THE KINGDOM OF THAILAND
NATIONAL ENERGY ADMINISTRATION
MINISTRY OF SCIENCE, TECHNOLOGY AND ENERGY

NAM MAE YUAM HYDROELECTRIC DEVELOPMENT PROJECT FEASIBILITY REPORT

VOLUME I

(Main Report)

MARCH, 1984

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to the request of the Government of the Kingdom of Thailand, the Government of Japan decided to conduct a survey on the Yuam River Hydroelectric Power Development Project and entrusted the survey to the Japan International Cooperation Agency (JICA). The JICA sent to Thailand a survey team headed by Mr. Isamu Kominami 5 times from August 16, 1982 to November 30, 1983.

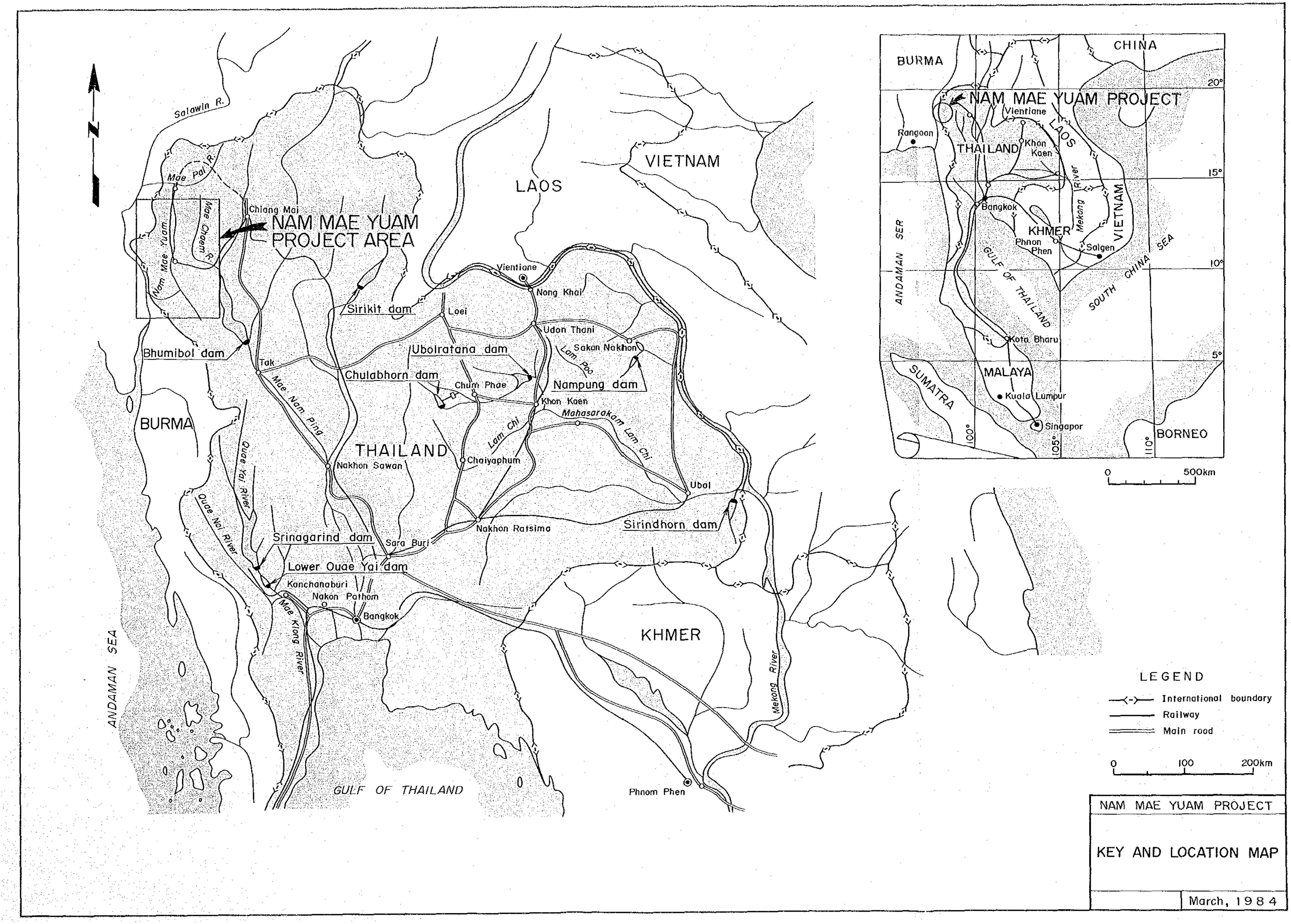
The team exchanged views with the officials concerned of the Government of Thailand and conducted a field survey in the project area. After the team returned to Japan, further studies were made and the present report has been prepared.

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.

Tokyo, March, 1984

Keisuke Arita
President
Japan International Cooperation Agency

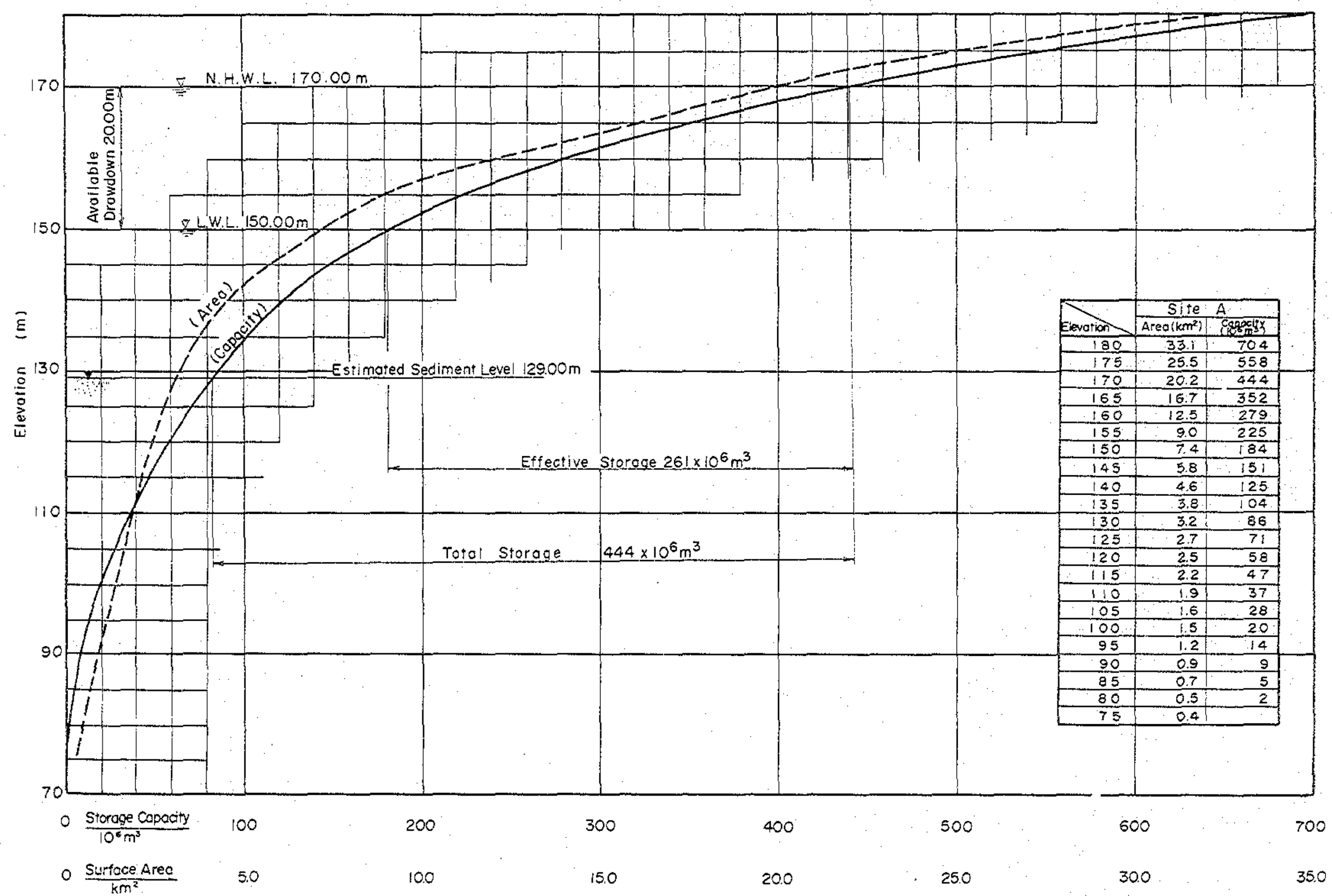


NAM MAE YUAM PROJECT
KEY AND LOCATION MAP
March, 1984

General Description of Project

Type of Power of Generation	: Storage Type	
Catchment Area	: 5,920 km^2	
Annual Inflow	: 2,800 x 10^6 m^3	
Reservoir	: Normal Heigh Water Level;	170m
	Total Storage Capacity;	444 x $10^6 m^3$
	Effective Storage Capacity;	261 x $10^6 m^3$
	Available Drawdown;	20m
Power Production	: Normal Effective Head;	87.30m
	Max. Turbine Discharge;	215m^3/sec.
	INSTALLED CAPACITY;	162MW
	ANNUAL ENERGY PRODUCTION;	565GWh
Dam	: Center Core Type Rockfill Dam	
	Height x Crest Length;	120m x 350m
	Volume;	4,650 x $10^3 m^3$
Water Way	: Headrace Tunnel Dia.x Length;	7.80m x 240m
	Penstock Dia.x Length x Line;	7.80m x 186m x 1
	Penstock Dia.x Length x Line;	5.50m-4.40m x 112m x 2
Spillway	: Design Flood;	6,200m^3/sec.
	Design Descharge;	4,770m^3/sec.
	Dissipator;	Ski-jump type
Turbine	: Type;	Vertical-shaft Francis
	Number of Units;	2
Generator	: Type;	Three-phase, A.C. Syncronous
Transmission	: Power Plant - Substation of Tak	
	Voltage x Distance;	230kv x 185 km
Construction Cost	: General Facilities;	3977.8 x 10^6 B
	Transmission & Others;	1770.2 x 10^6 B
	Total Construction Cost;	5,748 x 10^6 B
Economic Analyses	: Cost of Energy; (at Primary Substation)	1.24 B/kWh
	Benefit Cost Ratio;	1.105
	Annual Surplus Benefit;	70 x 10^6 B
	I.R.R.;	11.4 %
	Discount Rate;	10 %

Reservoir Area and Storage Capacity Curve



Elevation	Site A Area (km²)	Site A Capacity ($10^6 m^3$)
180	33.1	704
175	25.5	558
170	20.2	444
165	16.7	352
160	12.5	279
155	9.0	225
150	7.4	184
145	5.8	151
140	4.6	125
135	3.8	104
130	3.2	86
125	2.7	71
120	2.5	58
115	2.2	47
110	1.9	37
105	1.6	28
100	1.5	20
95	1.2	14
90	0.9	9
85	0.7	5
80	0.5	2
75	0.4	

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UNITS AND GLOSSARIES

(1) Units

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

(2) Glossaries

(i) Terms

US$	:	U.S. dollar
฿	:	Baht
hrs	:	Hours
yr	:	Year
ea.	:	Each
Max.	:	Maximum
Min.	:	Minimum
cct	:	Circuit
a.c.	:	Alternative current
ACSR	:	Aluminum Conductor Steel Reinforced
ASTM	:	American Standard for Testing and Materials
CA	:	Catchment Area
FY	:	Fiscal Year
GDP	:	Gross Domestic Product
IRR	:	Internal Rate of Return
PAX	:	Private Automatic Exchanger
PMF	:	Probable Maximum Flood
PMP	:	Probable Maximum Precipitation
UHF	:	Ultra High Frequency
VHF	:	Very High Frequency

(ii) Agencies

AIT	:	Asian Institute of Technology
EGAT	:	Electricity Genrating Authority of Thailand
EPDC	:	Electric Power Development Co., Ltd.
JICA	:	Japan International Cooperation Agency

MEA	:	Metropolitan Electricity Authority
NEA	:	National Energy Administration
NESDB	:	National Economic and Social Development Board
OPEC	:	Organization of Petroleum Exporting Countries
PEA	:	Provincial Electricity Authority

CONCLUSION AND RECOMMENDATION

CONCLUSION AND RECOMMENDATIONS

The economic growth in Thailand is so remarkable that power demand likely becomes 6,200MW, 36,900GWh by 1991, amounting to over double of the present and also seems to continue growing at an annual rate of over 6% after 1991.

On the other hand, assurance of oil substitute resources is very important for stable development of the Thai economy, and development of economical hydro power generation projects is, thus, considered significant.

The Nam Mae Yuam river is a tributary of the Salween river in the north-western part of Thailand, having catchment area as wide as 6,000 square kilometers where the rainfall is relatively heavy. The area concerned in this project is located 170km south-west of Chiang Mai, near the Burmese border.

It is concluded that the project is optimum in storage type with installed capacity 162MW and annual generated energy 565GWh. The generated power to be transmitted to Tak, 185km away, on a 230kV power line is suitable to meet the demand in Bangkok area.

The estimated construction expenditure is 5,748 x 10^6 baht, project economy being fully assured. On technical matters too, there are no specially hard problems. It is desirable that the project will be implemented as early as possible in 1990's.

