5	396.1	178.9	0	0	0	0	20.8	1050.1
1963	18.3	53.6	247.4	118.8	201.2	205.0	164.6	61.9	0	0	12.8	0	1083.6
1964	62.6	273.2	34.1	145.4	208.8	246.4	253.4	1.8	0	0	23.6	75.4	1324.7
1965	61.4	204.4	54.9	51.1	234.2	134.5	105.0	32.2	1.8	17.2	2.8	0	899.5
1966	7.4	226.7	122.7	121.7	212.3	125.3	97.6	8.4	22.9	0	0	0	945.0
1967	63.5	101.7	124.7	86.6	272.9	268.6	58.0	36.1	0	0	12.9	14.5	1039.5
1968	94.2	151.5	261.2	68.3	119.5	249.2	157.8	12.9	0	8.7	0	50.4	1173.7
1969	84.0	165.8	154.9	145.6	190.7	391.3	70.0	16.7	0	3.8	0.6	60.7	1284.1
1970	71.1	252.0	209.2	86.2	231.7	219.7	74.0	14.6	52.2	0	0	5.1	1215.8
1971	34.9	127.2	76.8	178.4	239.7	268.8	145.5	11.6	8.7	0	11.2	20.9	1122.9
1972	103.1	92.6	102.4	60.1	239.7	95.2	142.0	126.9	6.6	0	0	57.2	1025.8
1973	19.7	239.9	156.6	124.2	201.4	422.4	72.9	38.8	0	0	0	45.8	1321.7
1974	202.0	120.5	34.0	144.5	134.1	229.3	114.1	81.7	0	54.7	0	12.8	1127.7
1975	0	124.2	109.4	206.9	444.3	237.1	159.9	40.8	0	0	0	0	1322.6
1976	25.2	98.6	170.2	123.4	208.3	167.6	65.2	25.2	0	43.8	0	13.2	940.7
1977	71.4	168.9	20.3	114.1	211.2	329.0	120.8	0	0	21.9	88.9	0	1146.5
1978	110.1	71.8	39.6	218.4	158.9	181.3	101.1	0	0	0	6.4	0	887.6
1979	43.1	199.7	209.8	47.2	149.3	118.8	22.1	0	0	0	0	21.1	810.1
1980	21.0	116.4	192.0	216.8	65.2	199.1	107.8	22.5	16.8	0	4.6	18.4	980.6
1981	106.9	243.9	135.1	170.5	164.9	115.9	137.0	28.4	0	0	0	31.3	1133.9
1982	176.5	162.5	91.7	67.9	62.3	204.7	80.1	0	0				
Average	65.7	159.2	140.0	123.8	193.6	222.2	114.7	22.0	4.7	7.4	10.2	20.5	1090.3

Date Source : Hydrology Section,RID

Records of the annual maximum daily rainfall and its probability at A. Mae Tha station were described in Table 3.2-3, Appendix 3.2-1.

d) Hourly Rainfall

Continuous hourly rainfall records are available at RID's station w-15. Also, the data of the maximum hourly rainfall density are available for Lampang, Chiang Mai and Phrae, and are as shown below.

Duration in Hours (Unit: mm/hour)

Station	1/2	1	2	3	6	12	24
Lampang	46.8	60.5	72.5	79.8	84.7	87.6	96.4
Chiang Mai	55.5	75.0	120.0	166.5	166.5	166.5	166.5
Phrae	62.5	75.0	125.0	141.8	163.8	167.2	167.2

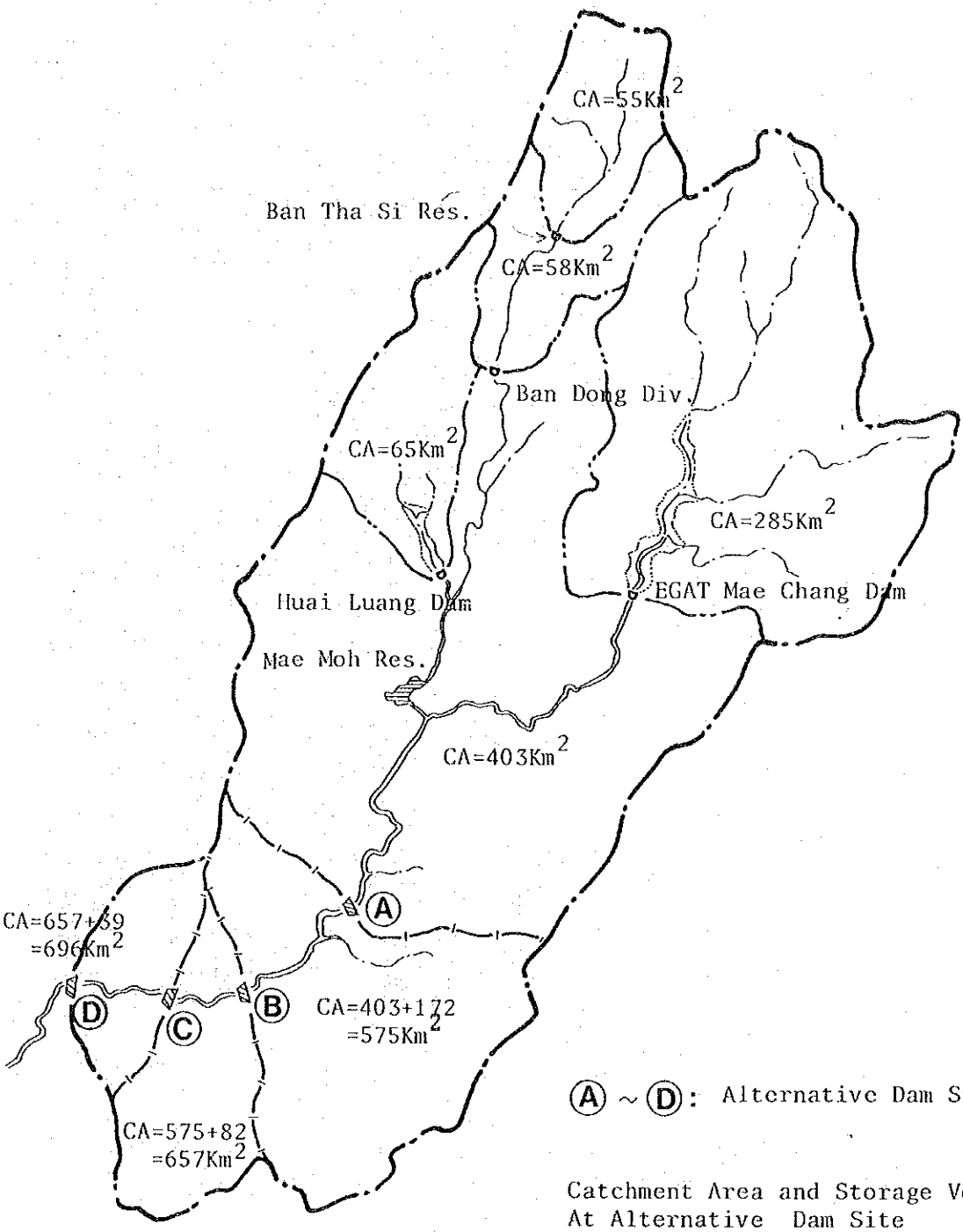
ii) River Runoff

The river runoff of the Mae Chang valley measured at station w-15 is illustrated in Fig.3.2-1. In Thailand, the annual period from April to March of the following year is taken as a hydrological year, and all the records observed during the period are compiled on this basis.

a) River Basin Area

The catchment area of the Mae Chang for this Project has been reduced owing to the construction of two new dams, EGAT Mae Chang Dam (C.A.= 285 km^2) and Huai Luang Dam (C.A. = 65 km^2). furthermore, two dams, Ban Tha Si Dam (C.A. = 55 km^2) and Ban Don Diversion Dam (C.A. = 58 km^2), are planned to be constructed in the near future. The catchment area for these two dams should also be deducted from the table watershed area.

FIG. 3.2-2 CATCHMENT AREA



Ⓐ ~ Ⓓ: Alternative Dam Site

Catchment Area and Storage Volume
At Alternative Dam Site

Dam Site	CA(Km^2)	V(MCM)
A	403	76
B	575	108
C	657	124
D	696	131

The storaged water in the EGAT Mae Chang dam is used to be cooling water for the Mae Moh power station and water storaged in the other dams, Huai Luang dam, Ban Tha Si reservoir and Ban Don diversion are utilized for the irrigation in the respective benefitial area. Due to these facts, the above-mentioned four catchment areas are excluded from the catchment area of the proposed dam. Even though the inflow will spill away, due to the limited dam capacity.

Considering these reductions, each catchment area for the four alternative dam sites have been estimated as shown in the following table and in Fig.3.2-2.

Catchment Area

Dam Site A	C.A. = 403 km^2
Dam Site B	C.A. = 575 "
Dam Site C	C.A. = 657 "
Dam Site D	C.A. = 696 "

Note: Original catchment area at Dam Site C of Mae Chang is 1,120 km^2.

b) Annual Runoff

The annual average runoff observed between 1971 and 1980 at station w-15 is 203.6 MCM, as shown in Table 3.2-5, which corresponds with a comparable runoff of 0.188 MCM per km^2 per year. On the basis of this runoff, each runoff for the four alternative dam sites can be calculated as follows:

Catchment Area & Annual Average Runoff

Dam Site	Catchment	Annual Average Runoff
A	403 km^2	76 MCM
B	575	108
C	657	124
D	696	131

c) Monthly Runoff

The following table shows the monthly runoff and monthly distribution rates.

Monthly Runoff and Ratio

	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.
Runoff	0.9	8.5	10.9	21.3	54.9	60.4	34.7	8.4
Percent	0.4	4.2	5.4	10.5	27.0	29.7	17.0	4.1

	Dec.	Jan.	Feb.	Mar.	Total	
	1.9	1.0	0.5	0.3	203.6	(unit: MCM)
	0.9	0.5	0.2	0.1	100.0	

The maximum runoff is concentrated in the period from August to October, and more than 70 percent of the annual runoff appears during this period. On the contrary, the runoff during the dry season is only six percent. The observed records of discharge at Station W-15 is shown in Table 3.2-4(1) to (11), Appendix 3.2-2.

d) Examination of Runoff

Observation of the runoff has continued at Station W-15 (Dam Site C) since 1970. However, there is a shortage of data from the point of view of water balance analysis.

Therefore, the rainfall record (1952 - 1981) for A. Mae Tha, were utilized to estimate runoff.

The method used was the reservoir Model method, and the period was from 1952 to 1970.

(1) Coefficient of Tank's slit

As a result of many trials the coefficient of the Tank's silt was decided as shown in Fig.3.2-1, Appendix 3.2-3.

Therefore, data for evaporation was taken from the daily average value recorded. Half of the value was applied in the case of rainy days.

Verification between recorded data and estimated data was made by applying the runoff coefficient.

(Unit: %)

Item	Runoff Coefficient		
	West Season	Dry Season	Annual
Recorded Data	18.7	8.1	17.2
Estimated Data	18.7	10.2	17.6

Details of the verification are shown in Table 3.2-5 and Table 3.2-6(1) to (5), Appendix 3.2-3.

(2) Estimation of Runoff

Runoff between 1952 and 1969 was estimated utilizing the previously mentioned coefficient of the Tank's slit. The results are shown in Table 3.2-6.

e) Flood

Flood analysis description at the alternative dam sites shall be made by using the flood records at station W-15.

Flood Records

Firstly, the maximum annual flood at the station is recorded as stated in Table 3.2-7.

Floods caused by the Mae Chang often occur between July and September. The most serious flood was recorded on the 13th of August in 1978, when the peak runoff reached 563 m^3 per second.

Table 3.2-5. Monthly Runoff

Monthly Runoff of Mae Chang at Ban Sop Po (W.15)

(Unit: MCM)

Water Year	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Annual Runoff (MCM)	Specific Runoff (MCM/km^2)
1970	0.8	10.3	39.6	22.3	102.2	93.1	24.5	6.5	4.6	1.6	0.9	0.5	306.9	0.274
1971	0.1	5.1	6.6	33.1	79.1	47.9	78.3	4.9	2.5	1.5	0.8	0.6	260.5	0.233
1972	3.3	1.5	3.1	2.3	47.8	16.3	40.4	7.2	2.8	1.5	1.0	0.9	128.1	0.114
1973	0.6	3.9	9.7	11.0	62.9	114.7	52.0	8.4	3.6	2.2	1.6	1.5	272.1	0.243
1974	5.5	9.8	11.5	4.8	68.1	56.5	13.8	41.3	2.8	2.2	0.5	0.2	217.0	0.206
1975	0.1	0.4	1.1	24.7	60.6	91.8	47.6	5.4	0.1	0.5	0.3	0.1	232.7	0.221
1976	0.0	0.5	2.1	7.4	23.5	41.9	22.6	5.5	0.4	0.3	0.0	0.0	104.2	0.099
1977	0.0	0.6	0.5	0.0	3.6	89.4	27.1	4.0	0.4	0.0	0.0	0.0	125.6	0.119
1978	0.0	26.9	2.4	61.4	113.0	88.5	63.8	5.6	2.6	1.1	0.5	0.3	366.1	0.347
1979	0.1	6.4	20.8	3.1	7.6	14.5	3.0	0.6	0.2	0.0	0.0	0.0	56.3	0.053
1980	0.0	6.6	27.7	4.7	6.4	29.4	6.8	2.2	0.2	0.0	0.0	0.0	84.0	0.080
1981	0.0	30.2	6.1	80.9	83.8	40.5	36.3	9.2	2.5	0.6	0.1	0.0	290.2	0.275
Total	10.5	102.2	131.2	255.7	658.6	724.5	416.2	100.8	22.7	11.5	5.7	4.1	2,443.7	
Average	0.9	8.5	10.9	21.3	54.9	60.4	34.7	8.4	1.9	1.0	0.5	0.3	203.6	0.188

Catchment Area: 1,120 sq.km (1970 - 1973), 1,055 sq.km (1974 - 1981)
Data Source: MONTHLY RUNOFF DATA of Hydrology Division
Note: Huai Luang Dam (C.A = 65 sq.km) began to store water in 1974

Table 3.2-6 Monthly Run off at Dam Site C

(Unit : MCM)

Year	Apr.	May	Jun.	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Annual
1952	0.2	0.3	0.2	4.3	23.1	33.0	4.5	3.0	0.8	0	0.1	0	69.5
1953	0	0.6	69.3	17.1	74.0	79.8	28.0	7.9	3.9	1.2	0.2	0	282.0
1954	0	16.4	6.7	2.5	12.8	29.0	87.2	4.2	1.6	0.2	0.5	0.9	162.0
1955	0.2	0.4	92.8	2.6	31.1	82.7	14.1	3.7	1.3	0.1	0	0	229.0
1956	6.4	12.3	6.6	13.8	65.8	62.1	12.1	4.7	1.9	0.3	0	0	186.0
1957	4.5	1.2	27.5	9.0	22.5	87.9	56.0	5.8	2.6	0.5	0.1	0	217.6
1958	1.5	2.7	11.2	16.4	33.0	40.8	8.7	4.0	1.5	0.2	0	0	120.0
1959	0.1	106.3	60.7	78.1	56.0	101.3	18.9	6.2	2.9	0.6	0.2	0	431.3
1960	0	20.0	12.3	28.1	40.9	71.7	19.6	5.8	4.0	1.1	0.2	0	203.7
1961	3.6	13.3	31.3	1.5	30.2	36.1	35.1	5.1	2.0	0.3	0	0	158.5
1962	0	0	0.1	12.4	9.9	142.6	95.1	8.0	3.6	0.9	0.1	0	272.7
1963	0	0	28.8	14.9	65.9	40.6	45.7	17.6	4.6	1.4	0.3	0	219.8
1964	0	48.5	6.8	6.3	44.9	70.1	130.4	7.2	3.5	0.8	0.2	4.6	323.3
1965	2.0	37.3	1.4	0.1	58.6	41.2	4.9	3.7	1.4	0.1	0	0	150.7
1966	0	14.8	39.3	8.6	27.1	48.8	5.6	4.2	1.9	0.4	0	0	150.7
1967	0	0.3	10.1	0.8	57.4	99.1	29.3	4.9	2.3	0.3	0	0	204.5
1968	0.2	6.0	42.4	10.2	18.6	57.9	59.7	5.4	2.4	0.5	0.1	0.7	204.1
1969	0.1	6.5	17.4	23.9	43.9	148.6	45.4	6.5	3.2	0.7	0.1	1.0	297.3
1970	0.8	10.3	39.6	22.3	102.2	93.1	24.5	6.5	4.6	1.6	0.9	0.5	306.9
1971	0.1	5.1	6.6	33.1	79.1	47.9	78.3	4.9	2.5	1.5	0.8	0.6	260.5
1972	3.3	1.5	3.1	2.3	47.8	16.3	40.4	7.2	2.8	1.5	1.0	0.9	128.1
1973	0.6	3.9	9.7	11.0	62.9	114.7	52.0	8.4	3.6	2.2	1.6	1.5	272.1
1974	5.5	9.8	11.5	4.8	68.1	56.5	13.8	41.3	2.8	2.2	0.5	0.2	217.0
1975	0.1	0.4	1.1	24.7	60.6	91.8	47.6	5.4	0.1	0.5	0.3	0.1	232.7
1976	0	0.5	2.1	7.4	23.5	41.9	22.6	5.5	0.4	0.3	0	0	104.2
1977	0	0.6	0.5	0	3.6	89.4	27.1	4.0	0.4	0	0	0	125.6
1978	0	26.9	2.4	61.4	113.0	88.5	63.8	5.6	2.6	1.1	0.5	0.3	366.1
1979	0.1	6.4	20.8	3.1	7.6	14.5	3.0	0.6	0.2	0	0	0	56.3
1980	0	6.6	27.7	4.7	6.4	29.4	6.8	2.2	0.2	0	0	0	84.0
1981	0	30.2	6.1	80.9	83.8	40.5	36.3	9.2	2.5	0.6	0.1	0	290.2

Remark) 1952 ~ 1969 : Estimated run off by Tank Model method, utilizing rainfall data at A. Mae Tha.

