No. 10

KINGDOM OF THAILAND

MASTER PLAN STUDY REPORT ON NAM YUAM RIVER BASIN HYDROELECTRIC DEVELOPMENT PROJECT

SUMMARY

MARCH 1987

JAPAN INTERNATIONAL CORPORATION AGENCY

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NAM YUAM RIVER BASIN
HYDROELECTRIC DEVELOPMENT
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PREFACE

In response to the request of the Government of the Kingdom of Thailand, the Japanese Government has decided to conduct a Master Plan survey on the Nam Yuam River Basin Hydroelectric Development Project and entrusted the survey to the Japan International Cooperation Agency. JICA sent to Thailand a survey team headed by Mr. Yasuo Takashima, Electric Power Development Co., Ltd., four times from July, 1985 to December, 1986.

The team had discussions with the officials concerned of the Government of Thailand and conducted a field survey in the Nam Yuam basin in Northern Thailand. After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of the Kingdom of Thailand for their close cooperation extended to the team.

March, 1987

Keisuke Arita

KEISUKE ARITA
President
Japan International Cooperation Agency

Nam Mae Ngao Dam Site

View from upstream
(End of rainy season)

Nam Mae Rit Dam Site

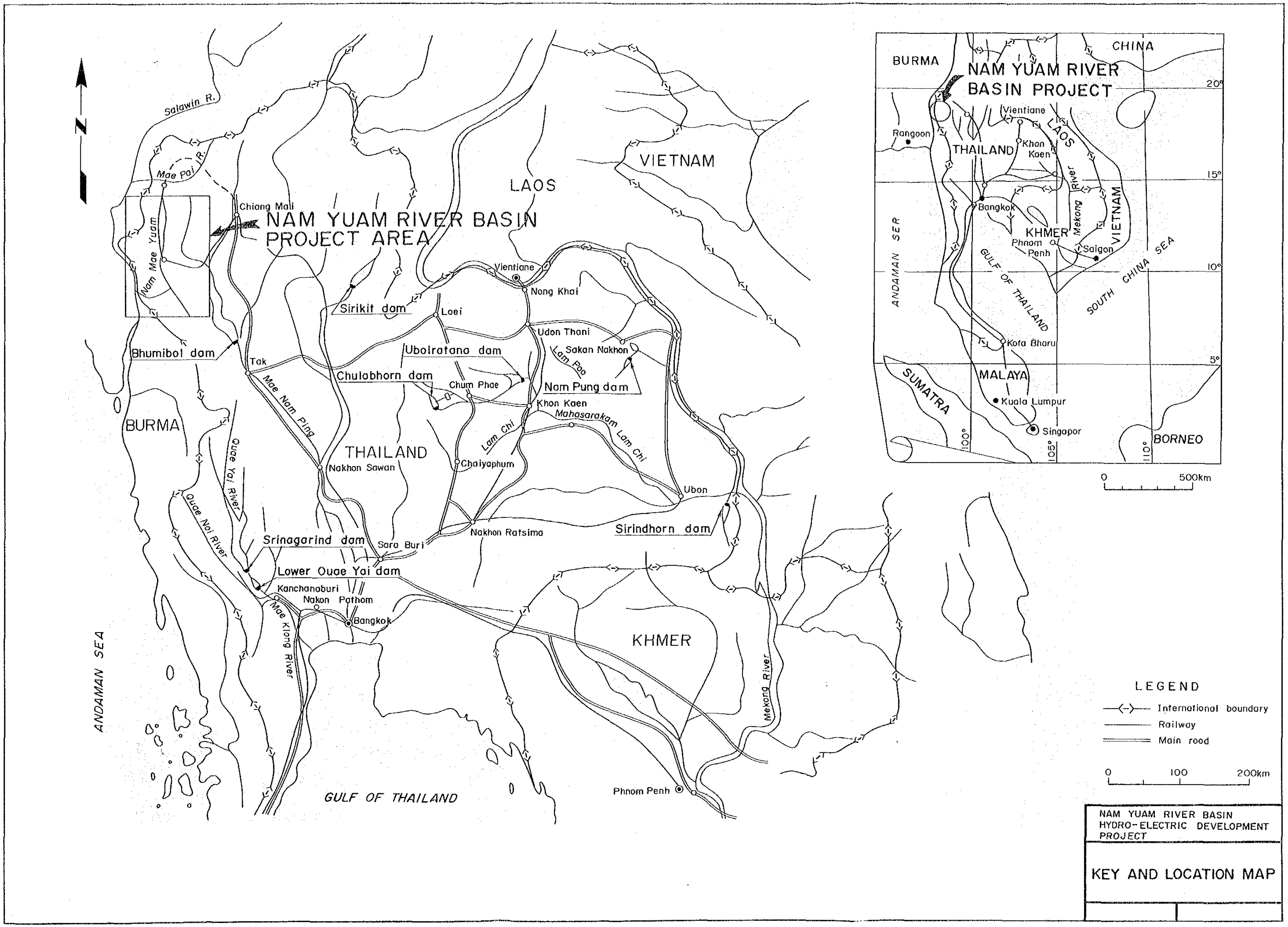
View from down stream
(End of rainy season)

Upper Yuam 1 Dam Site

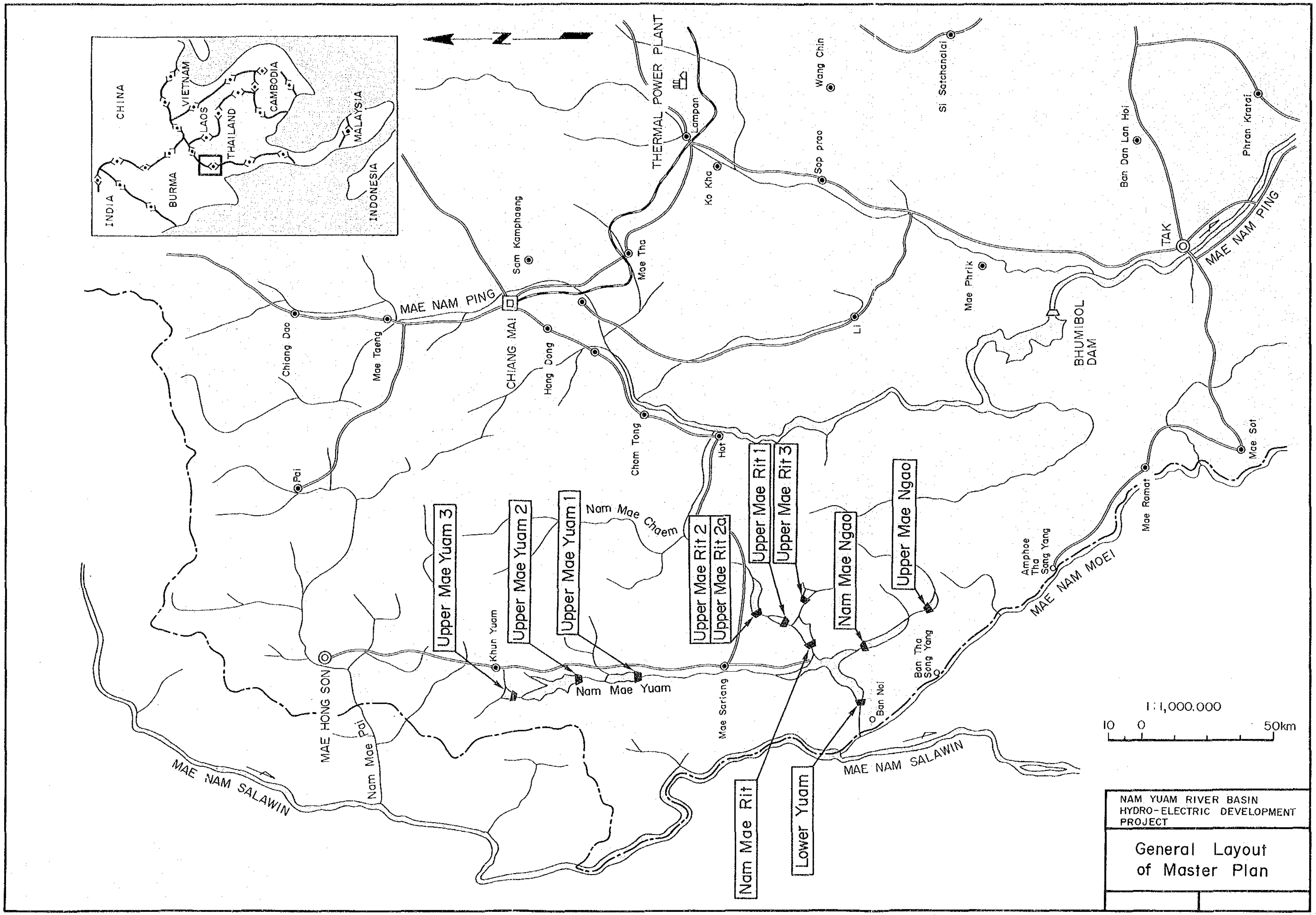
View from down stream
(End of rainy season)

Upper Yuam 2 Dam Site

View from up stream
(End of rainy season)



N
Salawin R.
Mae Pai R.
Chiang Mai
NAM YUAM RIVER BASIN
PROJECT AREA
Nam Mae Yuam
LAOS
VIETNAM
Vientiane
Nong Khai
Sirikit dam
Loei
Udon Thani
Sakan Nakhon
Lam Pao
Bhumibol dam
Tak
Ubolratana dam
Chulabhorn dam
Chum Phae
Nam Pung dam
Khon Kaen
Mahasarakam
Lam Chi
Mae Nam Ping
BURMA
THAILAND
Chaiyaphum
Nakhon Sawan
Quae Yai River
Quae Noi River
Ubon
Sirindhorn dam
Srinagarind dam
Sara Buri
Nakhon Ratsima
Lower Quae Yai dam
Kanchanaburi
Nakon Pathom
Bangkok
Mae Klong River
KHMER
Mekong River
ANDAMAN SEA
GULF OF THAILAND
Phnom Penh
BURMA
CHINA
NAM YUAM RIVER
BASIN PROJECT
Vientiane
LAOS
Rangoon
THAILAND
Khon Kaen
Mekong River
VIETNAM
Bangkok
KHMER
Phnom Penh
Saigon
ANDAMAN SEA
GULF OF THAILAND
SOUTH CHINA SEA
Kota Bharu
SUMATRA
MALAYA
Kuala Lumpur
Singapor
BORNEO
20°
15°
10°
5°
100°
105°
110°
0 500km
LEGEND
International boundary
Railway
Main road
0 100 200km
NAM YUAM RIVER BASIN
HYDRO-ELECTRIC DEVELOPMENT
PROJECT
KEY AND LOCATION MAP



NAM YUAM RIVER BASIN
HYDRO-ELECTRIC DEVELOPMENT
PROJECT

General Layout of Master Plan

CONTENTS

Table List

Figure List

CONCLUSION AND RECOMMENDATION

(1) Conclusion

The total installed capacity of electric power generating plants in Thailand is about 6,500 MW as of 1985. The annual increasing rates of the energy demands for the next 10 years are estimated to be 6% for the whole EGAT system and 10% for the Northern Region where the proposed projects are situated.

According to the load forecast, made by "the Load Forecast Working Group in Thailand", the peak power generation in 2000 will be 10,154 MW and the energy generation in the same year will reach 62,780 GWH in the EGAT whole system.

Further, EGAT forecast that the power and energy demand of Northern Region of Thailand in 1994 will reach 855 MW and 3,700 GWH level respectively. Extrapolating on the basis of these forecasts, the JICA team estimated that the power and energy demands of the region in 2000 would be grown up to 1,220 MW and 5,500 GWH respectively.

The present master plan study is concerned with the study on the hydroelectric power development plan in the Nam Yuam River Basin. (the Yuam River, the Ngao River and the Rit River).

Among nine projects preset by EGAT, four projects; Upper Mae Yuam 1, Nam Mae Rit, Upper Mae Rit 2a and Nam Mae Ngao were firstly ranked higher than others through the first stage study. The ensuing detailed stages of the study have revealed that Nam Mae Ngao No.2 Project was the most promising project from both technical and economical view points.

According to the final result, the installed capacity and the annual energy generation of Nam Mae Ngao No.2 Project are 120 MW and 250 GWH respectively.

This project has many prominent features that the runoff quantity of the Ngao River is plentiful (specific runoff 50 lit/sec/km^2 of this river is a rare value observable in rivers in Thailand), that the peak power supply capacity can be obtained without construction of a downstream equalization pondage, that the access road to the project site is already completed and that there are no significant environmental nor submergence problems forseen in the project area. These considerations lead to the conclusion that the construction of this project can be started immediately after the usual steps will be taken properly.

Therefore, it is an urgent need to proceed into the feasibility study with a provision that the high water level, tail water level, maximum turbine discharge, installed capacity, etc. should be re-examined in more detail.

Since the remaining three projects have less economic feasibility judging from the present study result, it is expected that these projects will be implemented in future when the economic circumstances will be improved.

(2) Recommendation

It is concluded that the feasibility study should be started as early as possible. In order to conform with this conclusion, the following works are recommended to be performed continuously.

1) Detailed survey of the Nam Mae Ngao Project area, in particular, levelling survey between Nam Mae Ngao Project and Lower Yuam Project.

2) Hydrological observation and/or data collection

   (a) for gaging stations at Ban Mae Ngao, Ban Mae Suat and Ban Wang Khan (EGAT)

   (b) for gaging stations at Ban Tha Rua and Sop Han (NEA)

   (c) for irrigation water-take and spilled water over the weir of the Mae Sariang irrigation facility (RID)

3) Geological test boring

   The location and quantities of the bore holes are shown on Fig. 3-5 and Table 3-2.

1. INTRODUCTION

1.1 Outline of the Projects Area

The Yuam river is a tributary of the Moei river which forms the boundary between Thailand and Burma. After merging the Yuam river, the Moei river joins with the Salawin river which rises from Tibet, flows down through Burma and finally drains into the Andaman Sea.

The Yuam river basin, therefore, is located in the northwestern corner of Thailand, and ranges over approximately 60 km in the east and west and 160 km in the north and south directions, having the catchment area of slightly more than 6,000 square kilometers.

Mountains of 1,000 m high class lie in a row in the north and south direction of the Yuam river basin, forming the topographic feature of a long basin. The center town is Mae Sariang (about 20,000 of population) belonging to the district of Changwat Mae Hong Son. The Yuam river originates at the northern end of the basin, flows south and merges the Rit river at the point of about 35 km south to Mae Sariang. After merging the Rit river, the Yuam river flows down south more 5 km to a confluence point of the Ngao river which is also a tributary but running up from the opposite direction, south to north. The Yuam river then turns the flows to west almost in right angle and joins with the Moei river near Hoei Varieu, a downstream hamlet of the Lower Yuam project site.

The national highway No. 108 connecting Changwat Chiang Mai and Amphoe Mae Sariang runs the east foot of Mt. Doi Inthanon (2,595 m high), which is the highest in Thailand, passes Amphoe Chom Thong, goes over the plateau in the east side of the Yuam river basin along the Chaem river, a tributary of the Ping river. The total distance between Changwat Chiang Mai and Amphoe Mae Sariang is approximately 200 km.

The midstream area of the basin is well developed in various irrigation facilities. Particularly, intake facilities have been constructed by the Royal Irrigation Department (RID) across the main river at the point about 13 km upstream of Amphoe Mae Sariang and a main irrigation canal, which has the capacity of about 3 m^3/sec, runs down on the right-bank tableland.

1.2 Background of the Project

Thailand's economic growth rate in 1970's marked at 7.4%, following Hong Kong, South Korea, Taiwan, Singapore, etc., being prominent in the Asian developing nations. Particularly, the growth of its industrial sector was significant, doubling the share in the whole economy compared with that in 1960's.

The installed capacity of electric power generating facilities of EGAT is 6,460 MW and the generated energy is 23,357 GWh in 1985. Composition of power source consists of 1,814 MW in hydro plant (28.1%) and 4,646 MW in thermal plant (71.9%).

Electricity demand increasing rates in the future, according to estimation by the "Load Forecast Working Group for Power Tariff Sub-committee", will reduce gradually from the estimated annual rate of 14% in 1983, to 6.5% in 1991, and afterwards it will continue almost constantly at the annual rate of 6%.

The electricity demand in 1991 is estimated to be 6,199 MW of power and 37,349 GWh of energy being about double of 3,204 MW and 19,066 GWh of those in 1983. Even after 1991, an annual increase of demand is considered to be 400 MW to 500 MW and 2,400 GWh to 3,200 GWh respectively.

The oil fired power generation shares large portion of the current electricity generation.

It is, therefore, significant for economic stability of the country to develop oil substitutive projects by utilizing indigeneous energy sources such as natural gas, lignite, hydropower etc., suppressing the increase of oil importation as much as possible under the government policy.

The main hydroelectric power resources development in Thailand has been carried out in large-scale projects such as Bhumibol (420 MW) on the Ping river, Sirikit (375 MW) on the Nam river, Srinagarind (360 MW) on the Quae Yai river and Khao Laem (300 MW) on the Quae Noi river. At present Chiew Larn (240 MW) is almost completed, and moreover Nam Chon (580 MW) which is planned in the upstream of

Srinagarind Dam is awaiting for the commencement of construction. As a result of these developments, it may be that the remaining possible large-scale hydroelectric power resources are limited mainly in the basin of the international rivers such as the Mae Khong river and the Salawin river, existing along the boundary. However, the Mae Khong river projects include internationally-complicated factors, so that it is very hard to imagine that the development will be realized in the near future. Under such circumstances, keen attention has been focussed recently to the Salawin river basin especially to the Yuam river basin, a tributary of the Salawin river and the investigation works necessary for the development has been carried out in these years.

Standing on the abovementioned background, the Master Plan has been projected by EGAT to formulate the Yuam river basin hyroelectric development as a whole thereby taking into consideration of the Lower Yuam project which has already been studied by NEA under the cooperation of JICA.

1.3 Outline of the Project

The study on the development plan was proceeded in two stages and an additional stage.

At the first stage, 9 sites for the master plan study were selected and the first field investigation and desk study on the basis of topographical maps of 1:50,000 were carried out. As the result of the first stage study, the 4 sites, Nam Mae Ngao, Nam Mae Rit, Upper Mae Rit 2a and Upper Mae Yuam 1, were found to be of high priority from economical point of view.

The second stage included the second field investigation for the 4 sites and the detailed study. Nam Mae Ngao site turned out to be of the highest priority.

The outline of the 9 sites is presented as follows.

Project Name	Dam Height (m)	HWL (m)	Total Storage (MCM)	Installed Capacity (MW)	Annual Energy Produc-tion(GWh)
Upper Mae Yuam 1	62	325	421.4	18.5	54.5
Upper Mae Yuam 2	65	380	178	11.4	37.0
Upper Mae Yuam 3	62	477	67.6	4.1	13.0
Nam Mae Rit	87	270	85.7	24.0	61.5
Upper Mae Rit 1	66	407	19.4	10.3	42.5
Upper Mae Rit 2					
Original	63	585	13.5	6.1	28.0
Alternative A	38	560	3.2	11.2	43.6
Upper Mae Rit 3	64	490	15.8	10.4	42.7
Nam Mae Ngao	114	260	661.2	116.9	245.2
Upper Mae Ngao	80	340	43.2	9.1	33.2

2. LOAD FORECAST

2.1 Load Forecast Review for Whole EGAT System

Electric power demand in the EGAT system has been increased at a surprising rate during the past 15 years. A peak power generation at 743 MW in 1970 has grown up to 3878 MW (5.2 times) in 1985 and an annual energy generation increased from 4095 GWh to 23357 GWh (5.7 times) during the same period.