The geology around structures including the dam is Mesozoic shale, which is solid and favorable for construction, bearing no problems. In the reservoir area, calcarious rocks are distributed to some extent, but there is almost no fear of water leakage, judging from the result of investigation widely performed in the area paying much attention to the watertightness of the area. It is noted, however, that treatment of calcarious rocks in the left bank right upstream of the dam should be careful, for which, in this study, watertightening treatment has been considered to some extent, thus the necessary cost was involved in the total cost. Detail investigation thereof has to be pursued as soon as possible by the time of definite design.

As a result of sampling and testing, the core material satisfactory in quality could be found in general around the area. However, it would be hard to collect full amount thereof at the tested area only. Therefore it is necessary to perform further investigation taking close area also into account. Use of incidental materials obtained in collecting rock materials is very appropriate with piling and mixing. Thus, investigation on rock materials in quarry sites, which is also needed in preparation of quarrying schedule, is desired to be proceeded as early as possible.

It is extremely important for project development and should be pursued as soon as possible to investigate the present state of environmental aspect of the area including resettlement of houses to be inundated by the reservoir, and upon considering the effect, necessary measures must be taken.

Technical investigation works necessary for further definite study are discussed in each chapter.

At last, it had been required in this feasibility study that this Yuam project should be compared with Pai No.6 or Chaem No.5 project. These two projects are still in a master plan stage and the investigation on environmental impact which is significant factor in developments has not yet been performed. Therefore, proper comparison in the priority would be difficult. But, comparing them simply in the technical and economic terms, Pai No.6 project is judged superior to Yuam project, and is concieved favorable to develop the Pai No.6 project first and then, with time lag of two or three years, to develop the Yuam project. On the other hand, Chaem No.5 project is considered rather difficult to be developed, judging from the economy of near future.

CHAPTER 1.

INTRODUCTION

CHAPTER 1. INTRODUCTION

1.1 Outline of The River Basin

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

The Yuam river basin, therefore, is located in the northwestern corner of Thailand, and, in viewing Chiang Mai as the center of the area, extends from its western part to the southwestern part belonging to the region adjacent to the Burmese border. The Yuam basin ranges approximately 60km east and west and about 160km north and south, having the catchment area of approximately 6,000 square kilometers.

Mountains of the 1,000m height class, which are the highest ones in Thailand, range in the east and west direction of the Yuam basin, forming the topographic feature of a long basin in the north and south direction. The center town is Amphoe Mae Sariang (about 20,000 of population) belonging the district of Changwat Mae Hong Son. The northern part of this basin and farther is the basin of the Pai river which is also a tributary of the same Salween river. The Yuam river rises from the northern end of this basin, flows south and joins the Ngao river, which is a tributary running down from the opposite direction, at the point about 40km south of Mae Sariang, and then turns the flow to south almost in right angle and joins the Moei river through the village of Ban Tha Rua and the damsite.

The national road No. 108 connecting Chiang Mai and Mae Sariang runs the east side foot of Mt. Doi Inthanon (2,595m high) soaring west-southwest of Chiang Mai, which is the highest in Thailand, passes Chom Thong, goes over the plateau in the east side of the Yuam basin along the Chaem river, the tributary of the Ping river, and reaches Mae Sariang. The distance thereof covers approximately 200km. The road then goes straight north and reaches Mae Hong Son, which is the center of the basin of the Pai river through Khum Yuam. On the other hand, the road extending south from Mae Sariang is under improvement and new construction. The section of the road about 40km down to the junction with the Ngao river is not yet paved but in good condition.

The basin inside is well developed in irrigation facilities, and so there are rich paddy fields. Particularly, an intake facility has been constructed by the Royal Irrigation Department at the point about 13km in upstream of Mae Sariang, from where the main irrigation canal of which the capacity is about $4m^3$/sec downs to the right-bank tableland. By virtue of this facility, paddy fields of about 1,200 hectares down to about 10km in the downstream area of Mae Sariang are irrigated. The mountaneous area of the basin is covered with broadleaved forests and also full of teak. The aerial survey reveals that the forest facies appear to be better than in upper catchment areas of adjacent rivers Pai and Chaem.

1.2 Historical Background

The Thai economy showed the average annual growth rate of 7.4 percent in 1970s, and in parallel with this development the growth rate of electricity demand achieved a level as high as 12% to 15% annually. The Lord Forecast Working Group for Power Tarriff Study Sub-committee is at present composed of five parties of NESDB, NEA, EGAT, MEA and PEA. According to the Load Forecast for Thailand Electric System, June 1982 worked out recently by this group, the annual demand growth in the future is forecasted to go down gradually from the level of 14% in early 1980s to 6% in 1990s.

NEA, taking account of such a demand growth, has pursued with full efforts the investigation on the feasibility of development of various power resources. Particularly, in connection with the development and application of indigeneous natural resources, i.e. hydro, natural gas, lignite or others. NEA is extremely in the positive stance. Under such circumstances, it has focused its attention recentry on the rich water resources in the northern part of Thailand, especially in the tributary basin of the Salween river which is still undeveloped, and has carried out in these years the investigation necessary for the development. The first investigation for it was the master plan for the Pai and Chaem rivers hydro electric power development carried out in previous years. The Yuam river plan in question follows the preceding plans as the investigation for the tributary basin of the same Salween river.

The hydro electric power resources development in Thailand has hitherto been made in big scales for some dams; e.g., Bhumibol Dam (420MW) on the Ping river, the tributary of the Chaophraya river flowing through from north to south in the country, Sirikit Dam (375MW) on the Nan river which is samely the tributary of the Chaophraya river, and Srinagarind Dam (720MW) on the Quae Yai river which is a tributary of the Mae Klong river. At present, Khao Loem Dam (300MW) on the Quae Noi river and Chiew Larn Dam (240MW) are being constructed, and moreover Upper Quae Yai Dam (580MW) which was planned in the upstream of Srinagarind Dam is awaiting for the commencement of construction. As a result of these developments, it can be thought that the remaining possible large-scale hydro electric power resources are, viewing the geographical conditions in Thailand, being limited mainly in international rivers such as the Mae Khong river and the Salween river, existing along the boundary.

However, the Mae Khong river has many nations of interest including internationally-complicated factors, so that it is very hard to imagine that the development is realized in the near future. From this viewpoint, too, the early development in the basin of the Salween river is hoped.

This Yuam river hydro electric power development plan is highly promising as the first large-scale hydro electric power development plan, in northern Thailand, in the basin of the Salween river along with the development plans in the Pai and Chaem river.

1.3 Scope of Works

The purpose of this investigation works lies in carrying out the feasibility study of the hydro electric power development project that NEA has planned for the Yuam river and in studying the technical and economic feasibility thereof. In addition, comparison with Pai No. 6 and Chaem No. 5 projects is also required, which have been planned for the adjacent Pai and Chaem rivers respectively and completed their preliminary investigation.

The investigation works are conducted for technical fields of civil engineering, geology and electric engineering aiming at electric generation, and for economic field to judge the project economy through estimating and analyzing the project benefit from these obtained investigation data. The field survey for conducting this study has been performed in two times; the first field investigation work was held from August 16 to September 15, 1982, and the second of it from October 16 to December 15, 1982. The team dispatch for supervising of the field survey work has been made three times; from February 22 to March 20, 1983, from June 12 to June 23, 1983, and from November 7 to 30, 1983.

The field survey covered the following aspects:

- o Social and economic background requiring development and electricity demand
- o Ground topography, geologic and natural river conditions in the basin of the Yuam river
- o Ground topography and geology at the sites of main structures such as dam, power plant and other appurtenant structures.

- o Investigation for the dam embankment materials and concrete aggregates.
- o Cost of construction materials, labor wages, construction cost for similar project, etc.
- o Route of transportation of construction materials, turbine and generator, etc.
- o Route of transmission lines and telecommunication facilities.
- o Collection of data necessary for studying.

Meanwhile, in the first field investigation trip, both the parties, JICA team and Thai officials discussed on and set up the list of consumable equipment for geological survey which are to be dornated from JICA and further on procedure of the test for core materials. As a result, in connection with consumable equipment for geological investigation, the articles listed in Table 1-1 have been confirmed, and the equipment have been handed over to Thai side at the second investigation trip. As for the test of core materials, laboratory tests were conducted under the contract which was made between the JICA survey team and the AIT (Asian Institute of Technology), and also the supplemental tests were carried out in NEA's laboratory. The feasibility study to be performed in Japan includes the following works, while such works that the topographical mapping of the sites, drilling works for geological survey, excavation of the test pit and sampling for core material tests etc. have been carried out by NEA.

- o Optimization study and layout of the project (including comparison with projects of Pai No. 6 and Chaem No. 5)
- o Hydrologic analyses
- o Analyses of geology at the planned sites
- o Analyses of core materials
- o Basic design of main structures such as the dam and power plant
- o Basic design of electric equipment
- o Planning of transmission line and system analysis

o Construction cost estimation and preparation of financial program
o Economic evaluation of the project
o Listing up of environmental issues

As for the environmental assessment, the detailed study will be performed and reported by NEA separately in addition to this F/S report. However, in this report, since the study items relating to environmental issues are required to be itemized, these items are shown in the following chapter.

The members of the field investigation team and the Thai officials concerned who gave heartful cooperation in the field investigation are as follows:

First survey:

Mr. Isamu Kominami	Team Leader	(EPDC)
Mr. Yoshihiro Nakazawa	Civil Engineer	(EPDC)
Mr. Nobuhiro Tsuda	Geologist	(EPDC)
Mr. Fuminori Arai	Civil Engineer	(EPDC)

Second survey:

Mr. Isamu Kominami	Team Leader	(EPDC)
Mr. Yoshihiro Nakazawa	Civil Engineer	(EPDC)
Mr. Osamu Kinouchi	Civil Engineer	(EPDC)
Mr. Fuminori Arai	Civil Engineer	(EPDC)
Mr. Nobuhiro Tsuda	Geologist	(EPDC)
Mr. Motoaki Sunami	Geologist	(AAS)
Mr. Tadao Sato	Electric Engineer	(EPDC)
Mr. Yukiteru Takeya	Electric Engineer	(EPDC)
Mr. Noboru Ito	Economist	(EPDC)

Supervision for field investigation works:

Mr. Yoshihiro Nakazawa	Civil Engineer	(EPDC)

Mr. Osamu Kinouchi	Civil Engineer	(EPDC)
Mr. Fuminori Arai	Civil Engineer	(EPDC)
Mr. Masahiro Shibata	Geologist	(EPDC)
Mr. Nobuhiro Tsuda	Geologist	(EPDC)

<u>Thai officials concerned, when the survey team visited Thailand</u>

Mr. Sutin Susila	Colombo Plan Sub-Division	(DTEC)
Mr. Tammachart Sirivadhanakul	Director, Regulatory Division	(NEA)
Mr. Suvat Saguanwongse	Director, Investigation and Planning Division	(NEA)
Mr. Winya Sinchermsiri	Head, Investigation Branch	(NEA)
Mr. Mohar Singh Monga	Head, Planning Branch	(NEA)
Mr. Sompong Sripyak	Chief, Engineering Geology Section	(NEA)
Mr. Aram Supakarn	Chief, Surveying Section	(NEA)
Mr. Lek Suwanthada	Acting Chief, Water Resources Planning Section	(NEA)
Mr. Somchai Kurupakorn	Engineering Geologist	(NEA)
Mr. Adul Chai aroon	Civil Engineer	(NEA)
Mr. Suebsak Punsri	Surveying Engineer	(NEA)
Mr. Phadet Saengsawang	Planning Engineer	(NEA)
Mr. Wichit Wetchaphan	Civil Engineer	(NEA)
Mr. Somnuk Leelittham	Civil Engineer	(NEA)
Mr. Manit Rodphai	Geologist	(NEA)
Mr. Kamol Karunamit	Geologist	(NEA)
Mr. Rangsan Sarochawikasit	Electric Engineer	(NEA)
Mr. Preecha Seneewongse	Project Economist	(NEA)
Mr. Kanung Srikaew	Project Economist	(NEA)