1970 ~ 1981 : Observed run off data.

Table 3.2-7 Annual Maximum Discharge

Station: W.15

Water Year	Mometary		Daily mean	
	Discharge (cms)	Date	Discharge (cms)	Date
1970	222	9/21	192	8/21
1971	306	10/3	232	10/3
1972	218	8/26	122	8/26
1973	222	9/20	156	9/30
1974	394	8/18	347	8/18
1975	301	9/1	205	9/1
1976	85	9/28	68	9/28
1977	269	9/6	134	9/7
1978	563	8/13	289	8/14
1979	54.2	7/17	24.3	7/15
1980	160	9/17	71	9/8
1981	263	7/7	227	7/7

Note: Flow computation: computed by annual rating curve.

Gauge reading frequency: 5 readings per day.

Period of record: 1968 - cont'd 1968 - 69 poor record.

Data source: Hydrology Section of Survey Division RID.

Design Flood

Due to a shortage of data of flood records, the design flood was estimated by the unit hydrograph method, using the daily rainfall at A. Mae Tha which has a long period of recorded data. The formula used for estimating flood design was "Nakayasu's Synthetic Unit Hydrograph Method", since this method is suitable when the runoff is from a mountainous district as in the case of this Project.

i) Synthetic unit hydrograph

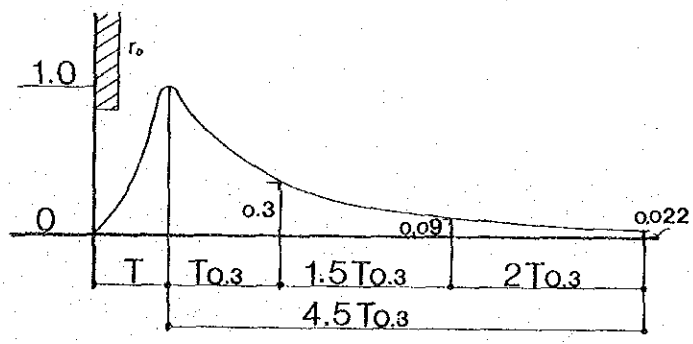
Nakayasu's Synthetic Unit Hydrograph was estimated by the following formula:

$t = 0 - T^{hr}$: $q = q_p (t/T)^{2.4}$: Ascent

$t = T - t_{0.3}$: $q = q_p \; 0.3^{(t-T)/T_{0.3}}$: Descent

$t = t_{0.3} - t_{0.09}$: $q = 0.3 \; q_p \; 0.3^{(t-T-T_{0.3})/1.5T_{0.3}}$: "

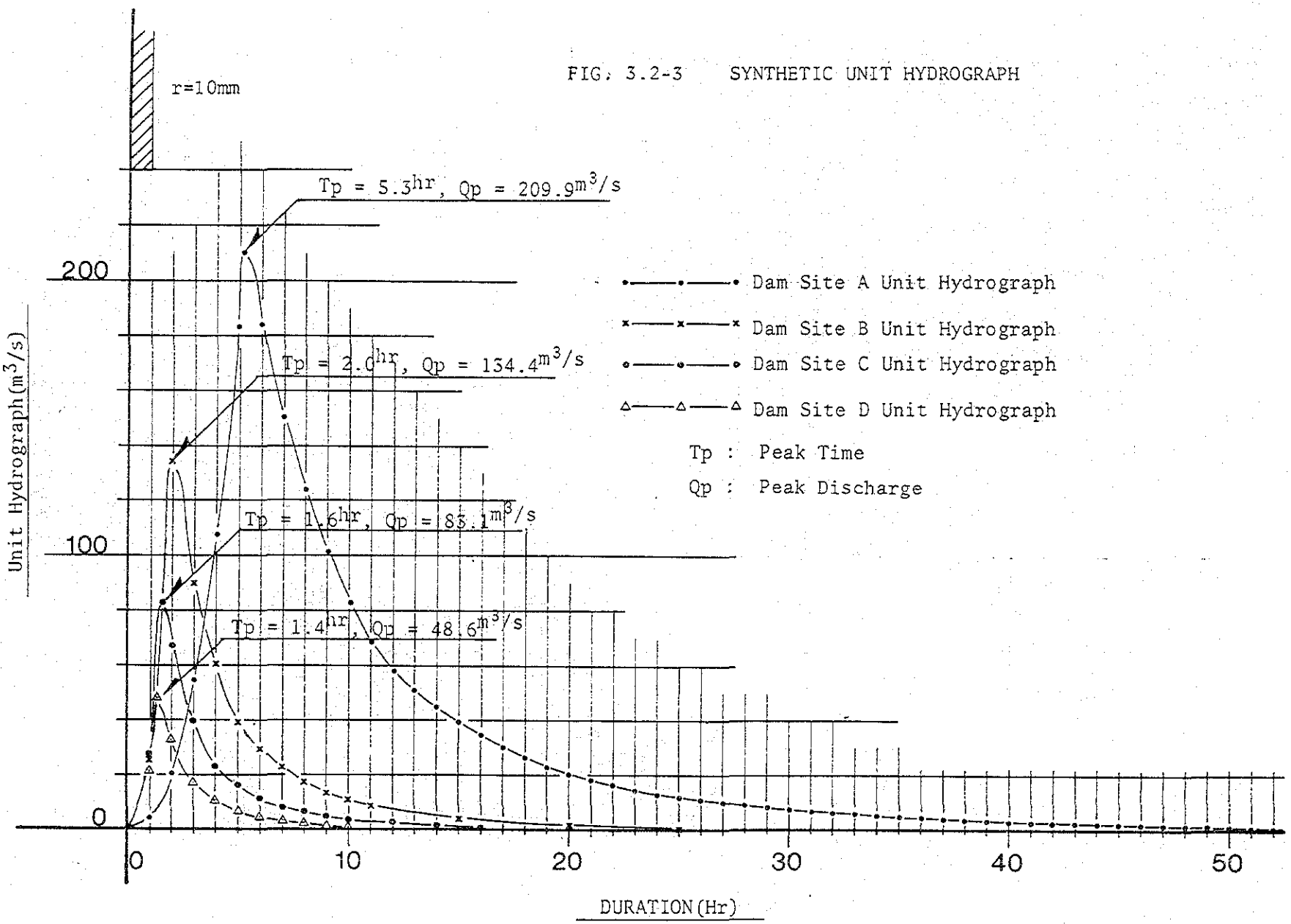
$t = t_{0.09} -$: $q = 0.09 \; q_p \; 0.3^{(t-T-2.5T_{0.3})/2T_{0.3}}$:"



Unit hydrograph at each alternative dam site, is shown in Fig.3.2-3.

However, the unit hydrograph at dam site B, C and D is shown as additional catchment area.

FIG. 3.2-3 SYNTHETIC UNIT HYDROGRAPH



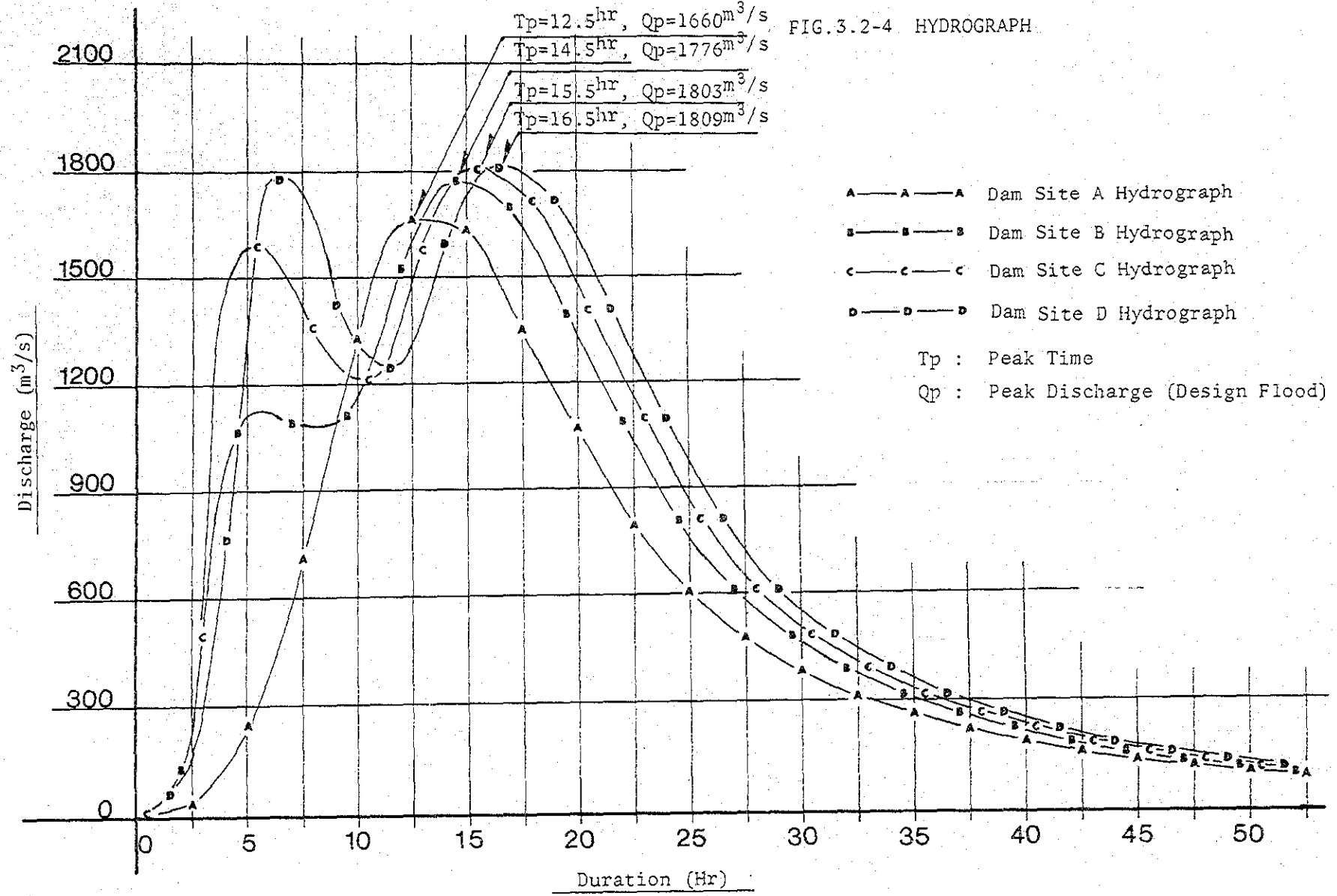


FIG.3.2-4 HYDROGRAPH

ii) Effective rainfall

Daily rainfall records for A. Mae Tha were used for estimating effective rainfall (192 mm: probability 1/1,000 - year). The distribution and loss rate of daily rainfall as referred to in "Study for Mae Moh Project Report", was applied and the effective rainfall was calculated as follows:

(Unit: mm)

Period hr	1	2	3	4	5	6	7
Percentage of 24-hr R 1/ (Accumulated Rainfall)	10	25	50	72	87	95	100%
Accumulated Rainfall	19	48	96	138	167	182	192
Hourly Rainfall	19	29	48	42	29	15	10
Loss Rate (-) 1/	10	5	5	5	5	5	5
Effective Rainfall	9	24	43	37	24	10	5

1/: Source: Study for Mae Moh Project Report, EGAT, June 1972.

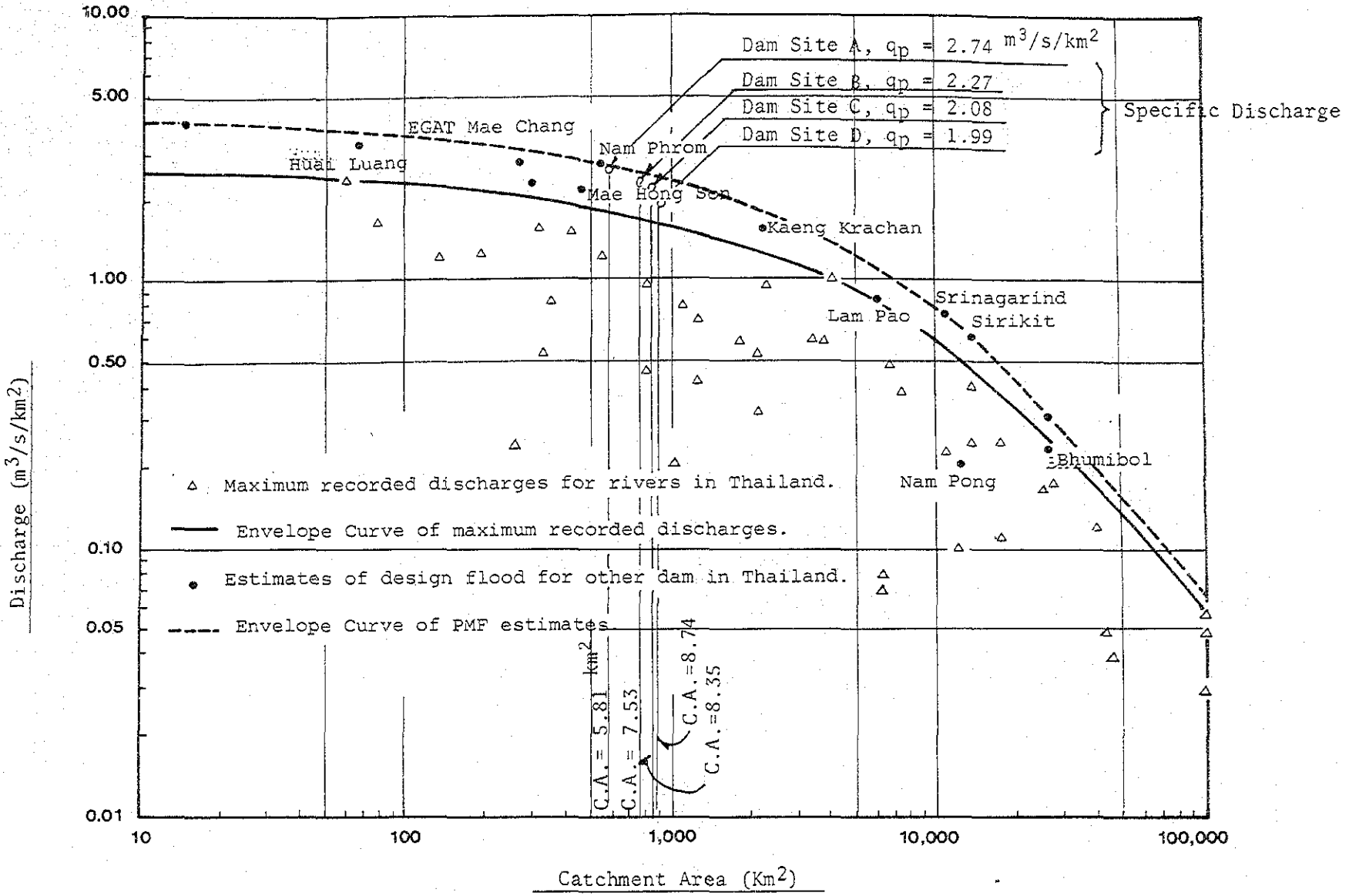
iii) Design flood

The hydrograph was estimated by applying an S-curve which utilized "Synthetic Unit Hydrograph" and "Design Storm".

The design flood was estimated in the following way:

The design flood at Dam Site A was was added to the "Hydrograph at Dam Site A" and then to the "EGAT spill discharge", after considering the concentration time to Dam Site A. The "Design flood at Dam Site B, C and D" were added to "Hydrograph of each additional catchment area B, C and D, considering the concentration time to each Dam Site B, C and D.

FIG. 3.2-5 COMPARATIVE FLOOD ESTIMATES AND MAXIMUM RECORDED DISCHARGE



EGAT Spill Discharge was referred to in the "MAE CHANGE PROJECT WATER SUPPLY FOR MAE MOH POWER PLANT, FINAL REPORT". The hydrograph for every Dam Site is shown in Fig.3.2-4.

Since three further upstream catchment areas, Huai Luang dam, Ban Tha Si reservoir and Ban Dong diversion, are small, so that these catchment areas are considered as a unified area to be included into the catchment area of the proposed dam.

The design flood of the EGAT Mae Chang dam was estimated by probability 1000-year return period. This design flood of EGAT Mae Chang dam is considered for the estimate of the design flood of the proposed dam by using an element of unit hydrograph analysis.

For reference, "Comparative Flood Estimates and Maximum Record Discharge" are shown in Fig.3.2-5.

From the above mentioned total hydrograph, the peak discharge value was calculated, and applied as the design flood value, as shown below:

Dam Site	A	B	C	D
Peak Discharge (m^3/s)	1,660	1,776	1,803	1,809
C.A. (km^2)	581	753	835	874
Specific Discharge ($m^3/s/km^2$)	2.74	2.27	2.08	1.99

Note: specific discharge is estimated except for the EGAT spill discharge

f) Sediment

Sediment was estimated from the suspended sediment data and discharge data, which were observed at the following stations on the Mae Wang, near the Project Area.

W - 4 : Ban Wan Khri (Catchment Area 10,442 km^2)
W - 10 : Kew Lom (Catchment Area 2,796 km^2)

i) Annual Specific Sediment

Based on "Suspended Sediment Data" and "Discharge Data", as shown in Tables 3.2-8 and 3.2-9 Appendix 3.2-4 the relationship between both was shown in the following equation;

$$Q_s = 35.35 \ Q_w^{1.266} \quad (r = 0.912)$$

where,

Q_s : Suspended sediment (ton/day)
Q_w : Discharge (m^3/s)
r : Correlation coefficient

See Fig.3-2-2 in Appendix 3.2-4.

