No. 56

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

MINISTRY OF INDUSTRY AND HANDICRAFT
LAO PEOPLE'S DEMOCRATIC REPUBLIC

MASTER PLAN STUDY ON HYDROELECTRIC POWER DEVELOPMENT IN THE SE KONG BASIN IN THE LAO PEOPLE'S DEMOCRATIC REPUBLIC

FINAL REPORT

SUMMARY

MARCH, 1995

ELECTRIC POWER DEVELOPMENT CO., LTD., TOKYO
NEWJEC INC., OSAKA
PASCO INTERNATIONAL INC., TOKYO

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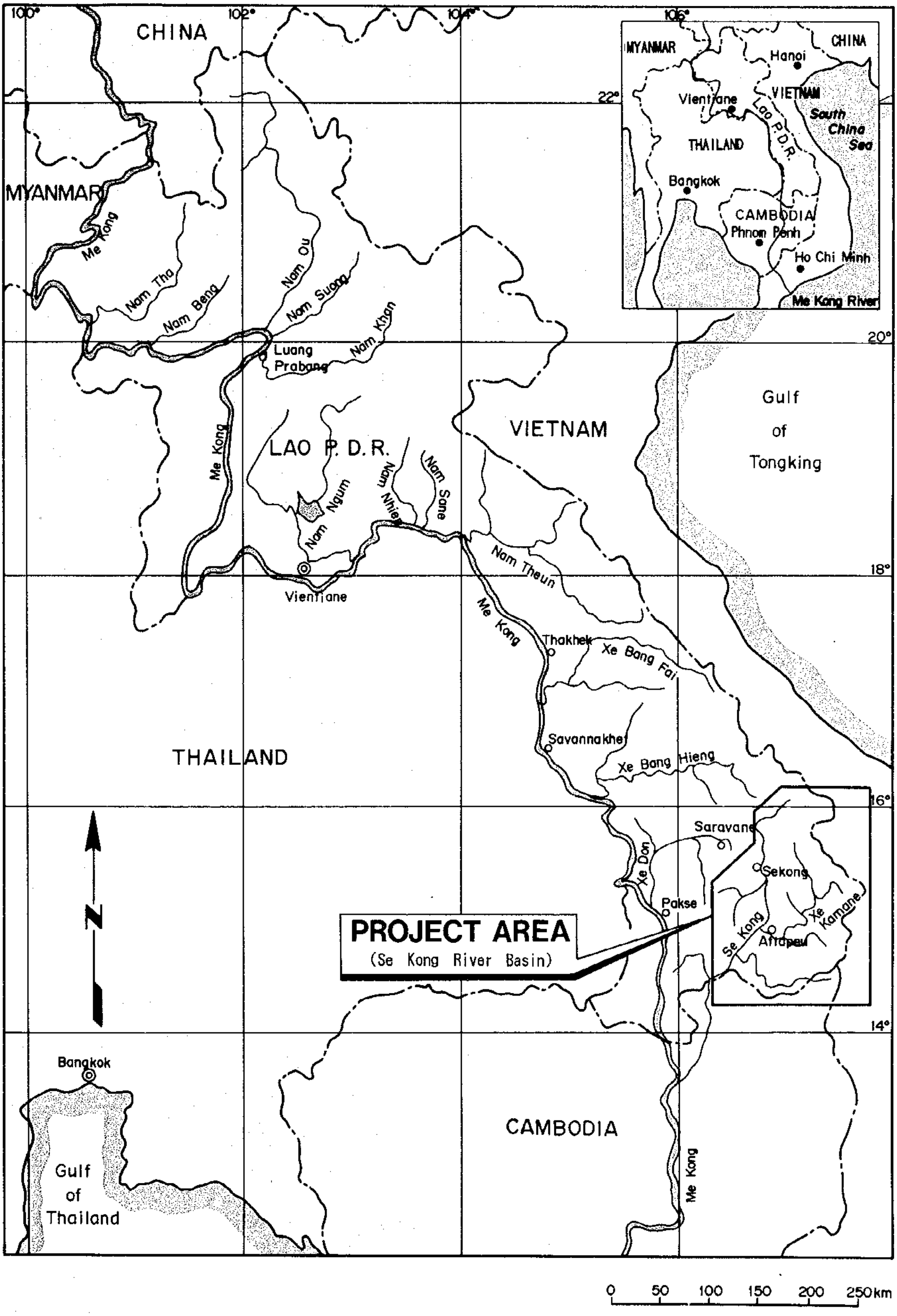
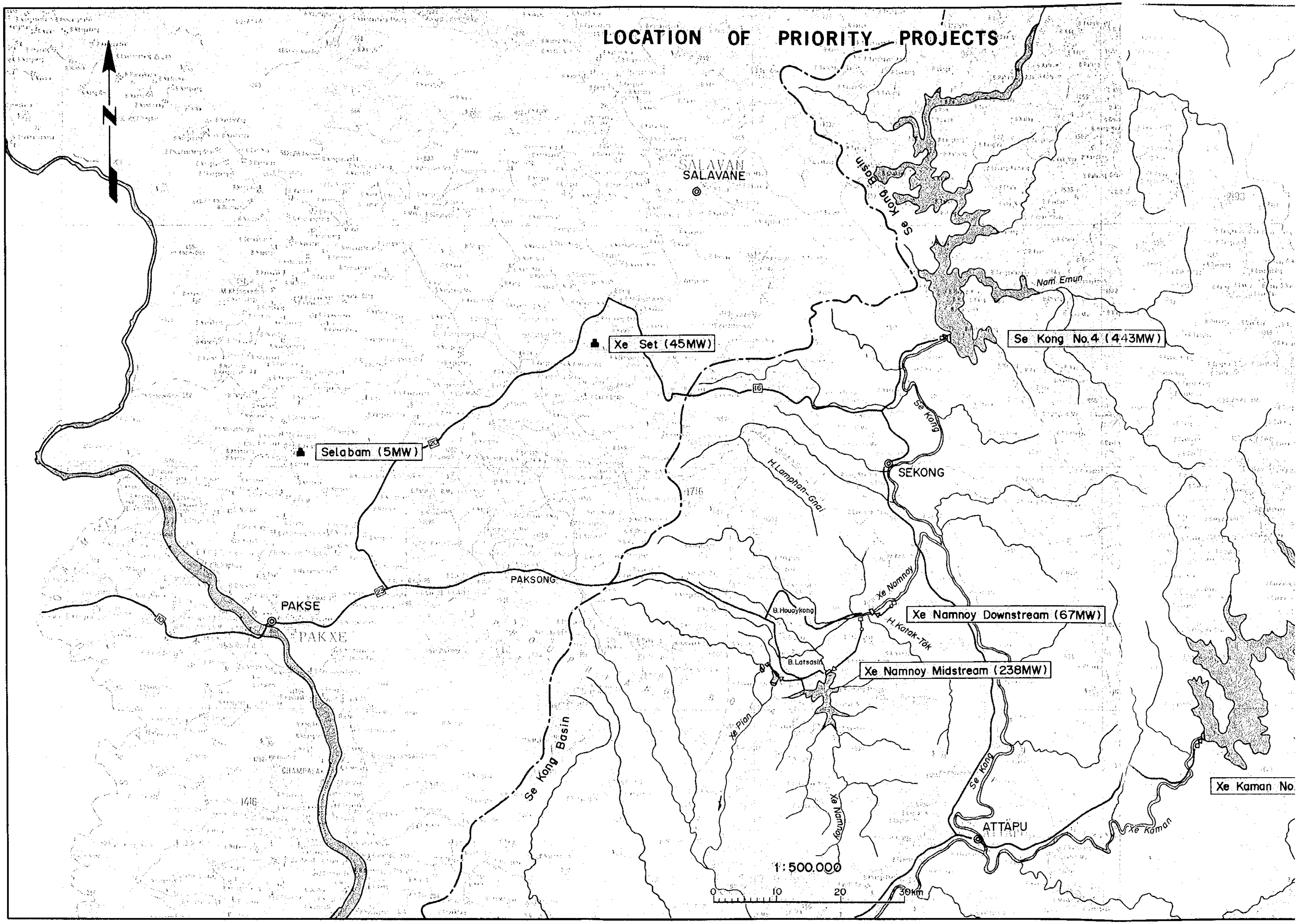
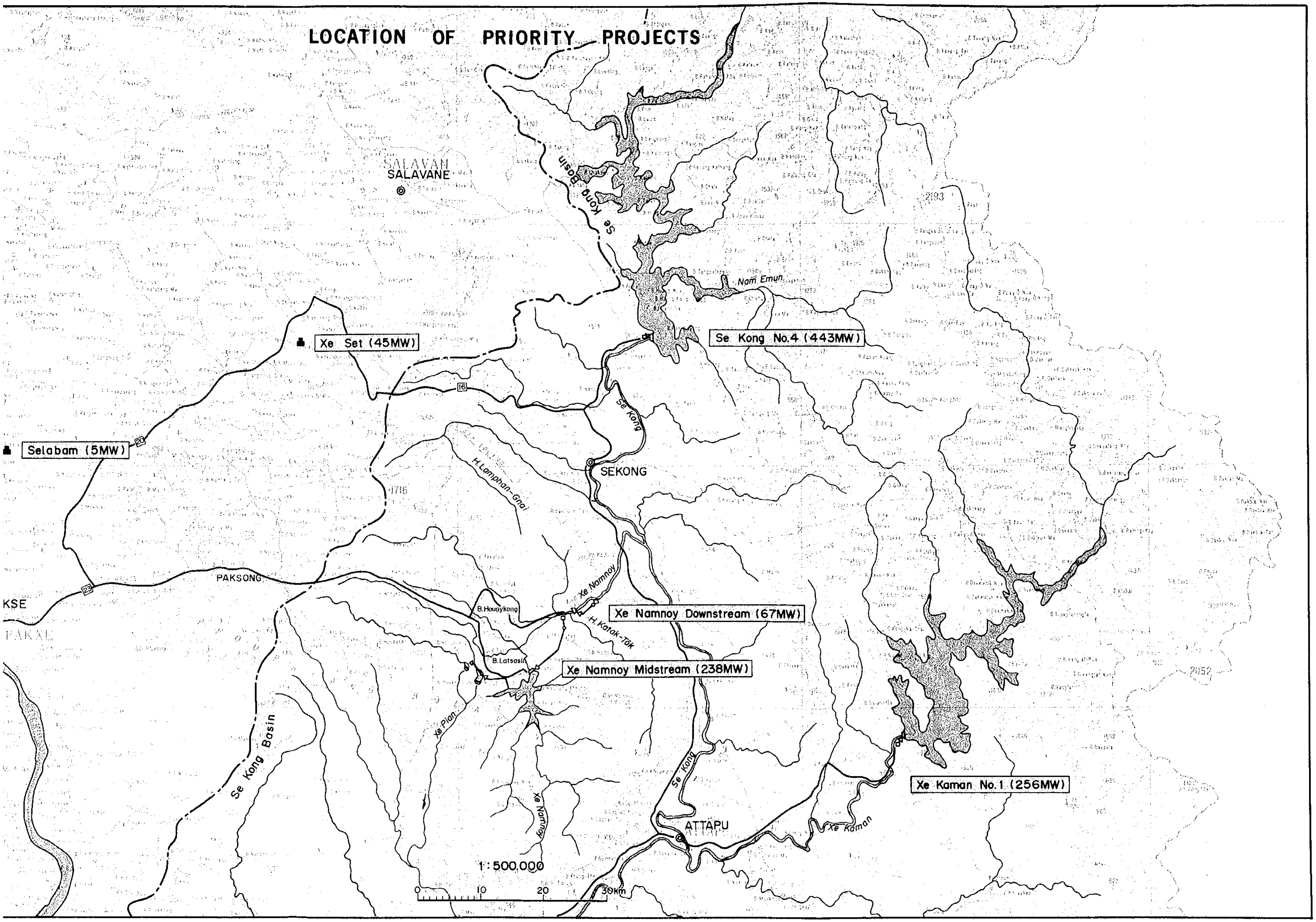
LOCATION OF PROJECT AREA