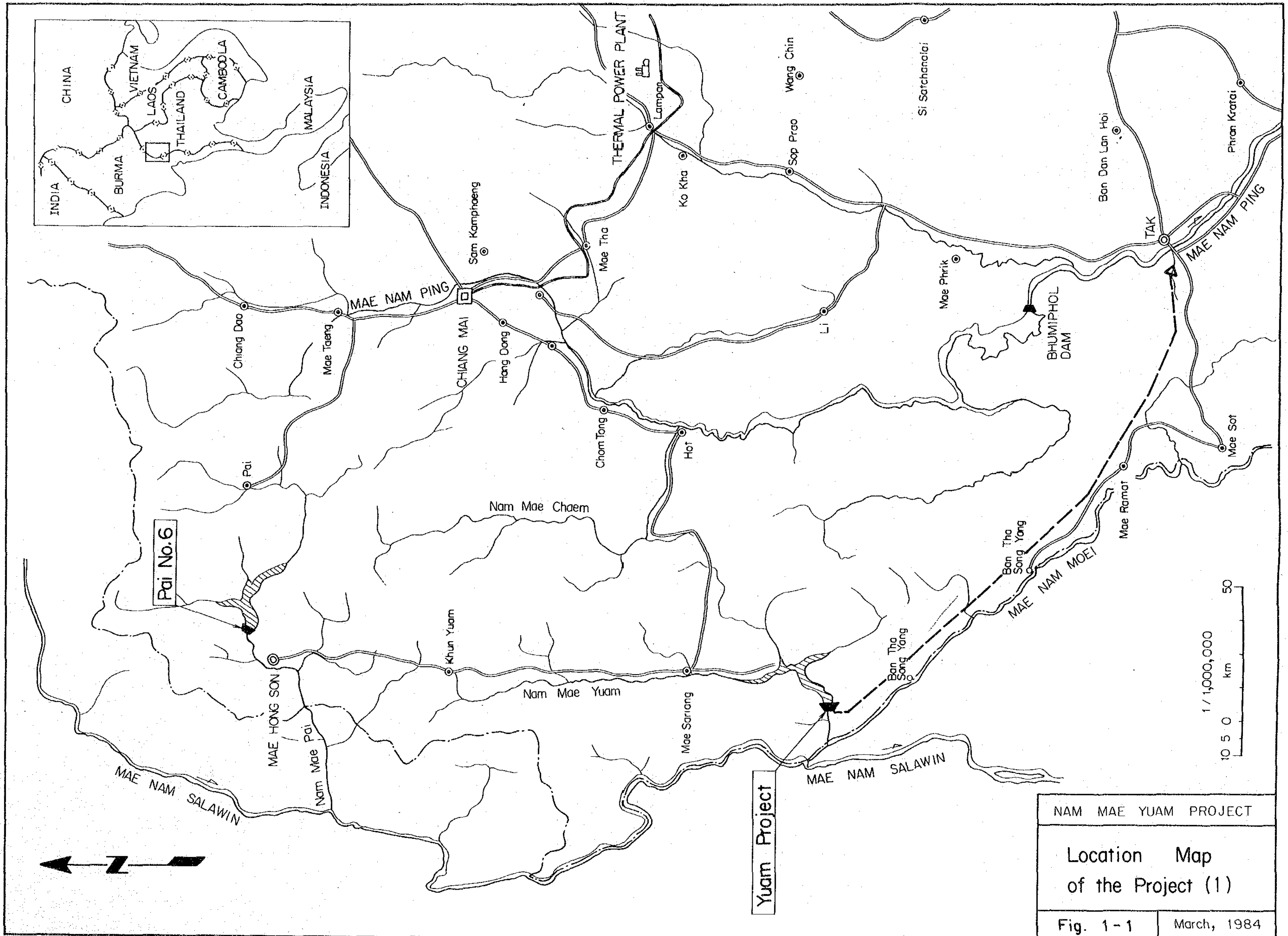
Mr. Payak Ratnarathorn	Chief, Water Resources Planning and Development Division	(EGAT)
Mr. Prasit Srisaichuea	Irrigation Engineer, Water Resources Planning and Development Division	(EGAT)
Mr. Niwat Kulkarnjanathorn	Agricultural Engineer, Water Resources Planning and Development Division	(EGAT)

1.4 Acknowledgement

The team wishes to express sincere appreciation and thanks to NEA and many other Thai officials concerned for their faithful and warm cooperation in achieving this study. We also wish to thank the officials of the Japanese embassy and the staff of JICA in Thailand who supported the team during their staying in Thailand.

Table 1-1 Drilling Consumption Equipment

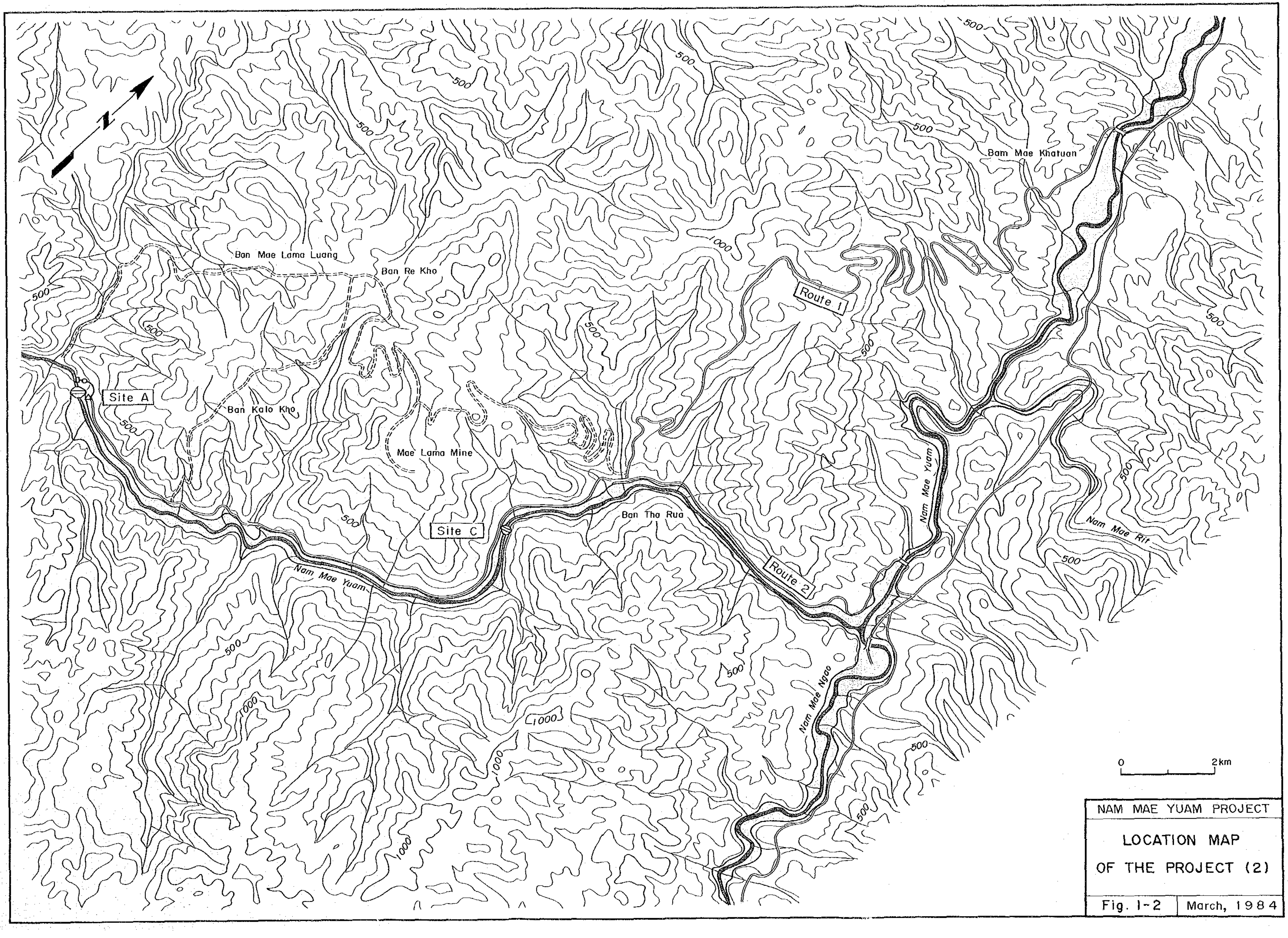
Item	Description	Quantity
1.	Double tube core barrel NW × 3.0 m	4 sets
2.	Double tube core barrel NW × 1.5 m	4 sets
3.	Outer tube, NW × 3.0 m	4 pieces
4.	Outer tube, NW × 1.5 m	4 "
5.	Inner tube, NW × 3.0 m	4 "
6.	Inner tube, NW × 1.5 m	4 "
7.	Core lifter, NW	60 "
8.	Core lifter case, NW	30 "
9.	Diamond Reaming Shell, NW (6.6 carat)	10 "
10.	Diamond Bit, NW (24 carat)	39 "
11.	Casing Shoe Bit (Diamond), NW (20 carat)	10 "
12.	Rod, NW × 3.0 m	45 "
13.	Rod, NW × 1.5 m	10 "
14.	Casing Pipe, NW × 3.0 m	40 "
15.	Casing Pipe, NW × 1.5 m	10 "
16.	Packer Rubber, NW	50 "
17.	Pressure Gage (35 kg/cm^2)	12 "
18.	Water meter	2 "



NAM MAE YUAM PROJECT

Location Map of the Project (1)

Fig. 1-1 March, 1984



NAM MAE YUAM PROJECT

LOCATION MAP OF THE PROJECT (2)

Fig. 1-2 | March, 1984

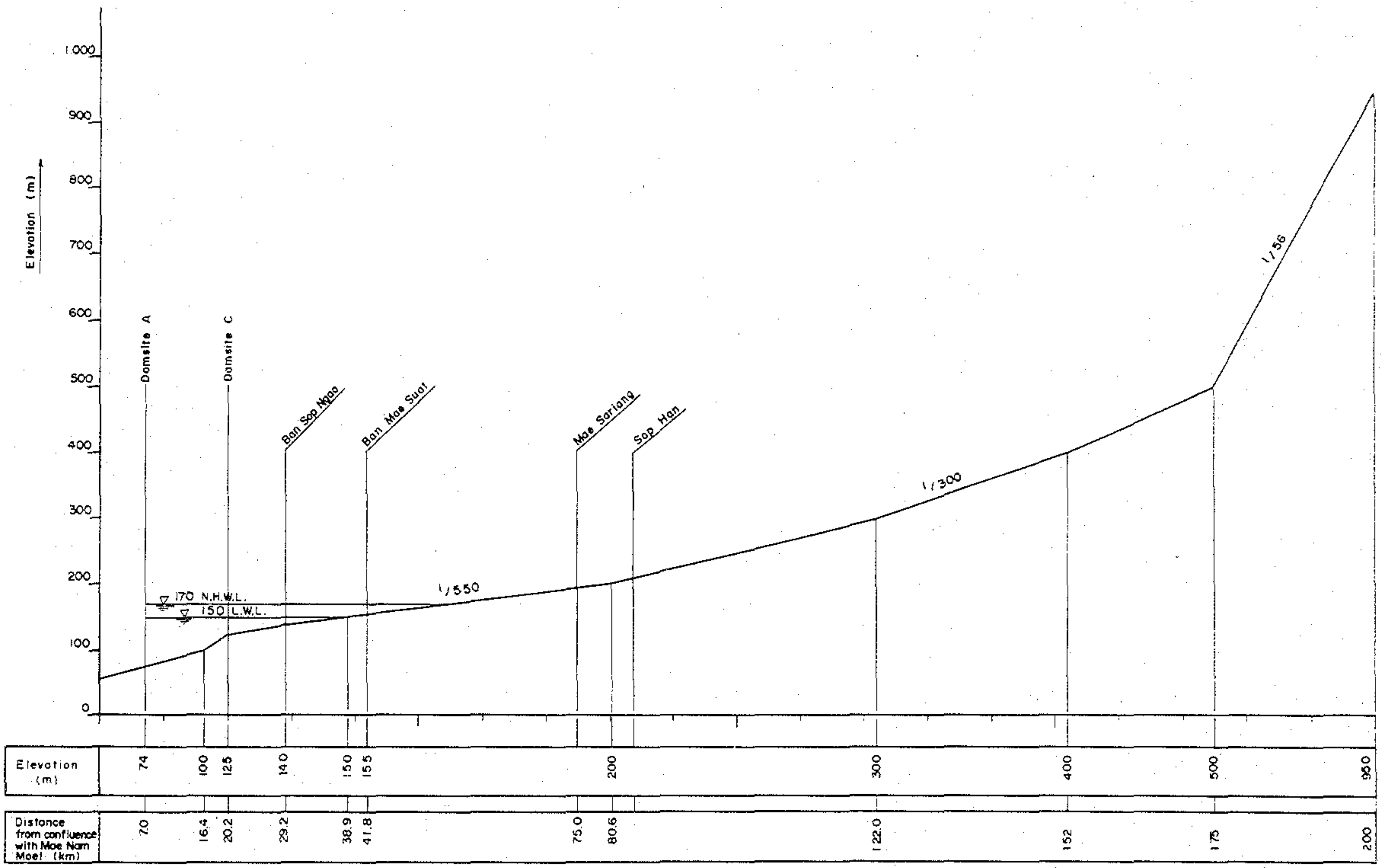


Fig. 1-3 Profile of Nam Mae Yuam

CHAPTER 2.

GEOLOGY

CHAPTER 2. GEOLOGY

2.1 Introduction

This Chapter 2 presents the geological conditions of this project based on the investigation works from 1982 to 1984. The geological investigation works described in Section 2.2 were carried out in cooperation with NEA and Japanese Survey team and the investigation revealed the general geological conditions for the hydroelectric power development project of which features are shown in Chapter 1.

It is previously known that calcareous rocks are partially distributed in the project area including its reservoir basin and careful study for reservoir watertightness is necessary.

As the accessibility for the field investigation is poor in this reservoir basin, previous existing data and aerophoto interpretation are utilized to the fullest for the survey. Field geological mapping is effectively carried out concentrating in the very important places. As the result of the survey, it is confirmed that the possibility of leakage from the reservoir is very small.

Further, geological mapping and drilling investigations including permeability tests have been carried out in the damsite, and the outline of geological condition of damsite is understood.