Applying this equation sediment at Dam Site C (W-15) was estimated as follows:

$$Q_w = 203.6 \ ^{mcm} = 6.45 \ m^3/s$$

C.A.= 657 km^2

$$Q_s = 35.35 \times 6.45^{1.266} = 374 \text{ ton/day}$$

$$d = \frac{374 \times 365 \text{ day}}{657 \times 106 \ (m^2)} = 0.208 \doteqdot 0.2 \text{ mm/year}$$

where,

d : Specific sediment

Furthermore, the "Bed load Sediment" which is 20 percent of the previous value was added. Accordingly, the annual specific sediment was estimated as follows:

$$d' = 0.2^{mm/year} \times (1 + 0.2) = 0.24^{mm/year}$$

When compared to data from neighbouring areas it can be seen that all data are relatively similar. Therefore, the design specific sediment was decided at 0.24 mm/year.

ii) Reference Data from Neighbouring Area

Mae Kuang Dam:

Estimated total sediment quantity is 145,000 m^3 (Catchment Area 569 km^2).

$$d = \frac{145{,}000\ m^2}{569 \times 10^6\ m^2} = 0.255\ mm/year$$

EGAT Mae Chang Dam:

Used 0.25 mm/year instead of original estimate 0.18 mm/year, based on the result of investigations at Huai Luang Reservoir.

iii) Estimation of Sediment

On the basis of previous specific sediment data, the estimated sediment of Case-5 and Case-6 was calculated as follows: The catchment area of Huai Luang and Mae Moh reservoir were excepted.

Out-flow of foreign materials from the mining quarry site is almost settled in the sedimentation pond at the mine and the Mae Moh reservoir located at the downstream of the lignite mine. Therefore, there seems to be not any adverse effect to the proposed dam site.

Dam Site	Excepting Catchment Area Huai Luang and Mae Moh Catchment Area (km^2)	Res. Sediment for 100 years (MCM)
Case-5		
Dam A	229	5.5
Div.C	254 1/	6.1
Case-6		
Dam A	229	5.5
Div.D	293 1/	7.0

Note 1/: Catchment area of diversion dams C and D show that downstream from Dam A.

3.2.3. General Geology

1) General Geology

The general geology of the Project Area consists of Paleozoic and the Mesozoic bedrocks and Tertiary and Quarternary sediments which are widely distribute over bedrock. (See Fig. 3.2-3, Appendix 3.2-5)

The Paleozoic rocks are composed of volcanic rocks of rhyolites, tuffs, aglomerates and andesites and develop ten kilometers wide from the northeast to the southwest of the Area, with the Mae Chang river running between.

The volcanic rocks forming a watershed area are developed along the highest mountain range of the Project Area with elevation ranging from EL.700 to 1,000 m, and this covers catchment areas of the Mae Chang river. Few tectonic lines are detected exerting direct influence upon the proposed dam sites, although the geological structure has a strike dip running from northeast to southwest.

The Mae Chang river flows down slightly meandering through the Area surrounded by the Paleozoic rock zones with many tributaries joining it in almost parallel with the mountain ranges of the Area

in NE-SW direction. The flow turns towards the west around the proposed dam site B of Ban Mai.

The Paleozoic rock is distributed up to the line between Ban Mae Tha and Ban Sop Po (Proposed dam site C). The mountain range stops thereabouts and a vast alluvium and diluvium plain which can be developed into an irrigation area continues from there to the western downstream.

Consequently, the topographical conditions limit the proposed dam sites available for small/medium-scaled dams to the basin around Ban Sop Po.

The Mesozoic bedrocks presumably belong to the Triassic Period and are mainly composed of marine sediments, limestones, conglomerates, sandstones, shales and tuffs, with the limestones occuring in the greatest volume.

The catchment area of the Mae Chang river lies in Lampang Group composed of the Mesozoic rocks surrounded by Paleozoic rocks, which substantially forms the bedrocks in most of the Area.

The Lampang Group can be classified into lowest, middle, and upper formations with the lowest formation is called volcanic rocks having the conglomerate and reddish sandstones in the deepest layer with slaty shales and tuffaceous sandstones overlying. There are many such volcano-origin structures found in the Project Area and the rocks found thereabouts are volcanic rocks. These volcanic rocks contacting the Paleozoic rocks distribute in a strip extending from northeast to southwest in the eastern and the western part of the Project Area, although they are not directly observable in the Area in the middle to the lower basin of the Mae Chang river.

The middle formation consists mainly of the limestone in mass with partially greenish shales, sandstones and conglomerates contained in mixture or in alternations of strata in some places. The middle formation is distributed in most of the Mae Chang river from the upper to lower stream, occupying more than half of the formations observed in the Mae Chang catchment area.

The proposed four dam sites are located in the middle stream of the Mae Chang river, which has the middle formation of the Lampang Group.

The Tertiary sediment deposits are called the Mae Mo Group and consist of sandstones, shales, carbonaceous shales, limestones and lignites. The Mae Mo Group is distributed from the upper to middle stream of the Mae Chang river.

The Quaternary deposits are composed of diluvium and alluvium sediments. The diluvium is distributed around the hilly land of foothills of the mountain range in lower or higher terraces.

These terrace deposits consist of gravel, sand, silt, and clay which are semiconsolidated sediments. They are called the Mae Taeng Group.

The alluvium is widely distributed as flood plain deposits along the Mae Chang river or its branches and also as a terrace at the foot of the mountains.

The Basaltic lava flow covers a very extensive area of the Pleistocene gravel beds from the middle to lower stream of the Mae Chang river, and especially on the right bank.

Irrigation area of the Project is mostly composed of terrace deposits in the form of semi or unconsolidated gravels, silt, sand, and clay.

2) Geology of Dam Sites

The four alternative dam sites of A, B, C and D located in the middle basin of the Mae Chang river were selected from the viewpoints of topography and geology. Geological inspection and sites survey were carried out at dam site C in 1970, and at dam sites A and D in 1983 by the RID team.

There lies a vastly developed alluvial and diluvial terrace along the both banks indicating that appropriate dam sites are limited (See Fig.3.2-4, Appendix 3.2-5) along dam sites A through D.

In case of a high dam, these terrace deposits will be one of factors to determine dam body except at dam site C.

Foundation rock along dam sites A through D is classified into the middle formation of Lampang Group mainly consisting of hard limestone and locally or alternately with sandstone, shale, conglomerate.

The major strike of the layers seems to be from NE to SW, however, as a whole the dip is various due to many small folds.

Although many small faults are found, none that affect the dam stability are discovered so far. As sandstone and shale are easily weathered, the outcrops observed are mostly not fresh, have fine cracks and are easily broken into breccia.

Limestone containing other rocks is like a plate with clear stratification; however, in the Area of massive limestone (near dam site C) outcrops seem hard and fresh in appearance but irregular solution topography is often identified such as in caves of more than ten meters depth.

Permeability of massive limestones has a tendency to be small in the vertical direction but some irregular parts of the deep rock show much permeability. In general, limestone zone containing sand stones and shales are expected to be less permeable and extend below the weathered zone of the rock surface.

Judging from the conditions of outcrops, river deposits composed of sand, gravel, clay, etc. seem less than eight meters in depth and therefore allow for easy treatment.

It may be said that the possibility of causing secondary damage such as large scale landsliding or water storage is nil for within the reservoir area. However, erosion of cliff-shaped alluvial terraces deposit of silt of five - six meters high along the river course may be increased.

3.2.4. Soil and Land Classification

1) General

The Project Area lies in the Mae Chang river basin at an elevation of 200 - 260 m. The climate of the Area is Tropical Savanna (Koppen "AW") which is characterized by its distinct rainfall regime, dry and wet seasons. Most lands in the Area are covered with the alluvial soils formed from semi-recent to old alluvium transported by the Mae Chang river and its tributaries.

At present there is a soil map (scale 1:100,000) and a land classification map (scale 1:50,000) are available for the Project Area. The soil map was prepared by the Soil Survey Div., Dept. of Land Development (DLD) in 1981, and the land classification map was made by the Soil and Geology Div., RID in 1973. These maps are useful for the feasibility study, even though the field surveys were carried out about ten years ago. Considering the possible changes in soil and land conditions during the period from the previous

field surveys up to the present the validity of these maps should be closely checked. Therefore, the main object of the present field survey was to check the applicability of the said maps under the present conditions.

To meet this purpose, the present field survey was performed, using topographical maps scaled 1:10,000 as base maps and a set of air-photos scaled 1:15,000, through the following procedures;

1) Data collection and review
2) Preliminary reconnaissance in the entire area
3) Photo interpretation
4) Selection of test pit and auger boring sites
5) Observation of soil profiles and sampling
6) Laboratory analysis of the samples

As a result of reviewing collected data and observing soil profiles in the Area, the applicability of these maps is concluded to be as follows:

Soil Map

The detailed reconnaissance soil map (Scale 1:100,000) covers the entire Project Area, and the changes of soil distribution pattern since the time when the map was published are restricted to an insignificant extent. Therefore, this soil map can be fully utilized without modification for the feasibility study.

Land Classification Map

The semi-detailed land classification map (scale 1:50,000) covers the entire Project Area. A new access road network was constructed within the Project Area after 1973. Accordingly, it was considered that the classes of lands adjacent to the new roads have been altered after construction. In consequence of the present

field survey, however, the effects of construction works to the topographical and drainage conditions were found to be restricted to a small extent, and these changes could be neglected on the map so that modification is not required at this time to make the land use plan of the feasibility study. In future, a detailed survey should be carried out for making the on-farm development program.

2) Landform and Parent Materials

Old levees and semi-recent terraces which have been formed of alluvium transported by the river are situated along the river course of the Mae Chang river and its tributaries. As a whole, the Project Area is composed of such alluvial terraces and bordered by undulating hilly slopes formed of colluvium and residiuum in the eastern and the southern bounderies.

The Mae Chang river displays a distinct contrast of landform patterns between the right bank and the left bank, as shown in Figure 3.2-6. Old alluvial terraces have been developed extensively behind the semi-recent terraces or old levees in the right bank. These old alluvial terraces occupy about half of the Project Area. Thus the landforms on the right bank show a gradual transition, that is, old levees and semi-recent terraces merge into old alluvial terraces.

On the other hand, the landforms on the left bank alter more abruptly. Dissected erosion surfaces on the hills approach close to the river except for the Mae Wah river basin. These hilly undulating landforms have been formed of limestone including shale in the upper stream, and of shale, slate and/or phyllite in the lower stream of the Mae Chang river in the vicinity of confluence with the Mae Wang river.

3) Soils in the Project Area

Various kinds of soils are distributed in the Project Area in accordance with changes in landforms. Major soils in each landform are briefly described hereinafter. Soil maps of the Project Area and the extent of each mapping unit are shown in Fig.3.2-7 and Table 3.2-8.

Flood Plain

The soils of flood plain (229 ha, 2.3% of the entire Project Area), composed of Tha Muang/Sanphaya association, develop in the Mae Wah river valley. Tha Muang series is a member of the loamy, mixed, non-acid family of Alluvial Soils (Typic Ustifluvents in the Soil Taxomomy, USDA). These soils have been formed from recent alluvium and occur on the higher parts of river levees. Because these soils are moderately well drained, they are mainly used for tobacco fields, vegetable gardens, or for orchards as well as settlement sites. Sanphaya series has similar parent materials and characteristics to the Tha Muang series, except that the former is mottled throughout but that the latter contains mottles in the lower C horizon. These soils occur on the parts of river levees lower than Tha Muang soils, and have a fine-loamy texture. Therefore, these soils are moderately well suited for paddy fields, and are used mainly for rice cultivation in the Project Area at present.

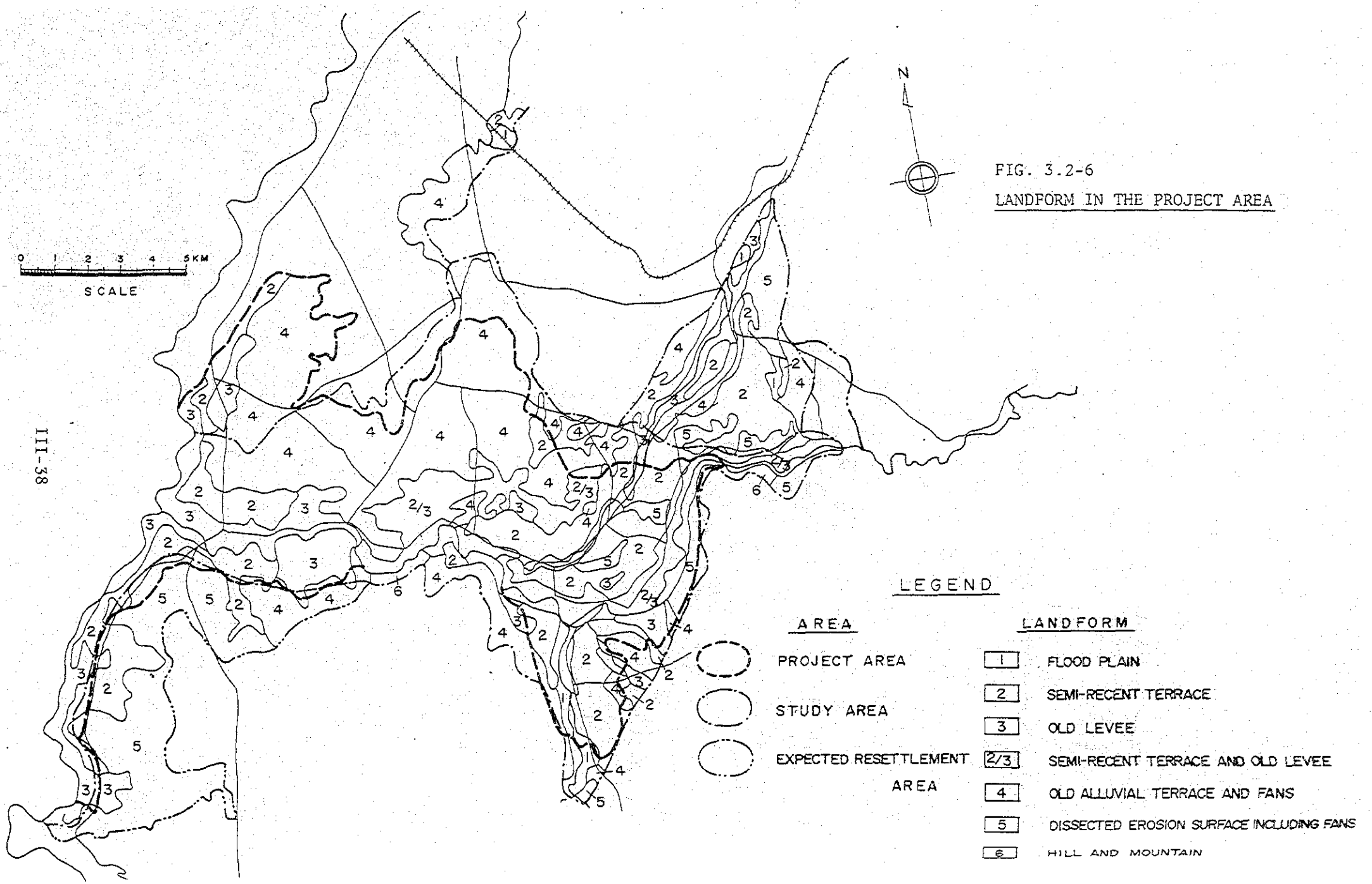


FIG. 3.2-6
LANDFORM IN THE PROJECT AREA

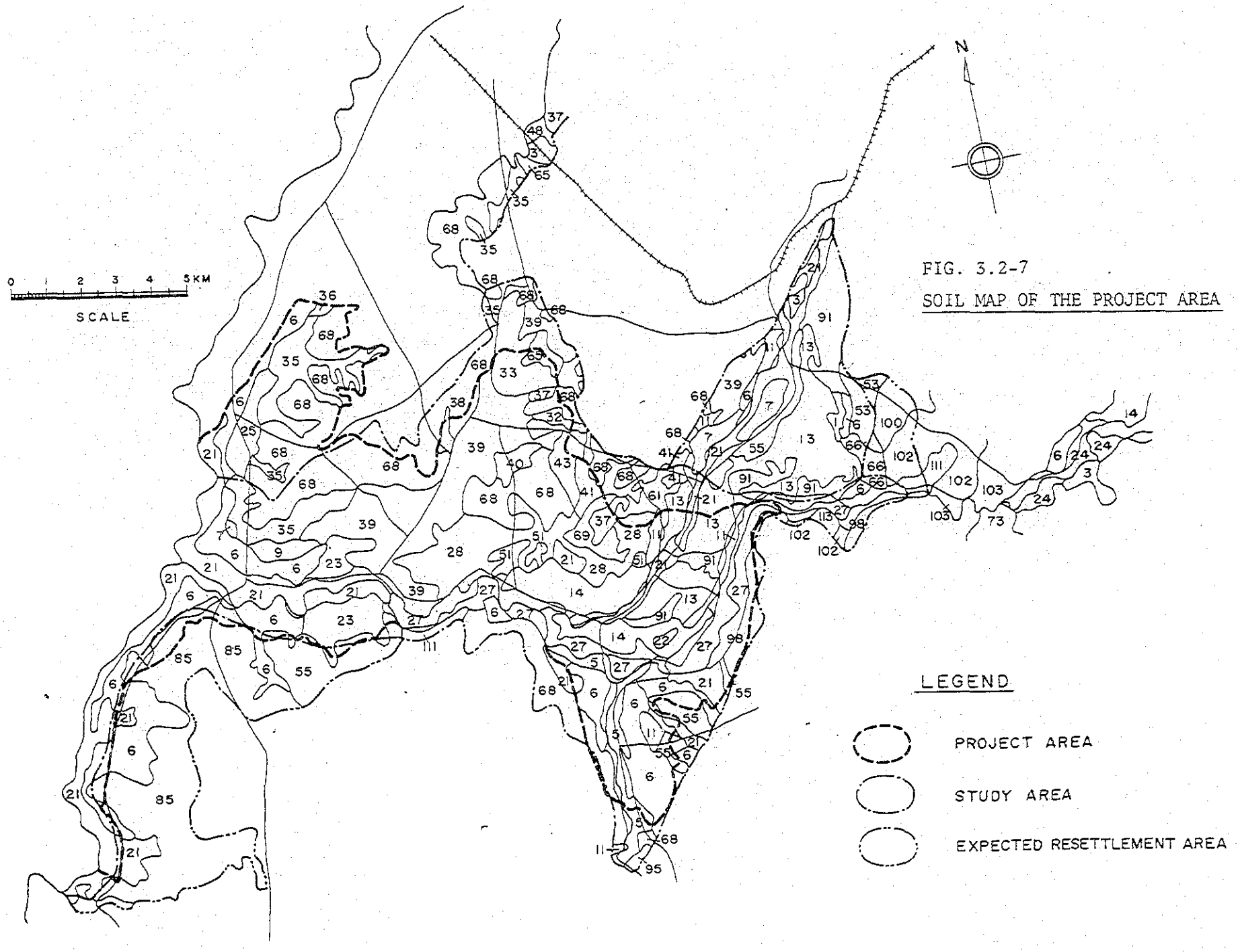


FIG. 3.2-7
SOIL MAP OF THE PROJECT AREA

Table 3.2-8. Extent of Soil Mapping Unit in the Project Area

(Unit: ha)