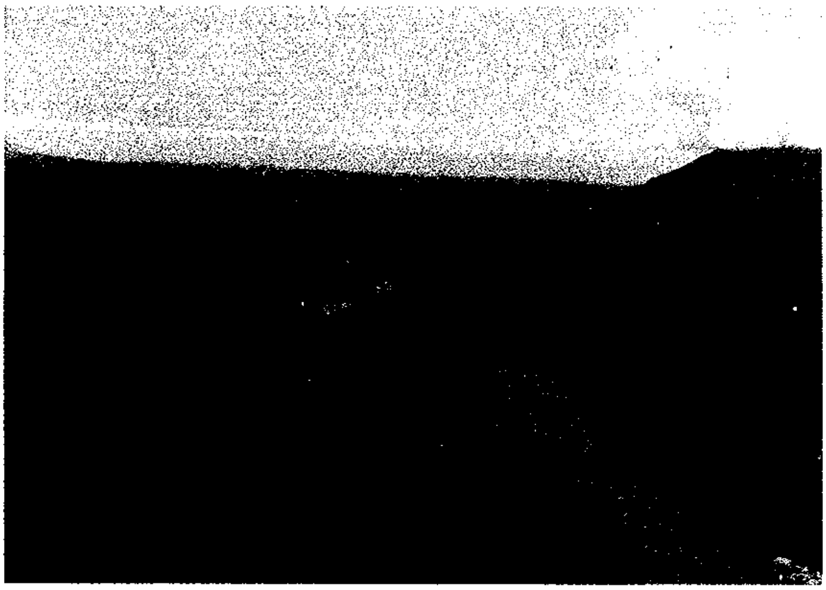




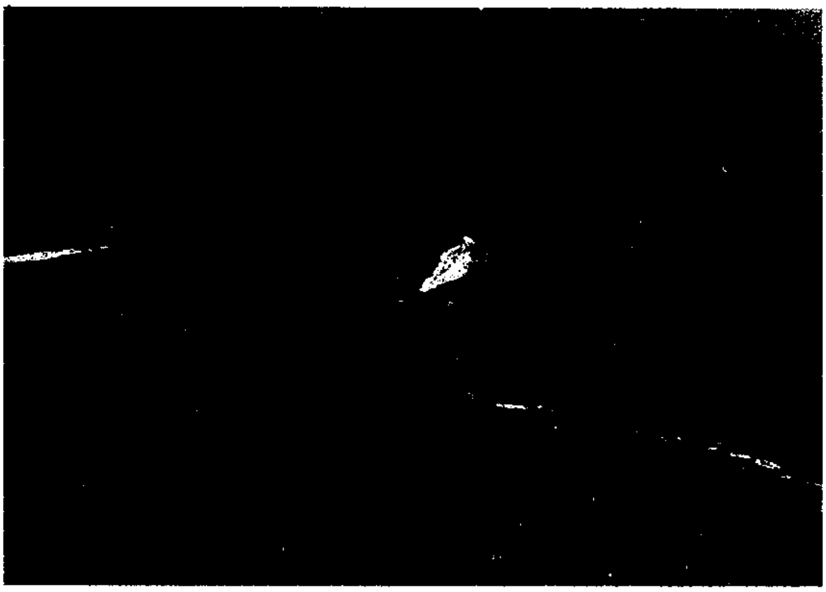
LOCATION OF PRIORITY PROJECTS
N
SALAVAN
SALAVANE
Se Kong Basin
Nam Emun
Se Kong No.4 (443MW)
Xe Set (45MW)
Selabam (5MW)
Se Kong
SEKONG
H.Lamphan-Gnai
PAKSONG
PAKSE
PAKXE
Xe Namnoy
B.Houaykong
Xe Namnoy Downstream (67MW)
H.Katak-Tök
B.Latsasin
Xe Namnoy Midstream (238MW)
Xe Pian
Se Kong Basin
CHAMPASAK
Se Kong
Xe Namnoy
Xe Kaman No.
ATTAPU
Xe Kaman
1:500,000
0 10 20 30km

LOCATION OF PRIORITY PROJECTS

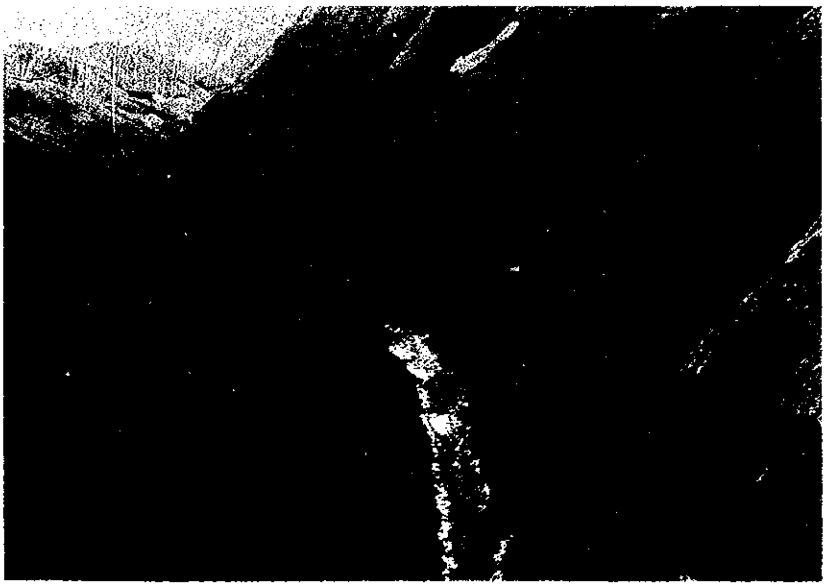




(1) Se Kong No. 3 Site
(View from upstream)