2.2 Geological Investigation Works

The investigation method and quantity carried out in this feasibility study are as follows:

o Aerophoto interpretation
  Interpreting area : about 700km^2 area including the reservoir and its surroundings.

Scale of photograph; 1:20,000 and 1:15,000.

- o Surface geological survey

  Surveyed area: along the rivers in the reservoir and its surroundings, damsite and its peripheries.

  Scale of topographic map; 1:10,000 (enlargement of 1:50,000 in and around reservoir).

  1:10,000 (aerial survey map, in reservoir)

  1:2,000 (surveyed map, around Damsite A)

- o Drilling (including the permeability test)

  Surveyed area: Damsite A area

  Number of holes: 11 holes, total length 745.5m

- o Test pit for core materials

  Surveyed area: Damsite A area   Number: 12 pits

- o Chemical analyses of rock

  Number of samples: 21 pieces

2.3 Regional Geology

1) Topography

The Yuam river rises from nearby Khun Yuam around lat. 19° N and long. 98° E, and flows south about 120km with meandering in the Mae Sariang basin. Meanwhile, the Ngao river, the largest tributary of the Yuam river rises around lat. 17.40° N and long. 98° E, flows about 40km north-northwest and joins the Yuam river. The Yuam river turns the direction to the west after joining the Ngao river and flows about 30km, and then joins the Salween river which forms the border between Thailand and Burma.

A basin stretches widely along the Yuam river from its source down to around the point about 25km south of Mae Sariang, but in the further downstream and along the Ngao river, steep valley is predominant.

The catchment area of the damsite A about $6,000km^2$ large has the topography stretching about 30 to 50km east and west and about 160km north and south as shown in Fig. 2-1. The west-side boundary of the catchment area faces the mountains having the height of 1,000m or so and stretching straightly south from Mt. Doi Wi Cho Lo (height 1,056m), and the east-side boundary faces the mountains having the height of 1,500 to 1,800m and stretching south from Mt. Doi Phate Do (1,821m high).

2) Geology

The project area, as shown in Fig. 2-1, consists mainly of Paleozoic and Mesozoic sedimentary rocks and Mesozoic granite.

Paleozoic rocks ranging from Cambrian to Carboniferous age are classified into the strata consisting mainly of non-calcareous rocks and the Ordovician strata consisting mainly of limestone. The former strata are distributed widely centering around the southern and eastern part of the project area, and the latter runs north and south in the belt shape within the strata consisting mainly of non-calcareous rocks.

Paleozoic rocks ranging from Carboniferous to Permian age and Triassic rocks are composed mainly of non-calcareous rocks, and are distributed in the large part of the northwestern section of the project area.

Granite is intruded into Paleozoic rocks in the whole of the eastern section of the project area, and is distributed in a long-stripe rock body of 10km to 20km wide north and south.

In the northern Thailand including the project area, Mesozoic orogenic movement having two phases of latest Triassic to Jurassic phase and Jurassic to Cretaceous phase occured, so that the existing geological structure is effected by this orogenic movement, and the structure in the north and south or northwest and southeast direction is conspicuous. The project area is also subjected to this effect, so that the strike of strata, the strike of folds and the strike of remarkable faults are mainly in the north and south or northwest and southeast direction.

2.4 Site Geology

1) Reservoir geology

(i) Topography

The reservoir area consists of mountain districts with the height of 700m to 1,000m. In lots of these mountain regions, the portion of the height of about 600m and above has the relatively mild profile. On the other hand, from the height of 600m or so down to around the river bed of the Yuam river, steep slopes are formed. Particularly, the region along the Yuam river in the down stream lower than the point joining the Ngao river forms steep valley, and the width of valley at the high water level (reservoir's width) is 100m to 300m.

In the upper stream from the joining point of the Yuam river with the Huai Ma Laum which is in the uppermost part of the reservoir, the valley bottom plain stretches along the Yuam river, and the width of the reservoir is as large as about 1km.

(ii) Geology

a) General geology

The reservoir area is composed of Paleozoic to Mesozoic rocks intruded by granite and basalt, Tertiary sediments and Alluvial deposits.

Paleozoic to Mesozoic rocks are widely distributed in the reservoir area, being composed of quartzite, quartose sandstone, alteration of sandstone and shale, shale, calcareous shale, calcareous sandstone and limestone. These rocks trend north-south or north-northwest, and dip 30° to 60° east or west.

Quartzite and quartzose sandstone are light grey or pinkish light grey, fine grained and hard. These rocks are, as shown in Fig. 2-2, distributed forming an anticlinal structure with an axis of fold in nearly the north and south direction along the Huai La Po Kra river and the Huai La Cho Kra river which are at almost midway between Damsite A and Damsite C. At around the western flank of the anticline it changes to the alternation of sandstone and shale.

The alternation of sandstone and shale is composed of grey to dark grey shale and grey, fine to medium grained sandstone. This strata change widely in rock facies, i.e., from the facies composed almost of shale to the one in which shale with the thickness of 1cm or less is interbeded in the sandstone 50cm to 1m wide. In addition, minor folds with the wavelength of 1m to 10m and the fold axis in the north and south direction are frequently observed. This alternation is distributed in east of the Huai La Cho Kra river, repeatedly beltwise in the north and south direction.

Shale, which is grey to black, and hard, is banded with the interval of a few cm to 20cm. This strata are repeatedly folded with the wavelength of about 50m, and furthermore a number of small folds are seen. The shale strata extend to north-northwest and south-southeast from damsite A with the width of about 400m. Neverthless, as indicated in article "Damsite Geology", its distribution is interrupted between around the left bank of the reservoir in the just upper stream of damsite A and about 1.8km south-southeast therefrom.

Calcareous shale, which is grey to black, is classified into two facieses; the same as non-calcareous shale and the one in which the black and grey layer are interbeded. In the latter case, the grey part is more solved, but solution cavity, in general, is hardly seen. And also, fairly lots of siliceous portions exist in calcareous shale distributed around the Nam Mae Rit river lying east of the reservoir.

Calcareous sandstone is a facies in which grey argillaceous lamina is interbeded in the light-brown arenaceous part. It is also divided into two facieses; the facies consisting almost of the arenaceous part alone and the one in which grey argillaceous lamina is densely contained. The former is massive and hard, meanwhile the latter has the behavior easy to cleave along argillaceous laminae. In this calcareous sandstone, solution cavity is hardly seen. These rocks, which strike NNW-SSE and dip 30° W, are distributed in the just upper and just down stream of Damsite A.

Limestone has two features; dark grey or light grey massive limestone and dark grey to grey or light brown one in which laminae are developed. Solution cavities 5cm to 40cm wide are frequently observed along the joint planes in the massive limestone. On the other hand, limestone in which laminae develop well is midway between a massive limestone and a calcareous sandstone both in chemical composition and in rock facies, and few solution cavities of 1cm or less in diameter are seen.

Tertiary sediments are distributed on both the bank of the Yuam river in the upper stream from the limit of backwater of reservoir, consisting of shale, sandstone and conglomerate which are of low consolidation. These Tertiary sediments can be easily distinguished from Paleozonic and Mesozonic rocks by aerophoto interpretation thanks to their topographic feature.

The Alluvial deposits are mainly in the form of a terrace deposit along the Yuam river, consisting of silt, sand and gravel. The Alluvial deposits develop widely along the Yuam river in the upper stream from the limit of backwater of the reservoir, and they are also distributed widely to some extent in around the left bank of the upper stream from Damsite A.

Granite is intruded into Paleozonic to Mesozonic rocks in the form of a small rock body about 6km long and about 3.5km wide along the Yuam river in the downstream of the Ban Tha Rua. According to the literature, this period of granite is of 70 to 80my, and it is fairly younger in age than the granite, which is of around 200my, distributed widely in the eastern part of the project area.

Basalt is distributed in the form of a small rock body about 3.5km and about 1.2km wide in the upper stream about one km away from the point joining the Yuam river with the Ngao river.

Folds observed in the reservoir area have their axis in the north-northwest and south-southeast direction and the wavelength of 2 to 4km.

A remarkable fault is seen in the east side of the upper stream of the Yuam river. This fault has NNW-SSE strike and almost vertical dip. The width of shear zone is a few meters. According to the results of aerophoto interpretation, this fault is imagined to extend south along the right bank of the Ngao river.

b) Karstification

o Chemical analyses of rocks and solution cavity

Aiming at knowing the carbonate mineral contents of rocks distributed in the reservoir area, some quantative chemical analyses of rocks were carried out. Number of samples analyzed is as follows:

Massive limestone;	7 pieces
Limestone with well-developed lamina (Laminated limestone) and sandy limestone;	8 pieces

Calcareous sandstone;	3 pieces
Shale, Sandstone;	3 pieces

The components analyzed are CaO, MgO, SiO_2 and Al_2O_3. The results of analyses are shown in Table 2-1. Massive limestone consists of 90 to 94% $CaCO_3$ and $CaMg(CO_3)_2$ and 5 to 8% SiO_2 and Al_2O_3 (4 to 8% SiO_2). In this massive limestone, it is very often for a solution cavity 5cm to 40cm wide to be formed along the joint plane, and some of those cases are filled with gravels.

The limestone with well-developed lamina and sandy limestone are composed of 77 to 85% $CaCO_3$ and $CaMg(CO_3)_2$ and 12 - 21% SiO_2 and Al_2O_3 (11 to 18% SiO_2). As for solution cavities, a small amount of these with the diameter about 1cm are seen in these rocks.

Calcareous sandstone is composed of 48 to 60% $CaCO_3$ and $CaMg(CO_3)_2$ and 32 to 44% SiO_2 and Al_2O_3 (27 to 42% SiO_2). In most cases no solution cavities are seen in calcareous sandstone.

Shale and sandstone are composed of 0 to 12% $CaCO_3$ and $CaMg(CO_3)_2$ and 84 to 89% SiO_2 and Al_2O_3 (81 to 85% SiO_2).

As described above, rocks other than massive limestone contain the larger content of SiO_2 and Al_2O_3 so that they have strong resistance against solution.

o Karst topography

According to aerophoto interpretations, a Karst topography is seen on the plateau of over 500 to 600m in height which is in the limestone distribution region.

Sink hole is of the elliptic or round shape with the diameter of 50 to 100m, and it has the feature that several holes are located in one area. It is impossible to interpret definite ponors from aerophotos. Instead, the geographical profile with several sink holes in the depression of 500m to 1,000m in diameter was identified by aerophoto interpretaion.

c) Running water

Main small rivers around the reservoir flow very often in non-calcareous or less calcareous rocks, and affluent running water is seen in March, too, which is in the dry season. In regions where non-calcareous rocks are distributed, in even such fairly small rivers as small rivers near Ban Tha Rua, small rivers on the right bank of Damsite A and the branch of the Huai Mae Lama Luang river, running water is seen throughout the year although there is a small descrepancy in discharge between in dry season and in rainy season. On the other hand, in small rivers which run between Damsite A and Ban Re Kho where limestone is distributed widely, running water is not seen in general except some few cases.

Some springs are seen in the foot of mountains covered with talus deposits in the area comprised of limestone. For example, around the upstream in the left bank of Damsite A (EL. 80m), on the upper stream about

1km in the right bank (EL. 90m), the upper stream about 2.5km away in the right bank (EL. 300m) and along the Yuam river on the upper stream from the junction with the Ngao river (EL. 90m), some springs are seen, but their outflows are small. The running water in major brooks are as follows:

Name of Brook	Running Water	Geology
Huai Mae Lamu	affluent (confirmed to EL 400m)	Alternation of sandstone and shale
Nam Mae Rit	affluent (confirmed to EL 200m)	Alternation of sandstone and shale (partially limestone and calcareous shale)
Huai Sai Yong	affluent (confirmed to EL 500m)	Alternation of sandstone and shale
Huai La Cho Kra	affluent (confirmed to EL 700m)	Quartzite (partially limestone)
Huai La Po Kra	affluent (confirmed to EL 200m)	Quartzite
Huai U Ya Kra	affluent (confirmed to EL 600m)	Calcareous sandstone and shale

(iii) Reservoir watertightness

Watertightness of the reservoir is conceived assured according to the following reason:

- o The reservoir stretches almost north south in the upper stream of the reservoir. On the reservoir left bank (east side) and right bank (west side) of this region, alternation of sandstone and shale is distributed north and south almost parallel with the reservoir. Furthermore, on the left bank, granite is intruded throughout the catchment area, farther east of this alternation distributing area. These non-calcareous rocks serve as the barrier against water leakage from the upper stream of the reservoir towards the right and left banks.

- In the middle and lower reaches of the reservoir, it stretches almost east and west. In the lower reaches (west) of the reservoir, shale strata which strike NNW-SSE and dip 30° to 60° S, almost perpendicular to the river, is distributed in the damsite A and its northern and southern area. This shale strata extend outside the catchment area on the right bank (north) of Damsite A, but it is distributed higher than the planned HWL 170m. In addition, around Damsite A, calcareous sandstone is distributed in the upper stream side (east side) of the shale strata, so that it can be conceived that these shale and calcareous sandstone form the barrier against water leakage from the middle and lower reaches of reservoir to the down stream (west).