Soil Mapping Unit	Right Bank		Left Bank		Total	
Flood Plain	18	0.2%	215	8.3%	233	20
5 Tha Maung/Sanphaya	18		215		233	
Semi-Recent Terrace	1,862	20.9	934	36.2	2,796	24.3
6 Mae Sai	538		893		1,431	
7 Hang Dong	10		-		10	
9 Phan	85		-		85	
11 Chiang Rai	100		41		141	
13 Mae Chang	458		-		458	
14 Mae Sai/Hang Dong	671		-		671	
Old Levee	871	9.8	886	34.3	1,757	15.3
21 Kamphaeng Saen	557		665		-	
22 That Pharom	17		-		17	
23 Si Satchanalai	120		221		341	
25 Kamphaeng Saen/Si Satckanalai	177		-		177	
Semi-Recent Terrace & Old Levee	1,474	16.5	111	4.3	1,585	13.8
27 Tha Muang/ Kamphaeng Saen	697		111		808	
28 Si Satchanalai/ Mae Tha	777		-		777	
Old Alluvial Terrace Fans	4,570	51.2	86	3.3	4,656	40.4
32 Lampang	30		-		30	
33 Lampang-basic Varient	185		-		185	
35 Roi Et	650		-		650	
37 Tha Tum	75		-		75	
38 On	29		-		29	
39 Mae Tha	1,256		-		1,256	
40 Roi Et/San Sai	78		-		78	
41 Lampang/Roi Et	94		-		94	
43 Roi Et/Korat	136		-		136	
51 Hang Chat	92		-		92	
55 Mae Rim	-		86		86	
61 Hang Chat/ Satuk-gravelly	17		-		17	

Soil Mapping Unit		Right Bank		Left Bank		Total	
65	Hang Chat/Satuk/San Pa Tong	18		-		18	
66	Mae Rim/Hang Chat/ Satuk	10		-		10	
68	Mae Rim/Hang Chat/ Korat	1,781		-		1,781	
69	Mae Rim/Korat/Satuk	119		-		119	
Disected Erosion Surface including Fans		131	1.4%	352	13.6%	483	4.2%
85	Muak Lek/Li/Ngao	-		173		173	
91	Pha Lat	131		-		131	
98	Takhli	-		179		179	
	Total	8,926	100%	2,584	100%	11,510	100%

Note: Detailed Reconnaissance Soil Map of Lampang Province 1981 Soil Survey Div., Dept. of Land Development.

Semi-Recent Terrace

The soils of semi-recent terraces are composed of Mae Sai, Hang Dong, Mae Chang series, and Mae Sai/Hang Dong association, and occupy larger portions in the Project Area. Mae Sai series is a member of the fine clayey, kaolinitic family of Hydromorphic Non-Calcic Brown Soils (Aeric Tropaqualfs) and formed from breach deposits. Because of argillic B horizon, these soils are somewhat poorly drained and may be frequently flooded by impounded rainwater during the wet season while drying out to deep levels in the dry seasons. These soils have drainage characteristics, making them suitable for rainfed paddy fields. In the Mae Pung Irrigation Area, tobacco, groundnuts and soybeans are cultivated under irrigation during the dry season. Hang Dong series belongs to the fine clayey, kaolinitic family of Low Humic Gley Soils (Typic Tropaqualfs). These soils have similar profile features to the Mae Sai series, but have a finer texture so that the drainage is poor.

The Mae Chang series is a member of clayey family of Hydromorphic Brown Forest Soils (Tropaqualfs) and formed from alluvium and occurs on basic igneous rocks such as basalt. They are very deep soils characterized by brown or greyish brown loam with brown mottles and are slightly acid in surface horizons and grey or dark grey clay with brown or yellowish brown mottles in subsurface horizons. These soils are poorly drained. Permeability is estimated to be slow and the surface runoff is slow with the groundwater table falling to lower than one meter during the dry season. At present, rainfed paddy fields accupy on these soils in the Project Area.

Old Levee

Kamphaeng Saen and Si Satchanalai series are major soils on old levees. Kampaheng Saen series is a member of the fine loamy, mixed family of Non-Calcic Brown Soils (Udic Haplustalfs). These soils have been formed of semi-recent alluvium and occur on breach deposits of semi-recent terrace as well as old levees. Having medium texture, these soils are well drained and used for intensive upland cropping such as tobacco, beans and vegetables including orchards. Si Satchnalai soils are distributed on flat to slightly undulating lands. These soils have a finer texture than Kamphaen Saen soils, and are moderately well drained. In the Project Area, these soils are mainly used for sugarcane.

Old Alluvial Terrace and Fans

The soils on old alluvial terraces and fans are mainly composed of Mae Tha series which belongs to Hydromorphic Non-Calcic Brown Soils (Paleustalfs), of Lampang and Roi Et series which belong to Low Humic Gley Soils (Aeric Paleaquults), and of Hang Chat, Mae Rim, and Korat series which belong to Red-Yellow or Grey Podzolic Soils (Paleustults or Oxic Paleustults). In the Project Area, eleven soil series including the above series are distributed in the form of independent soil series or their associates. These soils occupy a large extent of the Area along with soils of semi-recent terraces.

Mae Tha series is a member of fine silty family of Hydromorphic Non-Calcic Brown Soils are somewhat poorly drained and very deep soils characterized by brown or greyish brown silty clay loam or clay loam with strong brown mottles. The reaction is strongly to slightly acid. The Low Humic Gley Soils are somewhat poorly or poorly drained loamy soils which occur on flat to slightly undulating low terraces. Presently, major parts of these soils are used for paddy fields. On the other hand, the Red-yellow or Gray podzolic Soils are well or moderately well drained coarse-textured soils and occur on undulating to gently rolling middle to high terraces. In the Project Area, these soils are mainly covered by secondary Dipterocarp forest with bunch grasses (Imperata, Eupatorium spp.) due to the abandoned clearings. The original vegetation (mixed deciduous forest) has been removed to make way for shifting cultivation of upland crops and/or have been cut down to make charcoal.

Dissected Erosion Surface including Fans

The soils on the dissected erosion surface are distributed in higher elevation lands, that is, the fringe of the Project Area. These colluvium and residuum soils are insignificant in extent within the possible irrigable area by the proposed dam construction, but occupy an important position within the proposed resettlement area for the farmers who are living in lands which may be submerged in the course of dam construction (See Chapter 4.5). Along the left bank of the Mae Tha river, Pha Lat series, which belongs to Brown Forest Soils (Typic Haplustolls), are distributed intricately within the semi-recent terrace. These soils have been formed of residiuum of basalt, and contain a considerable amount of gravels, mainly laterite concretions. The secondary Dipterocarp forests cover these soils predominantly, and upland crops such as sugarcane are cultivated to a small extent. On the colluvial fans nearby the limestone hills at the upstream of the left bank of the Mae Chang river, the Thakli series which belongs to Rendzinas (Typic Calciustolls) is located. These soils are formed of limestone

colluvium and are well drained but have a lithic or paralithic contact within 50 cm of the soil surface. Therefore, most of these soils are occupied by secondary forest as a result of the abandonment of shifting cultivation. Associated with the Thakli series, the Lop Buri series which is a member of the fine clayey, montmorillonitic family of Grumsols (Typic Pellusterts) occurs in the depression adjacent to the limestone hills. These soils have been formed of marls and are moderately well drained. Because of a large content of montmorillonitic clay, these soils crack deeply and dry up during the dry season. These soils were occupied by mixed deciduous forests originally, but now mainly by sparse secondary forests after the abandonment of cultivation. On the undulating to hilly topography of erosion surfaces and and footslopes on the left bank of the Mae Chang river near the confluence of the Mae Chang and Mae Wang rivers, Muak Lek/Li/Ngao association prevails. These soils have been formed of residiuum and colluvium from shale, slate and other equivalent rocks and are well drained. Muak Lek series belongs to the loamy-skeletal, mixed family of Non-Calcic Brown Soils (lithic Haplustalfs) and Li series belongs to the loamy-skeletal, mixed family of the skeletal Reddish-Brown Lateritic Soils (Lithic - Haplustalfs). Ngao series is a member of Lithosols (lithic Ustorthents). All these soils are gravelly and shallow to parent rocks. Most of these soils have a vegetation of mixed deciduous and dry evergreen forest including some parts where the forest was cleared for shifting cultivation of upland crops.

4) Land Classification

The RID made a semi-detailed land classification survey for the Mae Wang Project Area of about 550,000 rai (88,000 ha) during 1972. This survey included entire Project Area of the Mae Chang Irrigation Project. Results of the survey were published in the report with a land classification map scaled 1:50,000 in 1973.

After reviewing the report, the land classification map was compiled for the feasibility study of the Mae Chang Irrigation Project as shown in Fig.3.2-8.

To carry out the semi-detailed land classification survey, the RID prepared the specifications as shown in Table 3.2-10, Appendix 3.2-6. According to the specifications, the lands in the Project Area were classified into a land class which shows the dominant limitation(s) for irrigation agriculture. The kinds of limitations and symbols are as follows:

Soil limitation in root zone (s)
Topographical limitation (t)
Impeded drainage (d)

Furthermore, all land classes were grouped into one of eight land class groups of which definitions and components were made by the RID as Table 3.2-9. The extent of each land class group was summarized in Table 3.2-10.

In terms of land class group in the Project Area, the area classified into the lands suitable for upland irrigation crops (U1 and U2) totals 1,666 ha, occupying 14.5 percent of the entire Project Area. On the other hand, the area classified into the lands for paddy rice production (R1 - R3) totals of 4,113 ha, occupying 35.7 percent. Besides, the area classified as U2/R2 (lands suitable for either upland crops or paddy rice production) is totally 2,567 ha, that is, 22.3 percent of the entire Project Area. The lands unsuitable for crop production under irrigation (U6/R6) occupy 2,135 ha or 18.6 percent. In addition, villages and other (river, pond etc.) occupy 995 ha and 34 ha, respectively.

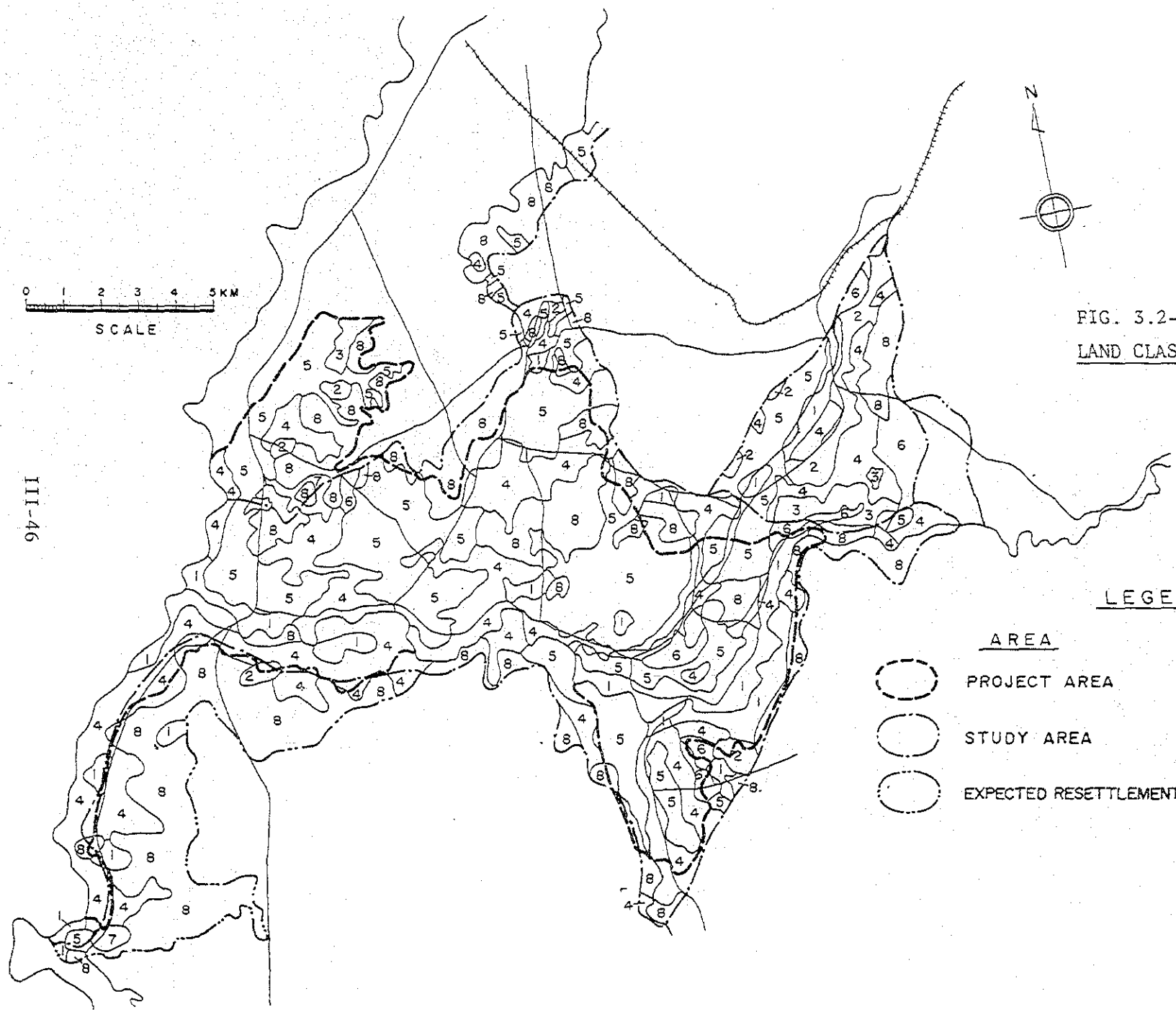


FIG. 3.2-8
LAND CLASSIFICATION MAP

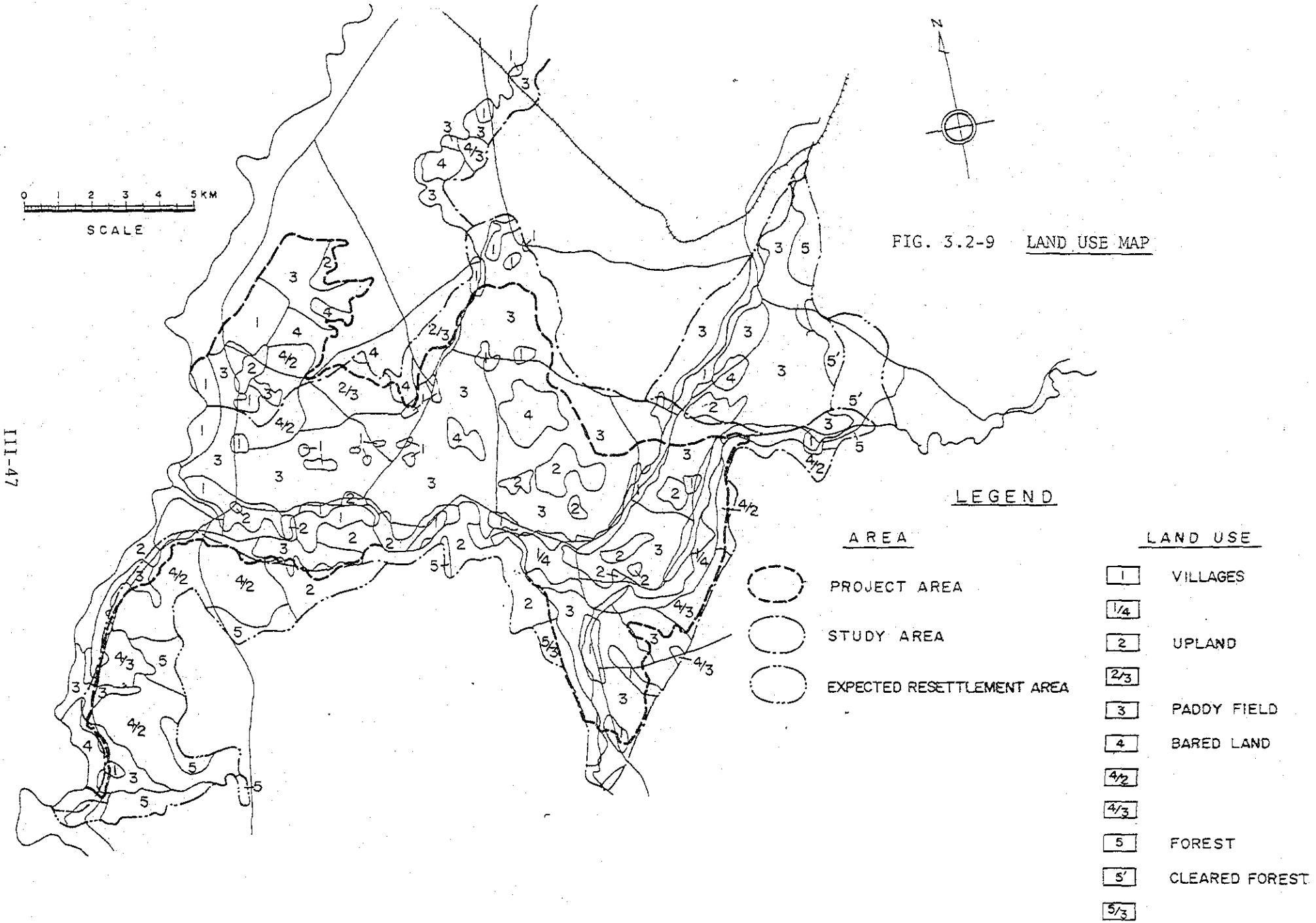


FIG. 3.2-9 LAND USE MAP

Table 3.2-9. Land Class Groups and Definitions

Land Class Group			Definition
Class	U1	:	Land best suitable for upland irrigation crops U1/R3s, U2t/R3st, U1/R2s, U2tR2st
Class	U2	:	Land less suitable for upland irrigation crops with one or more limitation in the soil, topography or drainage characteristics U2s/R2s, U2st/R3st
Class	U3	:	Land of distinctly restricted suitability for upland crops because of extreme limitations in the soils, topography or drainage characteristics U3s/R3s, U3st/R3st, U3s/R6s, U3st/R6st
Class	U2/R2	:	Land suitable for either upland crops or rice production with some limitation. U2s/R2s, U2st/R2st
Class	R1	:	Land best suited for rice production U3sd/R1, U3st/R2t, U2st/R2t, U2sd/R1, U2s/R1, U3st/R3st
Class	R2	:	Land adopted for rice production but with one or more limitations U3s/R2s, U2st/R2st, U6s/R2s, U6st/R2st
Class	R3	:	Land distinctly restricted for rice production because of extreme limitations U6s/R3s, U6st/R3st
Class	6	:	Lands unsuitable for the production of crops U6s/R6s, U6st/R6st