(2) Se Kong No. 4 Site
(View from downstream)

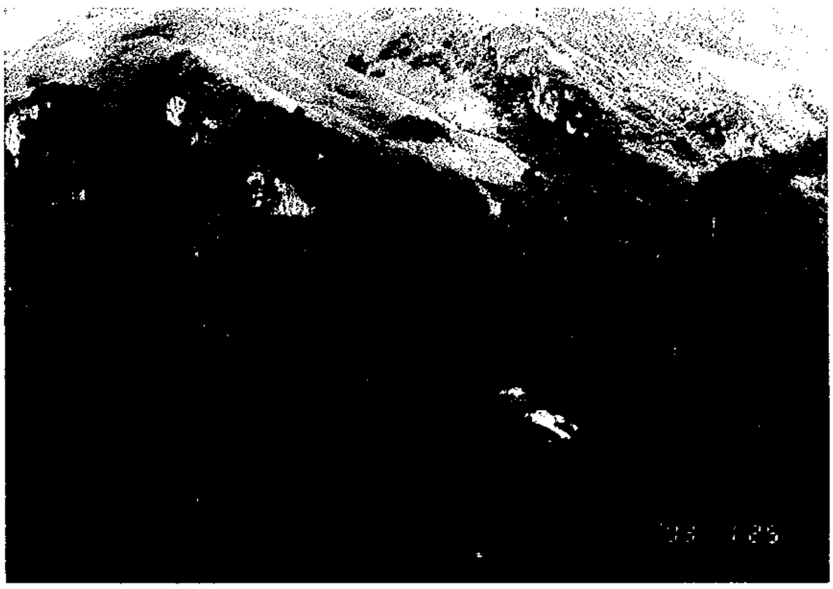


(3) Se Kong No. 5 Site
(View from downstream)

Photo A-1 Se Kong River Main Stream

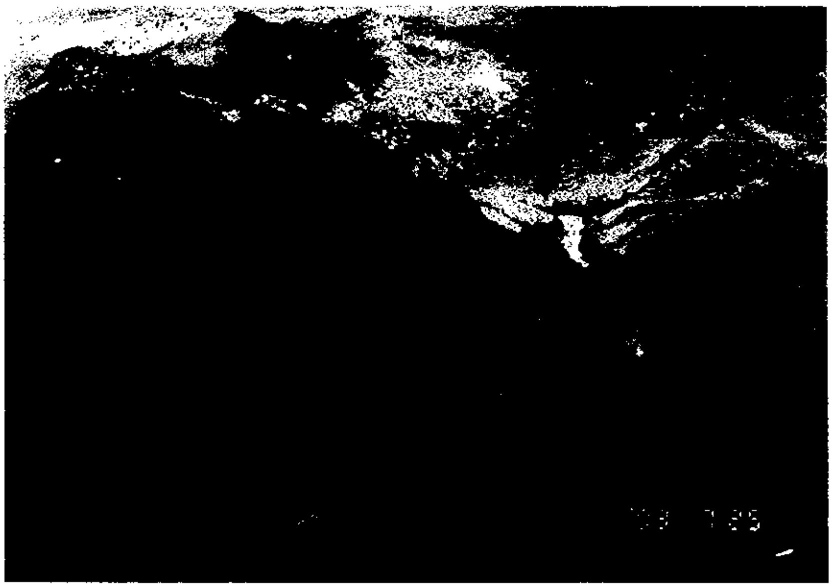
(1) Downstream of Xe Kaman No. 1 Site (View from upstream)

(2) Xe Kaman No. 1 Site Mid-stream Site (View from upstream)



(3) Xe Kaman No. 2 Site (View from downstream)

Photo A-2 Xe Kaman River (1)