The average annual growth rate of the peak power and energy generation are therefore 11.6% and 12.3% respectively. Considering the fact that during this period the oil crises hit the world twice and the economic activities in many other countries in the world had been stagnated quite a long time, these growth rates are very dominant and reflect the viability of Thailand's economy.

Based on these actual growth records, the load forecast for the next 16 years (1986 - 2001) has been made by the Load Forecast Working Group in Thailand. According to this forecast the peak power generation in 2001 will be 10154 MW (i.e. 2.6 times that of 1985) and energy generation in the same year will reach 62780 GWh (i.e. 2.7 times that of 1985). The average growth rates correspond to 6.2% and 6.4% respectively. Although decreased a little, these growth rates imply that the economic activities in this country for the next 16 years will still go up as vigorously as it has been.

The annual load factor of the whole EGAT system was 62.47% in 1970. It rose up to 70.69% in 1979 and after that stays within a 67% - 71% band width. (see Fig. 2-1)

These show that a pattern of power consumption in this country, especially in the greater Bangkok area is approaching to that of a developed country.

However as the country as a whole, a potential power demand seems still great. The load factor for the next 16 years will not be improved so much. This is reflected in the load forecast that the factor will remain at around 67 - 71% level increasing slightly from 68.75% in 1985 to 70.58% in 2001. (see Fig. 2-1)

2.2 Load Forecast Review for Whole PEA'S Service Area

PEA (Provincial Electricity Authority) supplies electric power to the whole country except Greater Bangkok area. The growth rate of PEA is much more than that of EGAT whole system. A power demand of 318 MW in 1973 was boosted to 1684 MW in 1984. This is in fact 5.1 times that of 1973 or an average 16.0% annual growth rate during these 11 years. The annual load factors also come up from 54.81% in 1973 to 55.25% in 1984.

In the past, many non-electrified rural areas were existed in Thailand, and only for very limitted areas were supplied power by isolated diesel power plants.

From the mid 70's, EGAT and PEA poured an especial effort to expand the power supply capabilities and to eliminate the non-electrified areas. As the results, almost 80% of the non-electrified villages had then been energized up to 1984.

The expansion program also included those areas which are nearer and surrounding the main demand centers as well as powering up the demand centers themselves.

All of these efforts have resulted in the miraculous growth rate as above described.

The power and energy demand in 1994 will be 4123 MW and 21876 GWh or 2.4 times and 2.7 times those of 1984 respectively. The corresponding average growth rates are 9.3% and 10.3% annually. (see Fig. 2-1)
Annual load factors will also go up from 55.25% in 1984 to 60.57% in 1994 which is a faster improvement than that of the whole EGAT system.

2.3 Load Forecast for Northern Region

According to the PEA's classification, Northern Region consists of 3 sub-regions, i.e. Northern Region I, Northern Region II and Northern Region III.

This area is almost the same region which is classified as Region 4 according to the EGAT definition, consisting of 16 provinces in the north and the northern part of the central areas.

The main load centers in the Northern Region are Chiang Mai, Nakhon Sawan, Chiang Rai, Phitsanulok, Phrae, etc. of which the biggest one is Chiang Mai, the second largest city in Thailand.
Since the Nam Yuam hydro power projects situate within this region, it is of especial necessity to study the power demand in the region.

According to actual records and forecast values by EGAT, power and energy demands in the Northern Region have soared up from 68.66 MW and 282.92 GWh in 1972 to 335.62 MW and 1350.04 GWh in 1984 or 4.9 times and 4.8 times respectively. These correspond to an average annual growth rates of 14.1% and 13.9% respectively which are almost comparable with PEA's whole service area as described in the foregoing section.

The annual load factor was fluctuated from 47.03% in 1972 to 45.93% in 1984. (see Fig. 2-1)

Note that the absolute values themselves of these factors are still pretty lower than those of PEA's whole service area.

As for the forecast, the power and energy demands will grown up to the levels of 855 MW and 3700 GWh in 1994 respectively or the expected average annual growth rates of 9.8% and 10.6% for the following 10 years. (1984 - 1994).

At the same time, annual load factor will be raised from 45.93% in 1984 to 49.41% in 1994.
But the growth rates for both power and energy will gradually slow down to around 7% in 1994 and the annual load factor approaches 50%.

So far as we have reviewed, the forecast up to 1994 have been confirmed to be reasonable.

Now therefore basing upon these forecasts, we will extend them further by the simple extrapolation method which will be highly supported by judgement.

According to these results, the power demands of the Northern Region will be 904 MW in 1995, 1221 MW in 2000, 1573 MW in 2005, 1935 MW in 2010 and 2719 MW in 2020.

2.4 Main Power Supply Area of Nam Yuam Hydroelectric Projects

The proposed installed capacities of Nam Yuam hydropower plants, Nam Mae Ngao, Nam Mae Rit, Upper Mae Yuam, etc. will range from about 10 MW to 120 MW as will be studied in later chapters.

It is tentatively assumed that the first target year is 2000 and that at least two of the Nam Yuam hydroelectric projects will have been operated.

As we have studied in the previous sections, power demands in 2000 will be 9680 MW in the whole EGAT system and 1,220.5 MW in the Northern Region.

Thus the proposed installed capacities of the Nam Yuam hydroelectric projects are very small if compared to the power demand of the whole EGAT system and even if they are compared with that of the Northern Region, they are only a fraction of it.

The Yuam river basin situates in the north-western part of Thailand, remotes about 700 km from Bangkok.

The electric power generated by the Nam Yuam hydroelectric projects will be transmitted to the Lamphun Substation over a 230 KV transmission line. The distance from the Yuam river basin to Lamphun is about 200 km and from Lamphun to Bangkok is about 500 km.

Since the Chiang Mai area is the biggest demand center in the Northern Region, it is most probable that the energy generated by the Nam Yuam hydroelectric projects will be absorbed in this region.

This supposition is also the most economical way with regard to the power flow because otherwise the power shall be transmmitted to the Bangkok area over 700 Km long transmission line.

The power demand in the greater Bangkok area will be supplied mainly by Bhumibol (535 MW), Sirikid (375 MW), Srinagrarind (360 MW) and Khao Laem (300 MW), all are situated nearer to the metropolitan area than the Nam Yuam hydroelectric projects. Thus in the following study, the Northern Region is set as the power supply area of the Nam Yuam hydroelectric projects.

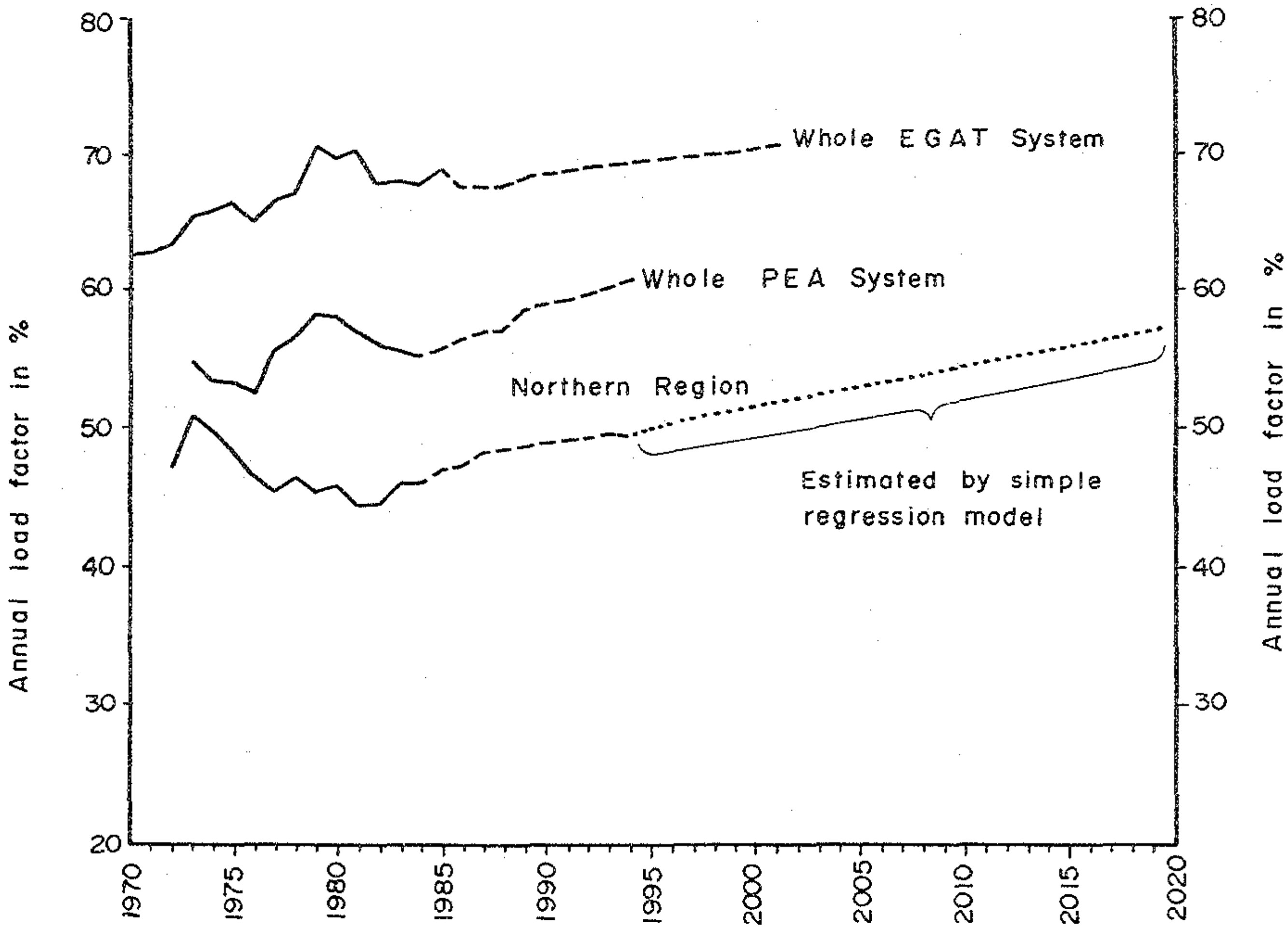


Fig. 2–1 Annual Load Factor

Source: E G A T: POWER DEVELOPMENT PLAN (1986-2001), Nov. 1985, Table 3-2, P.9, and
LOAD FORECAST WORKING GROUP: LOAD FORECAST, Sep. 1985, Table 2-4, P.8.

3. GEOLOGY

3.3 Topography and Geology of Project Area

3.3.1 Topography

The Yuam river rises from the vicinity of Khun Yuam near 19° north latitude and 98° east longitude, flows south through the Mae Sariang basin for approximately 120 km, eventually changes its course to the west, merges with the Moei river which is a major tributary of the Salawin river, after which it merges with the Salawin river comprising the border between Thailand and Burma.

Meanwhile, the Rit river, which is one of the tributaries of the Yuam river rises from the vicinity of 18°15' north latitude and 98°15' east longitude, changes its course from south to southwest, and then west, joining the Yuam river after running for about 50 km. As for the Ngao river which is the first of the tributaries of the Yuam river, it flows in the north-northwest direction for approximately 40 km from the vicinity of 17°40' north latitude and 98° east longitude to merge with the Yuam river.

A broad basin is developed along the Yuam river from near its fountainhead to the vicinity of about 25 km south of Mae Sariang, but downstream from this point and along the Ngao river is generally a steep gorge.

The catchment of the Yuam river basin of area approximately 6,000 km^2 extends north-south in a slender shape, being approximately 30 to 50 km in width and approximately 160 km in length.

The western boundary of the Yuam river basin consists of a mountainous terrains of around EL. 1,000 m which extends in a straight line southward from Mt. Wi Cho Lo (EL. 1,056 m), while the eastern boundary is the mountainous terrains extending southward at elevations of 1,500 to 1,800 m from Mt. Phate Do (EL. 1,821 m).

3.3.2 Geology

The project area, as shown in Fig. 3-1, consists mainly of Paleozoic and Mesozoic sedimentary rocks, and Mesozoic granite.

Paleozoic formations ranging from Cambrian to Carboniferous age may be divided into formations which are mainly non-calcareous rocks and the Ordovician formations which are mainly limestone. The former are widely distributed centered at the southern and eastern parts of the project area, while the latter are distributed in band-form in the north-south direction inside the formations that are mainly non-calcareous rocks.

Paleozoic formations ranging from Carboniferous to Permian age and Triassic formations are both mainly of non-calcareous rocks and are distributed making up most of the northwestern part of the project area.

Granite is intruded in Paleozoic formations at the entire eastern part of the project area and is distributed in the north-south direction as a slender rock body approximately 10 to 20 km in width.

Mesozoic orogenic movements of the two time phases of latest Triassic to Jurassic and Jurassic to Cretaceous have occurred in the northern part of Thailand including this area, the present geologic structure being dominated by this orogenic movement, and structures in the north-south to northwest-southeast directions are prominent. This project area, because of the influence of the above, has strikes of strata, strikes of folds, and strikes of remarkable faults that are chiefly north-south to northwest-southeast.

3.4 Outline of Geology of Nam Mae Ngao No. 2

1) Reservoir

The geology of the reservoir consists mainly of alternating beds of sandstone and shale, with lenses of limestone intercalated in small scale.

Moreover, at the part higher than high water level at the both banks, thick limestone beds are distributed.

Linearments are predominant along the Ngao River which are distinct and have good continuity.

One lineament passing through the right bank of the dam site and having the best continuity was confirmed to be a fault zone from the results of drilling.

2) Dam Site

The geology of the dam site consists mainly of alternating beds of sandstone and shale.

Further, the limestone bed has been confirmed at the ridges of both-bank sides.

Terrace deposits, river deposits, and talus deposits are distributed as surface deposits overlying the abovementioned bedrock.

The strikes of the formations are N30° - 50°W and roughly constant, whereas dips are 60° - 80°SW at the upstream part and 70° - 80°NW at the downstream part, so that an anticline having its anticlinal axis in the NW-SE direction is estimated to exist at the left-bank side of the dam axis.

The river-bed portion and parts of low elevation at the right and left banks consist of bedrock with no problem as a foundation of a rockfill dam with respect to both load bearing capacity and permeability. However, limestone is assumed to be intercalated with the alternating beds of sandstone and shale in parts.

Weathering is prominent at the ridge portion on the left-bank side, and there is a problem regarding load bearing capacity.

Moreover, since the thickness of the ridge is small, there will be a problem of watertightness, if the strongly weathered portion distributes at part lower than high water level.

Since limestone is assumed to be interbedded at the left abutment and ridge, there will be a problem of watertightness.

There is a possibility that two fault zones exist at the right abutment.

The limestone is distributed at the right-bank ridge. Since the thickness of the ridge is small, being 150 to 200 m near the dam axis, there will be a problem of watertightness.

3.4.7 Further Investigation Works

Nam Mae Ngao No.2 dam site is considered to be most promissing among the above mentioned six dam sites. Therefore, further geological investigation works for the Nam Mae Ngao No. 2 dam site are recommended as follows;

1) Reservoir

Surface geological investigation

to grasp the distribution and the properties of limestone, hydrogeological conditions and stabilities of slopes in the reservoir area and to confirm the results of aerophoto interpretation which support the supposition that the posibility of leakage from the reservoir is small.

2) Dam site

Surface geological investigation

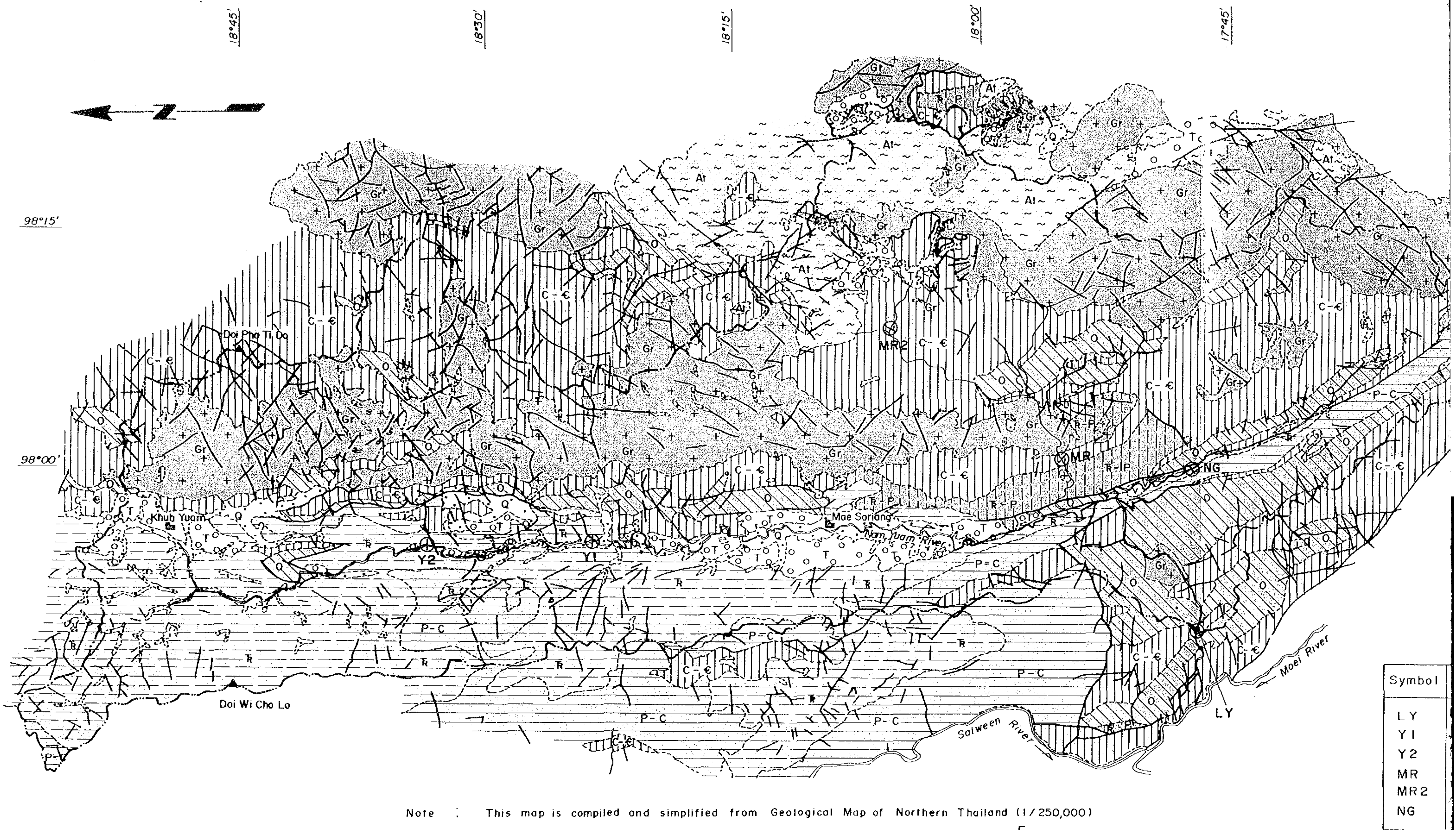
to confirm the detailed geological structure and distribution of limestone around the dam site.