Table 3.2-10. Land Classification

Land Class Group	Right Bank Sub-Area	Mae Wa Sub-Area	Sop Chang Sub-Area	Total	Percent
U_1	996	334	215	1,545	13.4
U_2	50	7	64	121	1.1
U_2/R_2	1,394	262	911	2,567	22.3
R_1	3,598	327	-	3,925	34.1
R_2	51	34	-	85	0.7
R_3	103	-	-	103	0.9
Sub-Total	6,192	964	1,190	8,346	72.5
U_6/R_6	1,942	66	127	2,135	18.5
Village	770	92	133	995	8.6
Others	22	8	4	34	0.3
Total	8,926	1,130	1,454	11,510	100.0

5) Natural Fertility of Topsoils

As the results of soil analysis conducted by the soil chemistry and Physics Laboratory, RID, the natural fertility of soils as well as the soil limitations from the viewpoint of the chemical properties were evaluated by applying the "Key for Estimating Natural Fertility" (See Appendix 3.2-6).

Table 3.2-11 shows the natural fertility of the topsoil (0-30cm) collected from the test pits and auger holes made in the Project Area. (The soil samples from auger holes were analyzed only for pH, EC and available-P.) In accordance with the Key, the natural fertility of each topsoil was estimated in either case of using for paddy or upland cropping. As shown in this table, most topsoils were estimated to have medium natural fertility levels in both cases of paddy and upland cropping. As a whole, available phosphorus and organic matter content limits the natural fertility levels.

As shown in the result of soil analysis, there are no soil limitations from the viewpoint of the chemical properties (pH, EC). for topsoils most soils show normal range of soil reactions.

Table 3.2-11. Natural Fertility of Topsoils (0-30 cm)

No.	CEC	Base Sat.	Org. Matter	Available-P	Wetland	Upland
1	19.8	54.6	0.98	4.3	M	M
2	18.7	64.5	1.1	3.1	M	M
3	19.6	52.8	1.3	3.4	M	M
4	17.9	68.2	1.8	165	mH	mH
6	19.4	60.8	0.52	5.0	M	M
7	25.1	59.1	0.99	3.7	M	M
10	10.6	64.9	0.94	6.3	mL	M
11	36.6	43.1	1.4	6.3	M	M
18	29.1	38.1	2.0	4.9	M	M
20	15.9	41.7	1.2	16.0	mH	mH
21	19.7	70.6	2.0	10.0	mL	M
26	13	65	2.0	8.4	M	M
29	67.0	89.7	3.6	50.4	H	H
30	35.8	52.8	1.3	87.8	mH	mH

No.	CEC	Base Sat.	Org. Matter	Available-P	Wetland	Upland
5				4.0		
8				4.5		
9				123		
12				12		
13				3.7		
14				310		
15				8.4		
16				5.1		
17				9.9		
19				4.0		
22				7.9		
23				4.6		
24				7.2		
25				5.4		
27				4.9		
28				5.6		
31				6.5		
32				4.0		

3.2.5. Seismology

According to the seismological report of Thailand seismic activities complied by the Network Head Quarters Studies and Research Division of the Meteorological Department during 1975 to 1983, earthquakes in Thailand distribute from the center of the north with a magnitude in the 3 to 5 range.

Figure 3.2-10 shows the distribution of earthquake epicentres of North Thailand. This map shows that there are no earthquakes within Lampang province. The majority of earthquake occur in neighbouring countries. Earthquake epicentres are shown in Figure 3.2-11 and are mostly distributed in the following places:

1) Burma from the South to the North
2) Along the border between Burma and Laos and Thailand
3) Andaman Sea

The probabilities of seismic occurrence in Thailand by zone is shown in Fig.3-2-7, Appendix 3.2-7. Each zone show the approximate destructive intensity of earthquakes. The Mae Chang Project Area is included in zone 1. Zone 1 means minor damage.

The coefficient of seismic force for the design was decided by using the maximum acceleration based on the data observed during the periods of 1975 to 1983 as shown in Table 3.2-14, Appendix 3.2-7.

The maximum acceleration was calculated by the Okamoto's formula. There are formula submitted by the Gutenberg-Richter and Esteva-Rosenblueth, but the maximum accelation estimated by these formula is small in comparison with that by Okamoto's formula.

Okamoto's formula is as follows:

$$\underset{10}{\text{Log}} \frac{AC}{640} = \frac{(D + 40)}{100} \times (-7.604 + 1.7244M - 0.1036M)^2$$

Where,

Ac: Maximum acceleration (Gal)
M: Magnitude
D: Distance from the dam site to the earthquake epicentre (km)

In case M=8 and D=400 were substituted in the above formula, the maximum acceleration becomes 7.5 Gal, and the ratio K of seismological acceleration to the gravity acceleration is 0.008. This value is too small to affect the Mae Chang Project area. The maximum acceleration at the dam site was calculated by using of the seismological data occurred within 400 km from the dam site. the results are shown in Table 3.2-14 Appendies 3.2-7. The maximum value of them is 26.2 Gal and the ratio K of seismological

FIG. 3.2-10 Distribution Of Earthquake Epicenters Of North Thailand

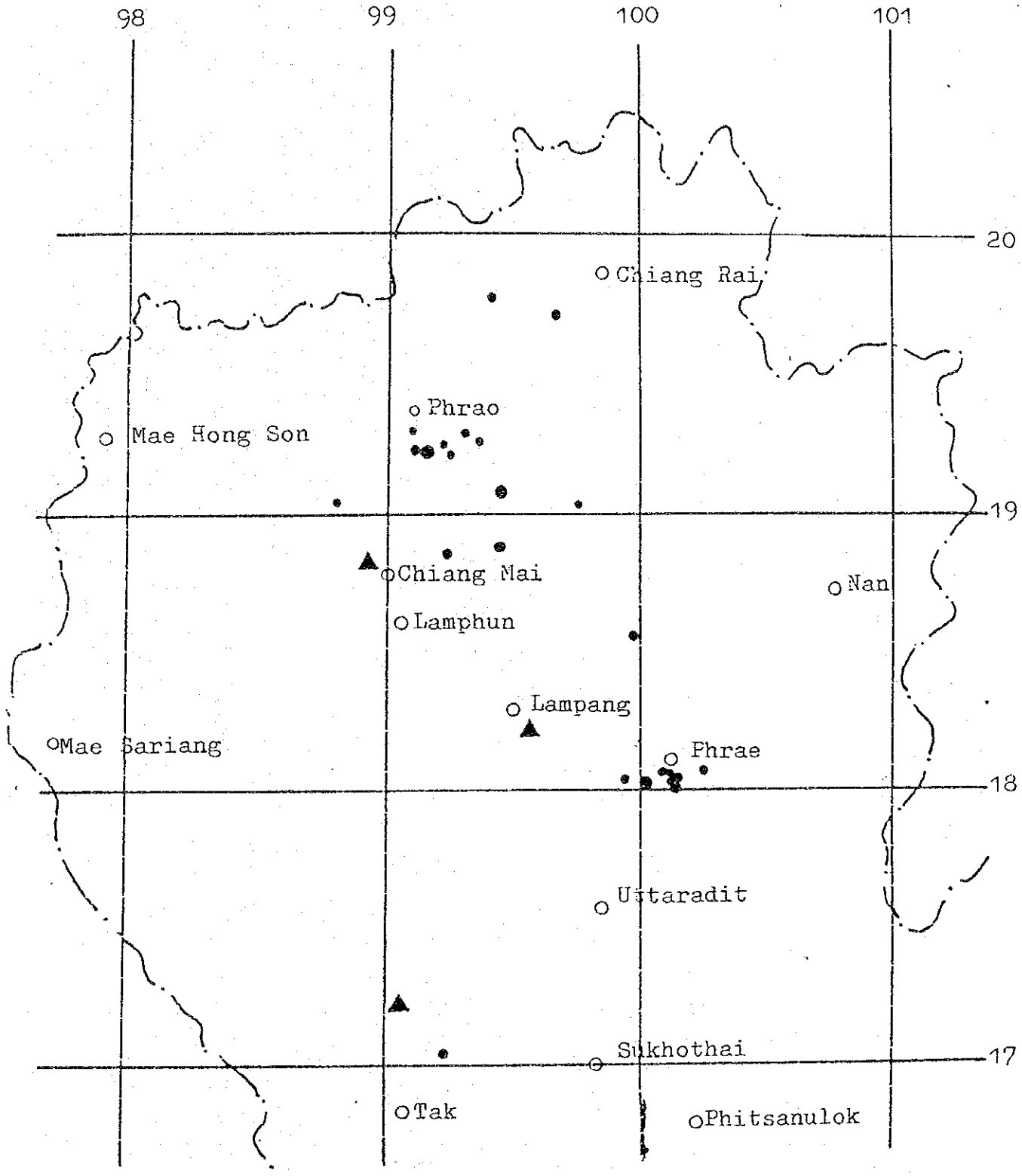
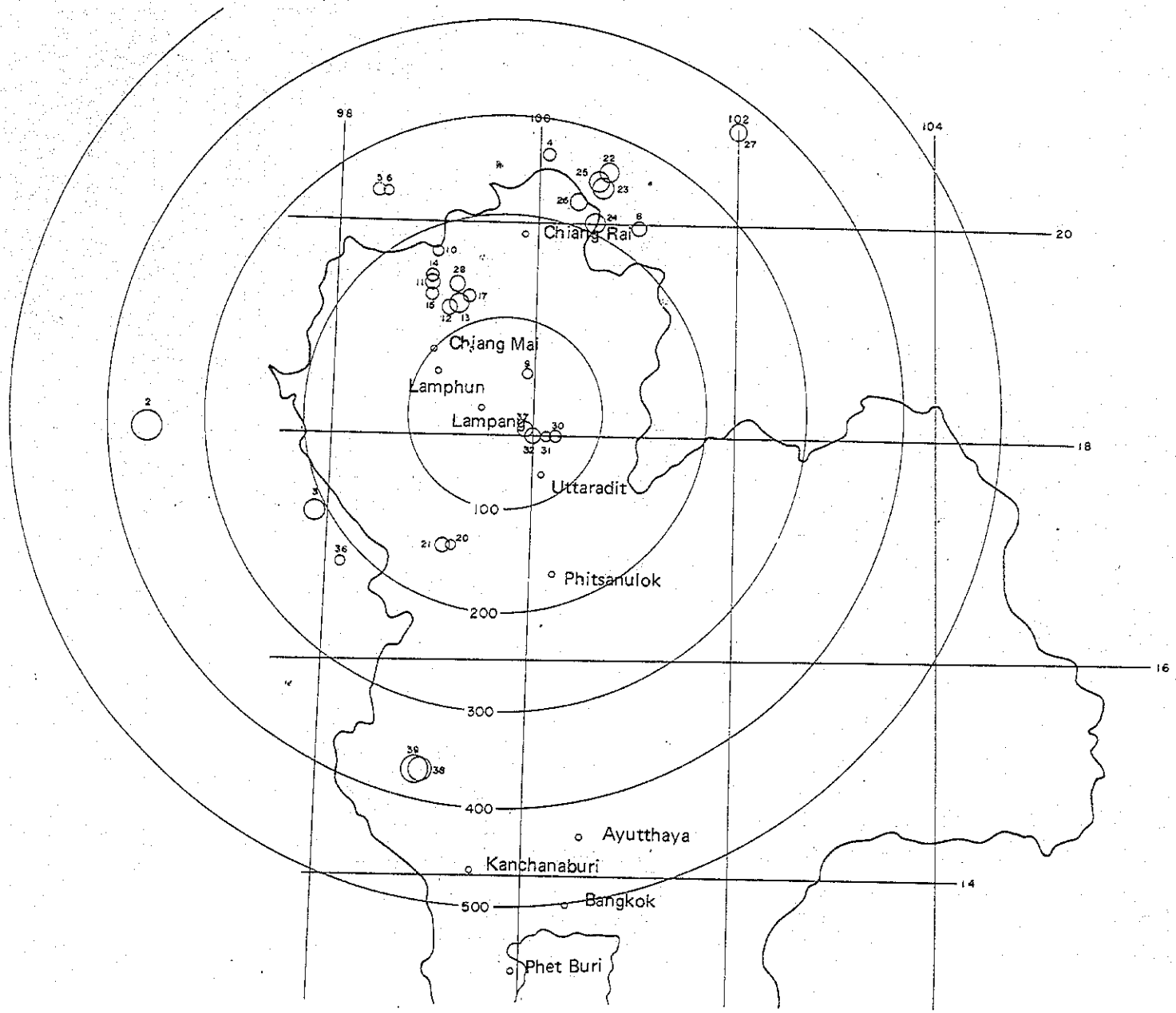


FIG. 3.2-11 Earthquake Epicenters In Thailand And Neighbouring Countries



acceleration to gravity acceleration is 0.027. It is sufficient to apply K=0.05 for the design of dam and structures. For a example, the EGAT Mae Chang dam was designed by K=0.05.

3.3. Present Agriculture

3.3.1. Land Use and Tenure

1) Land Use

The DLD published the land use map (scale 1:100,000) in 1977. This map was useful to get the general tendency of land use in the Project Area.

As shown in Fig.3.2-9, the present land use pattern in the Project Area is distinctively separated by the Mae Chang river, i.e., vast paddy field area spread on the flat or nearly flat terraces on the right bank, while uplands mainly sugarcane fields are distributed on the undulating hilly slopes on the left bank except for the Mae Wa river basin. Characteristics of the present land use in each bank are outlined as follows:

Right Bank

A narrow band of old levees along the Mae Chang river is mainly used for settlement sites including vegetable gardens and orchards. Extensive lands on semi-recent and old terraces behind the old levees are presently used for paddy fields except for some elevated lands situated in the center of the Area. These undulating hilly lands are now under sparse secondary Dipterocarp forests and shrubs as a result of cutting original mixed deciduous trees for lumbering and charcoal making. As regards the cultivated lands, only upper portions of the Mae Pung Canal and a narrow stretch of the Mae Tha Tank areas can get their irrigation water during the dry season. Remaining lands are rainfed and almost no crops can be cultivated in

the dry season. These dried lands are only used for grazing of cattle at present. Therefore, cropping intensities of most lands are still at a low level.

Left Bank

Only in the Mae Wa river basin, a similar land use pattern to that of the right bank can be found. Present land use on the left bank is characterized by upland cropping and shifting cultivation on the undulating hilly land. Upland mainly sugarcane fields are going into sparse shrubs or forests. Considerable portions of the original dry Dipterocarp forests and mixed deciduous forests have been cleared for upland crops. At the same time, significant portions of the cleared lands have been abandoned and lie under secondary Dipterocarp forest and shrubs facing an erosion problem. The Area of each category of present land use was measured by using a degigrammer on the topographical maps scaled 1:10,000, and the result was summarized as shown in Table 3.3-1.

Table 3.3-1. Land Classification

Land Use	Right Bank (ha)	Mae Wa (ha)	Sop Chang (ha)	Total (ha)	Percent (%)
Cultivation Land	6,134	692	885	7,711	67.0
Paddy	5,325	551	462	6,338	55.1
Upland	809	141	423	1,373	11.9
Forest	2,000	338	432	2,770	24.1
Village	770	92	133	995	8.6
Others	22	8	4	34	0.3
Total	8,926	1,130	1,454	11,510	

2) Land Tenure

The Project Area covers Amphoe Kho Ka and Mae Tha. According to data obtained at the Lampang Agricultural Extension Office, the farm land for both Amphoes was 216,340 rai and the number of farm households was 27,171 in 1982. Concerning land tenure, tenant farmers occupy 89.2 percent of the total farm households.

The number of farm households by each farm size was not available at the Amphoe office, therefore, the following estimation was made on the basis of the agriculture census of 1978.

Farm Size (rai)	Percentage (%)
less than 10	72
10 - 20	23
more than 20	5

The average farm size per farm household is estimated at 8 rai (Refer to Table 3.3-2, Appendix 3.3-1).

3.3.2. Agricultural Practices

The Area cultivated per farm household in the Project-related three Amphoes is about 8 rai (1.3 ha), which is much lower than the national as well as the provincial average.

Most of the cultivated lands are not provided with complete irrigation facilities.

The agricultural production in the Area has not been stable due to irregular distribution of monthly rainfalls, absolute shortage of total annual rainfalls, low level farming technique, and so forth.