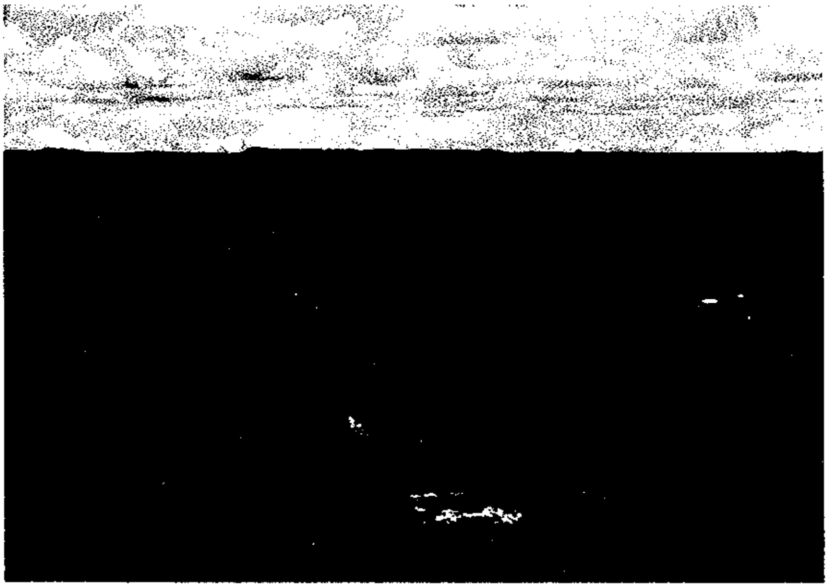
(1) Xe Kaman No. 3 Site
(View from downstream)

(2) Xe Kaman No. 4 Site
(View from downstream)

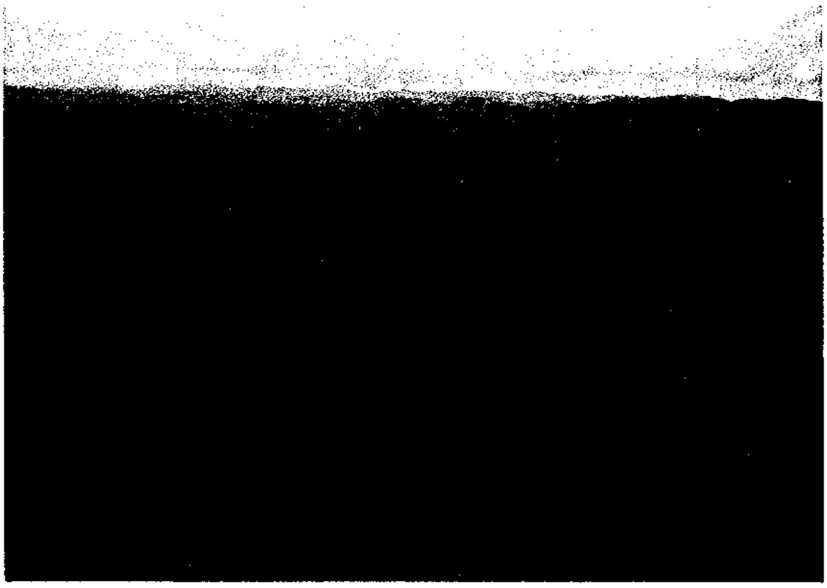
(3) Xe Kaman No. 4 Site
(View from downstream)

Photo A-3 Xe Kaman River (2)

(1) Xe Namnoy Midstream Site
(View from downstream)



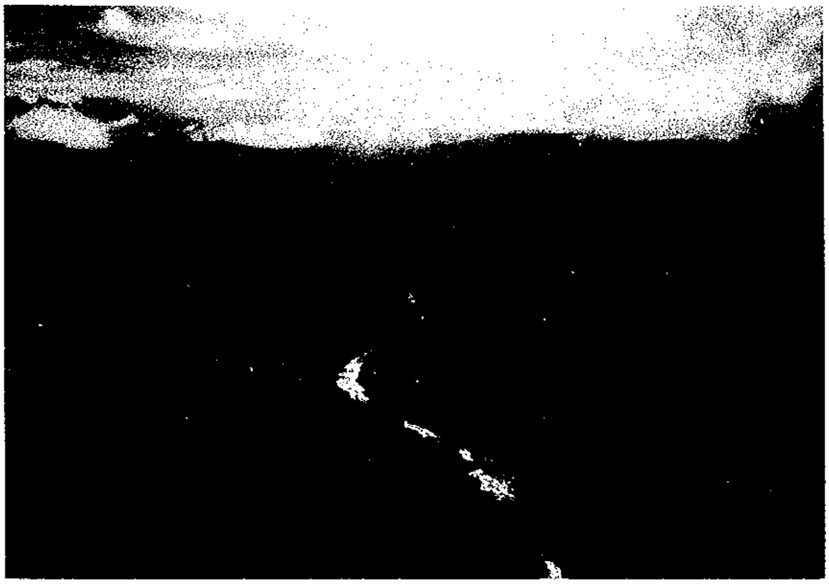
(2) Xe Namnoy Midstream Site
(View from downstream)