Drilling

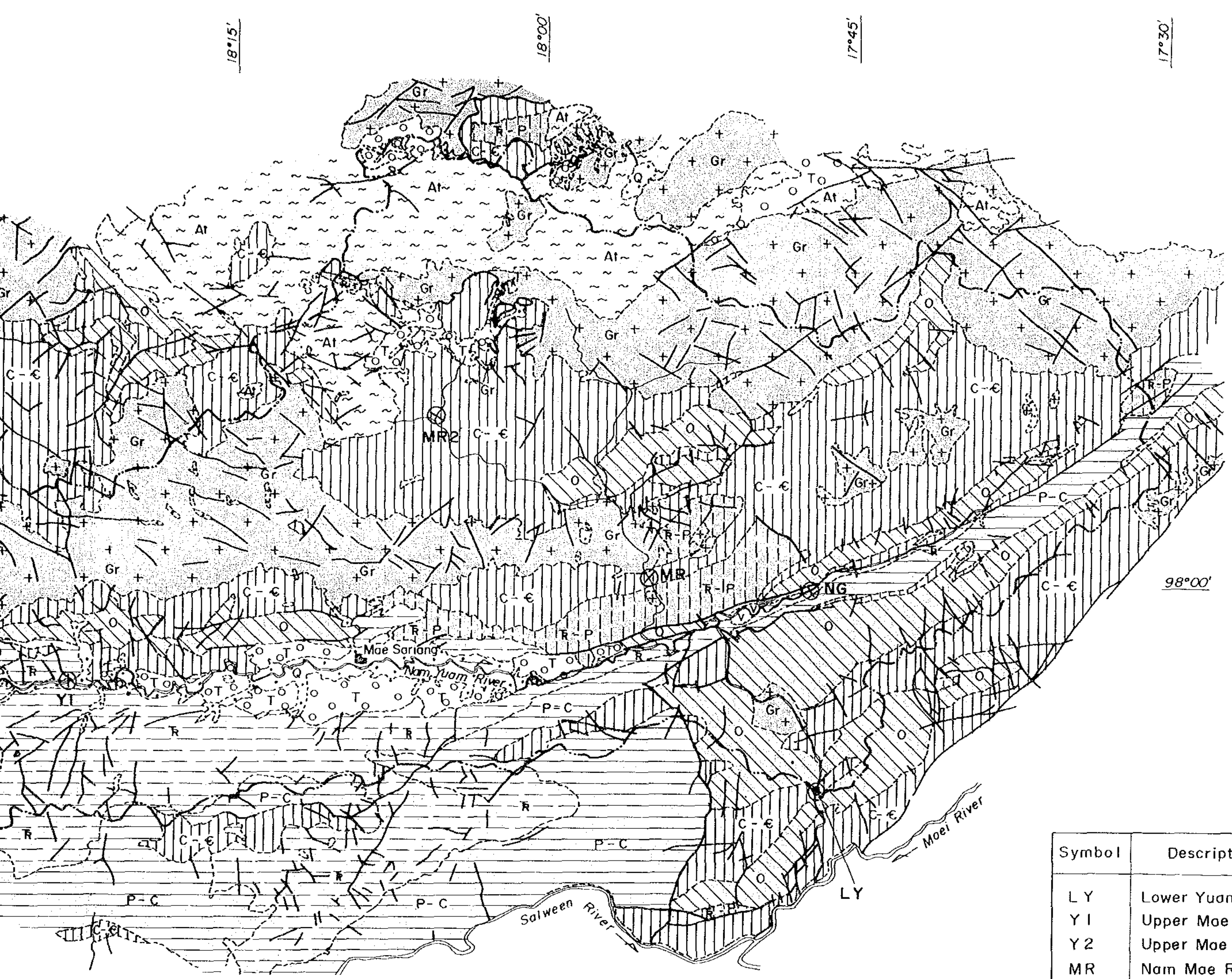
The contents, locations and quantities are indicated in Fig. 3-5 and Table 3-2.

Table 3–2 Additional Drill Hole in Nam Mae Ngao No. 2 Dam Site

Site	Hole No.	Coordinate		Elevation (m)	Direction	Length (m)
Dam	DR-5	1967, 005N	393, 630E	178.0	S70°W, 60°	100.0
	DR-6	1967, 050N	393, 770E	215.0	90°	60.0
	DR-7	1967, 090N	393, 915E	265.0	90°	100.0
Right-bank side ridge	DR-8	1967, 120N	394, 015E	310.0	90°	100.0
Dam	DL-3	1966, 960N	393, 480E	220.0	90°	60.0
	DL-4	1966, 925N	393, 375E	260.0	90°	100.0
Left-bank side ridge	DL-5	1966, 620N	393, 085E	270.0	90°	70.0
	DL-6	1966, 685N	393, 015E	310.0	90°	100.0
	DL-7	1966, 690N	392, 955E	305.0	90°	100.0
Total		9 Holes		790m		



Note : This map is compiled and simplified from Geological Map of Northern Thailand (1/250,000) prepared by German Geological Mission in 1981 and Geological Map of Thailand ⌜CHANGWAT CHIANG MAI⌟ (1/250,000) prepared by ROYAL THAI Department of Mineral Resources in 1970.



LEGEND

Cenozoic	Quaternary	Q	Gravel, Sand
Cenozoic	Tertiary	T	Conglomerate, Sandstone, Shale
Mesozoic	Triassic	Ŧ	Conglomerate, Shale, Sandstone, Limestone, Chert
Mesozoic	Triassic ~ Permian	Ŧ-P	Shale, Sandstone, Limestone
Paleozoic	Permian ~ Carboniferous	P-C	Sandstone, Shale, Chert, Conglomerate, Limestone
Paleozoic	Ordovician	O	Limestone, Shale
Paleozoic	Carboniferous ~ Cambrian	C-Є	Shale, Chert, Limestone, Sandstone
		~At~	Anatexitic aureole of Paleozoic granite with relics of lower Paleozoic and Precambrian rocks
		Gr	Granite
		Ba	Basalt
			Geologic boundary
			Fault

0 20 km

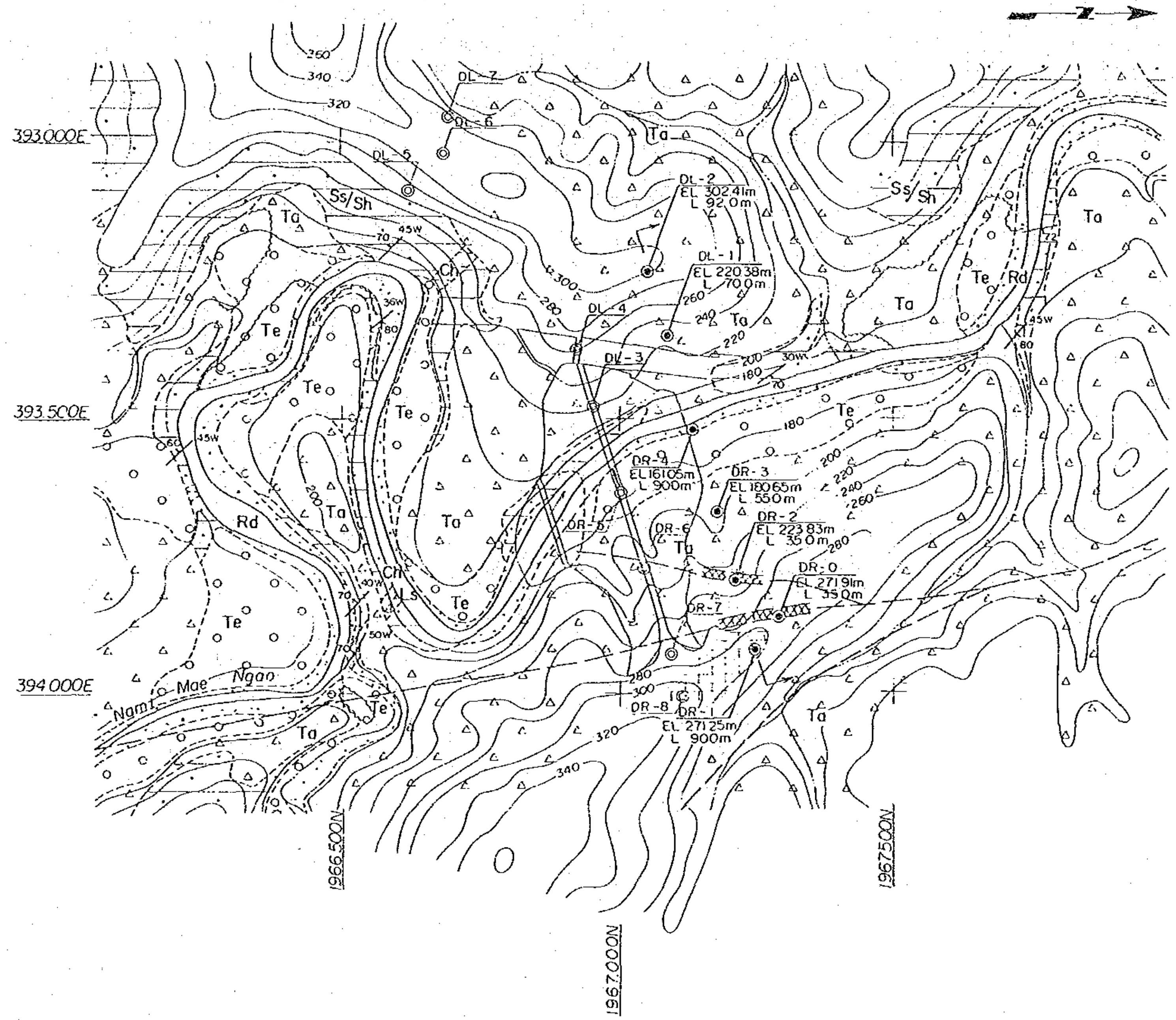
Symbol	Description
LY	Lower Yuam
Y1	Upper Mae Yuam 1
Y2	Upper Mae Yuam 2
MR	Nam Mae Rit
MR2	Upper Mae Rit 2a
NG	Nam Mae Ngao

p is compiled and simplified from Geological Map of Northern Thailand (1/250,000) d by German Geological Mission in 1981 and Geological Map of Thailand ⌈CHANGWAT MAI⌋ (1/250,000) prepared by ROYAL THAI Department of Mineral Resources in 1970.

NAM YUAM RIVER BASIN
HYDROELECTRIC DEVELOPMENT PROJECT

GEOLOGY
CATCHMENT AREA PLAN

Fig. 3-1



LEGEND

Ta	Topsoil, Talus deposit
Rd	River deposit
Te	Terrace deposit
Ss/Sh	Alternation of sandstone and shale
Ls	Limestone
Ch	Chert

70 50w — Strike and dip of strata

Geologic boundary

Fault (Confirmed)

DR-1 — Drill hole

Additional drill hole for feasibility study (Proposed)

Ditto (Inclined drill hole)

PLAN

0 — 500m

NAM YUAM RIVER BASIN
HYDROELECTRIC DEVELOPEMENT PROJECT

GEOLOGY

NAM MAE NGAO NO.2 DAMSITE

PLAN

Fig. 3-5

4. Meteorology and Hydrology

4.1 Meteorological Outline in the Project Area

The project area belongs to a tropical monsoon region, and the annual climate undergoes the strong effect of monsoons. Namely, in the season of May to October, during which south-west monsoon from the Bay of Bengal is strong, there is a large amount of rainfall in the area, forming the rainy season, and on the contrary, in the season of November to April, during which northeastern monsoon coming from the continent blows strongly, makes the dry season. The annual average precipitation is approximately 1,300 mm.

Temperature is high through the year, about 27°C on an average. Particularly, in April which is just before the rainy season, the daily highest temperature reaches almost 40°C. December and January which are in the dry season is the lowest temperature period in the year, and the daily lowest temperature goes down to 10°C or so.

Humidity is also high through the year. It is about 85% in the plain at midstream of the basin and over 90% in the southern mountaineous region of the basin. March and April in the end of the dry season are the least humid months through the year, and it is 60% or so sometimes. In other months, humidity is almost constant.

Annual average evaporation in the basin is about 1,300 mm measured by Class A Pan. It is large in the midstream area and northern area of the basin and small in the southern area thereof. Evaporation is largest in March and April, the end of the dry season.

4.2 Gaging Stations and Weather Observatory Stations in the Yuam River Basin

1) Gaging Stations

In the Yuam river basin, several runoff gaging stations and weather observatory stations have been operated by NEA, EGAT and MD (Meteorology Department) as shown in Table 4-1 and Fig. 4-1. The periods of observations are summarized in Fig. 4-2.

Of these gaging stations, Sop Han (NEA) and Ban Tha Rua (NEA) have been operated more than 16 years.

Three new gaging stations have recently been set up by EGAT for observation of runoffs of Ban Mae Ngao, Ban Mae Suat and Wang Khan.

2) Weather Observatory Stations

Five weather observatories are in the area, as shown in Fig. 4-1. Meteorological parameters are measured at those observatories.

In addition to the above observatories, three new observatories have been built by EGAT at the same place of new gaging station; Ban Mae Ngao, Ban Mae Suat and Wang Khan.

Table 4—1 Gaging and Observatory Stations of Nam Yuam River Basin

NO.	River	Station	Location	Code	Drainage Area (km^2)	Period
1	Nam Mae Yuam	Sop Han	Lat. 18°12.2' N Long. 97°56.1' E	NEA	2496	1966-
2	Nam Mae Yuam	Ban Tha Rua Pha Lae	Lat. 17°50' N Long. 97°54.8' E	NEA	5770	1968-
3	Nam Mae Rit	Ban Mae Suat	Lat. 17°53'30"N Long. 97°57'48"E	EGAT	1376	ARR.1.1983-
4	Nam Mae Ngao	Ban Mae Ngao	Lat. 17°51'18"N Long. 97°58'12"E	EGAT	935	MAY 1.1984-
5	Nam Mae Yuam	Ban Wang Khan	Lat. 18°23'18"N Long. 97°58'12"E	EGAT	1974	MAY 12.1984-
6	Nam Mae Yuam	Rid Weir	Lat. 18°21'56"N Long. 97°56'06"E	RID	2617	1976-
7		Mae Sariang	Lat. 18°9.8' N Long. 97°58' E	MD	—	1950-