The low agricultural production results from difficulties in successful annual rainfall forecasting, and the farmers' conservativeness in using a lot of agri-inputs in farming.

The manual labor force and draft animals are the main labor forces in this Area. The average number of laborers is estimated at 2.9 persons and the average number of domestic animals bread is 1.9 head per farm household including cattle and buffalos, of which 0.9 head are used for farming.

On the other hand, there seems to be little need to employ farming machines because of small cropping acreage and a high availability of family labor, single cropping in a year, etc.

Cropping acreage each crop is shown in Table 3.3-2. .

1) Agriculture in Wet Season

The wet season lasts for six months from May to October. During these months, such major crops as paddy, groundnuts, maize, sugarcane, pulses, etc. are grown, and paddy occupies about 53.3 percent of the total area. About 90 percent of the paddy planted is of glutinous rice varieties.

Paddy seeding is carried out from June to the middle of July and takes 30 to 35 days in the nursery. The Area prepared for the nursery bed requires five percent of the transplanted area. Transplanting is done from July to the middle of August. Harvesting is in the middle of November to December.

Maize corn is seeded in June and harvested in September. Concerning sugarcane, harvesting is made three times per one cycle which is equivalent to three years. The planting period is May and the harvest is made from February to April in the following year. The harvest for the last two years is carried out from January to April.

Vegetables and fruits are cultivated on comparatively fertile lands along the river and nearly residential areas. Major vegetables are cucumber, red pepper, string beans, squash, kale, onion and shallot, which are grown used for self consumption.

2) Agriculture in Dry Season

The dry season starts in November, lasting six months till April in the following year. It is quite difficult to grow crops in non-irrigable fields during these months.

The major crops grown in the dry season are groundnuts, soybeans, tobacco, etc. These are the so-called "cash crops" for which the farming management and control appear to be carried out quite well in relation to wet season crop cultivation.

Manpower is the main labor force in the dry season, although some draft animals are used.

Basin irrigation is primarily practised for soybean while furrow irrigation is practised for groundnut and tobacco.

Groundnuts are sown on the field preparing a 1.5 to 2.0 m of rows with 6 to 8 lines and their harvesting is in April. On the other hand, sowing of soybeans is practised from the middle of December to the middle of January and is harvested in March to April.

Tobacco cultivation is different from those of other crops. Tobacco seedlings grown at the curing station are distributed to each farm household. After harvesting, tobacco leaves are delivered to a curing station for drying. Fertilizers and agri-chemicals for tobacco cultivation are also distributed through this curing station. Transplanting is performed in October to November and harvesting is executed 6 to 7 times after transplanting.

Table 3.3-2. Present Planted Area by Crops

Crops	Lampang Province		Amphoe Kokha	Amphoe Mae Ta
	rai	%[1/]		
Paddy	502,254	0.9	41,775	67,577
Mungbean	2,249	0.07	-	-
Soybeans	13,307	16.7	-	897
Maize	28,191	1.7	1,300	1,591
Sugarcane	46,874	1.2	10.820	12,537
Groundnuts	84,655	11.0	-	12,352
Cotton	3,760	0.4	-	-
Tobacco	-	-	-	3,450
Garlic	-	-	-	2,384

Note: 1/ Proportion to the whole country

3) Animal Husbandry

Animal husbandry in the Project Area consists of cattle, buffaloes, pigs, chickens and ducks. Cattle and buffalo are mostly bred for farm work. In the Area, fodder crops are not cultivated and livestock depend upon wild grasses and rice straw, etc. According to the Amphoe statistical records, one farm household feeds one head of cattle, 0.9 head of buffalo, 0.8 head of pig and 5.3 chickens or ducks.

The programme of livestock breeding promotion will be established under the Changwat office after completion of the irrigation project. At present, there is a chicken farm in Tambon. Namjo, Amphoe Mae Tha feeds 10,000 broilers and ships 1,000 head per day. (Refer to Appendix.)

3.3.3. Agricultural Production

Agricultural production depends upon the amount of rainfall during the rainy season. Rainfall records in the rainy season show that recent rainfall in the year 1979, 1980, 1982 is less than the average value for 30 years and thus drought damages have occurred.

Irrigation facilities located in Amphoe Mae Tha are insufficient and therefore, paddy is usually not cultivated over the entire area. According to the statistical data prepared at both Amphoe agricultural extension offices, the planted area becomes 94.8 percent at the maximum and 69.8 percent at the minimum. The average value is 88.5 percent.

The harvested area is 94.6 percent at the maximum, 24.6 percent at the minimum and 77.4 percent on the average.

As regards other crops, precise data such as for paddy is not available and therefore detailed analysis is difficult.

The present yield is estimated on the basis of Changwat statistics, the Agricultural Extension Office and interviews with farmers.

The following Table 3.3-3 shows the planted and harvested area of the Project Area.

3.3.4. Agricultural Input Material

1) Agricultural Machinery

The necessity of agricultural machineries is low considering the small farm size per household and one crop per year. Related Amphoes in the Area have 800 units of tillers and about 100 units of tractors with more than 60 P.S. Concerning sprayers, hand sprayers

Table 3.3-3. Paddy Field, Planted and Harvested Area from 1973 to 1982 by Ampho

(Unit: rai)

	Ampho Kokha			Ampho Mae Ta		
Year	Paddy Field	Planted Area	Harvesed Area	Paddy Field	Planted Area	Harvested Area
1973	42,057	30,426	30,400	50,257	50,257	50,257
1974	42,057	32,193	32,090	52,175	51,619	51,619
1975	42,057	35,494	30,390	52,175	52,100	52,100
1976	42,057	38,142	37,046	66,959	60,496	60,496
1977	42,057	38,142	37,184	66,959	61,643	61,643
1978	42,057	40,643	32,416	66,959	60,281	60,281
1979	42,057	41,048	24,386	66,959	49,706	16,362
1980	42,057	40,654	40,347	73,277	67,716	67,716
1981	41,057	41,775	41,479	73,277	67,577	65,577
1982	42,057	42,057	14,084	73,277	38,441	14,345
Average	42,057	38,057	31,982	64,227	55,984	50,240
%	100.0	90.5	76.0	100.0	87.2	78.2
Total	106,284	94,041	82,222			
Average	100.0	88.5	77.4			

Source: Ampho Kokha, Mae Ta Agr. Extension Office

are mainly owned by tobacco cultivating farm households. Farm practices are mostly done by man or animal labor.

2) Agricultural Input Material

As regards seeds, the input amount is generally higher than that of the agricultural extension office. This results from insufficient sorting of seeds. In Changwat Lampang, the Lampang Seed Center which was established in 1978 distributes superior quality seeds of paddy, soybean and groundnut in order to renew old seeds.

Fertilizers and agri-chemicals are only applied for cash crops such as tobacco, sugarcane, and garlic. Those are distributed at the curing stations for tobacco and at the sugar refining factory.

3.3.5. Marketing Structure

According to farmers, middlemen, and processors of agricultural products interviewed during the field survey, problems with the distribution of crops very seldom occur due to the fairly satisfactory road network system existing in the Area and the ready availability of transport vehicles which are mainly light pick-up trucks. In the case of sugarcane which is grown in areas where access may be difficult the factory has its own grader to keep roads in a passable condition.

However, unstable or what the farmers consider unfairly low prices lead to marketing problems for a large percentage of the farmers. Also, a number of farmers complained that local middlemen took advantage of them by quoting lower than normal prices or using weighing scales that were inaccurate.

Group marketing activities are not widespread, therefore, the farmers have no combined bargaining power which mean they will have to accept the market price at the time of harvest.

The marketing channels of several of the main crops being grown in the Area are described below.

Rice : Although there is a large demand for this crop distribution is quite limited since household consumption, seed, and payment in kind for land rent and labor take approximately 90 percent of the crop. The remainder is normally purchased by middlemen or agricultural cooperatives to be sold at the provincial market. Fluctuating prices, lower than normal year yields and increasing farm production costs were pointed out as problems which lower the profitability of marketing this crop.

Sugarcane : The Lampang Sugar Factory which is a public corporation location in Ko Kha Town is the major purchaser of this crop. Farmers desiring to grow this crop must make a contract with the factory before planting and the price is fixed at the time of signing the contract. Farmers are only allowed to harvest their crop after factory inspectors have tested it for purity and a factory controlled truck is dispatched for transportation. The cost of transportation which is borne by the farmer and depends on the distance and the weight and is calculated as 70 ฿ per ton per 20 km. The factory can process a maximum of 2,000 tons of sugar cane per day.

Tobacco : Marketing of this crop is carried out by curing stations located adjacent to or nearby the tobacco fields. Every farmer sells his crop to the curing station where he has made a verbal agreement before planting. Since this crop is produced for export on a quota basis, set according to fluctuating world market demands, prices are fixed at the time of

planting. Farmers must transport their crop to the curing stations after receiving permission to harvest by the curing station inspectors. Cost of transportation is 70 ฿ per ton by light pick-up truck.

Peanuts and Soybean : These are normally sold to middlemen or primary processors such as drying and sorting companies which in turn sell their products to brokers in Bangkok.

Pineapple : Although commonly sold on a retail basis directly to consumers at local markets or road side stands this product is also purchased by the Universal Food Company, Ltd. (UFC) for processing into juice at its canning factory in lampang.

Other : There are no specific marketing channels. Farmers sell to middlemen who come to the village or at local markets.

3.3.6. Agricultural Research and Extension

1) Research

Within Changwat Lampang, there is only one agricultural experiment station. This is Lampang Horticultural Experiment Station. It was established in 1974 and holds 16 staff and about 300 ha of land. The said station is responsible for studies on vegetables, fruit trees and flower plants. One of the main objectives of the station is to find varieties suited to the Area.

Within the Project Area there are no other experiment stations dealing with such major crops as paddy, peanut, soybean, garlic and so on. But in Chiang Mai which is about 90 km away to the northwest, there is the Faculty of Agriculture, Chaing Mai

University, Mae Jo Agricultural Experiment Station, and Sampatong Rice Experiment Station. To the south there is Sri Samrong Agricultural Experiment Station in Changwat Sukothai. These institutions are situated in places where climatic conditions are nearly the same as those of the Project Area. Experimental results obtained in these institutions must be applicable to the Project Area. The only difficulty expected is in relation to soil conditions. In the Project Area, the same soil is turned alternately into upland and lowland conditions. On the other hand in the above-mentioned stations, upland is used permanently as upland, and lowland permanently as lowland.

There is a Thai-Australian Land Development Project (TALD) team stationed in Lampang. But at present its main work is the land reclamation in Changwats Nan and Phrae.

As for educational facilities, there is Lampang Agricultural College, Lampang Agricultural Research Laboratory and Training Center. The college was established in 1972 and holds 40 teaching staff and 400 students of whom 20 percent are female. The overwhelming majority (95%) of the graduates of the school become civil servants of the Government, both central and local, and the staff of the various agricultural enterprises. the laboratory aims at agricultural research on various fields and the center helds a short term lecture for agricultural research workers and farmers.

2) Extension

Agricultural extension of Thailand, since its reorganization in 1966, gradually began to reach the average farmers. However, owing to the shortage of staff and various facilities, it could not be said that DAE served the farmers well. With the introduction of dry season cropping, importance of agricultural extension was recognized and since 1977, with the aid of World Bank (IBRD), National Agriculture Extension Project was started. Thus, number of

agricultural extension agents were greatly increased and facilities were improved. For example, number of agricultural extension agents for Changwat Office and those for three Amphoes within the Project Area were respectively increased to 18 and 49 persons.

These agricultural extension agents are to have regular meetings at fortnightly intervals with the staff of agriculture-related organizations, such as Plant Protection Team, RID, Land Development Department, Animal Husbandry Department, etc. to exchange knowledge and to strengthen communications.

Each agricultural extension agent is responsible for 1,000 farmers and one farmer out of ten is designated as a contact farmer who is to be the link between agricultural extension agents and farmer in general.

3.3.7. Agricultural Cooperatives and Crediting

1) Agricultural Cooperatives

At the time of the survey there were a total of 13 agricultural cooperatives existent in Lampang Province. Two of the 13 are presently carrying out activities within the Project Area; Mae Tha Agricultural Cooperative, Ltd. in Amphoe Mae Tha, and Ko Kha Agricultural Cooperative, Ltd. in Amphoe Ko Kha.

The major activities of the above-mentioned agricultural cooperatives may be summed up as follows;

a) Financial

i) providing loans to members both short and medium term
ii) accepting members' demand or time savings deposits

b) Marketing

i) members crop purchasing and selling
ii) processing of products (rice milling, peanut shelling, etc.)

c) Purchase and procurement of farm inputs for sale to members

d) Providing, at a reasonable charge, crop production services such as pumping of irrigation water, building of weirs, construction of irrigation and drainage facilities, etc.

e) Extension of agricultural knowledge and techniques

f) Crop planning

g) Management training by the Cooperative League of Thailand

Main problems which are being faced by all of the agricultural cooperatives were stated to be; cooperatives lack of or inability to obtain funds for loans to members, inability of borrowers to repay loans due to poor crop yields, and lack of vehicles, equipment and workers for carrying out activities.

2) Crediting

Agricultural cooperatives provide short and medium term loans for which only members are eligible to apply. The terms, including purposes of loan, maximum amounts loanable, rates of interest and periods of repayment are listed below.

a) Short term loan or production credit
purpose - for purchase of farm inputs such as seeds, fertilizer, pesticide, minor tools and implements, to pay for labor costs and family living expenses

amount of loan - not more than 60 percent of the assessed value of the products produced with the proceeds of the loan

interest - 14 percent per annum

period of loan repayment - within 12 months or in a special case not more than 18 months

b) medium term loan

purpose - for use as an investment in the purchase or construction of agriculturally related facilities or equipment which are normally utilized for more than one production season

amount of loan - not more than 30,000 ฿ depending on the case

interest - 14 percent

period of lean repayment - within three years

The total number and total value of loans provided by the four agricultural cooperatives in 1982 are shown in Table 3.3-4.

Table 3.3-4. Number and Amount of Loans Provided by Agricultural Cooperatives in 1982

Name	No. of Members	No. of Short Term Loans	Total Amount ฿	No. of Medium Term Loans	Total Amount ฿
Mae Tha Agri-Coop., Ltd.	1,230	801	2,489,453	906	3,993,706
Ko Kha Agri-Coop., Ltd.	1,795	1,029	3,664,607	1,727	6,420,186

Source: Cooperative Officials

3.3.8. Farmers' Organization

Three types of groups set-up by the Amphoe level Agricultural Extension Offices and supervised directly by Tambon Extension Agents (E. A.'s) are being promoted in Lampang Province. The most directly associated with agricultural activities is the Farmers' Association with the other two being mainly training and guidance groups, namely the Housewives' Home Economic Group and the 4-H Club.

The Farmers' Association is a corporate juridical person receiving financial subsidies from the central government. Membership in the association requires a one time membership fee payment of 20 Baht and the purchase of at least one share of the association's stock at a cost of 50 Baht.

Main activities of the associations are; issuance of shares at 50 Baht each which can only be purchased by members, acquiring funds for capital, granting loans to members both for short and medium term, storage and marketing of members products to increase bargaining power, procurement of farm inputs for sale to members either on a credit basis or at prices lower than those prevailing on the market, and the transfer of agricultural knowledge and techniques to the members. There are a total of 88 such associations in Lampang Province.

Membership in the Housewives' Home Economics Group is free of charge to young housewives who desire to gain knowledge in such areas as health and nutrition. There are a total of 159 such groups in Lampang Province.

Membership in 4-H Clubs in also free of charge and limited to single persons ranging in age from ten to 25 years. The clubs main activities are practical training in the planting and growing

of crops, and the care and raising of livestock. There are a total of 137 such clubs in Lampang Province.

3.4. Irrigation, Drainage, and On-Farm Conditions

3.4.1. Irrigation Conditions

In the Project Area, the farming practices such as nursery bed preparation, land soaking and puddling are carried out as farmers' group works starting in the middle of May. These works, however, depend upon rainfalls.

According to the local farmers, rainfall amount during the irrigation period fluctuates in each year and the farmers suffered from shortage in irrigation water. In the Area, there exist major irrigation facilities such as Mae Pung canal, Mae Tha tank and Mae Wa weir. In addition to these facilities, small scale irrigation structures are installed under financing by Amphoe or farmers. For relieving the Area from drought, such facilities and water resources are insufficient to supply irrigation water.

In the rainy season, paddy is planted as a major crop and along the Mae Chang river and hilly areas, sugarcane is under cultivation. In the dry season, major crops planted are upland crops such as tobacco, garlic, groundnut, and soybean, whereas paddy is very limited in its cultivaton in the comparatively lowlying lands along the right bank of the Mae Pung canal.

The farm ditches are provided so sparsely that most of fields are irrigated by the plot-to-plot method which brings the difficulty of a stable water supply in the dry season.

Irrigation for tobacco and groundnuts is made by gravity flow or pumping with 7- to 10-day intervals, preparing furrows after harvesting of paddy.

3.4.2. Drainage Conditions

Present drainage systems distributed in the Project Area are largely divided into the right bank and left bank of the Mae Chang river.

The right bank area forms comparatively gentle topography with a 1 to 200 slope toward the southwest where streams or "Huai" such as Huai Mae Pung, Huai Mae Tha, and Huai Mae Phaet are developed for irrigation and drainage purposes.

On the left bank, Nam Mae Wa, Huai Pong, Nam Mae Ping form alluvial plains and other small streams develop through the hills, although being very chart in their water courses are very short.

Most of the Huai excluding Huai Mae Pung flow around four meters lower than the paddy fields and excess water from farm land and hilly areas is easily drained by gravity. This means that severe inundation will not occur in the Area.

However, part of Huai Mae Pung running through the low land of the Area has only one meter difference between the field and the bottom of a canal. Once heavy rainfall occurs, low lands will be inundated. To relieve these lands from inundation, rehabilitation, i.e., enlargement of canal sections is quite necessary.