(3) Xe Namnoy Midstream Site
(View of reservoir area)

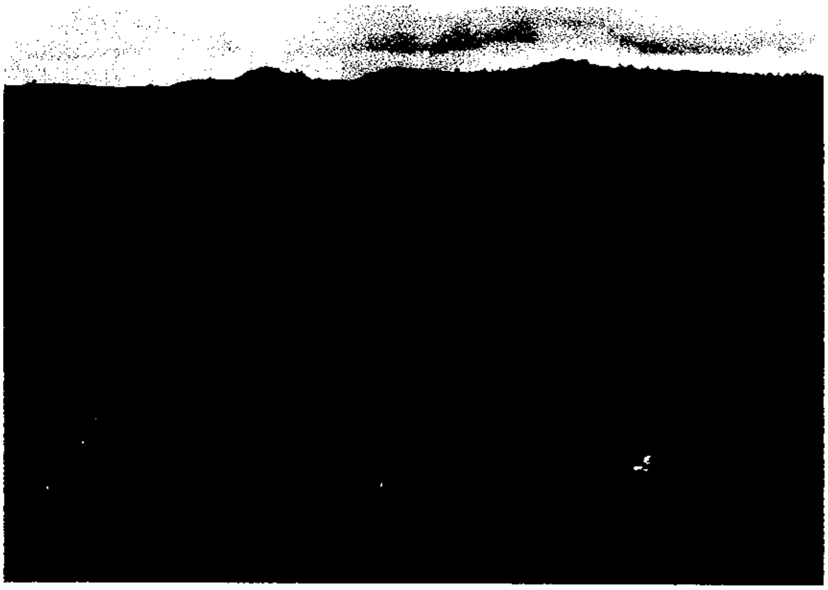
Photo A-4 Xe Namnoy River (1)

(1) Xe Namnoy Downstream Area
(View from upstream)

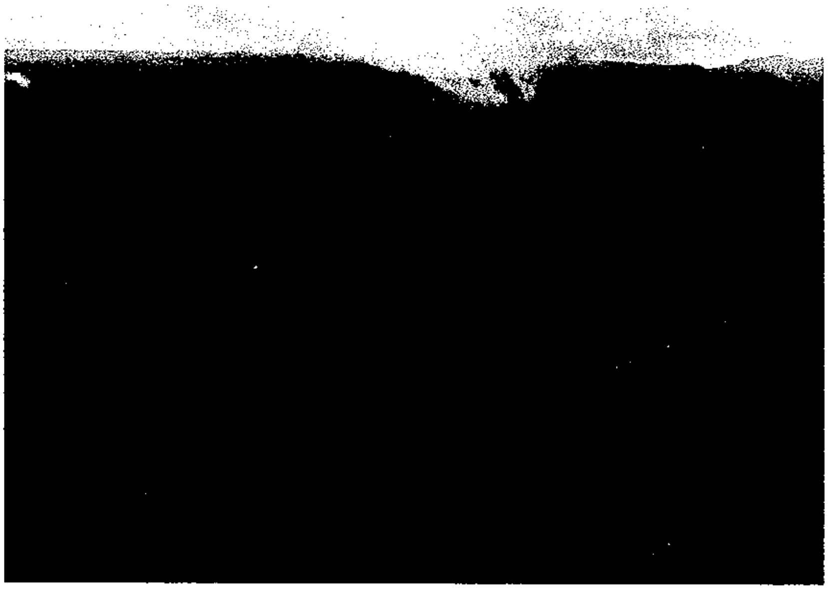


(2) Xe Namnoy Downstream Site
(View from upstream)

Photo A-5 Xe Namnoy River (2)



(1) Downstream of
Xe Pian Site
(View from downstream)