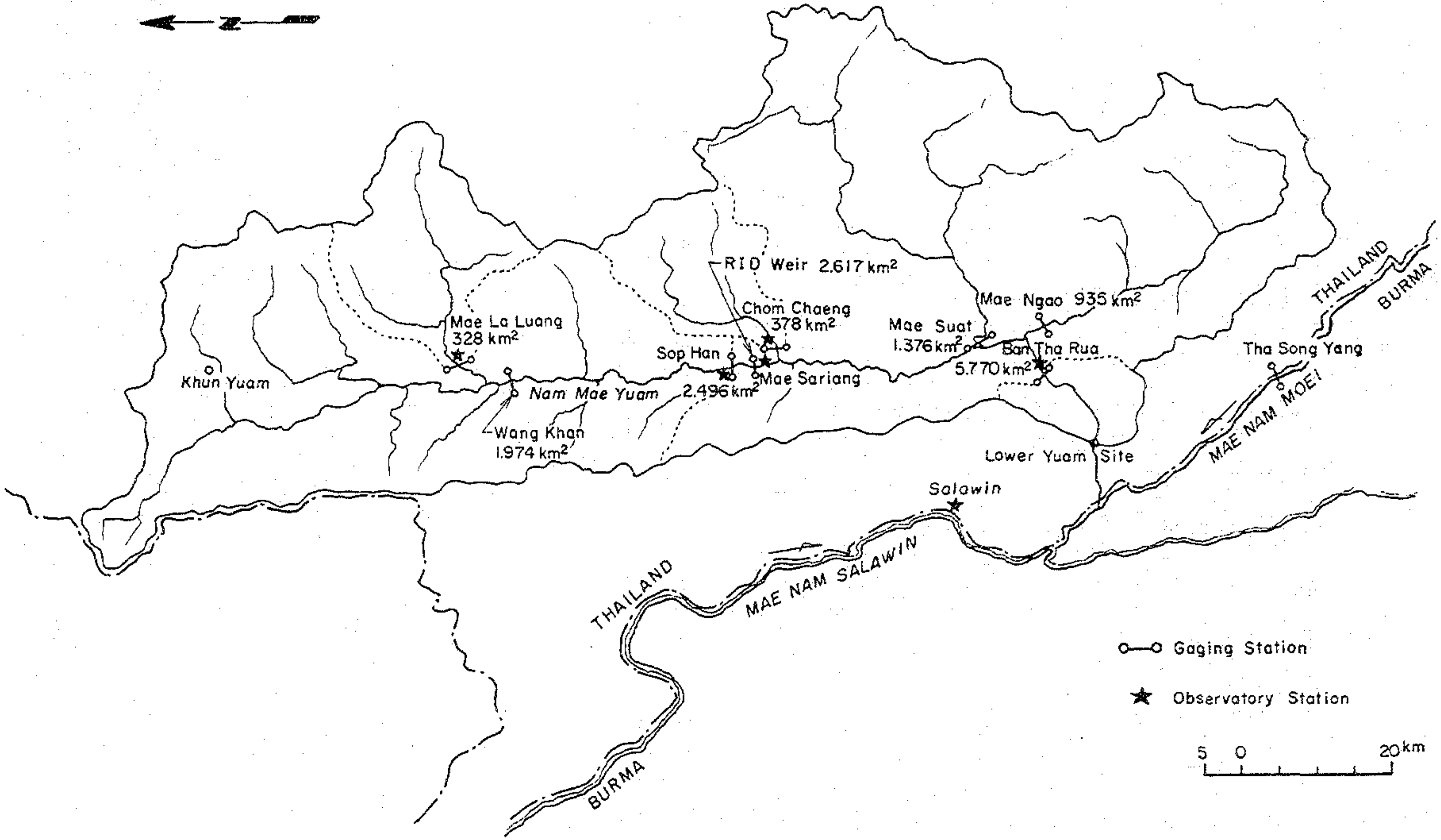


Fig. 4–1 Gaging and Observatory Stations

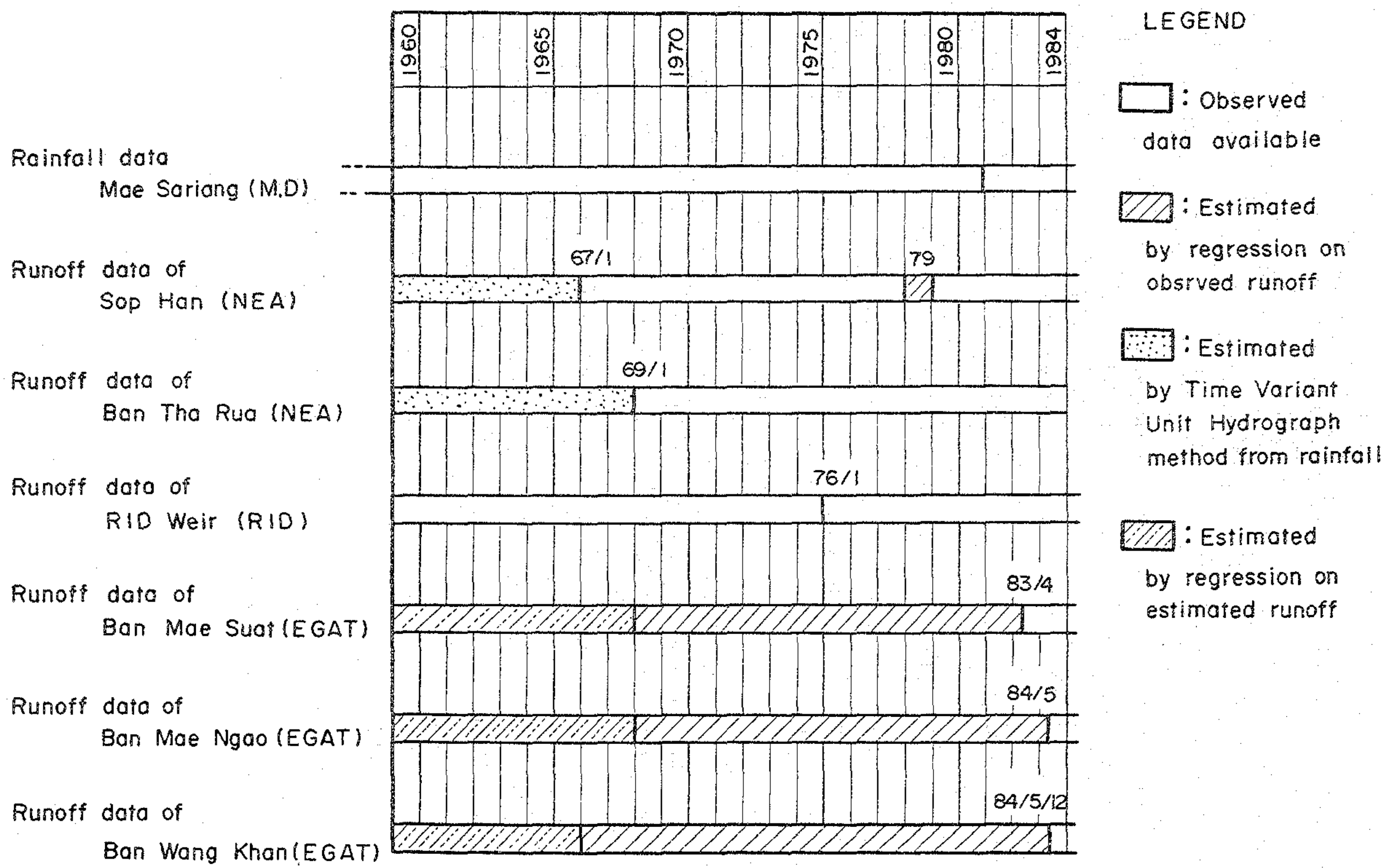


Fig. 4–2 Observed & Estimated Periods of Runoff Data, Nam Yuam River Basin

5. DEVELOPMENT PLAN

5.1 Basic Items

1) Location of the Dam Site

The projects to be studied in the Master Plan are nine (9) projects, illustrated on the Fig. 1-1.

The basic figures of the projects are shown on Table 5-1.

2) Catchment Area and Storage Capacity Curve

The three kinds of topographical map listed below can be utilized.

Scale	1:250,000	whole river basin
Scale	1:50,000	- ditto -
Scale	1:5,000	Nam Mae Ngao, Nam Mae Rit and Upper Mae Yuam 1

The measurement of both catchment area and storage capacity curve has been made by EGAT using 1:50,000 scale map and handed over to the JICA survey team during the first field survey.

The team checked the catchment area and the area-capacity curve of each project. The exactitude of the catchment area measured by EGAT has been confirmed and the value was adapted for the inflow calculation as shown on Table 5-1. Regarding to the area-capacity curves, some discrepancies have been found out. So the team checked the area-capacity curve again using 1:25,000 scale map, enlarged from 1:50,000.

However, final volumes were measured by 1:5,000 scale map for the major three planned reservoirs; Nam Mae Ngao, Nam Mae Rit, and Upper Mae Yuam 1 in the second stage.

5.2 Procedure for Study of Development Plan

1) Study Procedure

The study of the development plan is to be made divided into the three stages described below.

a. First Stage

The principal objective of the first stage is to find out the economical feasibility of the planned projects; Nam Mae Ngao, Nam Mae Rit, Mae Upper Mae Yuam 1 and other six projects, at the preliminary study level.

Comparison studies are made for individual projects varying dam heights, effective storage capacities, installed capacities, etc.

The study results are described in Clause 5-3.

b. Second Stage

Taking into account the study result in the first stage, the selected projects are examined more in detail.

In the study, Lower Yuam on which the feasibility study was already completed in 1984, is regarded as if it is an existing power station therefore the increment of power and energy of the station is considered to be an additional benefit.

The study results are described in clause 5-4.

c. Additional Stage

In the additional stage, following studies have been made, based upon the third minutes of meeting.

i) Detailed optimization study of Nam Mae Ngao No.2, applying the up-dated fuel prices which were given by EGAT.

ii) Study of the incremental benefit of Lower Yuam due to the regulation effect of Nam Mae Ngao No.2 applying the same up-dated fuel prices.

The study results are described in the clause 5-5.

5.3 Individual Development Plan (First Stage Study)

The projects to be studied in the first stage study of the Master Plan are nine pre-selected projects.

Number of main cases studied in this stage including some alternative cases are as following:

Upper Mae Yuam 1	.....	12 cases
Upper Mae Yuam 2	.....	12 cases
Upper Mae Yuam 3	.....	3 cases
Nam Mae Rit	.....	12 cases
Upper Mae Rit 1	.....	4 cases
Upper Mae Rit 2	.....	9 cases
Upper Mae Rit 2a	.....	3 cases
Upper Mae Rit 3	.....	4 cases
Nam Mae Ngao (Site No.2)	.....	16 cases
Nam Mae Ngao (Site No.3)	.....	8 cases
Upper Mae Ngao	.....	9 cases
Total:		92 cases

Reservoir operation study was performed for each case to maximize the firm capacity, firm energy and secondary energy given the various high water levels and low water levels (i.e., given the various effective heads and various effective reservoir capacities).

The details of the study results were included in the "Interim Report, Master Plan Study on Nam Yuam River Basin Hydroelectric Development Project, Nov. 1985" and the computer output volumes submitted and explained to EGAT in November 1985, so that those details have not been attached here.

The summary of the study results are shown on Table 5-14-1. On this table, only the most economical case among several cases studied is listed for each of the nine projects. (Note that either Upper Mae Rit 2 or Upper Mae Rit 2a constitutes one project, and either Nam Mae Ngao Site No.2 or Nam Mae Ngao Site No.3 will be Mae Ngao Project.)

It is seen also that Nam Mae Ngao Site No.2 is the most promising project (B/C = 1.67, rank 1) followed by Upper Mae Rit 2a (rank 2), Nam Mae Rit (rank 3), Upper Mae Yuam 1 (rank 4), etc. in this order.

The B/C ratios of these four upper ranked projects are nearly equal to or greater than 1.0. Taking into account of these results and other relevant information as described in the following subsections, it is judged that the above four projects were deserved for the objects of the next stage of study.

5.4 Selected Main Project (Second Stage Study)

In this stage, further detailed studies were performed for the four main projects selected in the first stage study.

Main items studied more in detail are as following:

1) 1:5,000 scale map prepared by EGAT was used as against 1:50,000 scale map used for the first stage study.

2) Evaporation loss from the proposed reservoir surfaces was estimated and deducted from the inflow so that net inflow were input to the reservoir simulation program. In order to estimate the loss, however, pre-simulation of the reservoir operation was needed to obtain the monthly variation of the reservoir surface area.

3) Three daily plant factors, 0.15, 0.20 and 0.25 were adopted for comparison purpose as against only one daily plant factor of 0.25 in the first stage study.

4) High water levels and low water levels were varied with narrower intervals than those adopted in the first stage study taking into account the new information collected through the second field survey.

5) Runoff regulation effect of Nam Mae Ngao on Lower Yuam was newly studied. The incremental benefit due to this effect will be described in the later section.

6) Several transmission line routes were compared for formulating the optimal transmission scheme. The details of the study are contained in Chapter 7.

7) Irrigation benefit which would be expected to accrue from the development of Upper Mae Yuam 1 was studied. Although the details of the study are explained in Chapter 10, the result shows up a negligible incremental irrigation benefit.

However, following basic values were unchanged from those adopted in the first stage study.

a) Fuel prices, other relevant costs and coefficients of the alternative thermal power plants which were used for the economic evaluation of the hydro power projects.

b) Discount rate, 10%

Based upon the above new information and additional requests for the variation of basic values, the number of cases studied in the second stage excluding pre-run cases for evapolation loss estimation has come up to:

Upper Mae Yuam 1	3 cases
Nam Mae Rit	12 cases
Upper Mae Rit 2a	8 cases
Nam Mae Ngao	24 cases
Effect on Lower Yuam	8 cases
Total:	55 cases

Among these, only Upper Mae Rit 2a was studied using 1:50,000 scale map and Upper Mae Yuam 1 was studied belatedly to others after the 1:5,000 scale map was availed to the team on September 1986.

The reservoir operation study was performed for each case employing the same procedure as adopted in the first stage study.

The details of the results were included in the "Master Plan Study on Nam Yuam River Basin Hydroelectric Development Project, Study Result (Second Stage), June, 1986", "The Master Plan Study on Nam Yuam River

Basin Hydroelectric Development Project, The Second Progress Report, August 1986" and in particular, the computer output volumes submitted and explained to EGAT in June 1986.

From these results it is seen that Nam Mae Ngao (No.2 Site) Case (1) is most economical for individual development scheme, but from the view point of integrated development scheme, Nam Mae Ngao plus Lower Yuam is most superior.

All the other projects, Upper Mae Yuam 1, Nam Mae Rit and Upper Mae Rit 2a resulted in the B/C ratios less than 1.0. Therefore, the key projects in the Nam Yuam river development planning should be Nam Mae Ngao and Lower Yuam which are to be further studied in the next stage of the study.

5.5 Additional Study

When the first stage and the second stage studies were being proceeded in 1985, the world oil price was at its highest level so that the evaluations of the benefit of the hydropower projects were made based upon that highest price level.

However, from the beginning of 1986 to around July 1986 the oil price has come down drastically to the present low price level and remains, it seems, calmly at this price level.

Although there are no assurances the price level would rocket up again, it was requested that the benefits of the hydro power projects selected in the previous stages should be re-evaluated based on the present low price level from a conservative view point.

Discussion was held between EGAT officials and team members at the end of the June 1986 on the fuel costs which would be adopted in the additional stage of study.

The finally concluded fuel costs are shown on Table 5-23 as base case and summarized and compared with those adopted in the previous stages in the same table.

It is seen that the adopted diesel oil price at 3.68 ฿/lit of the base case is only 56% of the one at 6.6 ฿/lit adopted in the previous stage.

Moreover, it is requested also that the fuel prices should be varied on several levels to see the impact of the oil price reduction on the project economy.

Accordingly, in the additional stage, following number of cases were studied

Nam Mae Ngao (Individual Development)	6 cases
Lower Yuam (Individual Development)	6 cases
Nam Mae Ngao & Lower Yuam (Integratd Development)	6 cases
Total:	18 cases

However, the reservoir operations themselves undergo no change from the ones studied in the second stage.

Using these results, economic evaluation of the projects were performed for the various fuel cost cases as above described.

The result of the base case calculation shows that the B/C ratio of Nam Mae Ngao individual development project has come down to 1.2 from that of 1.3 attained in the second stage of study.

Also, the B/C ratio of the Nam Mae Ngao and Lower Yuam integrated development scheme reduced from the previous stage value of 1.4 to 1.3.

Even these reduced values, however, are well above the ballance point of B/C=1, especially when the integrated development scheme will be realized.

As for the proposed dam site of Nam Mae Ngao project, further survey and investigation works based on the topographical and geological conditions are needed towards the start of the feasibility study.

5.6 Incremental Benefit of the Lower Yuam Project

1) Combination of the Projects

For the incremental benefit study of Lower Yuam, the effects of Nam Mae Rit and Upper Mae Yuam 1 have to be taken into account together with Nam Mae Ngao.

However, the Nam Mae Ngao project is the most important and superior among the four projects in terms of both the scale and the feasibility. Therefore the outline of the basin development plan can be obtained almost definitely in the integrated development plan of Nam Mae Ngao and Lower Yuam.

Accordingly, the following cases were studied.

- Dam and installed capacity are fixed at Feasibility Study level.
- Dam is fixed at Feasibility Study level but installed capacity is optimized.

2) River runoff Data

The river runoff data for 11 years at Ban Tha Rua, spanned between 1970 and 1980, have been used in the feasibility study made by JICA in 1984.

However, in the present study, the runoff date of Ban Tha Rua have been extended from 11 years to 25 years, spanning between 1960 and 1984, by means of the regression analyses.

Accordingly, the extended runoff data for 25 years were adopted for the reservoir simulation study and the power and energy calculation of Lower Yuam.

3) Construction Cost

The construction cost of Lower Yuam has been reviewed applying the same work quantities of the feasibility study and the same unit price of the master plan study.

4) Incremental Benefit

As mentioned above, the incremental benefit was studied based upon the combination with Nam Mae Ngao and the reservoir operation using the extended runoff data. The results are shown in Table 5-20, 5-21 and 5-22 for the second stage of study, and in Table 5-26 for the additional stage of study. Note that in the additional stage, only the incremental benefit that accrues from the later case above (i.e. Dam is fixed but installed capacity optimized) was studied because this case is more realistic than the former case (i.e. Dam and installed capacity are fixed).

The leftest column in Table 5-20, designated by case 0 corresponds to the values of the feasibility study made by JICA in 1984 which is the individual development plan without any effect from the upstream projects.

In this case, the economic feasibility is still dominant in terms of Benefit-Cost ratio (B/C); 1.519.

Table 5–1 Basic Figures of Each Project

NO.	Project name		Coordinates				CA	Tailrace W.L.
			Dam site		Power house		(km²)	(m)
			N°	E°	N°	E°		
1	Upper Mae Yuam 1		18° 23' 52"	97°54' 48"			1,967	262.0
2	Upper Mae Yuam 2		18° 33' 20"	97°54' 41"			1,149	326.5
3	Upper Mae Yuam 3		18° 45' 27"	97°51' 21"			447	428.0
4	Nam Mae Rit		17°55' 11"	98°00' 07"			1,268	192.0
5	Upper Mae Rit 1		17°59' 55"	98°04' 10"	17°57' 04"	98°04' 00"	686	281.0
6	Upper Mae Rit 2	Original	18° 04' 35"	98°05' 55"	18° 03' 28"	98°05' 55"	525	491.0
		Alternative A			18° 01' 55"	98°04' 49"		407.0
7	Upper Mae Rit 3		17°56' 24"	98°08' 17"	17°57' 07"	98°04' 18"	349	281.0
8	Nam Mae Ngao	Site 2	17°47' 24"	97°59' 42"			835	163.0
		Site 3	17°46' 14"	98°00' 38"			756	171.0
9	Upper Mae Ngao		17°35' 10"	98°06' 37"			159	271.1
	Lower Yuam (NEA)		17°49'	97°49'			5,920	73.2

Table 5–14–1 Summary of First Stage Study, Master Plan of Nam Yuam River Basin

10 December, 1985

	Unit	Upper Mae Yuam 1	Upper Mae Yuam 2	Upper Mae Yuam 3	Nam Mae Rit	Upper Mae Rit 1	Upper Mae Rit 2	Upper Mae Rit 2a	Upper Mae Rit 3	Nam Mae Ngao (Site No.2)	Nam Mae Ngao (Site No.3)	Upper Mae Ngao 1
C.A.	Km^2	1967	1149	447	1268	686	525	525	349	835	756	159
Annual Inflow	MCM	570	333	129.5	395	214	163	163	108.6	1304	1182	249
Case No.		1	9	1	7	2	8	11	4	15	6	8
Project Type 1)		SG	SG	SG	SG	PG	PG	PG	SG	SG	PG	PG
Dam Height	m	75	65	62	83	66	63	38	64	95	100	80
Tunnel Length	m	-	-	-	-	5100	2110	5845	6800	-	-	-
HWL	m	325	380	477	270	407	585	560	490	250	260	340
NIWL	m	319.7	374.2	470.7	265.5	401.8	579.4	556.9	482.3	240.8	253	335
LWL	m	315	370	467	260	397	575	555	475	230	245	330
TWL	m	262	326.5	428	192	281	491	407	281	163	171	271.1
Total Storage	MCM	455	178	67.6	79	19.4	13.5	3.2	15.8	478	538	43.2
Draw down	m	10	10	10	10	10	10	5	15	20	15	10
Effective Storage	MCM	190	75	32.3	22.5	8.1	5.3	0.8	9.7	251	218	15.2
Gross Head	m	63	53.5	49	78	126	94	153	209	87	89	68.9
Effective Normal-Head	m	55.8	46.1	41.3	71.2	90.9	83.7	126.9	172	75.2	79.3	61.8
95% Firm Discharge	CmS	12.5	7.1	2.8	5.55	2.72	2.0	1.6	1.73	20.6	18.2	2.2
Max.Turbine Discharge	CmS	50.1	28.4	11.3	22.2	12.9	8.3	9.9	6.94	82.6	79.9	16.8
Installed Capacity	MW	24.4	11.4	4.1	13.8	10.3	6.1	11.0	10.4	54.2	55.2	9.1
Firm Capacity	MW	22.3	10.4	3.7	12.7	8.2	5.6	6.8	10.0	46.4	45.4	4.3
Associated Capacity	MW	4.2	2.1	0.7	5.1	3.9	2.4	4.4	3.2	18.7	17.7	3.6
Annual Energy-Production	GWH	76.0	37.0	13.0	61.0	42.5	28.0	44.0	42.7	220.7	212.0	33.2
Firm Energy	GWH	49.0	23.0	8.1	28.0	17.9	12.0	15.0	21.8	101.5	99.0	9.4
Secondary Energy	GWH	27.0	14.0	4.9	33.0	24.6	16.0	29.0	20.9	119.2	113.0	23.8
Capacity Factor 2)		0.36	0.37	0.36	0.50	0.47	0.52	0.46	0.47	0.46	0.44	0.42
Construction Cost	10^6฿	1335.9	822	475	968	837.2	561.1	599.9	838.1	2021	2139	909.1
Annual Benefit	10^6฿	141.1	67.5	23.7	103.6	70.8	46.5	69.2	74.1	374.3	361.2	50.5
for Firm KW	10^6฿	56.6	26.4	9.4	32.3	20.8	14.2	17.3	25.4	117.9	115.3	10.9
for Firm KWH	10^6฿	50.0	23.5	8.3	28.6	18.3	12.2	15.3	22.2	103.5	101.0	9.6
for Associated KW	10^6฿	15.9	7.9	2.6	19.3	14.7	9.1	16.6	12.1	70.7	66.9	13.6
for Secondary KWH	10^6฿	18.6	9.7	3.4	22.8	17.0	11.0	20.0	14.4	82.2	78.0	16.4
Annual Cost	10^6฿	148.3	91.2	52.7	107.4	92.9	62.3	66.6	93.0	224.3	237.4	100.9
B-C	10^6฿	△7.2	△23.7	△29.0	△4.4	△22.1	△15.8	2.6	△18.9	150	123.8	△50.4
B/C	10^6฿	0.95	0.74	0.45	0.96	0.76	0.75	1.04	0.80	1.67	1.52	0.50
Annual Energy Cost	฿/KWH	1.95	2.46	4.05	1.76	2.19	2.22	1.51	2.18	1.02	1.12	3.04
Simulation Case No.		Y1B325.10	Y2B380.10	Y3B477.10	R0B270.10	R1D407.10	R2D585.10	R2aD560.5	R3B490.15	N02B250.20	N03D260.15	N1D340.10
Rank of the Project		4	7	9	3	6	-	2	5	1	-	8
Selected Project for the Second Stage-Study		*			*			*		*		