According to the on-foot survey, present drainage systems are meandering and their canal sections are partly insufficient for drainage. In addition to these narrow sections, degenerated or damaged structures such as pipes, box culverts, weirs and bridges are found on the right bank and affect drainage functions.

With the Project, all of the Huai mentioned above will function only as drainage canals. Improvement or rehabilitation of are made

for the old facilities and narrow sections so as to secure smooth drainage.

3.4.3. On-farm Conditions

The on-farm of the Area is not consolidated even at the existing irrigation area, Mae Pung, and the shape of plots varies and its size ranges from 0.08 to 0.5 rai based on the survey carried out at Ban Muang San Si. Irrigation is practised by the plot-to-plot method providing notches at each plot.

At present, the farm lands in the Area where upland crops are grown after paddy is harvested are irrigated by preparing furrows. In the rainfed fields during the dry season, soils become rigid to crack heavily and yet the fields are turned become muddy once the irrigation is practised.

No farm roads are provided along the main farm ditches, and therefore, transportation of tobacco and garlic products depends on manpower.

3.4.4. Existing Irrigation Projects

In the Study Area there are several existing irrigation projects, namely Mae Wang Irrigation Project, Mae Tha Tank Project, Mae Wa Weir Project, Small Scale Irrigation Project (SSIP) and some others promoted mostly by RID.

1) Mae Wang Irrigation Project

This is the major irrigation project in the region of upper Mae Wang basin and its main facilities are the Kew Lom Dam and the Mae Wang Diversion Weir. Mae Wang Left Canal, one of the main canals, reaches the Project Area diverted from the Mae Pung Diversion Weir at the end of the canal and flows into the Mae Pung Main Canal (MPMC). The MPMC is diverted into two main canals, namely the Mae

Pung Left Canal and the Mae Pung Right Canal within the Project Area and supplies water to an area of about 2,500 ha (net) mainly in the wet season.

The Feasibility Report on the Mae Wang-Kew Lom Irrigated Agriculture Development Project of March 1980, reported by JICA, referring to the water balance in the Mae Wang Project, says that the shortage of irrigation water in the dry season would not be solved completely without water supply from the Mae Chang Dam to the Mae Pung Area.

2) Mae Wa Project

The Mae Wa Project was completed in 1976 in the Area of Ban Bom and Ban Kiew in the lower basin of Huai Mae Wa, one of the left tributaries of Nam Mae Chang. The irrigation network is composed of three facilities, namely diversion weir, newly constructed main canal, and improved lateral canals on the left bank of the river. The Project features are as follows:

Irrigable area	2,500 rai (in wet season)
	1,000 rai (in dry season)
Diversion weir	W = 32 m, H = 2.5 m
Crest level	253.50 m (MSL)
Main canal	2.74 km
Lateral canal	7.80 km

3) Electric Pumping Project (EPP by NEA)

Two Electric Pumping Projects, constructed by the National Energy Administration (the Ministry of Science, Technology and Energy), are located in the Project Area, namely in Ban Sop Po (Project Area: 3,150 rai) and Ban Nam Thong (Area = 3,500 rai). Main facilities except lateral canals have already been constructed the operation have started from wet season cultivation on 1983.

3.4.5. Operation and Maintenance

RID (IRO-2 and Mae Wang Project Office) and the water users group engage in the operation and maintenance of irrigation facilities in the Project Area, the former controlling the main facilities and the latter maintaining facilities beyond the turn out of the lateral canals.

Irrigation Regional Office 2 is responsible for five Changwats, namely Lampang, Phrae, Nan, Phayao and Chiang Rai. The Mae Wang Project Office controls Mae Wang Irrigation Project including Mae Pung Project, Huai Mae Tha Reservoir Project, and Mae Wa Project. The Mae Wang Project Area is divided into 12 Zones each of which is about 10,000 rai.

The zone man reports to the Irrigation Inspector of the Project Office the acreage planned to be cultivated by the users group in the next season. After receiving the request of the users group, the Project Office estimates the quantity of discharge from each of the diversion weirs, decides the rotation for supplying the diverted water, and directs the zone man concerning the gate operations. Following this, the gate man operates the gate, records the gaging staff, and inspects the facilities conditions. In case of slight damages, the zone man and gate man repair them and the Project Office and the Mechanical Section of IRO-2 take charge of major repairs and canal clearing.

The water user groups carry out the operation and maintenance of facilities beyond the turn out of the lateral canals by hand. The water users group have an agreement in general concerning the selection method of chief (or head), the clearing of the canal, the repairing the weir in their irrigation systems, and the penalty for disobeying the agreement. All the groups are recognized to perform canal clearing before wet season cultivation.

CHAPTER IV : THE PROJECT

CHAPTER IV. THE PROJECT

4.1. Objectives and Components of the Project

4.1.1. Objectives

The Mae Chang Irrigation Project (the Project) was implemented to provide water resources through the construction of a storage dam and to supply irrigation water to both the rainfed area and the existing irrigated area through a diversion dam in order to offset the gap in land use and agricultural income between the Project Area and neighboring irrigated agricultural areas by increasing the land productivity and agricultural income. Blessed with favorable soil, climatic and topographic conditions the Project Area has a great agricultural potential and it is expected that agriculture with high land productivity can be materialized in the Project Area through the provision of irrigation facilities.

The Project aims i) to intensify land use and increase agricultural production through water resource development by constructing a storage dam and irrigation system, ii) to create employment opportunities throughout the year for farmers in and around the Project Area, and iii) to improve the farm land for stable production and the rural environment for better farm life by construction of irrigation and drainage facilities and road networks together with the strengthening of the agricultural extension services.

The following work will be implemented to attain the objectives of the Project:

i) To construct a storage dam and a diversion dam,
ii) To construct irrigation and drainage facilities,
iii) To introduce modernized agricultural techniques with proper water management, and

iv) To establish/reorganize the farmers' organization and to strengthen the agricultural extension services.

4.1.2. Project Components

Project components have been considered as follows:

i) Water Resources development

A storage dam and diversion dam shall be constructed to provide water resources for irrigated agriculture.

ii) Irrigated agricultural development

Roads and fully organized agricultural extension services shall be provided to develop irrigated agriculture, irrigation and drainage canals.

iii) Hydropower development

To provide power for the operation and maintenance of the irrigation system and to electrify villages neighboring the dam to be constructed as a second phase development.

4.2. Plan Formulation

4.2.1. Alternative Studies for Optimum Scale of Development

Alternative studies for optimum scale of development for the Mae Chang Irrigation Project have been discussed on the following items in view of irrigated agricultural development; (i) alternative dam sites for the storage dam, (ii) lineation of the Project Area and (iii) agricultural development plan. Since Mae Chang Irrigation Project aim at the development of irrigated agriculture by the development of water resources, the alternative dam sites are

studied first and then the remainder of the above-mentioned items are considered in the following manner:

1) Alternative Case Studies

Through the field reconnaissance and the field survey along the Mae Chang basin, four alternative dam sites were selected on the basis of the maximum scale of dam construction on the geological and topographical basis, and studied for the following cases:

Case - 1: Storage Dam A at the Alternative Dam Site A
Case - 2: Storage Dam B at the Alternative Dam Site B
Case - 3: Storage Dam C at the Alternative Dam Site C
Case - 4: Storage Dam D at the Alternative Dam Site D

Aside from the above-mentioned alternatives, two cases of diversion dam plans taking into consideration social and environmental aspects of the reservoir area to be submerged by the dam construction, were also studied. In the alternative Cases 2, 3 and 4, there will be much a number of difficulties to be faced in the reservoir area if dam construction is made at the maximum scale at each site. On the other hand, although construction of only a diversion dam at alternative dam sites C or D can reduce the difficulties in the reservoir area, the storage capacity will be much less than expected. In order to make storage capacity as large as possible, combinations of storage dam A and either diversion dam C or D were considered for Cases 5 and 6.

In addition to the above-mentioned alternative cases, diversion dam only plans were also studied as Case 7 and Case 8. Case 7 is an alternative plan construction of diversion dam C only, while Case 8 is for diversion dam D only.

Finally, for selection of optimum scale of development plan, 11 alternative cases were studied as shown in Appendix 4.2-1.

2) Lineation of the Project Area

The Mae Chang Irrigation Project Area consists mainly of the three sub-areas, of the Right Bank sub-area, Mae Wa sub-area and Sop Chang sub-area. Among them, the Right Bank sub-area is located on the right bank of the Mae Chang and is formed as the main area of the Project, while Mae Wa and Sop chang sub-areas are located on the left bank of the Mae Chang.

The Areas to be involved in the Project vary in the amount of available water resources. These have been studied on an engineering and also economically basis for the following cases:

Case-6 : Same Case with alternative dam sites study
Covering all sub-areas as for comparative standard

Case-6a: Covering the sub-areas of Right Bank and Sop Chang

Case-6b: Covering the sub-areas of Right Bank and Mae Wa

Case-6c: Covering the Right Bank sub-area only

3) Cropping Pattern

In order to use available water resources effectively and natural rainfall as effective rainfall for irrigation as much as possible, paddy is planned to be grown in the whole project area in the wet season while upland crops such as groundnuts, soybeans, tobacco and garlic are to be grown in the prospective area of the Project in the dry season depending upon the availability of the water resources. The above-mentioned cropping pattern was used only for alternative case studied. After selection of the proposed

cases, the cropping pattern was studied in detail and some revision was made for the case studies.

4) Results of the Alternative Case Studies

Aside from the aforementioned anticipated results of analyses in the engineering aspects, analysis and study on the economical aspects were made on a preliminary basis. Analyses and studies on the social and environmental aspects of the reservoir area to be submerged by dam construction were made based upon the cost estimates for compensation for private properties in the reservoir area and the resettlement cost for the inhabitants concerned regardless of non-physical aspects such as sociological/environmental aspects.

a) Alternative Case Studies

The results of the alternative case studies on Case 1 to 8 on a preliminary basis for the selection of alternative cases are summarized as follows:

Case	Effective Storaged Capacity (MCM)	Project Area (ha)	Cropping Intensity (%)	Construction Cost excluding Price Escalation		Preliminary Estimated I.E.R.R. (%)
				Total (M฿)	Per rai (฿)	
Case-1	35	7,310	135	1,078	23,590	9.8
" 2	58	7,310	170	1,858	40,675	7.3
" 3	72	7,310	195	1,506	32,960	9.8
" 4	87	7,252	195	1,183	26,100	11.2
" 5	42	7,310	160	1,167	25,500	9.9
" 6	37	7,252	160	965	21,300	11.7
" 7	7	7,310	100	757	16,600	9.2
" 8	2	7,252	50	555	12,300	4.9

As for the lineation of the Project Area, the alternative case studies on Case 6, 6a, 6b and 6c on a preliminary basis clarifies that the case with the larger project area will attain higher a IERR than the case with the smaller project area.

This is shown by the following:

Case	Available Water Resources (MCM)	Project Area (ha)	Cropping Intensity (%)	Construction Cost excluding Price Escalation Total (M฿)	Construction Cost excluding Price Escalation Per rai (฿)	Preliminary Estimated I.E.R.R. (%)
Case-6	37	7,252	160	965	21,300	11.7
" 6a	37	6,339	170	852	21,500	11.6
" 6b	37	6,126	170	832	21,700	11.3
" 6c	37	5,213	185	791	24,300	10.3

b) Selection of Optimum Scale of Development

Social and environmental impact of the dam construction as well as the engineering and economical aspects should be carefully consideredfor for the alternative case studies.

According to the results of the field survey, the following points on the affected reservoir area should particularly be noted:

i) Losses of farm land

Case	Farm Land to be submerged
Storage Dam A	410 rai (0.9% of Project Area)
Storage Dam B	7,749 " (17.0% of Project Area)
Storage Dam C	9,314 " (20.4% of Project Area)
Storage Dam C	6,589 " (14.4% of Project Area)
Diversion Dam C	894 " (2.0% of Project Area)
Diversion Dam D	254 " (0.6% of Project Area)

ii) Number of families in Resettlement Area

Case	Family	Resettlement Area
Storage Dam A	22 families	260 rai
Storage Dam B	1,024 "	11,300 "
Storage Dam C	1,328 "	14,700 "
Storage Dam D	819 "	9,100 "
Diversion Dam C	103 "	1,200 "
Diversion Dam D	0 "	0 "

Compensation and resettlement of the affected reservoir area on storage dam B, C and D are too big and not on a practical scale for implementation. On the other hand, that of storage dam A and diversion dams C and D have much less influence and are possible choices for implementation.

In conclusion, alternative Cases 5 and 6 which are construction of the storage dam A with either the diversion dam C or D should be given priority and more detailed studies should be carried out for these.

4.2.2. Development Plan

1) Detailed Studies on Alternative Cases 5 and 6

For the detailed studies, a supplementary field investigation and survey on the selected dam sites and the Project Area were carried out during the second field works based on the data of actual topographical survey and geological exploratory boring. Design of storage dam A and the diversion dams C and D reported in the alternative case studies were modified somewhat due to topographical and geological conditions. Detailed information on this matter will be discussed in the later chapters.

The results of the detailed studies on Cases 5 and 6 for the proposed development plan are summarized as follows:

Description	Case - 5	Case - 6
Development Scheme	Storage Dam A with Diversion Dam C	Storage Dam A with Diversion Dam D
Effective Storage Capacity	42 MCM (35 + 7 MCM)	37 MCM (35 + 2 MCM)
Project Area (Cultivation Land)		
Present Area	52,200 rai (8,346 ha)	47,400 rai (7,576 ha)
Irrigable Area	50,600 rai (8,095 ha)	45,900 rai (7,349 ha)
Proposed Cropping Pattern		
Wet Season Crops		
Paddy	40,500 rai (6,480 ha)	36,400 rai (5,819 ha)
Upland Crops	10,100 rai (1,615 ha)	9,500 rai (1,530 ha)
Dry Season Crops		
Upland Crops	15,200 rai (2,430 ha)	16,100 rai (2,570 ha)
Total Annual Crops	65,800 rai (10,525 ha)	62,000 rai (9,919 ha)

2) Proposed Development Plan

According to the results of the detailed case studies on Cases 5 and 6 as shown in the table, the economic internal rate of return (EIRR) for Cases 5 and 6 are 13.6 per cent and 13.5 per cent, respectively, which are both higher than the opportunity cost of investment. Therefore, from the point of view of economics, both Case 5 and 6 can be said to be economically feasible.

However, since the Mae Chang Irrigation Project aims at the development of irrigated agriculture by the development of water resources, the amount of total storage capacity and usable water resources are much more important measures. The results of studies

made are based on the average meteorological and hydrological data.

In case of a drought year, the difference in storage capacity will be very effective in stabilizing the agricultural production and so.

It is recommended that the development of Case 5 should be given first priority and Case 6 second priority.

4.2.3. Land Use Plan

The proposed land use in the Project Area was studied on the basis of the data available for the present land use and land classification. The proposed land use in the Project Area is compared with the present land use as shown in Table 4.2-1, and the land use plan shown in Figure 4.2-1.

According to the result of land classification study, the groups of U1, U2, U2/R2, R1, R2, and R3 (8,346 ha, 72.5% of entire Project Area) are proposed to be used for cropping lands under irrigation. The lands belong to U1 and U2 groups (1,666 ha, 14.5%) are more suited for upland cropping than paddy cropping mainly due to the topographical condition and soil texture, therefore, those lands will be used for upland cropping such as tobacco and sugarcane etc. The lands belong to the groups of R1, R2, R3, and U2/R2 (6,680 ha, 58.0%) will be used for paddy cropping. Both groups of R1 and U2/R2, the lands (6,492 ha, 56.4%) can be used for double cropping, while the lands belong to R2 and R3 groups (188 ha, 1.6%) will be used for only paddy cropping in the wet season, but not in the dry season.

Most of the present forest lands, which are classified into U6/R6 group (2,135 ha), will be conserved their natural environment. But some parts of them will be converted to cultivation lands. These lands to be converted (635 ha) are mainly sparse secondary remainning after abandoned cultivation.