- Possible leakage passes from the middle and lower reaches of the reservoir towards the left bank (south side) or right bank (north side) of the reservoir, if existing, are the following two passes: along the limestone strata distributed north and south which pass between Damsite A and the La Cho Kra river and cross almost perpendicularly to the river, and along the limestone strata distributed north and south which pass between Ban Tha Rua and the junction of the Yuam and Ngao rivers. However, in order that these limestone strata reach the level lower than the height 170m (planned HWL) of other catchment areas, the former requires the distance of 15km or longer while the latter requires at least 30km. Furthermore, as described already, the solution cavities seen in these limestone strata vary between 5cm and 40cm in diameter, not showing any distinct continuity. Therefore, possible leakage to flow through such limestone strata along these long distance is considered quite small.

- In the reservoir, remarkable fault is observed on the left bank (east side) of the Yuam river in the upper reaches of the reservoir. This fault has N-S strike and almost vertical dip, parallel to the reservoir, and does not reach outside the catchment area. Furthermore, almost all of it pass non-calcareous rocks, and no solution along faults arises. Therefore, the possibility of water leakage passing through the fault is hardly imagined.

- From aerophoto interpretation, remarkable lineament showing possible fault is detected along the La Cho Kra and La Po Kra rivers. However, quartzite is distributed in this region, and considering that along both the rivers, running water is seen up to the planned HWL 170m and higher even in a dry season, the possibility of water leakage from this lineament is likely none.

2) Geology of damsite A

(i) Geology

The damsite is located in a V-shaped valley of which the river bed width is about 40m. The right-bank slope has the inclination of about 35°, and talus deposits spread slightly thick around the river bed. However, the thickness of talus deposits is small up to around the HWL (EL 170m), and outcrops are seen in some places. On the other hand, the left-bank slope has the inclination of about 40°, and provides many outcrops from around the river bed up to around the HWL height. In the further high elevation, the inclination of slopes is slightly smaller and covered with talus deposits.

The damsite is composed mainly of shale and calcareous sandstone. Shale is distributed from around the upper stream about 50m away from the dam axis down to the down stream. It strikes N10-20°W and dips 30 to 60° SW, almost parallel with the dam axis. This shale is dark grey to black, and fairly fresh and hard. The bedding plane develops with the interval of a few cm to 20cm, and joints striking N40 to 60°E dipping 70 to 80° SE are seen. However, these bedding and joint planes stick, in general, to each other, nothing be inserted. As described in subsection "Reservoir Geology", it is confirmed that this shale strata extends to north (right bank side) for a few kilometers, but its distribution is interrupted around 600m away south-southwest from the damsite.

Calcareous sandstone is distributed around the cofferdam in the almost same strike and dip as in shale. Some of calcareous sandstone contain grey argillaceous lamina densely, and the rest of them are massive with less lamina. Both the types are hard and solid, but the former has the feature to be easily split along their lamina. A part of this calcareous sandstone strata comprises of limestone with well-developed lamina as seen in brooks on the right bank in the upstream of the dam axis.

Two prominent faults exist in the vicinity of damsite A. One of them, of which shear zone is 200cm wide, is observed around the right bank of dam axis. It strikes N15°W and dips 75° W. Another one, of which shear zone is 200cm wide, is observed on the left bank about 100m upstream of the dam axis. It strikes N55°E and dips vertical. Neither the former nor the latter has fault caly inside the shear zone, and the traces of bedding planes remain. Furthermore, around the faults seen on the upper stream from the left-bank of damsite, 10 to 20cm-wide shear along the bedding plane is seen.

(ii) Consideration

Judging from chemical analyses of rocks constituting the dam foundation, the results obtained from the drilling including the permeability test and the ground geological conditions, the following evaluation can be offered for Damsite A from the standpoint of engineering geology.

- Rocks distributed in Damsite A has a sufficient load resistance for the foundation of the planned dam.

- Judging from chemical analysis data of calcareous sandstone distributed in Damsite A.

There is almost no possibility of presence of large caves affecting the dam construction.

- o Results of permeability tests are as follows;

  In the deep part of the dam foundation, the permeability from the river bed to the right bank varies 1 to 4 Lu and the permeability on the left bank varies 3 to 7 Lu, showing the low figure.

  On the other hand, packer could not be set up in the drill hole at some places in the shallow part of the dam foundation. Gravity tests were carried out at those places instead of packer method permeability tests. The results of the gravity tests indicate 10^{-4}cm/sec order as coefficient of permeability.

  Judging from the above results, rocks at damsite A is regarded as groutable rocks.

- o In a part of the catchment area on the left bank in the just upper stream of the damsite, limestone is distributed down to below the planned HWL, and running water is not seen on the surface. According to drilling DL-4 (EL 191.4 m) which was drilled in this area the ground-water level lies 43m below the surface, while according to drillings DL-1 and DL-2 the ground-water level is not known. Therefore, to know the ground-water level throughout the wide area on the left bank, additional exploration is needed.

3) Geology of main structure sites

Intake, headrace, penstock, power house and spillway are in general suited in hard shale.

- o Intake site is in a steep ground profile and talus deposits are thin. Shale constituting the foundation is hard and solid almost sufficiently.

- o The ground where the penstock are laid has an gentle slope and is covered with thick talus deposits. Therefore, an additional exploration to investigate the conditions of bedrock and the thickness of talus deposits is required.

- o The foundation of the power house is in general composed of hard shale, and the talus deposits on the hinterslope are not so thick, no problem be found.

- o Around the downstream area of the spillway are occupied by thick talus deposits and weathered rocks, so that it is necessary to pay attention to the stability of the face of slope.

4) Geology of damsite C

(i) Geology

Damsite C is located in the upper stream about 12km away from Damsite A and in the downstream about 3km from Ban Tha Rua.

The damsite has the shape of a V-figured valley of which the river bed width is about 30m, and its slope of the left bank inclines about 40° and that of the right bank inclines about 35°.

Dam foundation consists of granite intruded into Paleozoic rocks. Although this granite is strongly weathered in the high elevation, fairly fresh and hard granite crops out by erosion along the Yuam River from the river bed to planned high water level (EL. 175m). However, joints having E-W strike and 20° S dip, N-S strike and vertical dip, N40° W strike and vertical dip, are created, and weathering has proceed along the joint plane so that many of them are of the blockwise shape with the diameter of a few meters. The thickness of river deposits may be 5m or so judging from the ground profile.

(ii) Consideration

- o Granite constituting damsite is conceived sufficient in terms of the load resistance to the foundation of the concrete dam of the presently-planned scale, with no special problems.

- o As for permeability, the high permeability zone along the joints can be regarded, but it can be thought to fully improve it by the ordinally grout treatment.

5) Additional investigation works

To pursue a further detailed designing for Damsite A and main structure sites, the additional geological survey shown in Table 2-2 and Fig. 2-4 is considered necessary. The number of additional investigation works is as follows:

Drillings 8 holes 800m

Table 2-1 Quantitative Chemical Analysis of Rock

Locality No.	Locality	Rock Name	Result of analysis		1/ Result of norm calculation		2/ Result of norm calculation		Remarks
			Composition	% (wt)	Composition	% (wt)	Composition	%(wt)	
①	Nam Mae Rit	Limestone (massive)	CaO	51.57	$CaCO_3$	92.08	$CaCO_3$	90.08	Width of solution cavity is 10 - 40 centimeters
			MgO	0.79	$MgCO_3$	1.69	$CaMg(CO_3)_2$	3.69	
			SiO_2	4.76			SiO_2	4.76	
			Al_2O_3	1.09			Al_2O_3	1.09	
			Total	58.21	Total	93.77	Total	99.62	
②	Tributary of Huai Mae Lama EL.350 m	Limestone (massive)	CaO	51.11	$CaCO_3$	91.18	$CaCO_3$	88.78	Width of solution cavity is 30 - 50 centimeters
			MgO	0.97	$MgCO_3$	2.02	$CaMg(CO_3)_2$	4.43	
			SiO_2	3.68			SiO_2	3.68	
			Al_2O_3	0.43			Al_2O_3	0.43	
			Total	56.19	Total	93.20	Total	97.32	
③	Left bank downstream of A dam axis	Limestone (massive)	CaO	50.68	$CaCO_3$	90.48	$CaCO_3$	87.98	Width of solution cavity is 1 - 5 centimeters
			MgO	0.99	$MgCO_3$	2.11	$CaMg(CO_3)_2$	4.61	
			SiO_2	4.89			SiO_2	4.89	
			Al_2O_3	0.40			Al_2O_3	0.40	
			Total	56.96	Total	92.59	Total	97.88	
④	Ban Tha Rua	Limestone (massive)	CaO	51.06	$CaCO_3$	91.08	$CaCO_3$	89.48	Width of solution cavity is 1 - 10 centimeters
			MgO	0.65	$MgCO_3$	1.35	$CaMg(CO_3)_2$	2.95	
			SiO_2	5.57			SiO_2	5.57	
			Al_2O_3	1.76			Al_2O_3	1.76	
			Total	59.04	Total	92.43	Total	99.76	
⑤	Right bank upstream of A dam axis	Limestone (massive)	CaO	50.66	$CaCO_3$	90.38	$CaCO_3$	88.38	Width of solution cavity is 20 - 30 centimeters
			MgO	0.79	$MgCO_3$	1.69	$CaMg(CO_3)_2$	3.69	
			SiO_2	6.37			SiO_2	6.37	
			Al_2O_3	1.34			Al_2O_3	1.34	
			Total	59.16	Total	92.07	Total	99.78	
⑥	Tributary of Huai Mae Lama EL.270 m	Limestone (massive)	CaO	49.25	$CaCO_3$	87.88	$CaCO_3$	84.58	Width of solution cavity is 10 - 50 centimeters
			MgO	1.34	$MgCO_3$	2.78	$CaMg(CO_3)_2$	6.09	
			SiO_2	7.85			SiO_2	7.85	
			Al_2O_3	0.41			Al_2O_3	0.41	
			Total	58.85	Total	90.66	Total	98.93	
⑦	Ban Re Kho	Limestone (massive)	CaO	49.76	$CaCO_3$	88.78	$CaCO_3$	87.48	Width of solution cavity is 1 - 30 centimeters
			MgO	0.51	$MgCO_3$	1.10	$CaMg(CO_3)_2$	2.40	
			SiO_2	4.67			SiO_2	4.67	
			Al_2O_3	2.05			Al_2O_3	2.05	
			Total	56.99	Total	89.88	Total	96.60	
⑧	Tributary of Huai Mae Lama Luang EL.230 m	Limestone (laminated)	CaO	44.19	$CaCO_3$	78.87	$CaCO_3$	71.46	Solution cavity is rare
			MgO	2.99	$MgCO_3$	5.14	$CaMg(CO_3)_2$	13.65	
			SiO_2	15.05			SiO_2	15.05	
			Al_2O_3	0.65			Al_2O_3	0.65	
			Total	62.88	Total	84.01	Total	100.81	
⑨	Right bank upstream of A dam axis	Limestone (laminated)	CaO	40.71	$CaCO_3$	72.67	$CaCO_3$	60.95	Solution cavity is rare
			MgO	4.72	$MgCO_3$	9.87	$CaMg(CO_3)_2$	21.58	
			SiO_2	16.12			SiO_2	16.12	
			Al_2O_3	0.77			Al_2O_3	0.77	
			Total	62.32	Total	82.54	Total	99.42	
⑩	Right bank upstream of A dam axis	Limestone (laminated)	CaO	39.75	$CaCO_3$	70.96	$CaCO_3$	57.25	Solution cavity is rare
			MgO	5.51	$MgCO_3$	11.55	$CaMg(CO_3)_2$	25.26	
			SiO_2	17.38			SiO_2	17.38	
			Al_2O_3	1.28			Al_2O_3	1.28	
			Total	63.92	Total	82.51	Total	101.17	
⑪	Tributary of Huai Mae Lama Luang EL.310 m	Siliceous limestone	CaO	42.19	$CaCO_3$	75.27	$CaCO_3$	67.86	Width of solution cavity is 1 centimeter
			MgO	2.98	$MgCO_3$	6.24	$CaMg(CO_3)_2$	13.65	
			SiO_2	11.20			SiO_2	11.20	
			Al_2O_3	1.31			Al_2O_3	1.31	
			Total	56.68	Total	81.51	Total	94.02	

Table 2-1 Quantitative Chemical Analysis of Rock (cont'd.)