1) Project Type, SG : Storage Type
PG : Pondage Type

2) Capacity Factor = $\frac{\text{Annual Energy Production (MWH)}}{\text{Installed Capacity (MW)} \times 8760 \text{ (hr)}}$

Table 5-14-2 Summary of Second Stage Study

	Unit	Mae Ngao (Site No.2)	Mae Rit	Mae Rit 2a	Upper Yuam 1
C.A.	Km^2	835	1,268	525	1,967
Annual Inflow	MCM	1,292	395	163	567
Case No.		3	2	3	1
Project Type 1)		SG	SG	PG	SG
Dam Height	m	114	87	38	62
Tunnel Length	m	-	-	5,845	-
HWL	m	260	270	560	325
NIWL	m	248.4	262.9	556.9	319.4
LWL	m	235	255.0	555	315
TWL	m	163	192	407	277
Total Storage	MCM	661.2	85.7	3.2	421.4
Draw down	m	25	10	5	10
Effective Storage	MCM	355.2	34.7	0.8	188.1
Gross Head	m	97	78	153	48.0
Effective Normal-Head	m	82.5	68.5	126.9	41.0
95% Firm Discharge	CmS	24.9	6.18	1.56	13.2
Max. Turbine Discharge	CmS	166.2	41.2	10.4	53.0
Installed Capacity	MW	116.9	24.0	11.2	18.5
Firm Capacity	MW	97.9	21.3	11.1	16.5
Annual Energy-Production	GWH	245.2	61.5	43.6	54.46
Firm Energy	GWH	128.6	28.0	14.5	36.17
Secondary Energy	GWH	116.5	33.5	29.1	18.29
Daily Plant Factor	%	15	15	15	25.0
Capacity Factor	%	23.9	29.2	44.5	33.6
Construction Cost	10M฿	3,373	1,273	698	1,791
Annual Benefit	10M฿	488.5	115.8	68.7	100
for Firm KW	10M฿	171.8	37.4	19.5	29
for Firm KWH	10M฿	197.5	43.0	22.3	55.6
for Secondary KWH	10M฿	119.2	35.4	26.9	15.4
Annual Cost	10M฿	374.4	141.3	77.5	198.8
B/C	10M฿	1.305	0.82	0.858	0.503
Simulation Case No.		No2A260.25b	ROA270.15b	R2aA560.5b	Y1V325.10b

1) Project Type, SG: Storage Type

PG: Pondage Type

Table 5–20 Integrated Development including Transmission Line Nam Mae Ngao No. 2 + Lower Yuam

Case No.	Unit	Individual	Lower Yuam : Dam & Installed capacity are fixed.				Lower Yuam : Dam fixed. Installed capacity optimized			
		0	I	II	III	IV	V	VI	VII	VIII
Case No. of Ngao No. 2			②N#2A260·20b	③N#2A260·25b	④N#2A260·30b	⑤N#2A260·35b	②N#2A260·20b	③N#2A260·25b	④N#2A260·30b	⑤N#2A260·35b
Case No. of Lower Nam Yuam		①Y#VI70·20δ	⑨Y#VI70·20d	③Y#VI70·20c	④Y#VI70·20b	⑤Y#VI70·20a	⑩Y#AI70·20d	⑥Y#AI70·20c	⑦Y#AI70·20b	⑧Y#AI70·20a
Installed capacity	MW		268.7	278.4	284.7	286.5	350.3	374.0	389.7	398.5
Ngao No. 2	MW	—	106.7	116.9	122.7	124.5	106.7	116.9	122.7	124.5
Lower Nam Yuam	MW	162.0	162.0	161.5	162.0	162.0	243.6	257.1	267.0	274.0
Firm capacity	MW		233.6	237.6	237.9	233.5	304.2	320.5	328.8	330.5
Ngao No. 2	MW	—	93.3	97.9	97.6	93.2	93.3	97.9	97.6	93.2
Lower Nam Yuam	MW	139.9	140.3	139.7	140.3	140.3	210.9	222.6	231.2	237.3
Annual firm energy	GWH		399.8	421.1	432.1	434.3	399.8	421.1	432.1	434.3
Ngao No. 2	GWH	—	122.6	128.6	128.3	122.5	122.6	128.6	128.3	122.5
Lower Nam Yuam	GWH	181.6	277.2	292.5	303.8	311.8	277.2	292.5	303.8	311.8
Annual secondary energy	GWH		399.1	374.0	358.5	352.8	399.1	383.3	367.2	360.8
Ngao No. 2	GWH	—	128.9	116.5	112.5	113.7	128.9	116.5	112.5	113.7
Lower Nam Yuam	GWH	357.3	270.2	257.5	246.0	239.1	270.2	266.8	254.7	247.1
Construction cost for generating f.	M฿	4340	7628	7712.7	7780	7814	8307	8528.2	8656.1	8740.7
Ngao No. 2	M฿	—	3286	3373	3438	3472	3286	3373	3438	3472
Lower Nam Yuam	M฿	4340	4342	4339.7	4342	4342	5021	5155.2	5218.1	5268.7
Construction cost for transmission f.	M฿	400	465.5	465.5	465.5	465.5	745.5	745.5	745.5	745.5
Ngao No. 2	M฿	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5
Lower Nam Yuam	M฿	400	400.0	400.0	400.0	400.0	680.0	680.0	680.0	680.0
Total benefit	M฿	824.7	1320.6	1331.6	1331.2	1318.9	1460.8	1504.4	1519.7	1520.3
unit benefit for firm capacity	฿/KW	1755	2271	2309	2336	2365	2060	2071	2077	2078
benefit for total firm capacity	M฿	245.5	530.5	548.6	555.8	552.3	626.6	663.8	682.8	686.7
unit benefit for firm energy	฿/KWH	1.536	1.137	1.113	1.097	1.082	1.248	1.231	1.223	1.221
benefit for total firm energy	M฿	278.9	454.7	468.7	474.1	470.1	498.8	518.4	528.3	530.3
unit cost for secondary energy	฿/KWH	0.8405	0.8405	0.8405	0.8405	0.8405	0.8405	0.8405	0.8405	0.8405
benefit for total secondary energy	M฿	300.3	335.4	314.3	301.3	296.5	335.4	322.2	308.6	303.3
Total annual cost		543.0	925.2	934.8	942.3	945.9	1034.8	1060.2	1074.7	1084.1
for generation facilities 0.111	M฿	481.7	846.7	856.1	863.6	867.4	922.1	946.6	960.8	970.2
for transmission facilities 0.112	M฿	44.8	52.1	52.1	52.1	52.1	83.5	83.5	83.5	83.5
for transmission losses Benefit x2%	M฿	16.5	26.4	26.6	26.6	26.4	29.2	30.1	30.4	30.4
B – C	M฿	281.7	395.4	396.8	388.9	373.0	426.0	444.2	445.0	436.2
B/C		1.519	1.427	1.424	1.413	1.394	1.412	1.419	1.414	1.402
Annual energy cost	฿/KWH	1.01	1.16	1.18	1.19	1.20	1.30	1.32	1.34	1.36
Case to be adopted				△				○		

Table 5-21 Incremental Benefit of Lower Yuam due to the Effect of Nam Mae Ngao No. 2 Development (Lower Yuam: Dam & Installed Capacity are Fixed at F/S Levels — Second Stage)

		Individual Development			Integrated Development	Increase
		Nam Mae Ngao	Lower Yuam	Total	Nam Mae Ngao & Lower Yuam	
Case No.		③ NØ2A 260-25b	① YØV170-200	(1)+(2)	Case II	(4)-(3)
	Unit	(1)	(2)	(3)	(4)	(5)
Installed Capacity	MW	116.9	162.0	278.9	278.9	0
Firm Capacity	MW	97.9	139.9	237.8	237.6	- 0.2
Annual Energy Production						
Firm Energy	GWH	128.6	181.6	310.2	421.1	110.9
Secondary Energy	GWH	116.5	357.3	473.8	374.0	-99.8
Total	GWH	245.1	538.9	784.0	795.1	11.1
Construction Cost						
Generating F.	M฿	3373.	4340.	7713	7713	0
Transmission F.	M฿	65.5	400.	465.5	465.5	0
Total	M฿	3438.5	4740.	8178.5	8178.5	0
Annual Benefit						
for Firm Capacity	M฿	171.8	245.5	417.3	548.6	131.3
for Firm Energy	M฿	197.5	278.9	476.4	468.7	- 7.7
for Secondary Energy	M฿	119.2	300.3	419.5	314.3	-105.2
Total	M฿	488.5	824.7	1313.2	1331.6	18.4
Annual Cost						
for Generating F.	M฿	374.4	481.7	856.1	856.1	0
for Transmission F.	M฿	7.3	44.8	52.1	52.1	0
for Transmission Losses	M฿	9.8	16.5	26.3	26.6	0.3
Total	M฿	391.5	543.0	934.5	934.8	0.3
B - C	M฿	97.0	281.7	378.7	396.8	18.1
B/C		1.248	1.519	—	1.424	—
Energy Cost	฿/kwh	1.60	1.01	—	1.18	—
Incremental Benefit	M฿					18.1

Table 5–22 Incremental Benefit of Lower Yuam due to the Effect of Nam Mae Ngao No. 2 Development (Lower Yuam: Dam is Fixed at F/S Level, Installed Capacity is Optimized – Second Stage)

		Individual Development			Integrated Development	Increase
		Nam Mae Ngao	Lower Yuam	Total	Nam Mae Ngao & Lower Yuam	
Case No.		③ NØ2A 260-25b	① YØV170-200	(1)+(2)	Case VI	(4)−(3)
	Unit	(1)	(2)	(3)	(4)	(5)
Installed Capacity	MW	116.9	162.0	278.9	374.0	95.1
Firm Capacity	MW	97.9	139.9	237.8	320.5	82.7
Annual Energy Production						
Firm Energy	GWH	128.6	181.6	310.2	421.1	110.9
Secondary Energy	GWH	116.5	357.3	473.8	383.3	− 90.5
Total	GWH	245.1	538.9	784.0	804.4	20.4
Construction Cost						
Generating F.	M฿	3373.	4340.	7713	8528.2	815.2
Transmission F.	M฿	65.5	400.	465.5	745.5	280.0
Total	M฿	3438.5	4740.	8178.5	9273.7	1095.2
Annual Benefit						
for Firm Capacity	M฿	171.8	245.5	417.3	663.8	246.5
for Firm Energy	M฿	197.5	278.9	476.4	518.4	42.0
for Secondary Energy	M฿	119.2	300.3	419.5	322.2	− 97.3
Total	M฿	488.5	824.7	1313.2	1504.4	191.2
Annual Cost						
for Generating F.	M฿	374.4	481.7	856.1	946.6	90.5
for Transmission F.	M฿	7.3	44.8	52.1	83.5	31.4
for Transmission Losses	M฿	9.8	16.5	26.3	30.1	3.8
Total	M฿	391.5	543.0	934.5	1060.2	125.7
B − C	M฿	97.0	281.7	378.7	444.2	65.5
B/C		1.248	1.519	—	1.419	—
Energy Cost	฿/kwh	1.60	1.01	—	1.32	—
Incremental Benefit	M฿					65.5

Table 5-23 Fuel Price Variations for Alternative Thermal Plants

Fuels	Unit	Case #			Fuel prices adopted in the second stage of study 4)
		No.1 1) Base Case	No.2 2)	No.3 3)	
Natural Gas	฿/MBtu	5) 71.09	75.16	79.24	87.38
Diesel Oil	฿/lit	6) 3.68	4.41	5) 5.14	6.60
Imported Coal	฿/kg	1.484	1.619	1.755	2.025
Lignite	฿/kg	0.5332	0.5332	0.5332	0.5332

1) Given by EGAT on July 3, 1986

2), 3) Assumed by the JICA team

4) Given by EGAT on Oct. 7, 1985 (Letter No. EGAT 32004/51394)

5) 83 ฿/MBTu - Tax 11.9053 ฿/MBTu = 71.0947 ฿/MBTu

6) 6.17 ฿/lit - Tax 2.525 ฿/lit + Transport by ship 0.035 ฿/lit = 3.68 ฿/lit

1 US$ = 26.5 ฿

Table 5–26 Incremental Benefit of Lower Yuam due to the Effect of Nam Mae Ngao No. 2 Development (Lower Yuam: Dam & Installed Capacity are Fixed at F/S Level – Additional Stage)

		Individual development			Integrated development Nam Mae Ngao & Lower Yuam	Increase
		Nam Mae Ngao	Lower Yuam	Total (1)+(2)		
Case No.		(3) NØ2A 260.25b	(1) YØV170- 170.20o		Case VI	(4)-(3)
	unit	(1)	(2)	(3)	(4)	(5)
Installed capacity	MW	116.9	162.0	278.9	278.9	0
Firm Capacity	MW	97.9	139.9	237.8	237.6	-0.2
Annual energy production						
Firm energy	GWH	128.6	181.6	310.2	421.1	110.9
Secondary energy	GWH	116.5	357.3	473.8	374.0	-99.8
Total	GWH	245.1	538.9	784.0	795.1	11.1
Construction cost						
Generating f.	M฿	3,373	4,340	7,713	7,713	0
Transmission f.	M฿	65.5	400	465.5	465.5	0
Total		3,438.5	4,740	8,178.5	8,178.5	0
Annual benefit						
for firm capacity	M฿	171.8	245.5	417.3	548.6	131.3
for firm energy	M฿	197.5	278.9	476.4	468.7	-7.7
for secondary energy	M฿	119.2	300.3	419.5	314.3	-105.2
Total	M฿	488.5	824.7	1,313.2	1,331.6	18.4
Annual cost						
for generating f.	M฿	374.4	481.7	856.1	856.1	0
for transmission f.	M฿	7.3	44.8	52.1	52.1	0
for transmission losses	M฿	9.8	16.5	26.3	26.6	0.3
Total	M฿	391.5	543.0	934.5	934.8	0.3
B-C	M฿	97.0	281.7	378.7	396.8	18.1
B/C		1.248	1.519	-	1.424	-
Energy cost	฿/KWH	1.60	1.01	-	1.18	-
Incremental benefit	M฿					18.1

6. PRELIMINARY DESIGN

6.1 Civil Main Structure

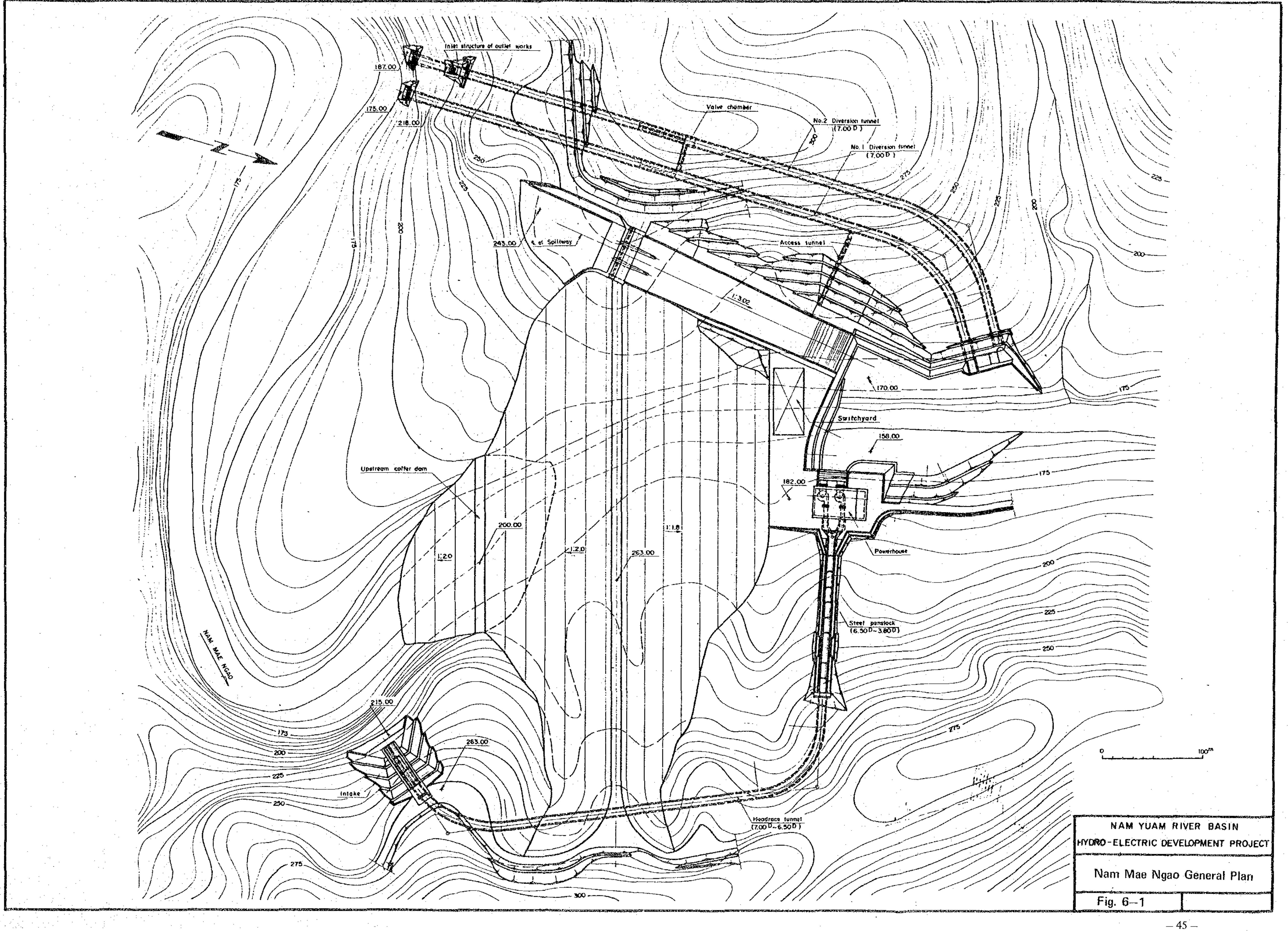
Preliminary design has been carried out for the selected four projects; Nam Mae Ngao, Nam Mae Rit, Upper Mae Yuam 1 and Upper Mae Rit 2a, based upon the basic figures, studied in the previous Chapter 5 "Development Plan".