Table 4.2-1. Present and Proposed Land Use in the Project Area

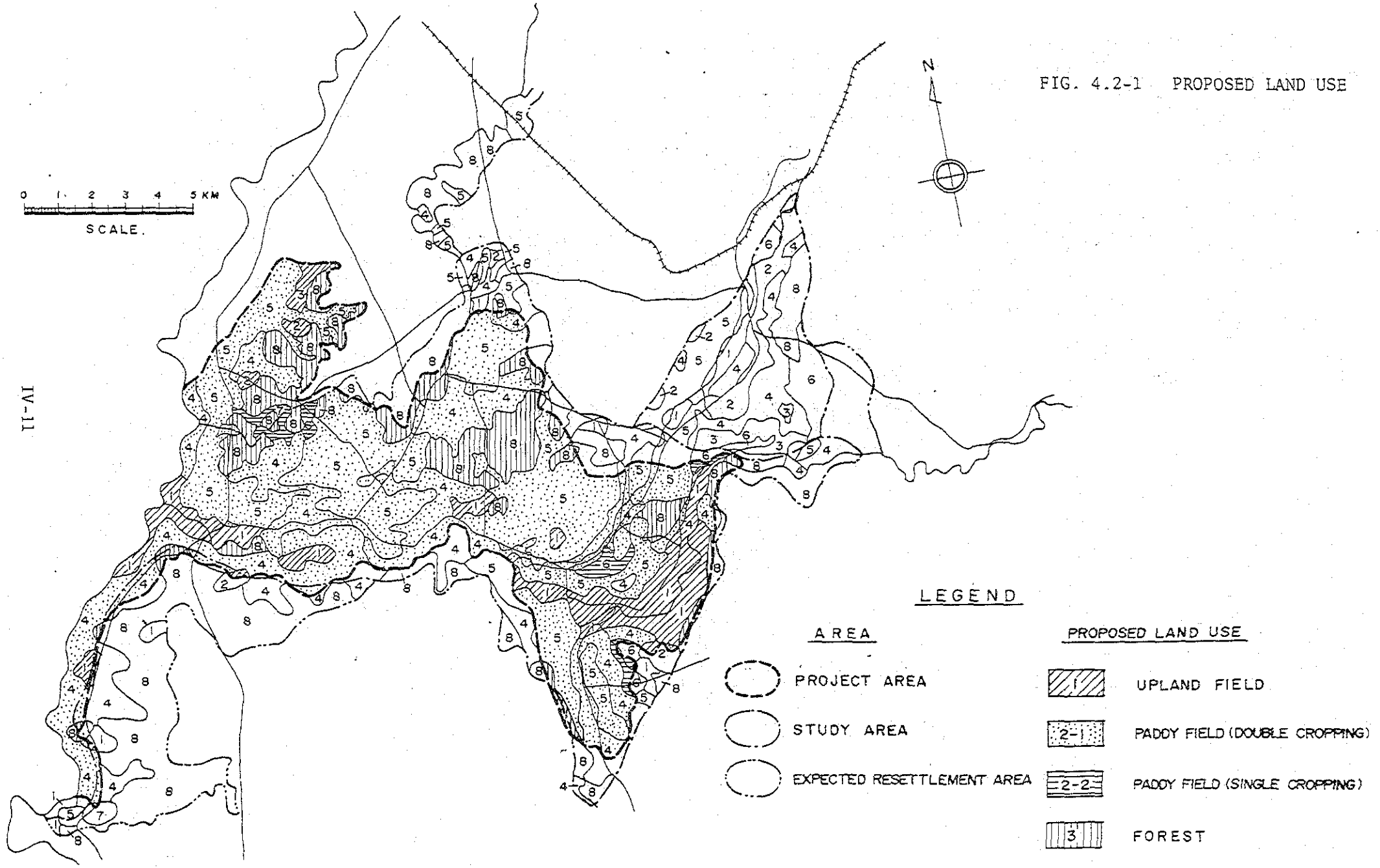
(Unit: ha)

Land Categories	Present Land Use				Proposed Land Use				Conversion
	Right Bank	Mae Wa	Sop Chang	Total	Right Bank	Mae Wa	Sop Chang	Total	
Cultivation Land	6,134	692	885	7,711	6,192	964	1,190	8,346[1/]	+ 635
Paddy	5,325	551	462	6,338	5,146	623	911	6,680	+ 342
Upland	809	141	423	2,373	1,046	341	279	1,666	+ 293
Forest	2,000	338	432	2,770	1,942	66	127	2,135	- 635
Village	770	92	133	995	770	92	133	995	-
Others[2/]	22	8	4	34	22	8	4	34	-
Total	8,926	1,130	1,454	11,510	8,926	1,130	1,454	11,510	-

1/ Double cropping rice and field crops; 8,158 ha, rice only; 188 ha

2/ River, pond etc.

FIG. 4.2-1 PROPOSED LAND USE



4.2.4. Irrigation Plan

1) Irrigation Water Requirement

Reference crop evapotranspiration (ETo) was estimated by the Penman method based on the meteorological data observed at Lampang Station.

The consumption for each proposed crop was obtained by multiplying the estimated ETo value by the crop coefficient which is determined based on the data listed in "Irrigation Water Requirement", Technical Release No.21, US Department of Agriculture and data observed actually at Mae Tang Crop Water Requirement Experimental Station, Changwat Chiang Mai, RID.

Irrigation water requirements for the proposed cropping pattern are obtained on the basis of the consumptive use of crops and additional water supply for land preparation of paddy and upland crops as follows:

Irrigation Water Requirements 1/ (Unit: mm)

Proposed Crops	Season	Water Requirement
Paddy	Rainy	813
Groundnuts	"	295
	Dry	425
Soybeans	Rainy	274
	Dry	368
Tobacco	"	447
Garlic	"	390
Sugarcane	Year Round	1,302

Note: 1/ Detailed computations are shown in Appendix 4.2-2.

The effective rainfall is defined in various ways depending on computation methods. In this study the effective rainfall is determined by the RID method as mentioned in Appendix 4.2.-2.

As regards the upland crops, the maximum effective rainfall was estimated at 38 mm in consideration of the available soil moisture measured in the Project Area. The following figures are selected for irrigation efficiencies:

Crops	Field Application Efficiency	Operation Efficiency	Conveyance Efficiency	Overall Irrigation Efficiency
Paddy	0.70	0.90	0.85	0.54
Upland	0.60	0.90	0.85	0.46

Diversion water requirements are calculated in considering the effective rainfall, irrigation efficiency, and irrigation water requirements. Such requirements by crops in the period of 1970 to 1981 are computed and their average values are given as follows:

Diversion Water Requirement (Unit: mm)

Proposed Crops	Season	Water Requirement
Paddy	Rainy	714
Groundnuts	"	193
	Dry	673
Soybeans	Rainy	167
	Dry	684
Tobacco	"	805
Garlic	"	746
Sugarcane	Year Round	1,368

2) Irrigable Area

The Project Area covers 50,600 rai (8,095 ha) of cultivated land in net, provided that intake water level is taken at EL 251 m

at the proposed diversion dam C (Case 5). On the other hand, in case such water level is at EL 248 m at the proposed diversion dam D (Case 6), the Area covers 45,900 rai (7,349 ha) of cultivated land in net.

Proposed Irrigable Area (Unit: rai)

Case	Sub Area			Total
	Right Bank	Mae Wa	Sop Chang	
Case 5 - Gross[1/]	38,700	6,000	7,500	52,200
- Net	37,600	5,800	7,200	50,600
Case 6 - Gross[1/]	35,200	4,900	7,300	47,400
- Net	34,100	4,800	7,000	45,900

Note: Cultivated land only

3) Design Discharge for Irrigation Canal

According to the proposed cropping pattern, the maximum water requirement occurs on the last day of paddy land preparation.

The design discharge of main and lateral irrigation canals is thus determined at 1.30 liter/sec/ha, taking into consideration the weighted average of maximum water requirements on paddy and upland crops and irrigation efficiency.

4) Upland Field Irrigation Schedules

Infiltration Rate

The infiltration test in the field which is essential for the upland field irrigation schedules on upland crops was conducted at

five places during the field survey, taking the land classification and the conditions of present land use into account.

To measure the infiltration rate, a cylinder infiltrometer was used and the reading of the water depth within the cylinder was made at the interval of every five to 10 minutes at the initial stage and 30 minutes after one hour.

Results of the infiltration rate measurements were plotted on a logarithmic paper, by which the basic infiltration rate was obtained by 2.1 mm/hr on an average. This figure shows that the furrow irrigation method will be suitable for upland crops.

Depth and Interval of Irrigation Application

In parallel with measurements of the infiltration rate, soil samples were taken to analyze the physical properties such as specific gravity, porosity, field capacity, and wilting point. of the soils in the field.

Average Physical Properties of Soil

Real Specific Gravity	(g/cm^3)	2.62
Apparent Specific Gravity	(g/cm^3)	1.32
Porosity	(%)	49.6
Field Capacity	(%)	16.7
Wilting Point	(%)	7.5

In the conditions as above, depth and interval of irrigation application are determined as below:

Depth and Interval of Irrigation Application

Depth (TRAM)	(mm)	38
Maximum Evapotranspiration	(mm/day)	4.5
Irrigation Interval	(days)	9

4.2.5. Reservoir Plan

The water balance simulation study has been conducted for the following two cases.

Case-5 Dam A + Diversion Dam C
Case-6 Dam A + Diversion Dam D

1) Water Balance Study

A water balance study on the reservoir has been made with a unit interval of ten days from 1952 to 1981. The date of this study is as follows.

* Reservoir Size

The reservoir size was determined during the second field survey (Refer to 4.4.1. - 4.4.3.)

* Capacity and Area Curves of the Reservoir

For the capacity and Area curves of each reservoir, refer to 4.4.1. - 4.4.3.

* Reservoir Loss

The annual evaporation amount from the reservoir surface is estimated to be 1,470 mm on the average.

Average Monthly Evaporation

(Unit: mm)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.
W-15 (Dam Site C)	82.3	107.0	153.7	197.8	157.6	146.3	129.7
	Aug.	Sep.	Oct.	Nov.	Dec.	Total	
	117.9	110.8	98.7	87.9	80.0	1,469.7	

* Reservoir Inflow

Inflow into reservoir A and diversion dam C and D is estimated as shown in Table 3.2-6.

The planned inflow is estimated for the planned catchment area, each catchment area is shown as below:

	Planned Catchment Area		
Dam or Div. Dam	Dam A	Div. Dam C	Div. Dam C
Catchment Area	403 km^2	254 km^2	283 km^2

* Water Demand

Water demand refers to irrigation water and base flow. Such demands as domestic water and factory water are negligibly small, and would be covered by the return flow of irrigation water. The following are the irrigation water and base flow for each case.

	Irrigation Water	Base Flow
Case-5	69.7 MCM	0.05 m^3/s
Case-6	66.7 "	0.05 "

2) Optimum Reservoir Size

From the results of the water balance study on the reservoir and diversion dam as mentioned in the previous sub-section, the following have been clarified.

Item	Case-5 Dam A + D. Dam C	Case-6 Dam A + D. Dam D
Total Storage Capacity	40 + 7 MCM	40 + 2
Effective Storage Capacity	35 + 7	35 + 2
Irrigation Demand	69.7	66.7
Cropping Intensity	130%	135%

3) Reservoir Operation

Reservoir operation is required to supply the irrigation demand and release water to the downstream as base flow. Advance reservoir water release for the purpose of flood control has not been taken into consideration. Hydropower generation will also be in conformity with the water release for irrigation demand from Storage Dam A.

a) Verification of Water Balance Study on the Reservoir

The water balance study on the reservoir over a period of 30 years has revealed that water shortages have occurred six times, once each in 1962, 1967, 1977, 1979 and 1980, as shown in Tables 4.2-2, 4.2-3 and Figures 4.2-2, 4.2-3.

These phenomenon was analyzed, utilizing rainfall data at A. Mae Tha and runoff data, as shown below;

i) 1962 water year: Annual runoff was more than average, but 87 per cent of the annual runoff flowed into the reservoir during September and October. Most of the runoff flowed downstream as spill discharge. There was a shortage of effective runoff for this reason.

ii) 1967 water year: Similar to 1962 water year, 77 percent of the annual runoff flowed into the reservoir. A large amount of the runoff flowed downstream as spill discharge. Therefore, the amount of runoff lost as spill discharge could not be utilized as irrigation water.

iii) 1977 water year: Annual runoff was equal to a probability of 1/6 drought year. There was scarcely any runoff from May to July in the wet season. Furthermore, the previous year was equal to a probability of 1/10 drought year, and

reservoir capacity did not recover to full water level, resulting in a shortage of water.

iv) 1979 water year: Both rainfall and runoff showed a probability of a 1/46 drought year. For the water balance simulation, this year can be excepted from the study.

v) 1980 water year: Annual runoff was equal to a probability of 1/17 drought year. The influence of previous extreme drought year was continued until this year which revealed a shortage of water.

From the above-mentioned analysis, droughts occurred 5 times and 1979 and 1980 water years were years of exceptional shortage of water.

Therefore, there was damage to agricultural production from the water shortage.

The 1981 water year has more than average runoff. From the water balance simulation, reservoir capacity was estimated to recover to full water. Therefore, water shortage year are estimated to and after two years.

Accordingly, from the results of the water balance simulation, the following case revealed that drought years once every ten years, are suitable to this project study.

		Case-5	Case-6
Cropping Intensity	(%)	130	135
Cropping Area	(ha)	10,525	9,919
Wet Season	(ha)	8,095	7,349
Dry Season	(ha)	2,430	2,570

Table 4.2-2 Water Balance Simulation

Case 5, Cropping Intensity 130%

Main Dam Reservoir (MCM)				Diversion Dam (MCM)					
Spill A(13)	Short-age A(12)	Water Supply A(9)	Inflow to Reservoir A(1)	Spill A(4)	Short-age A(5)	Inflow to Diversion Dam A(2)	Water Require-ment A(3)	Annual Rainfall (mm)	Year
(6.18)	(0)	(0)	(1.72)	(0)	(0)	(0.85)	(9.08)	867.9	1952
104.45	0	20.20	129.28	41.09	20.20	63.64	58.59	1225.8	1953
25.01	0	50.41	74.47	16.84	50.41	36.66	81.45	1063.0	1954
60.17	0	45.51	106.08	40.13	45.51	52.22	71.06	1009.8	1955
45.44	0	35.76	85.63	21.85	35.76	42.15	70.07	1103.3	1956
53.88	0	35.06	100.07	29.03	35.06	49.26	67.21	1118.5	1957
7.32	0	53.21	55.41	13.63	53.21	27.28	76.34	956.2	1958
157.09	0	29.90	198.34	77.90	29.90	97.64	65.66	1448.4	1959
52.89	0	33.60	93.62	26.60	33.60	46.09	67.30	1128.0	1960
28.13	0	41.87	73.43	22.70	41.87	36.15	72.05	952.0	1961
77.65	4.00	40.76	125.30	46.15	40.76	61.68	63.49	1050.1	1962
75.31	0	22.85	100.89	26.08	22.85	49.67	62.83	1083.6	1963
109.41	0	33.08	147.16	54.43	33.08	72.44	64.17	1324.7	1964
30.62	0	49.27	71.99	24.64	49.27	35.44	73.23	899.5	1965
17.84	0	45.69	69.31	18.46	45.69	34.12	75.08	945.0	1966
36.22	10.67	48.74	94.28	30.36	48.74	46.41	72.94	1039.5	1967
45.50	0	41.61	93.55	25.17	41.61	46.06	76.85	1173.7	1968
97.13	0	34.90	136.69	47.26	34.90	67.29	65.98	1284.1	1969
104.95	0	31.72	140.79	42.84	31.72	69.31	71.53	1215.8	1970
83.96	0	34.01	120.04	42.80	34.01	59.10	62.06	1122.9	1971
10.43	0	40.95	59.06	10.47	40.95	29.08	69.60	1025.8	1972
85.44	0	34.18	124.52	38.28	34.18	61.30	66.61	1321.7	1973
69.98	0	31.88	106.97	34.86	31.88	52.67	67.45	1127.7	1974
86.78	0	25.52	115.76	39.23	25.52	56.99	55.86	1322.6	1975
7.38	0	44.94	51.29	5.55	44.94	25.25	69.90	940.7	1976
8.50	15.65	48.08	61.60	17.10	48.07	30.33	67.89	1146.5	1977
145.15	0	25.87	178.12	55.37	25.87	87.69	74.34	887.6	1978
0	15.87	73.43	28.45	4.24	73.43	14.01	87.01	810.1	1979
0	20.60	54.09	41.06	10.19	54.09	20.22	73.78	980.6	1980
(0)	(12.16)	(17.72)	(0)	(0)	(17.72)	(0)	(17.72)	1133.9	1981

Table 4.2-3 Water Balance Simulation

Case 6, Cropping Intensity 135%

Main Dam Reservoir (MCM)				Diversion Dam (MCM)					
Spill A(13)	Short-age A(12)	Water Supply A(9)	Inflow to Reservoir A(1)	Spill A(4)	Short-age A(5)	Inflow to Diversion Dam A(2)	Water Require-Ment A(3)	Annual Rainfall (mm)	Year
(5.80)	0	(2.61)	(1.72)	0	(2.61)	(0.98)	(8.66)	867.9	1952
93.88	0	28.82	129.28	50.66	28.82	73.41	56.83	1225.8	1953
25.71	0	51.10	74.47	20.81	51.10	42.29	77.38	1063.0	1954
55.77	0	51.11	106.08	47.29	51.11	60.23	67.67	1009.8	1955
39.82	0	39.30	85.63	26.45	39.30	48.62	67.04	1103.3	1956
51.04	0	39.33	100.07	35.22	39.33	56.82	64.51	1118.5	1957
5.14	0	53.82	55.41	17.05	53.82	31.46	33.17	956.2	1958
152.58	0	36.45	198.34	91.36	36.45	112.63	63.10	1448.4	1959
44.46	0	40.02	93.62	33.02	40.02	53.16	64.67	1128.0	1960
22.57	0	48.86	73.43	27.17	48.86	41.69	68.89	952.0	1961
75.20	3.17	42.86	125.30	55.77	42.86	71.15	61.13	1050.1	1962
66.82	0	28.96	100.89	32.89	28.96	57.29	60.69	1083.6	1963
102.84	0	39.98	147.16	65.00	39.98	83.56	61.86	1324.7	1964
26.00	0	54.99	71.99	29.36	54.99	40.88	69.96	899.5	1965
12.45	0.82	51.44	69.31	22.73	51.44	39.36	71.65	945.0	1966
39.09	10.21	50.31	94.28	37.60	50.31	53.53	69.76	1039.5	1967
39.67	0	47.13	93.55	47.13	31.98	53.12	73.16	1173.7	1968
94.07	0	38.13	136.69	57.15	38.13	77.62	63.41	1284.1	1969
97.31	0	37.43	140.79	52.43	37.43	79.95	68.43	1215.8	1970
81.99	0	37.52	120.04	50.95	37.52	68.16	59.94	1122.9	1971
7.74	0	42.84	59.06	13.65	42.84	33.54	66.70	1025.8	1972
84.88	0	34.81	124.52	46.95	34.81	70.71	64.01	1321.7	1973
63.74	0	38.18	106.97	41.43	38.18	60.74	64.62	1127.7	1974
82.01	0	32.03	115.76	47.07	32.03	65.72	54.31	1322.6	1975
7.49	0	44.28	51.29	8.47	44.28	29.12	67.01	940.7	1976
7.33	15.16	49.96	61.60	21.56	49.96	34.98	65.11	1146.5	1977
139.22	0	31.73	178.12	66.73	31.33	101.13	70.15	887.6	1978
0	13.15	69.66	28.45	5.28	69.66	16.15	82.31	810.1	1979
0	21.66	55.39	41.06	12.51	55.39	23.31	70.52	980.6	1980
0	(13.23)	(18.62)	(0)	(0)	(18.62)	(0)	(18.62)	1133.9	1981