Locality No.	Locality	Rock Name	Result of analysis		1/ Result of norm calculation		2/ Result of norm calculation		Remarks
			Composition	% (wt)	Composition	% (wt)	Composition	%(wt)	
⑫	Left bank downstream of A dam axis	Limestone (laminated)	CaO	42.42	$CaCO_3$	75.67	$CaCO_3$	69.56	Solution cavity is not observed
			MgO	2.44	$MgCO_3$	5.14	$CaMg(CO_3)_2$	11.25	
			SiO_2	11.03			SiO_2	11.03	
			Al_2O_3	0.64			Al_2O_3	0.64	
			Total	56.53	Total	80.81	Total	92.48	
⑬	Left bank downstream of A dam axis	Sandy (limestone)	CaO	26.99	$CaCO_3$	48.14	$CaCO_3$	10.21	Solution cavity is rare
			MgO	15.28	$MgCO_3$	31.96	$CaMg(CO_3)_2$	69.89	
			SiO_2	13.03			SiO_2	13.03	
			Al_2O_3	8.01			Al_2O_3	8.01	
			Total	63.31	Total	80.10	Total	101.14	
⑭	Ngao river	Limestone (banded)	CaO	42.94	$CaCO_3$	76.67	$CaCO_3$	73.87	Solution cavity is not observed
			MgO	1.13	$MgCO_3$	2.36	$CaMg(CO_3)_2$	5.16	
			SiO_2	18.19			SiO_2	18.19	
			Al_2O_3	0.65			Al_2O_3	0.65	
			Total	62.91	Total	79.03	Total	97.87	
⑮	Nam Mae Rit	Limestone (laminated)	CaO	42.35	$CaCO_3$	75.57	$CaCO_3$	73.67	Solution cavity is rare
			MgO	0.75	$MgCO_3$	1.60	$CaMg(CO_3)_2$	3.50	
			SiO_2	18.28			SiO_2	18.28	
			Al_2O_3	3.15			Al_2O_3	3.15	
			Total	64.53	Total	77.17	Total	98.60	
⑯	Left bank upstream of A dam axis	Siliceous Limestone (Calcareous sandstone)	CaO	23.69	$CaCO_3$	42.24	$CaCO_3$	21.42	Solution cavity is rare
			MgO	8.40	$MgCO_3$	17.54	$CaMg(CO_3)_2$	38.36	
			SiO_2	26.66			SiO_2	26.66	
			Al_2O_3	5.26			Al_2O_3	5.26	
			Total	64.01	Total	59.78	Total	91.70	
⑰	Left bank upstream of A dam axis	Calcareous sandstone	CaO	21.95	$CaCO_3$	39.14	$CaCO_3$	26.92	Solution cavity is not observed
			MgO	4.92	$MgCO_3$	10.29	$CaMg(CO_3)_2$	22.50	
			SiO_2	41.84			SiO_2	41.84	
			Al_2O_3	2.48			Al_2O_3	2.48	
			Total	71.59	Total	49.43	Total	93.74	
⑱	Left bank upstream of A dam axis	Calcareous sandstone	CaO	21.29	$CaCO_3$	38.03	$CaCO_3$	26.72	Solution cavity is not observed
			MgO	4.56	$MgCO_3$	9.53	$CaMg(CO_3)_2$	20.84	
			SiO_2	35.68			SiO_2	35.68	
			Al_2O_3	4.65			Al_2O_3	4.65	
			Total	66.18	Total	47.56	Total	87.89	
⑲	Right bank of A dam axis	Shale	CaO	0.57			$CaCO_3$		
			MgO	2.69			$CaMg(CO_3)_2$	12.36	
			SiO_2	84.03			SiO_2	84.03	
			Al_2O_3	0.26			Al_2O_3	0.26	
			Total	87.58	Total		Total	96.65	
⑳	Huai Mae Luma	Sandstone	CaO	2.19			$CaCO_3$	1.40	
			MgO	0.99			$CaMg(CO_3)_2$	4.61	
			SiO_2	81.09			SiO_2	81.09	
			Al_2O_3	3.15			Al_2O_3	3.15	
			Total	87.42	Total		Total	90.25	
㉑	Right bank upstream of A dam axis	Sandstone	CaO	Trace			$CaCO_3$	-	
			MgO	0.05			$CaMg(CO_3)_2$	0.18	
			SiO_2	84.84			SiO_2	84.84	
			Al_2O_3	3.88			Al_2O_3	3.88	
			Total	88.77	Total		Total	88.90	

1/ All CaO are calculated as $CaCO_3$ and all MgO are calculated as $MgCO_3$

2/ All MgO are calculated as $CaMg(CO_3)_2$ and remaining CaO are calculated as $CaCO_3$

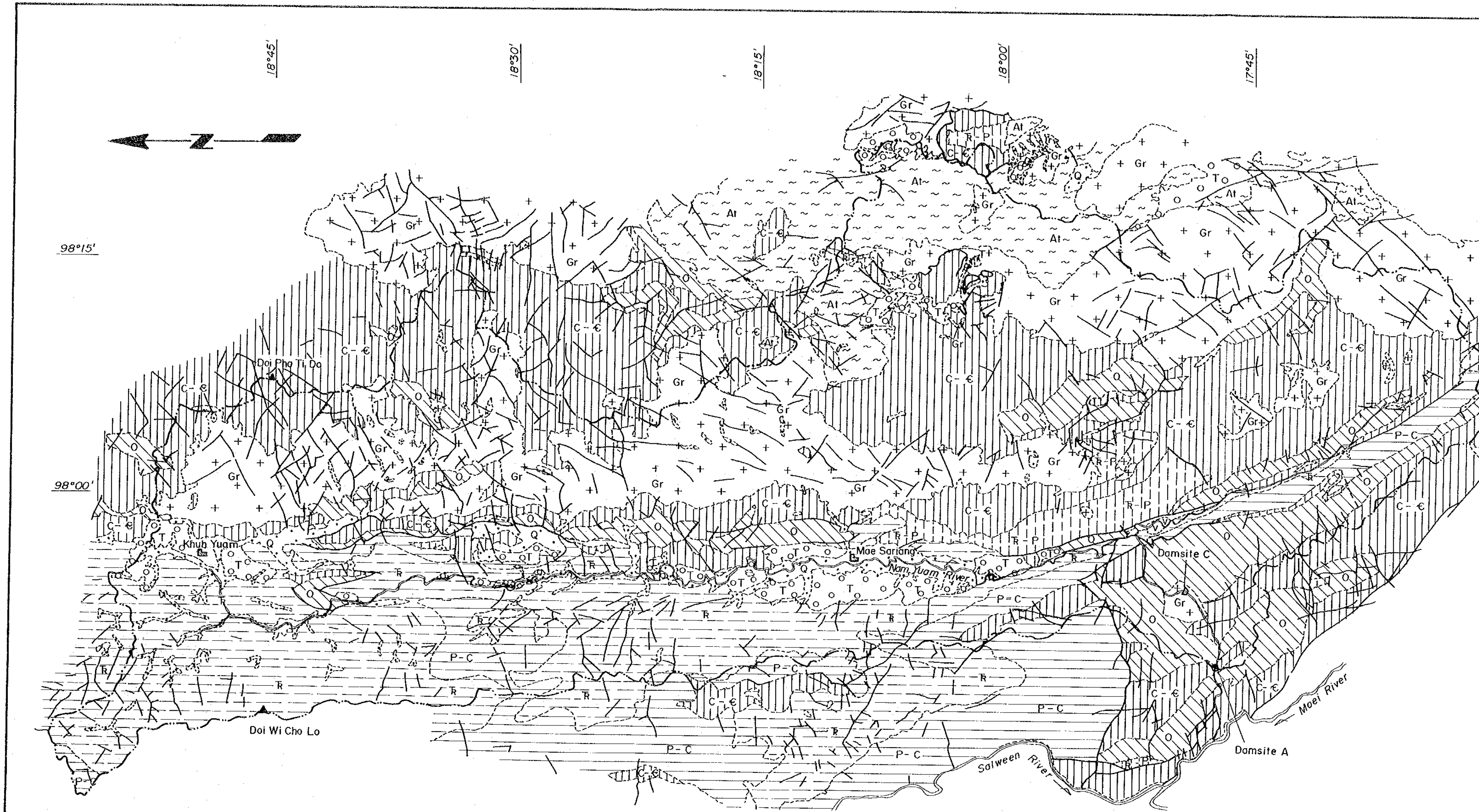
Table 2-2 Location of Completed Drill Hole and Additional Drill Hole (Proposed) in Damsite A

Completed Drill Hole

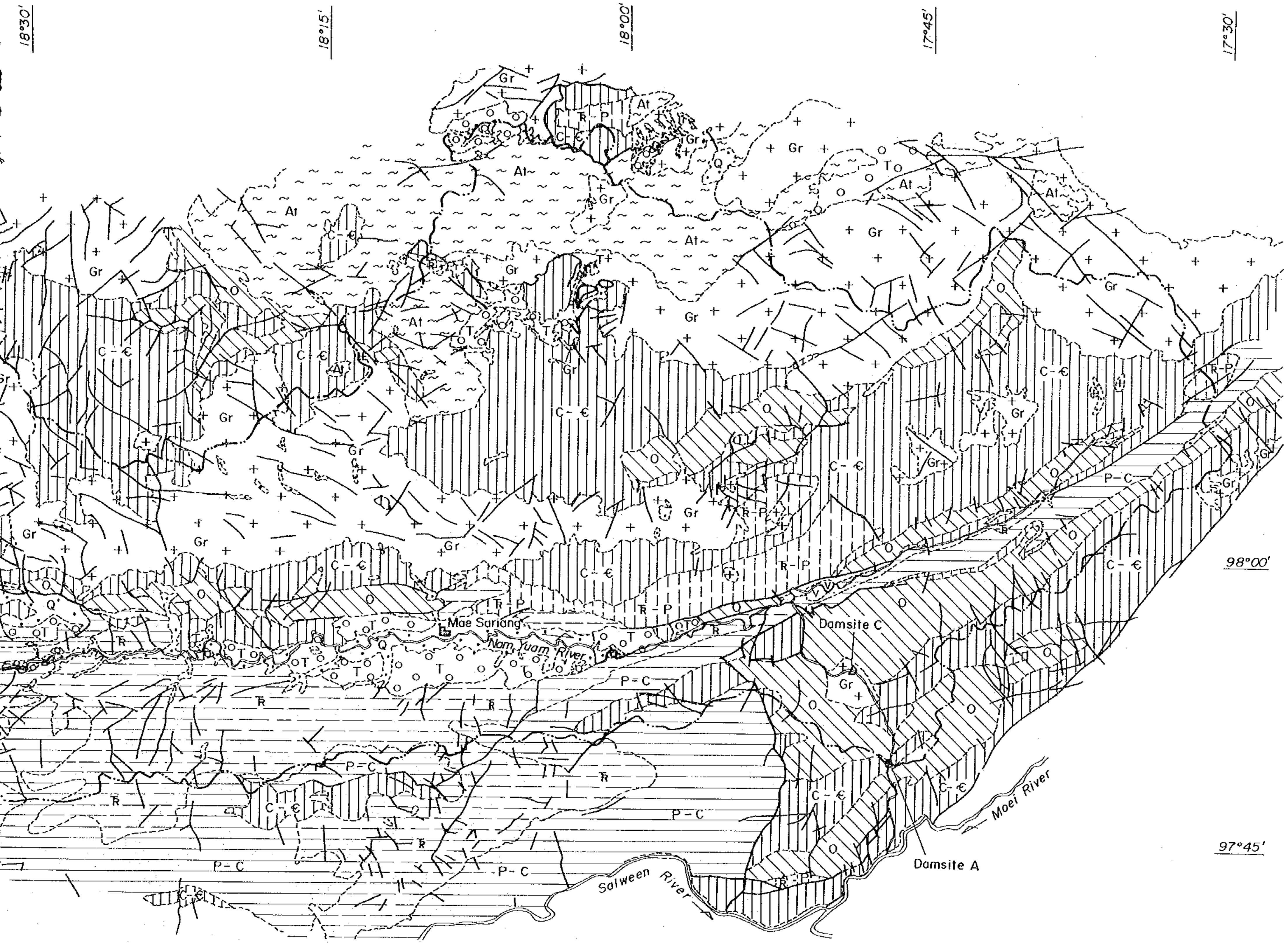
Site	Hole No.	Coordinate		EL. (m)	Direction	Length (m)
Dam	DR-1	1966,551.8N	375,447.3E	142.2	90°	60
	DR-2	1966,502.2N	375,412.9E	103.9	90°	80
	DL-1	1966,286.9N	375,168.2E	186.6	90°	80
	DL-2	1966,350.7N	375,194.1E	151.1	90°	60
	DL-3	1966,430.9N	375,229.3E	90.7	90°	120
	DL-4	1965,774.5N	375,425.7E	191.4	90°	80
	DU-1	1966,424.9N	375,397.6E	74.5	S59°W 60°	22
	DU-2	1966,333.3N	375,398.2E	91.3	N31°E 60°	120
Intake	I-1	1966,516.2N	375,483.6E	143.6	90°	40
Powerhouse	P-1	1966,669.5N	375,088.3E	90.8	90°	40
Spillway	S-1	1966,395.3N	375,014.2E	126.2	90°	43.5
Total	11 Holes					745.5

Additional Drill Hole (Proposed)

Site	Hole No.	Coordinate		EL. (m)	Direction	Length (m)
Dam	DR-3	1966,449N	375,378E	74	S59°W 55°	120
	DR-4	1966,648N	375,497E	217	90°	120
	DL-5	1965,902N	375,188E	320	90°	150
	DL-6	1966,050N	375,219E	258	90°	120
	DL-7	1966,273N	375,272E	196	90°	120
	DL-8	1966,349N	375,318E	132	90°	100
Penstock	PS-1	1966,637N	375,198E	114	90°	30
Spillway	S-2	1966,446N	375,063E	131	90°	40
Total	8 Holes					800



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.