Topographic maps used for the preliminary design were 1:5,000 scale map for Nam Mae Ngao, Nam Mae Rit, and Upper Mae Yuam 1 and 1:50,000 scale map for Upper Mae Rit 2a.

Preliminary design drawings are shown on Fig. 6-1 through 6-13. However, those basic figures and preliminary design drawings should be required further review at the next feasibility study stage.

Outline of Each Project

Name of Project	Nam Mae Ngao	Nam Mae Rit	Upper Mae Yuam 1	Upper Mae Rit 2a
Dam				
Type	Rockfill Dam	Rockfill Dam	Rockfill Dam	Rockfill Dam
Height (m) x Length (m)	114 x 542	87 x 285	62 x 520	38 x 105
Volume ($10^3 m^3$)	5,360	2,100	2,307	177
Waterway				
Inner Diameter (m)	7.0 - 6.5	4.1 - 3.8	4.5 - 4.2	2.5 - 1.8
Length (m)	700	417	259	6,230
Power Plant				
Output (MW)	116.9	24	18.5	11.2
Max. Discharge (m^3/sec)	166.2	41.2	53.0	10.4
Turbine				
Type	Vertical-shaft Francis	Vertical-shaft Francis	Vertical-shaft Francis	Vertical-shaft Francis
Output (MW)	59.8	12.3	9.5	5.8
Number of Units	2	2	2	2
Generator				
Type	Three-phase, AC, Synchronous	Three-phase, AC Synchronous	Three-phase, AC, Synchronous	Three-phase, AC, Synchronous
Capacity (MVA)	65.1	13.4	10.3	6.3
Number of Units	2	2	2	2