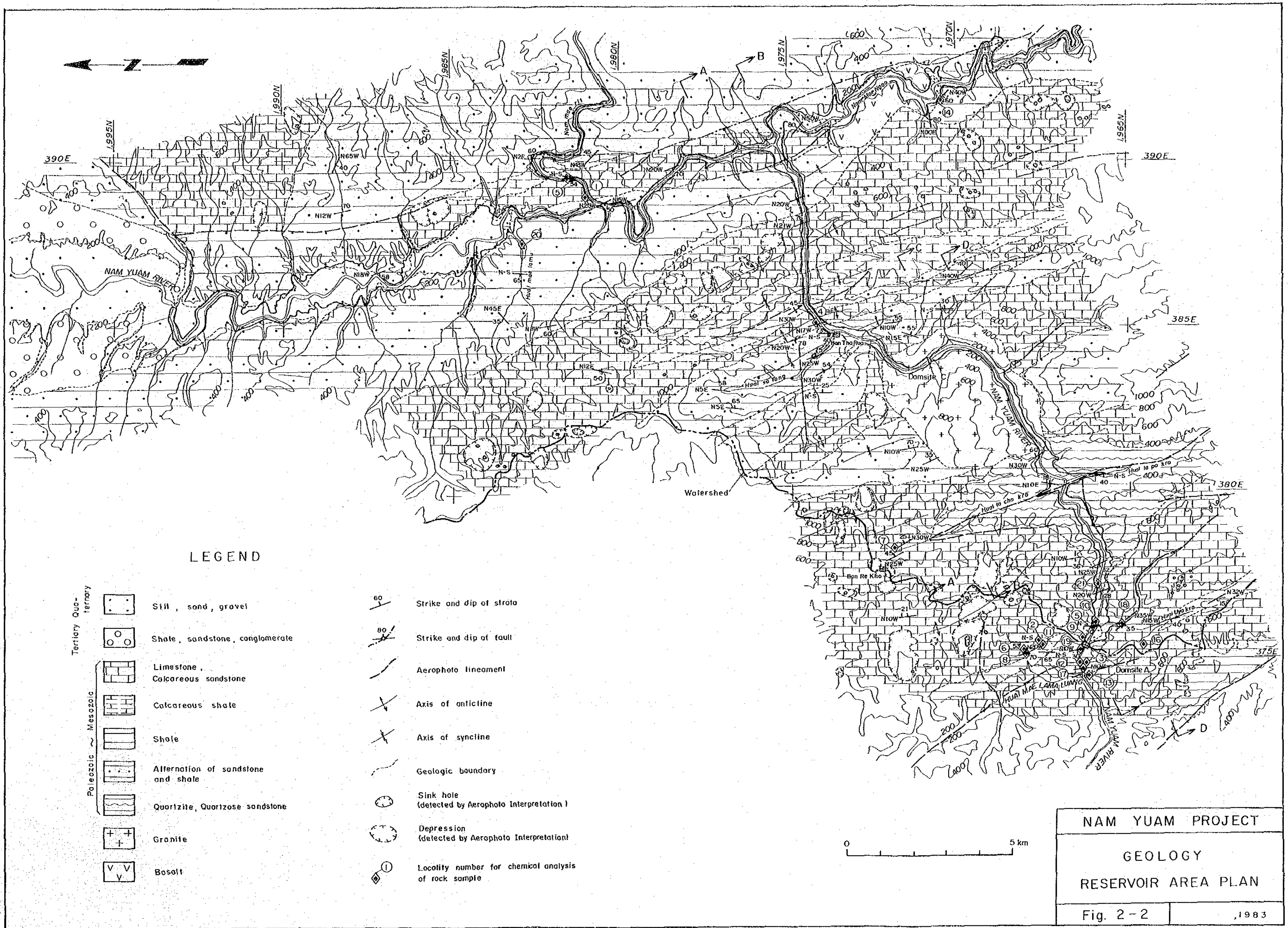
LEGEND

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
			Catchment area

0 — 20 km

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.

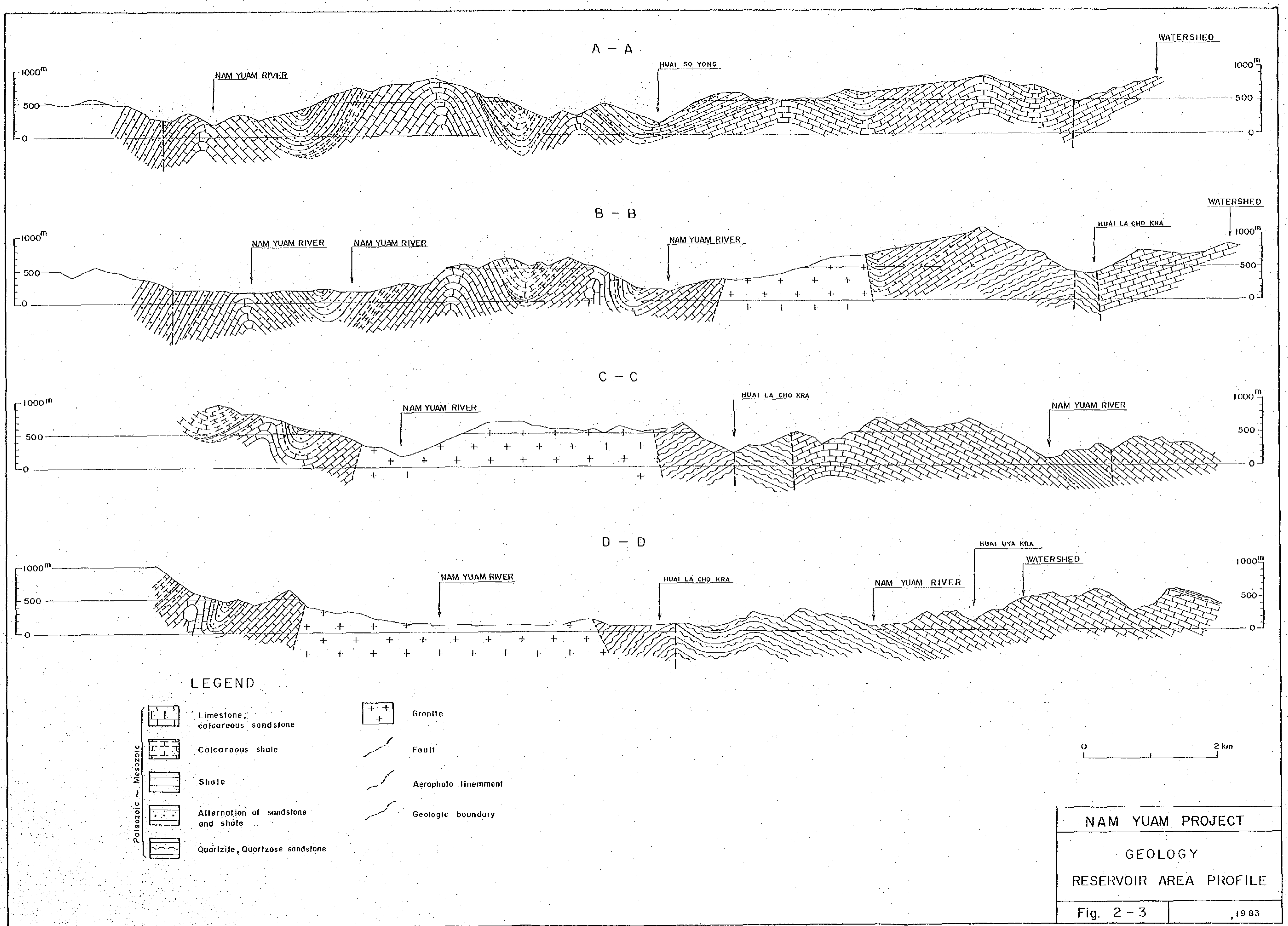
NAM YUAM PROJECT	
GEOLOGY CATCHMENT AREA PLAN	
Fig. 2 - 1	1983



NAM YUAM PROJECT

GEOLOGY
RESERVOIR AREA PLAN

Fig. 2－2 ,1983

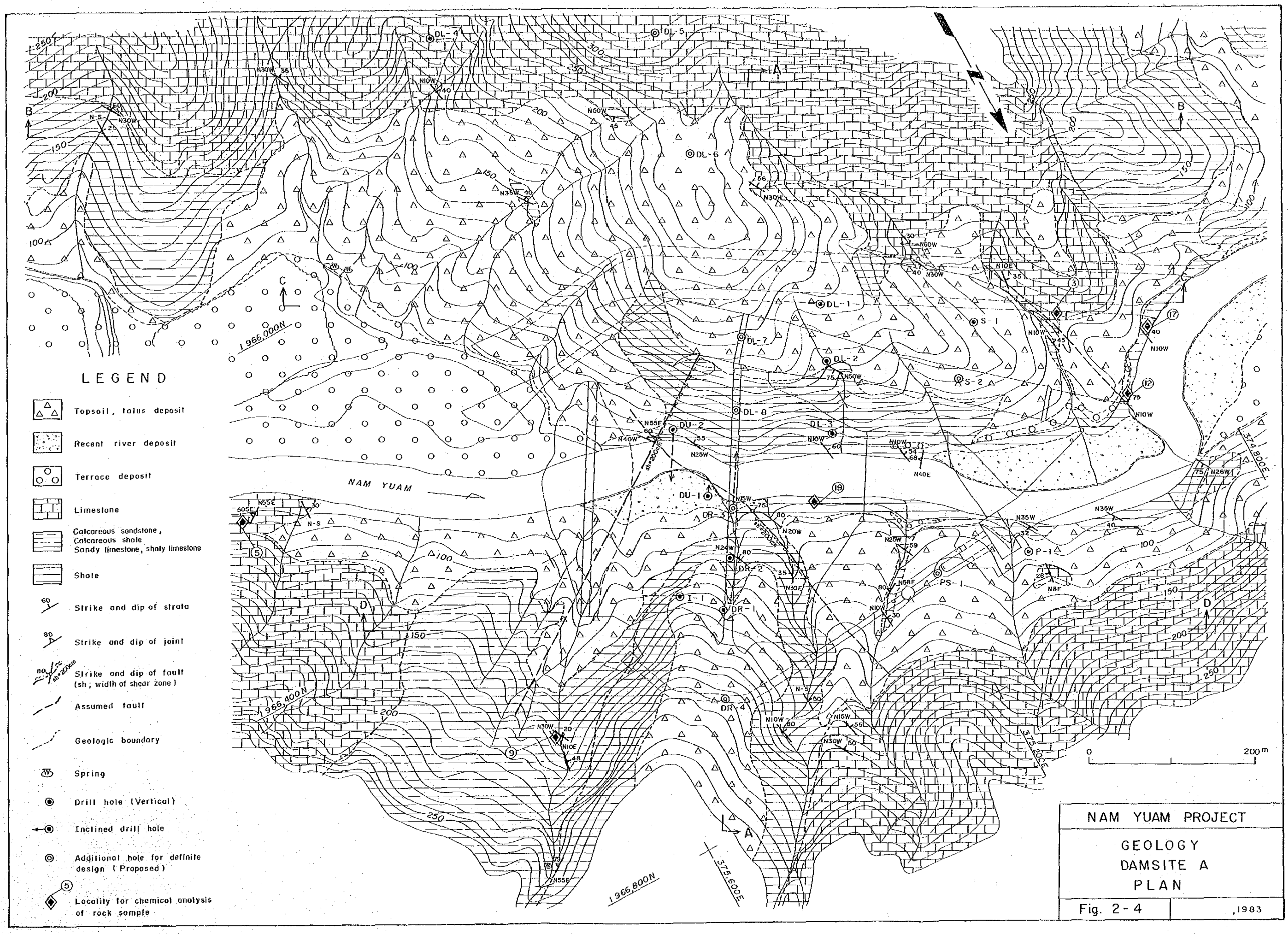


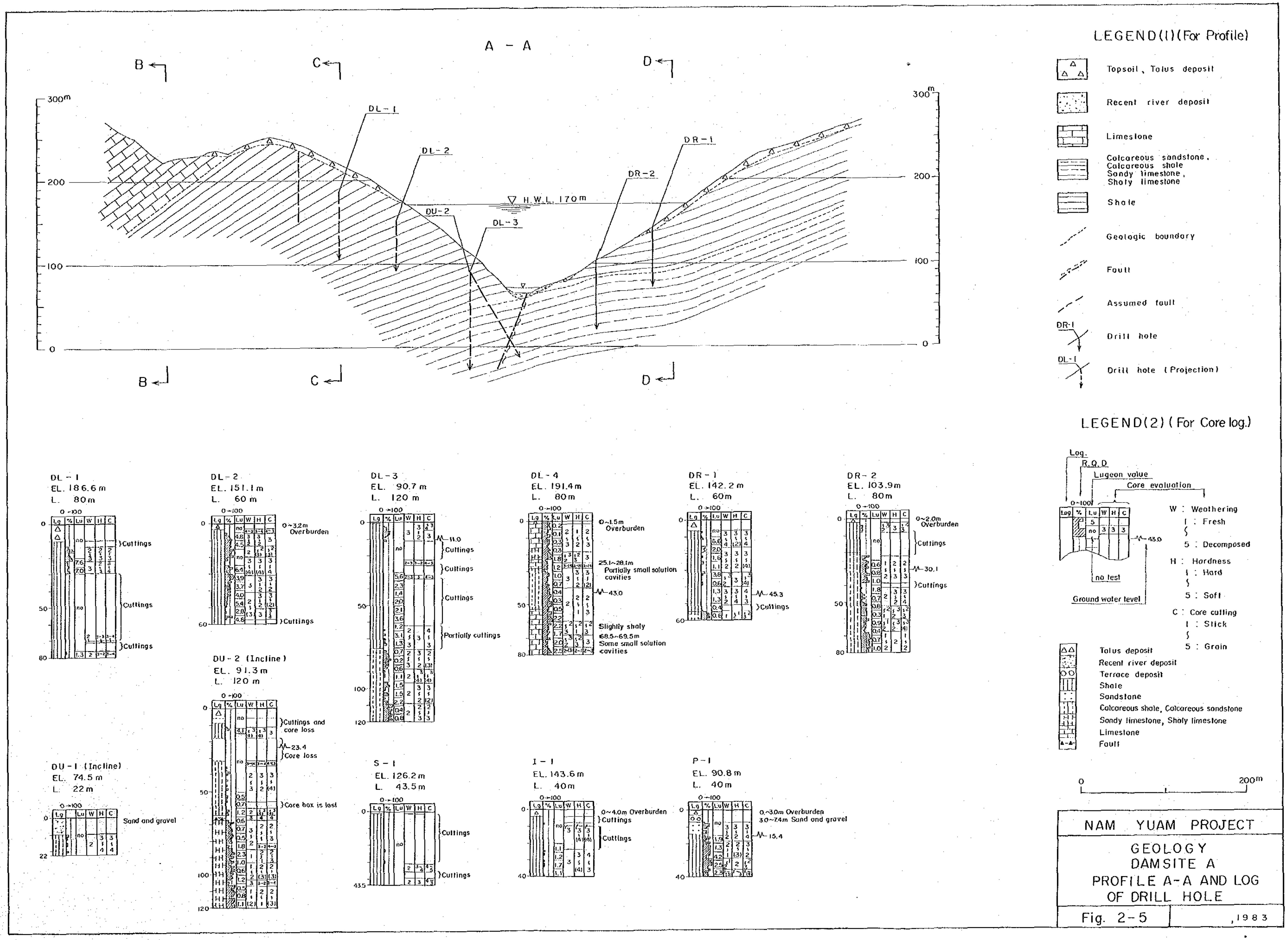
NAM YUAM PROJECT

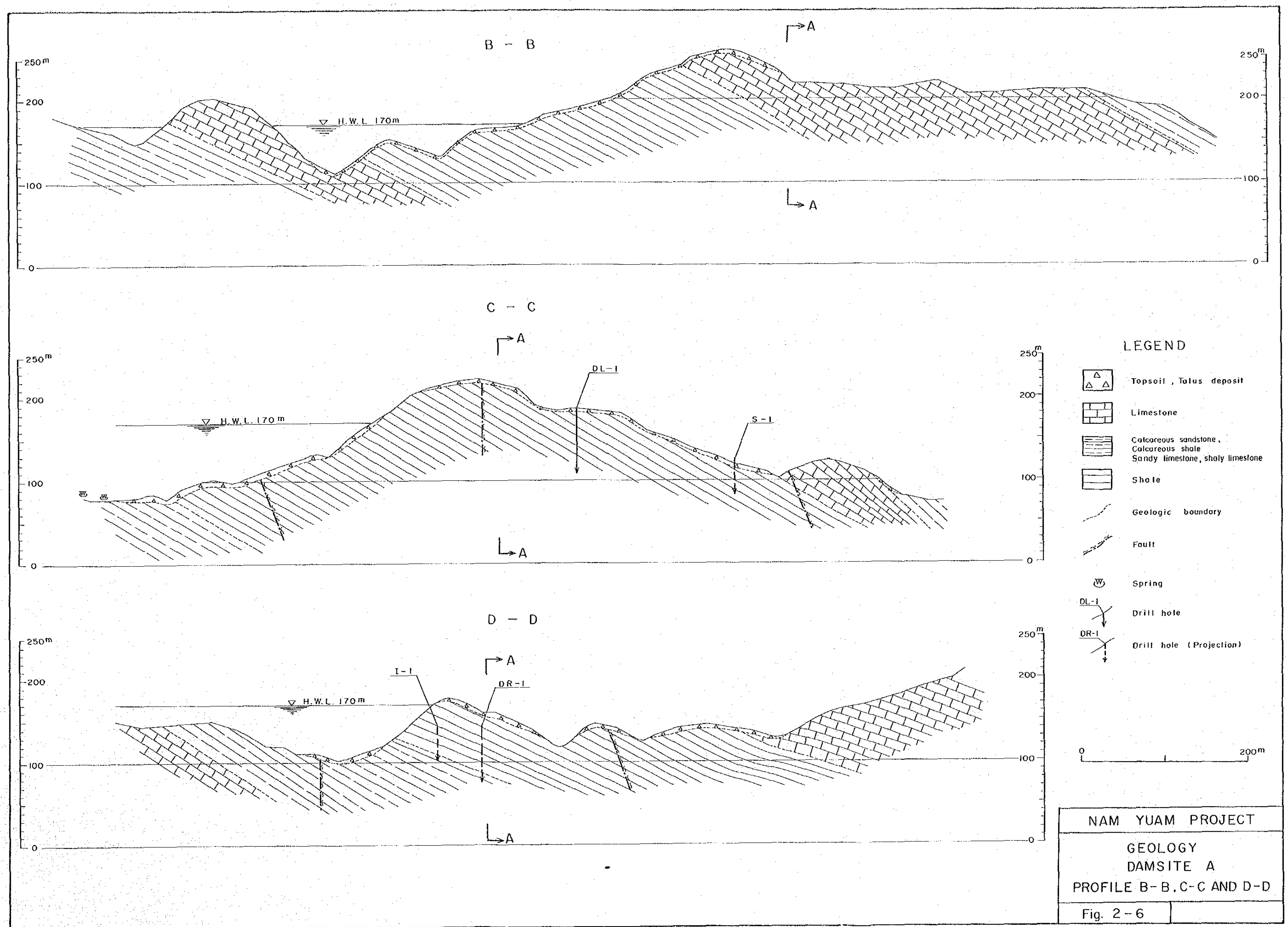
GEOLOGY

RESERVOIR AREA PROFILE

Fig. 2 – 3 ,1983


NAM YUAM PROJECT
GEOLOGY
DAMSITE A
PLAN
Fig. 2-4
,1983
LEGEND
Topsoil, talus deposit
Recent river deposit
Terrace deposit
Limestone
Calcareous sandstone, Calcareous shale
Sandy limestone, shaly limestone
Shale
Strike and dip of strata
Strike and dip of joint
Strike and dip of fault (sh; width of shear zone)
Assumed fault
Geologic boundary
Spring
Drill hole (Vertical)
Inclined drill hole
Additional hole for definite design (Proposed)
Locality for chemical analysis of rock sample
NAM YUAM
1 966,000N
1 966,400N
1 966,800N
374,800E
375,200E
375,600E
DL-1
DL-2
DL-3
DL-4
DL-5
DL-6
DL-7
DL-8
DU-1
DU-2
DR-1
DR-2
DR-3
DR-4
I-1
S-1
S-2
P-1
PS-1
0
200m

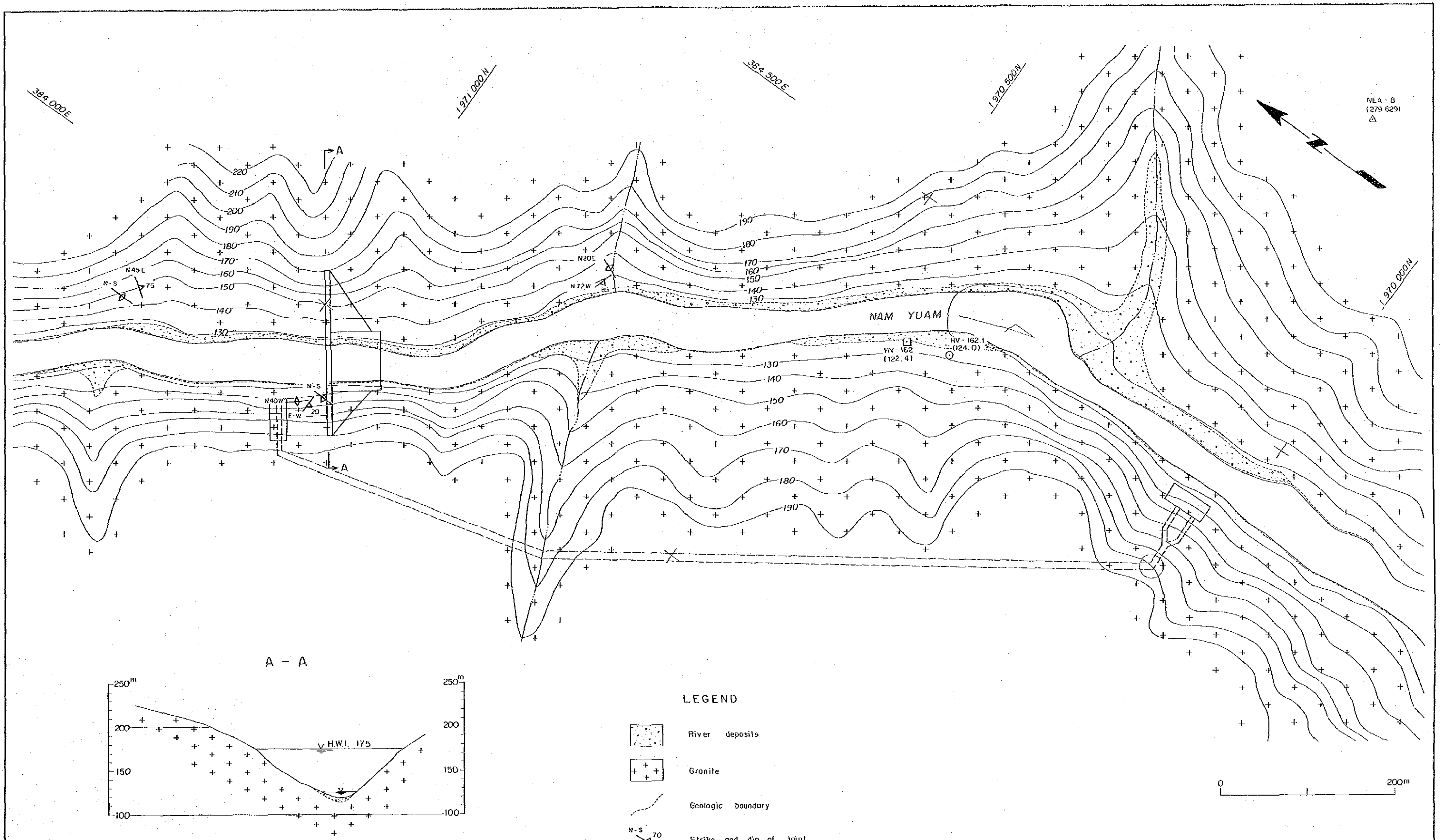

A - A
B
C
D
300m
200
100
0
DL-1
DL-2
DU-2
DL-3
DR-1
DR-2
H.W.L. 170m
LEGEND(1)(For Profile)
Topsoil, Talus deposit
Recent river deposit
Limestone
Calcareous sandstone, Calcareous shale, Sandy limestone, Shaly limestone
Shale
Geologic boundary
Fault
Assumed fault
Drill hole
Drill hole (Projection)
LEGEND(2) (For Core log.)
Log.
R.Q.D
Lugeon value
Core evaluation
no test
Ground water level
W : Weathering
1 : Fresh
5 : Decomposed
H : Hardness
1 : Hard
5 : Soft
C : Core cutting
1 : Stick
5 : Grain
Talus deposit
Recent river deposit
Terrace deposit
Shale
Sandstone
Calcareous shale, Calcareous sandstone
Sandy limestone, Shaly limestone
Limestone
Fault
DL-1 EL. 186.6m L. 80m
DL-2 EL. 151.1m L. 60m
DL-3 EL. 90.7m L. 120m
DL-4 EL. 191.4m L. 80m
DR-1 EL. 142.2m L. 60m
DR-2 EL. 103.9m L. 80m
DU-2 (Incline) EL. 91.3m L. 120m
DU-1 (Incline) EL. 74.5m L. 22m
S-1 EL. 126.2m L. 43.5m
I-1 EL. 143.6m L. 40m
P-1 EL. 90.8m L. 40m
Cuttings
0~3.2m Overburden
Partially cuttings
0~1.5m Overburden
25.1~28.1m Partially small solution cavities
Slightly shaly
68.5~69.5m Some small solution cavities
0~2.0m Overburden
Cuttings and core loss
Core loss
Core box is lost
Sand and gravel
0~4.0m Overburden
0~3.0m Overburden
3.0~7.4m Sand and gravel
0 200m
NAM YUAM PROJECT
GEOLOGY
DAMSITE A
PROFILE A-A AND LOG OF DRILL HOLE
Fig. 2-5
,1983



NAM YUAM PROJECT

GEOLOGY
DAMSITE A
PROFILE B-B, C-C AND D-D

Fig. 2-6



NAM YUAM PROJECT

GEOLOGY
DAMSITE C
PLAN AND PROFILE

Fig. 2-7 | 1983