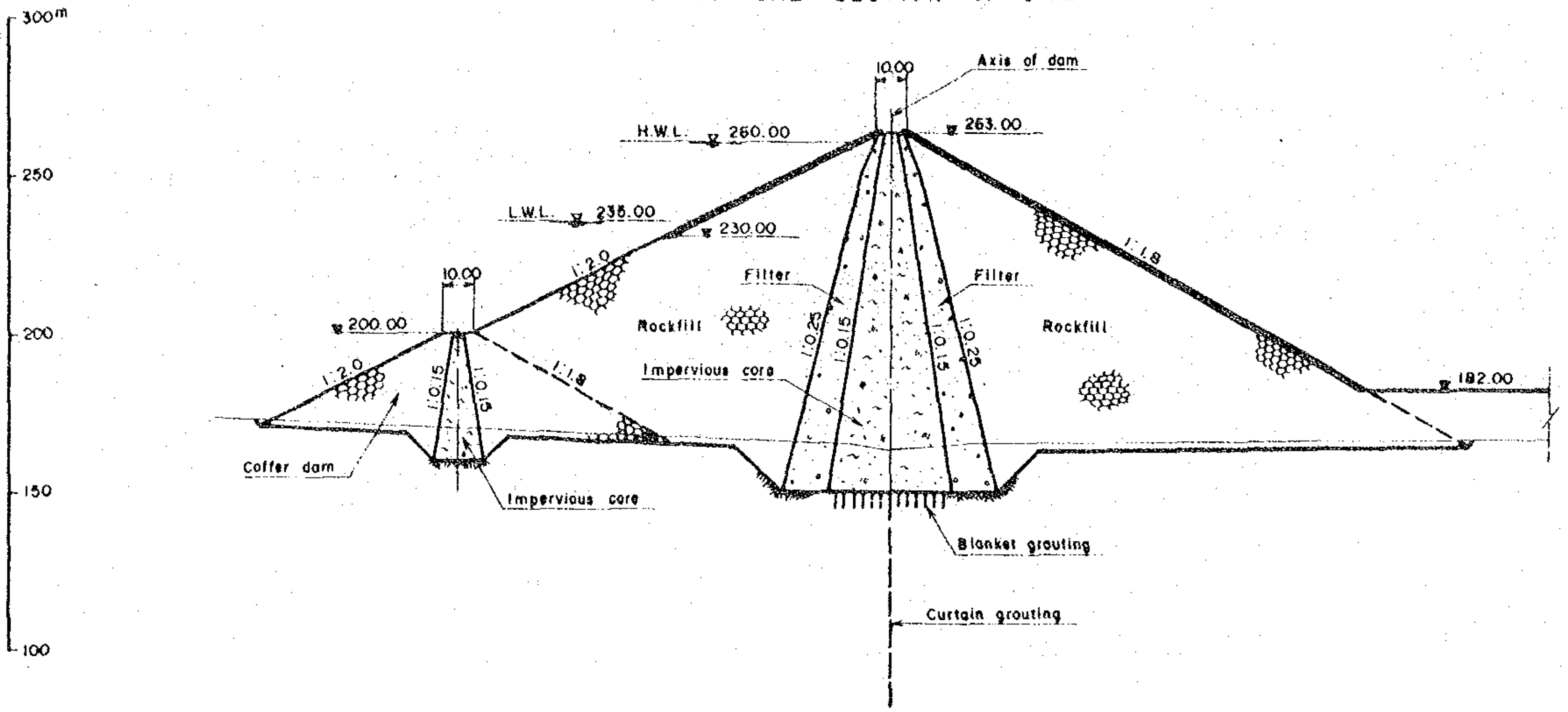


NAM YUAM RIVER BASIN
HYDRO-ELECTRIC DEVELOPMENT PROJECT

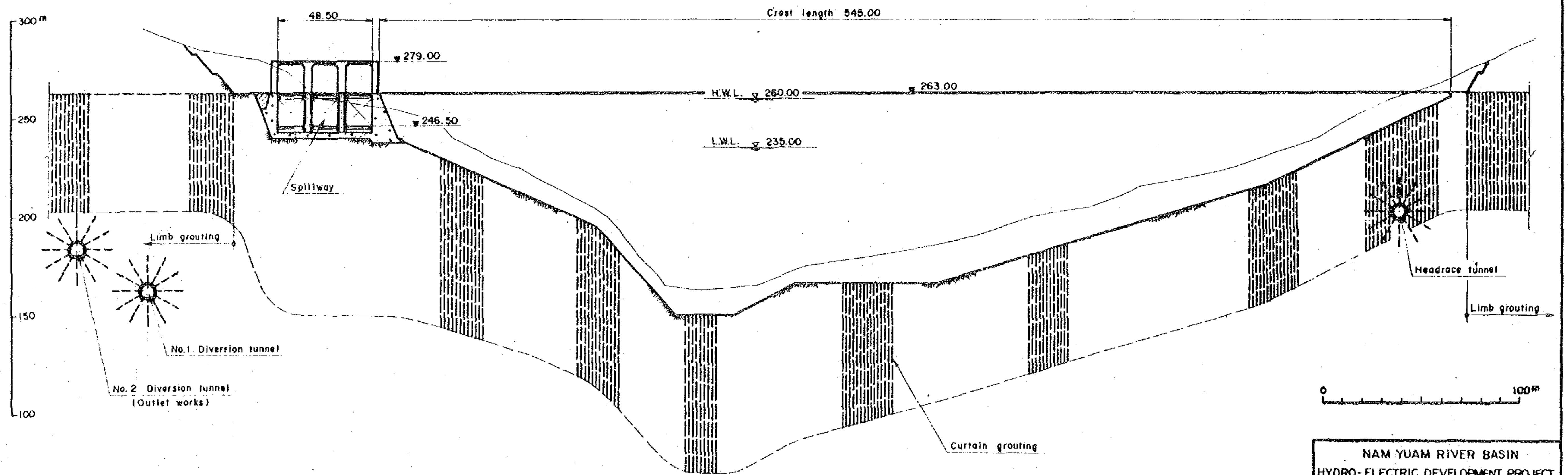
Nam Mae Ngao General Plan

Fig. 6–1

TYPICAL SECTION OF DAM



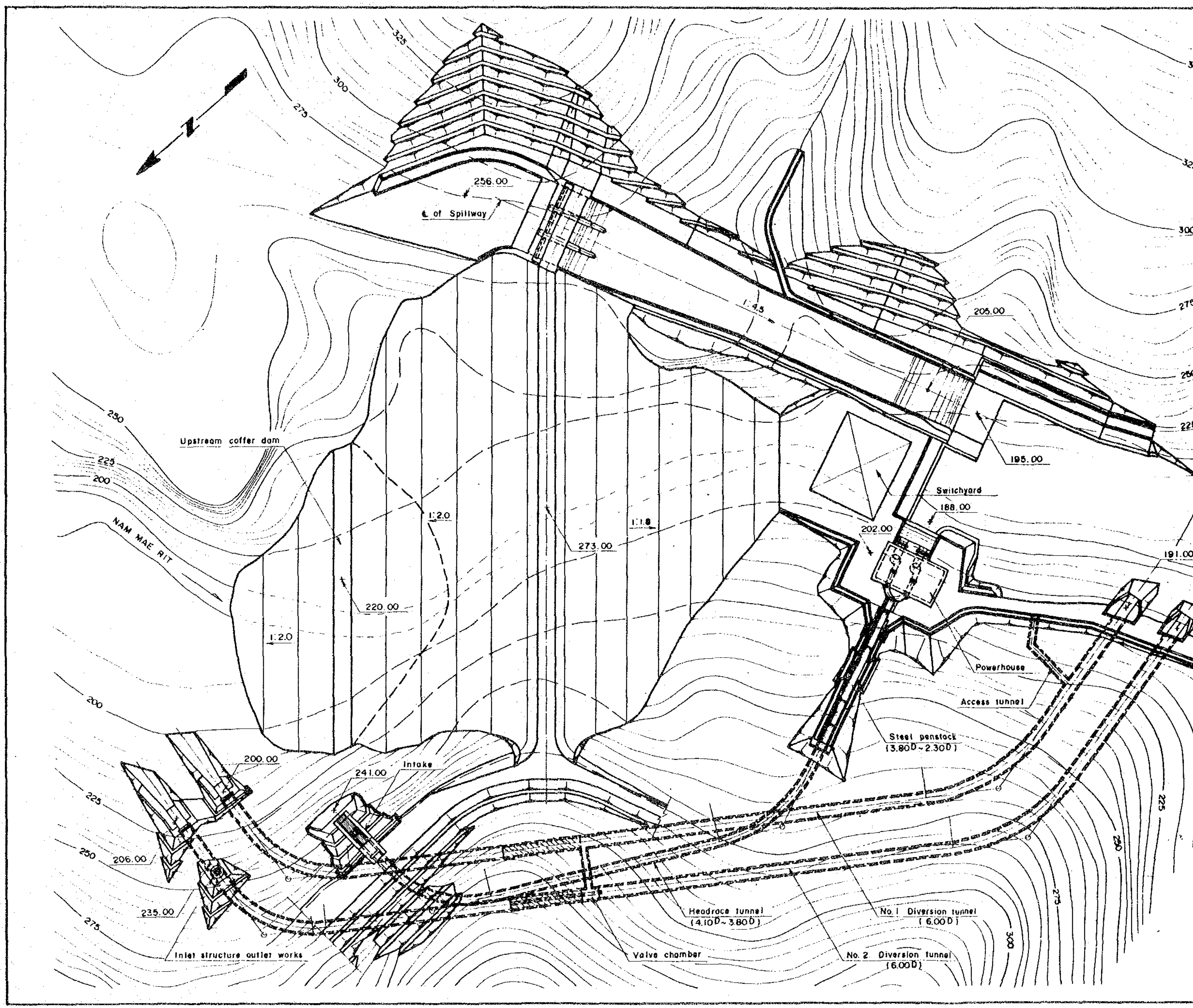
PROFILE OF DAM



NAM YUAM RIVER BASIN
HYDRO-ELECTRIC DEVELOPMENT PROJECT

Nam Mae Ngao Dam

Fig. 6-2

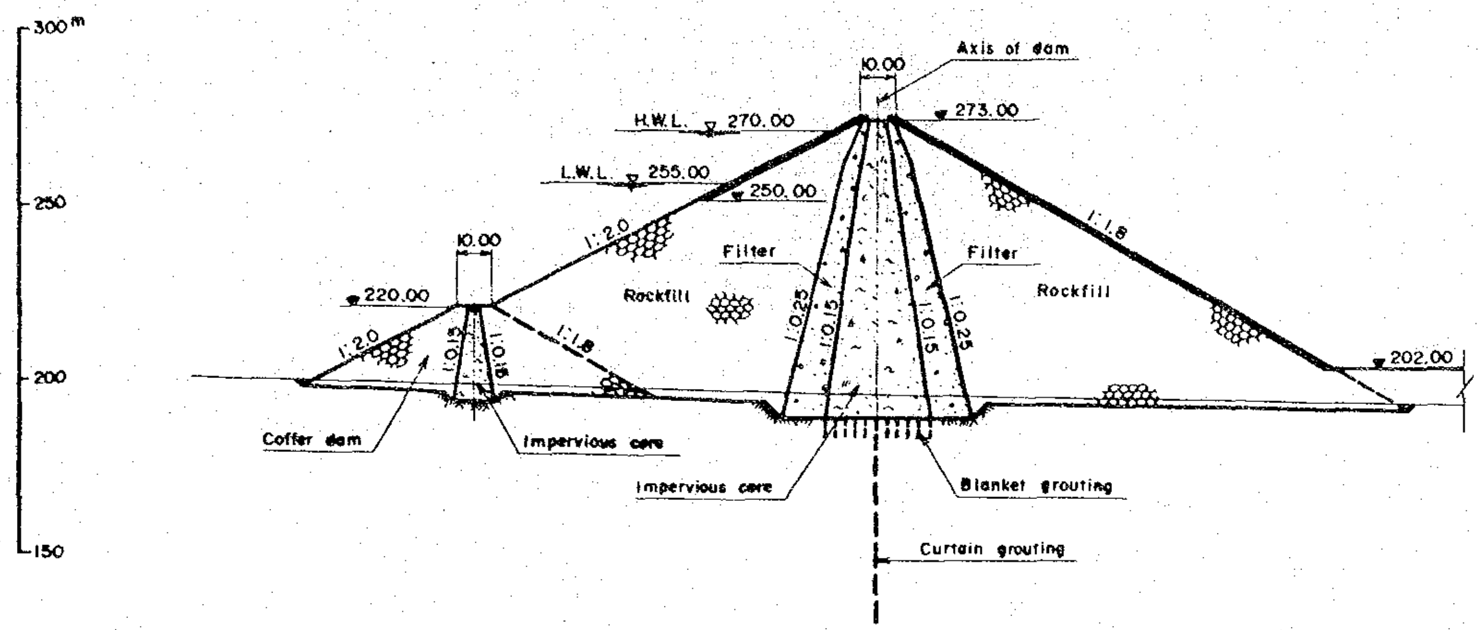


NAM YUAM RIVER BASIN
HYDRO-ELECTRIC DEVELOPMENT PROJECT

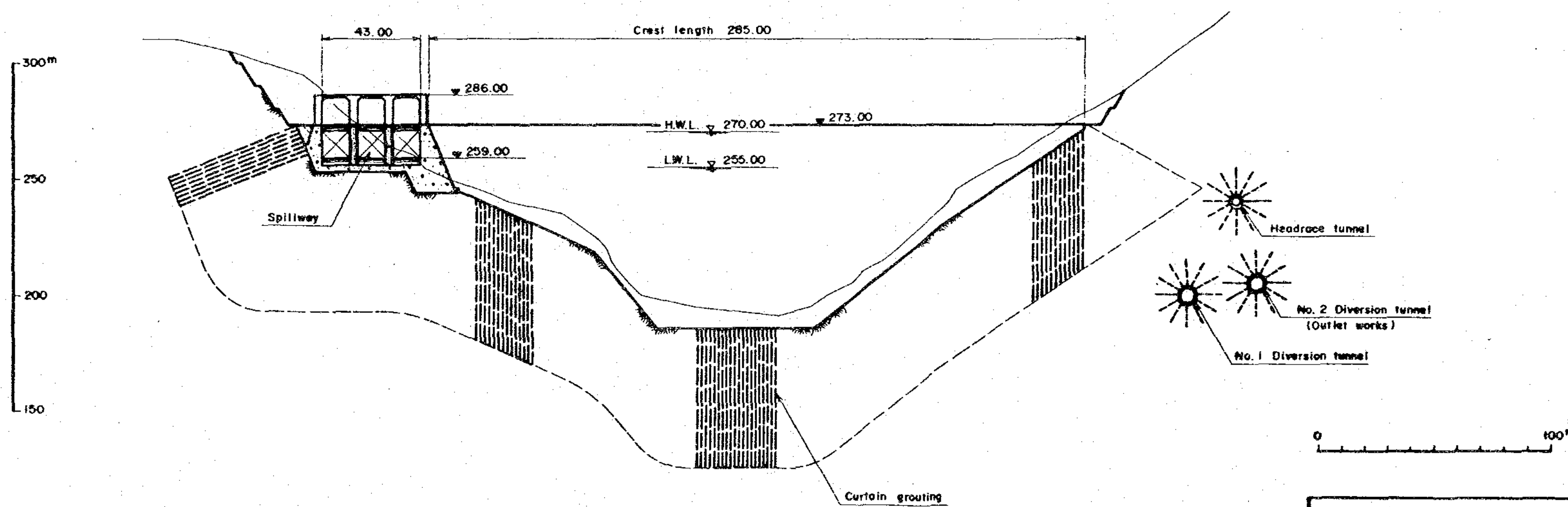
Nam Mae Rit General Plan

Fig. 6–5

TYPICAL SECTION OF DAM



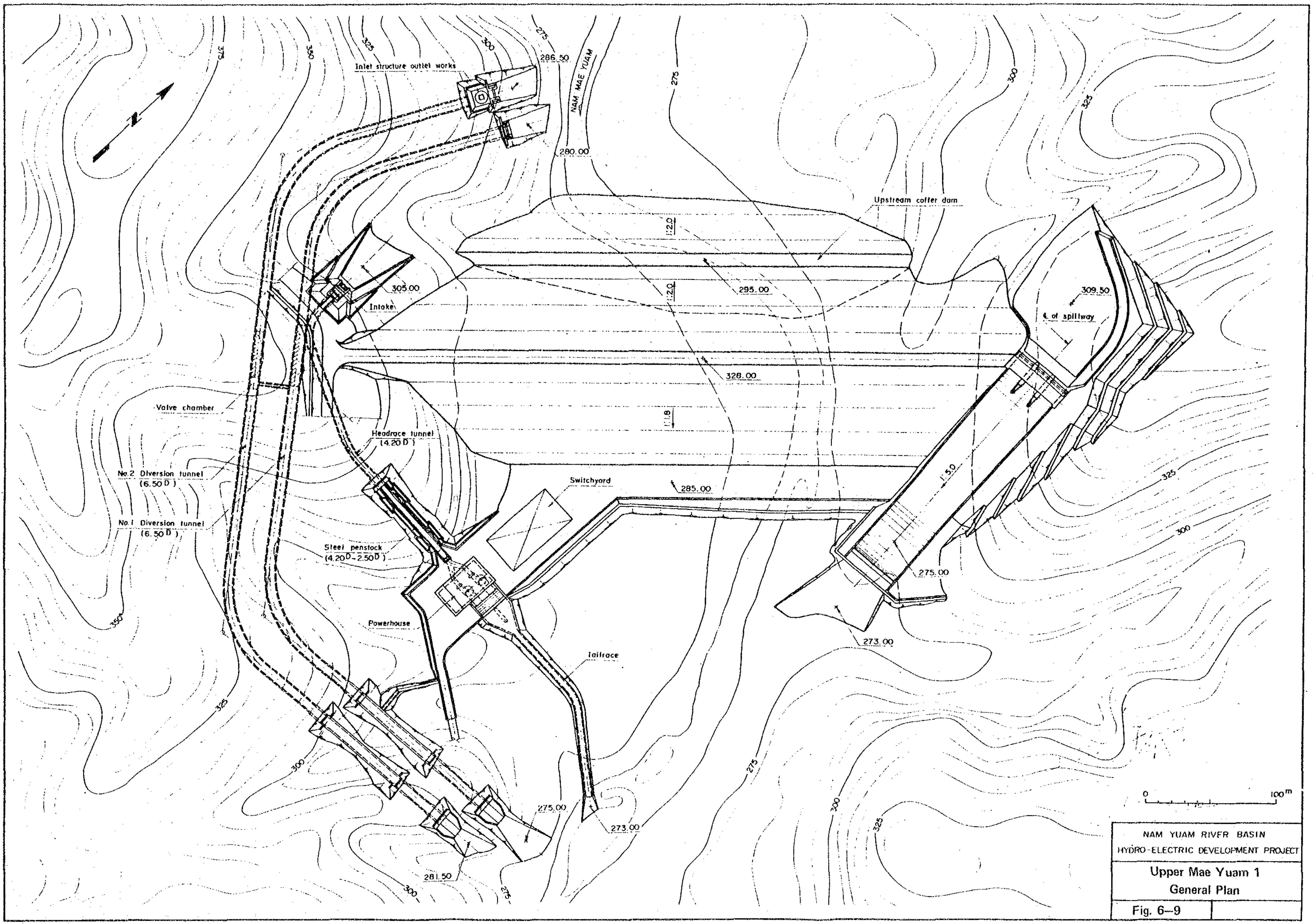
PROFILE OF DAM



NAM YUAM RIVER BASIN
HYDRO-ELECTRIC DEVELOPMENT PROJECT

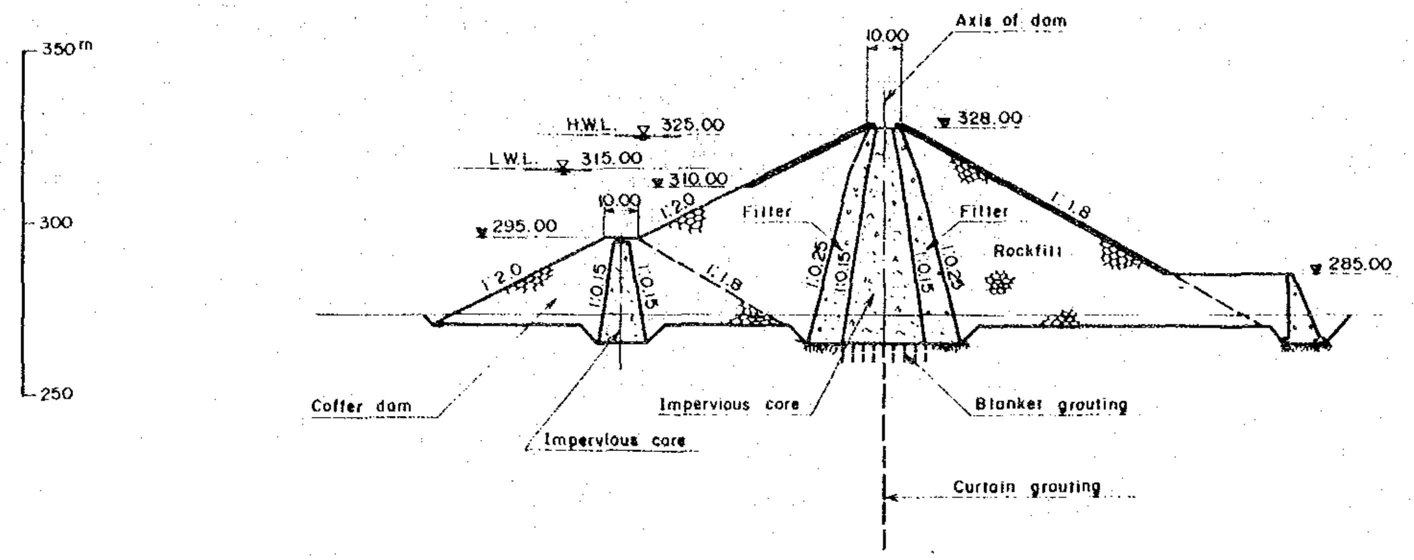
Nam Mae Rit Dam

Fig. 6–6

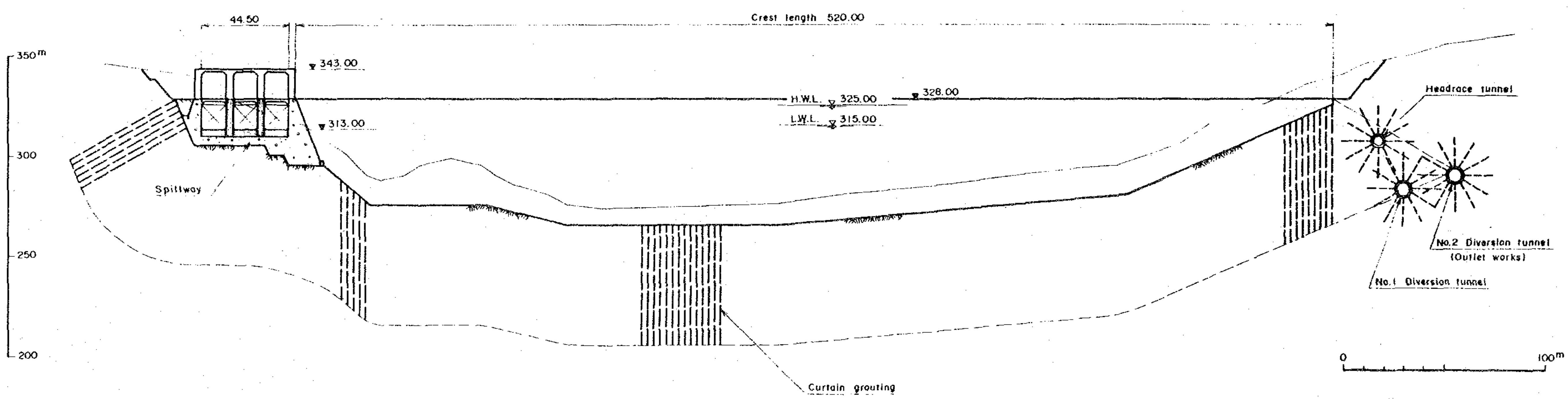


NAM YUAM RIVER BASIN
HYDRO-ELECTRIC DEVELOPMENT PROJECT
Upper Mae Yuam 1 General Plan
Fig. 6–9

TYPICAL SECTION OF DAM



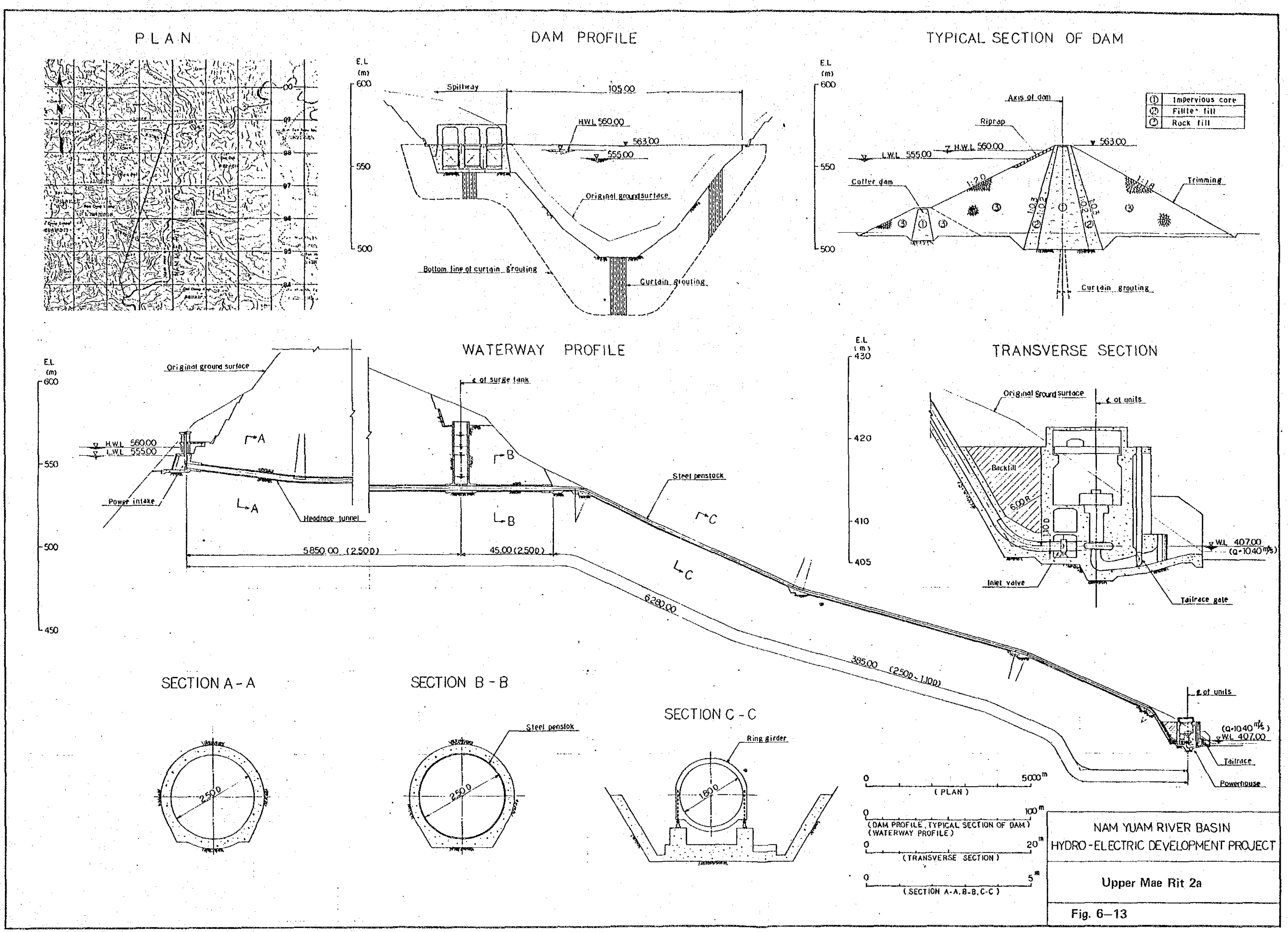
PROFILE OF DAM



NAM YUAM RIVER BASIN
HYDRO-ELECTRIC DEVELOPMENT PROJECT

Upper Mae Yuam 1 Dam

Fig. 6–10



NAM YUAM RIVER BASIN
HYDRO-ELECTRIC DEVELOPMENT PROJECT

Upper Mae Rit 2a

Fig. 6–13

7. POWER TRANSMISSION LINE SYSTEM PLAN

7.5 Preliminary Design of Transmission Line

1) Transmission line route

For transmitting the electric power generated by Nam Mae Ngao, Nam Mae Rit, Upper Mae Rit 2a, and Upper Mae Yuam 1 to the Region 4, as stated hereinbefore, the northern route has been taken as the object of examination, and it has been ascertained that the northern route connected to Lamphun 2 substation is more advantageous.

The northern route to be constructed in this project is outlined hereunder. Reference is to be made to Fig. 7-7.

When constructing the transmission line, the availability of the existing roads which can be utilized for transporting the machines and materials has great effect on the construction costs. Nam Mae Ngao, Nam Mae Rit, and Upper Mae Rit 2a power stations are situated in the less developed mountaineous area northwest in Thailand and the access conditions are poor. Following about 150 km from Lamphun 2 substation to Mae Sariang and about 29 km from Mae Sariang to upper Mae Yuam 1 site, the route runs in parallel with the well paved national highway. No difficulty in the construction will be encountered in this section.

Nam Mae Ngao, Nam Mae Rit, Upper Mae Rit 2a projects are situated in the less developed mountaineous area, therefore, it is recommended that the implementing agency of the feasibility study of the Nam Mae Ngao, Nam Mae Rit, and Upper Mae Rit 2a project should be familiarized with the actual condition of the said road project and reflect the results of such informations in the selection of transmission line route.

In selecting Mae Sariang Switching Station site, it is essential that deliverate considerations be given to the coordination of the proposed 230 kV transmission line of the Lower Yuam Project with the residential areas etc.

2) Transmission line voltage and number of circuits

Reinforcement for transmission of the electric power generated by Nam Mae Ngao, Nam Mae Rit, Upper Mae Rit 2a, Upper Mae Yuam 1 Power Station requires to construct the transmission line of nominal voltage of 230 kV mentioned above.

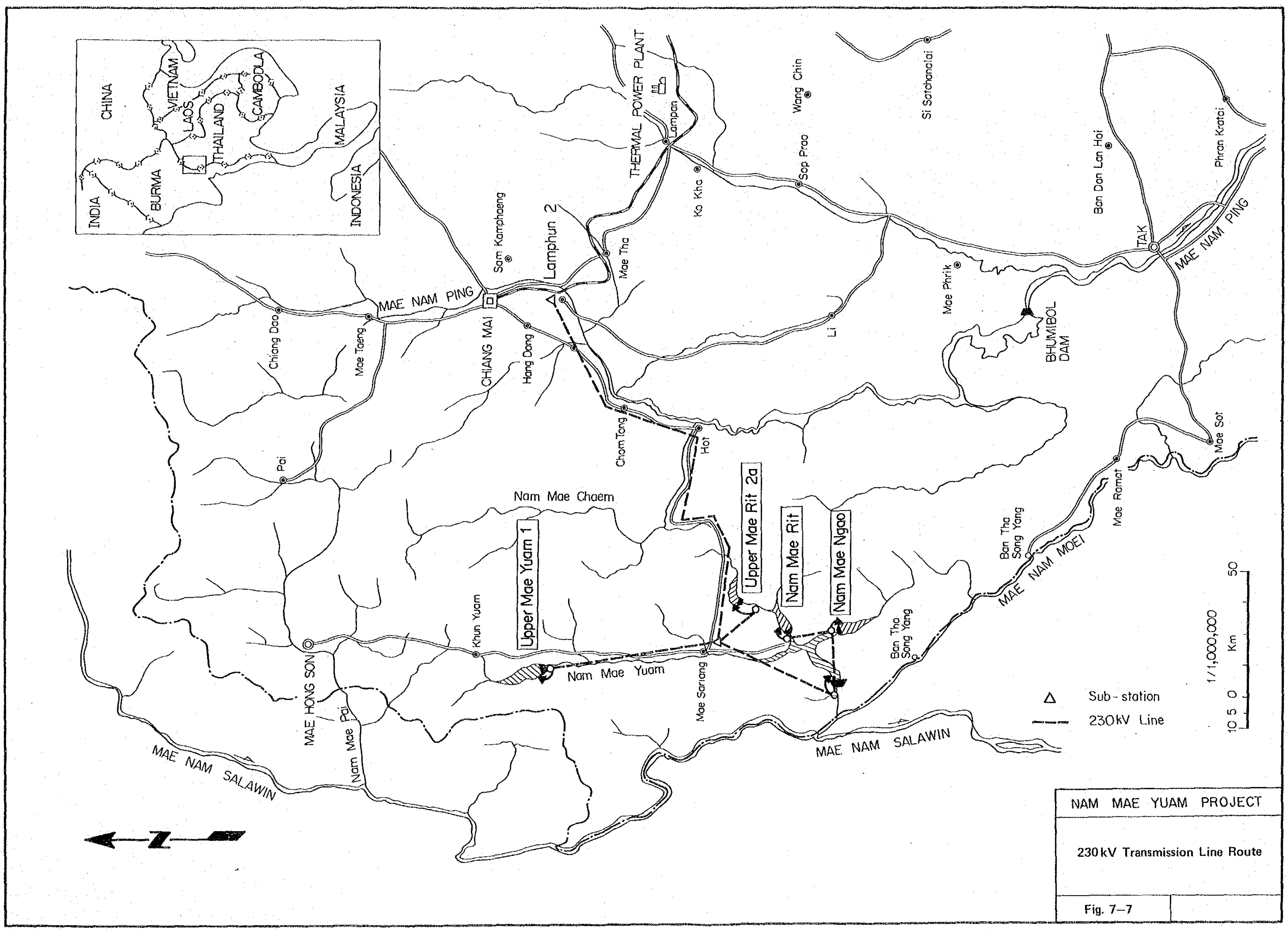
The two-circuits would be required by reference to the criteria currently adopted by EGAT inconnection with operation of their transmission line facilities.

3) Phase conductor

The size of conductor is determined in view of ampacity which corresponds with the power of Nam Mae Ngao, Nam Mae Rit, Upper Mae Rit 2a, and Upper Mae Yuam 1, stability and corona disruptive critical voltage etc.

In order to transmit the power by 230 kV, 1272 MCM or 795 MCM was selected, and in order to transmit the power by 115 kV, 795 MCM or 477 MCM was selected upon examination of the EGAT's standards.

However, in selecting 795 MCM (230 kV), it is recommended that deliverate consideration be taken to the design of transmission line steel tower etc. at feasibility study level.



NAM MAE YUAM PROJECT

230kV Transmission Line Route

Fig. 7–7

8. CONSTRUCTION PLANNING AND COST ESTIMATION

8.1 Construction Planning

Fig. 8-1 to Fig. 8-4 show the construction schedules of each project. These were made, taking into consideration the construction scales, methods, weather conditions, etc.

The condition for carring out these schedules is that preparing roads for construction and arranging camping facilities should be completed beforehand.

The construction cost of the projects are shown in Tabel 8-1.

Table 8-1 Construction Cost of Nam Mae Ngao

Unit: M฿

Item	Total	Currency	
		Foreign	Local
Preparation Works	144.2	0	144.2
Compensation	0.2	0	0.2
Civil Works	1,834.5	1,009.0	825.5
Hydraulic Equipment	152.3	114.2	38.1
Electrical Equipment	698.9	594.1	104.8
Telecommunication & Transmission line	89.5	62.8	26.7
Duties & Taxes	220.4	0	220.4
Sub-total	3,140.0	1,780.1	1,359.9
Engineering Fee	157.0	94.2	62.8
EGAT Administration	94.2	0	94.2
Interest during Construction	442.2	0	442.2
Grand Total	3,833.4	1,874.3	1,959.1

(Based on Case No.3 at the second stage study)

(As of July 1986 price level)

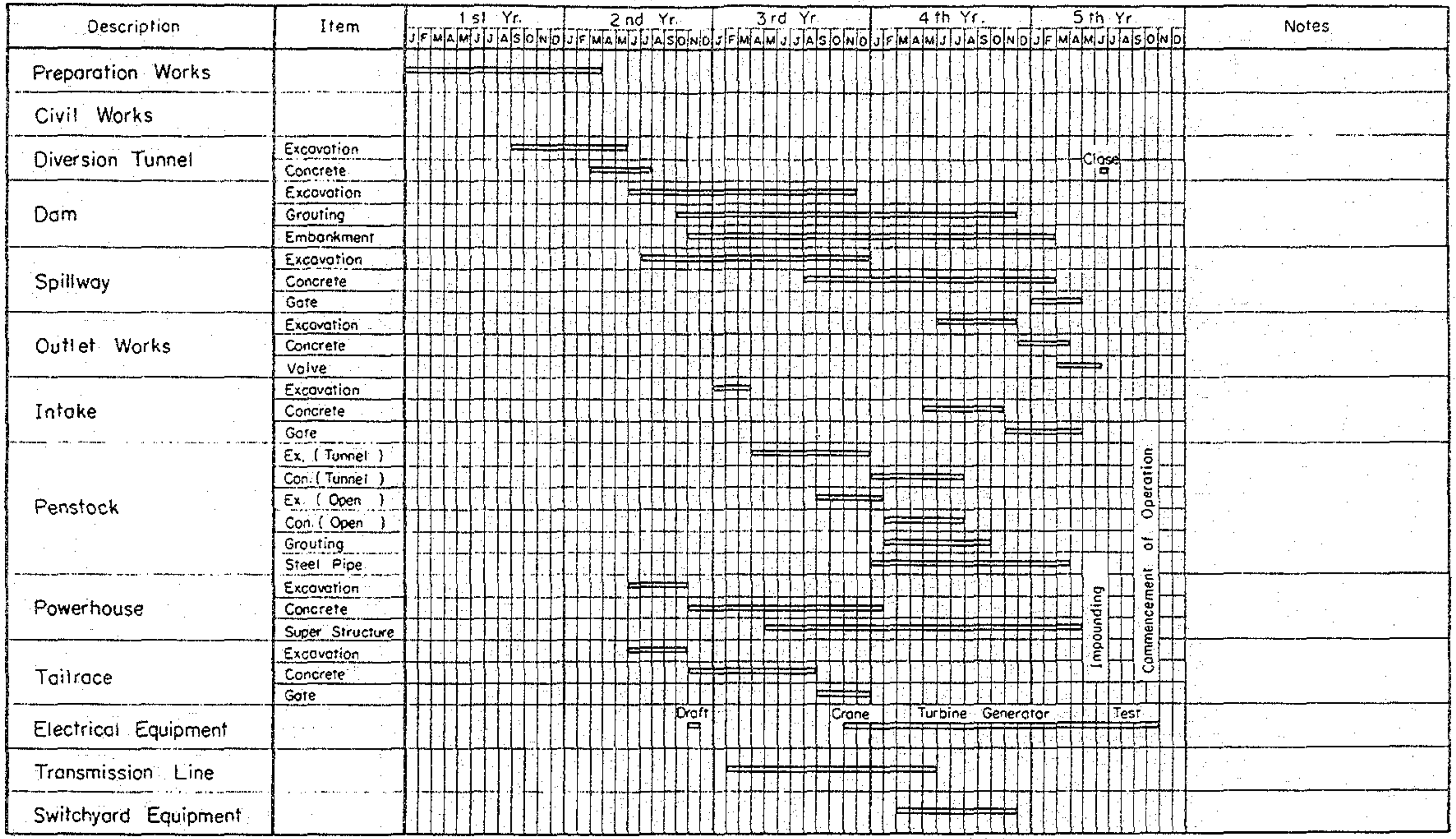


Fig. 8–1 Construction Schedule Nam Mae Ngao

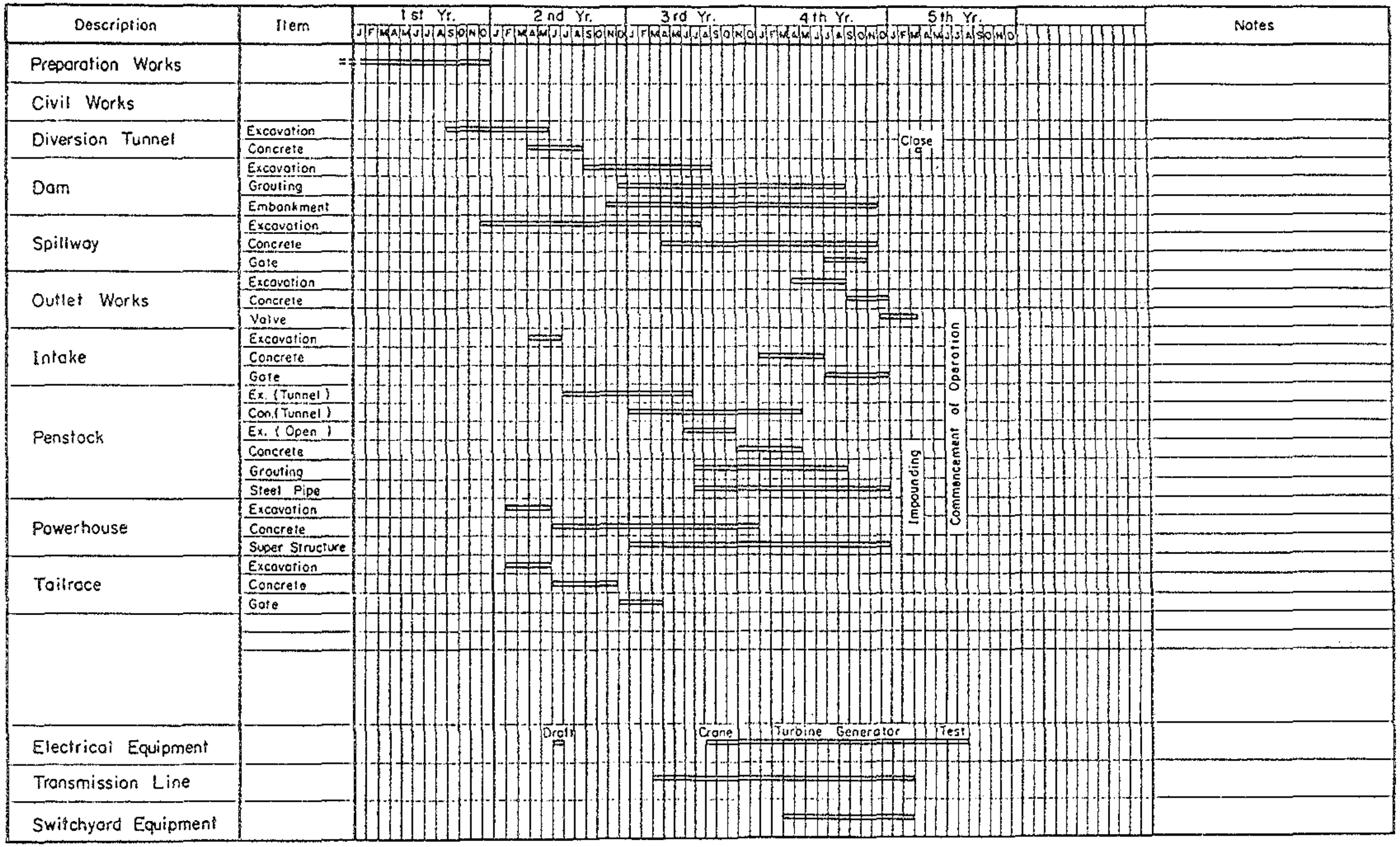


Fig. 8–2 Construction Schedule Nam Mae Rit

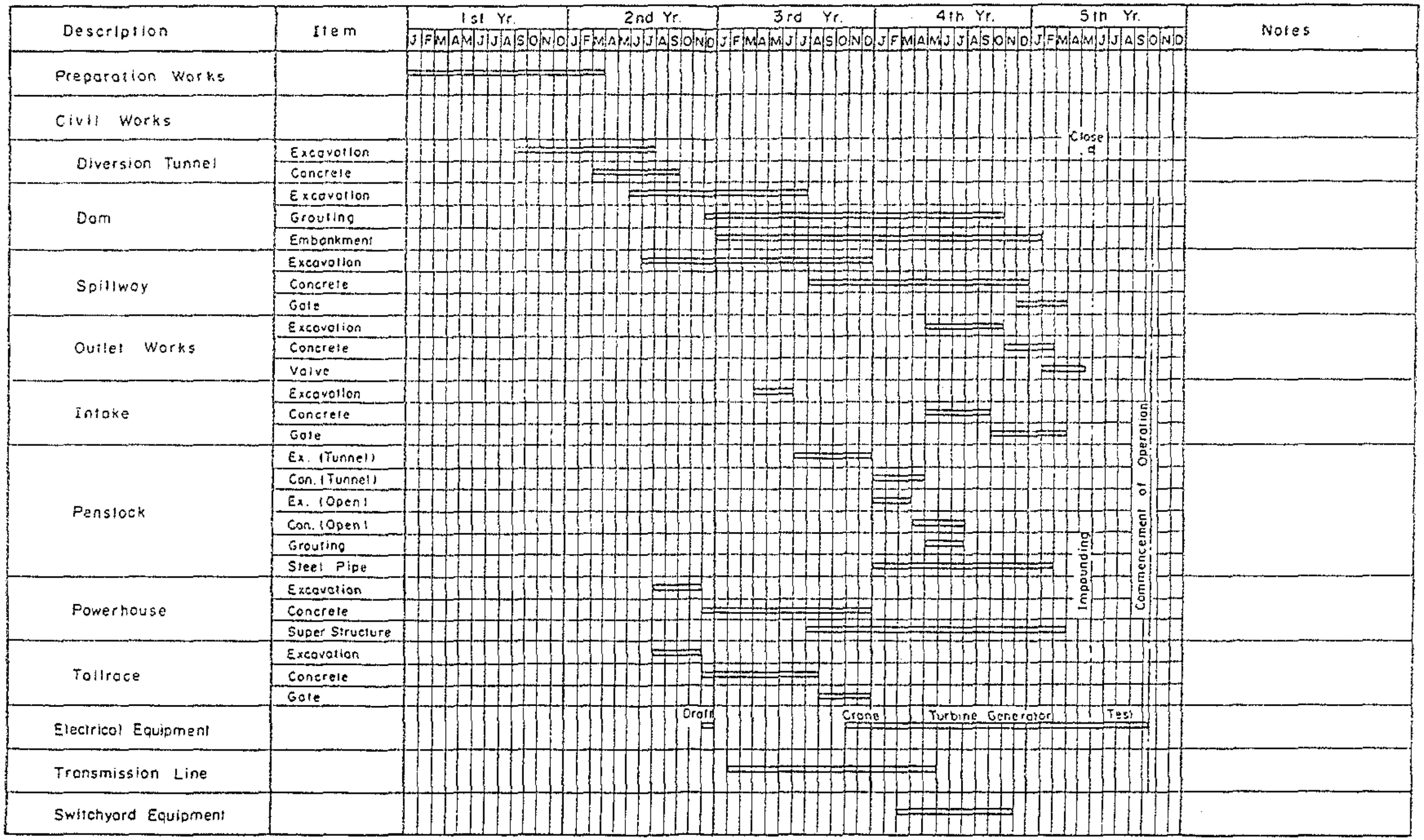


Fig. 8–3 Construction Schedule Upper Mae Yuam 1

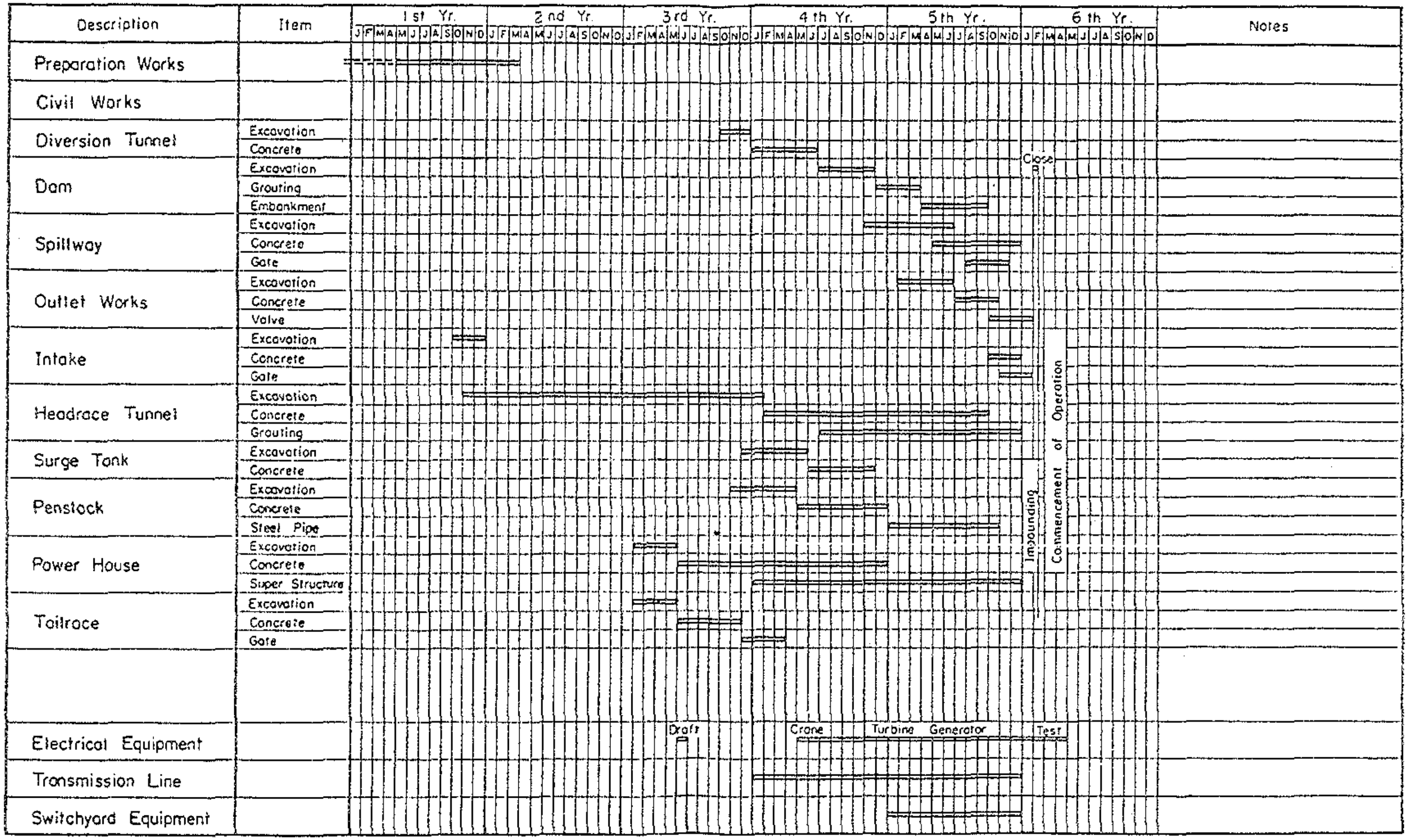


Fig. 8–4 Construction Schedule Upper Mae Rit 2a

9. ECONOMIC EVALUATION

9.2 Alternative Thermal Power Plants

In order to evaluate the benefit of the hydro power plant, an optimal combination of thermal power plants to supply the power for the demand region should firstly be considered.

As is studied already, the load of the Northern Region will be 1,221 MW in 2000 which we set as the first target year to be studied.

A combination of gas turbine, thermal power plant and lignite thermal plant is considered to be appropriate for covering this demand.

Now these thermal plants have their own features: in case of the gas turbine, for example, the capital cost per kW is lowest but the fuel cost per kWH is higher so it is generally suited for supplying peaking energy. On the other hand, in case of a modern high efficiency thermal power plant, the situation is reversed so it is planned to assume a middle or a base load.

That is that each type of power plant has its own territory within which it is most economically operated.

Therefore the problem with which we are concerned is to find these territories in definite (real) terms.

A so-called screening curve method [1)] is adopted here to solve the problem.

Combination of the following three types of thermal power plants were adopted as the appropriate alternative thermal plants for the evaluation of the benefit of the hydro power plant:

i) Gas turbine plant

fuel: natural gas for the first 25 years and diesel oil for the second 25 years

ii) Steam thermal power plant

fuel: natural gas for the first 25 years and imported coal for the second 25 years

iii) Lignite thermal power plant

fuel: lignite for the whole 50 years

Basic economic criteria and basic costs of these thermal plants are as shown on Table 9-1 for base case.

Based on these criteria, the annuitized fixed cost and variable cost for each of these thermal plants were calculated using the annual cost method as shown on Table 9-2 through Table 9-4.

The results for the base case are summarized as follows:

	kW-cost B/kW.a	kWh-cost B/kWh
Gas turbine	1810.1	1.0285
Steam thermal	3062.9	0.7190
Lignite	4735.8	0.5171

(price level: 1986)

9.3 Benefit of the Hydro Power Projects

The capacity and energy of each hydro power project which were calculated by the reservoir operation study for each case of variations as described in clause 5.4, were fitted under the load duration curve.

Since the capacities and energies estimated by the reservoir operation vary case by case, the positions that these capacities and energies occupy under the load duration curve differ correspondingly.

Consequently, the thermal costs that were replaced by these hydro power projects are different from case to case.

Thus the benefits of all the cases of the variations of the hydro power projects were calculated.

9.4 Costs of the Hydro Power Projects

The construction costs of all the cases of the variation of the hydro power projects were estimated.

The annuitized capital costs then were calculated basing upon the construction cost using the same discount rate (10%) as adopted in the calculation of the benefits described in the foregoing sections.

Thus the capital recovery factor, CRF is 0.10086 for the assumed project life of 50 years for the generation facilities and 40 years for the transmission facilities.

The operation and maintenance costs for the hydro power project and transmission line are estimated at 1% of the construction costs.

Thus the annuity factor of 0.111 is applied for the annuity costs or the generation facilities and 0.113 for the transmission facilities.

9.5 B - C and B/C

Using the results of benefits and costs as above obtained, B-C and B/C were calculated for all the cases of the study.

It is seen that the case NO2A260.25b of Nam Mae Ngao No.2 project is the most economical one in case of the individual development (B/C=1.22) and case No.2A260.25b of Nam Mae Ngao plus case YOA170.20c of Lower Yuam is most preferable (B/C=1.35) in case of integrated development even if the fuel price goes down to the lowest level.

The "scope of work" on the present study preclude the study of Lower Yuam project except the study on the incremental benefit which will accrue from Lower Yuam project due to the regulation effect of the Nam Mae Ngao project.

The evaluation result of this incremental benefit is shown on Table 9-11. It is seen that the annual benefit of Lower Yuam project will be increased as much as 58 million baht.

This amount to about 13.5% of the annual benefit of Nam Mae Ngao individual development, 429.3 million Baht.