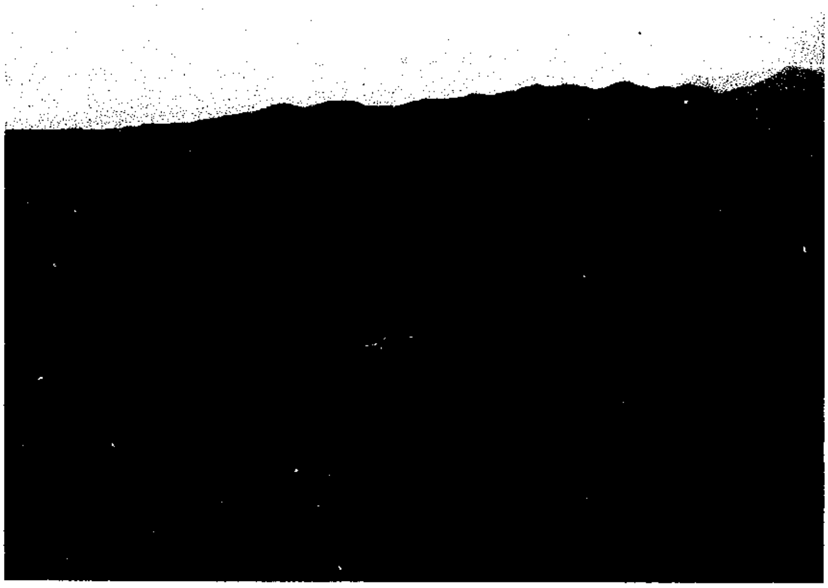


(2) H. Katak Tok Site
(View from downstream)

(3) H. Katak Tok Site
(View from downstream)

Photo A-6 Xe Pian, H. Katak Tok Rivers

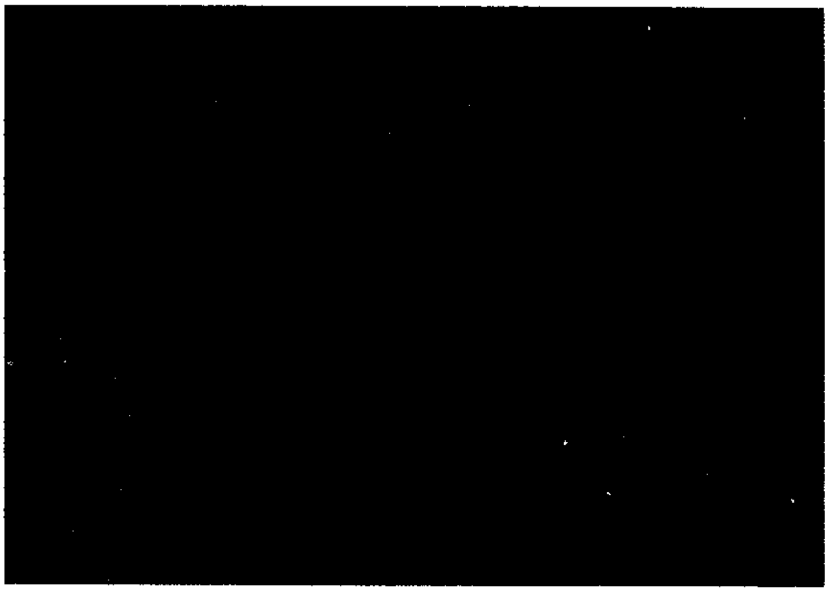
(1) Nam Kong No. 1 Site
(View from downstream)



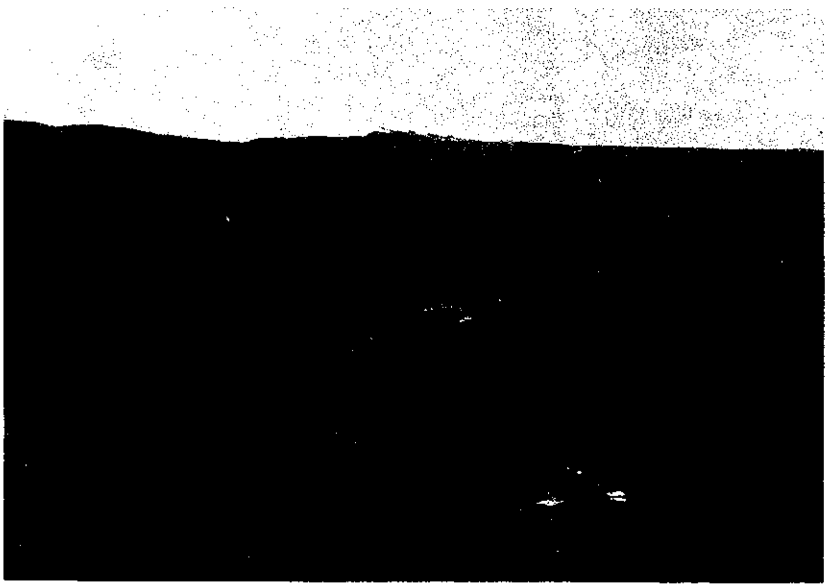
(2) Xe Xou Reservoir Area
(View from downstream)

Photo A-7 Nam Kong, Xe Xou Rivers

(1) Dak E Meule Site
(View from downstream)



(2) Dak E Meule Site
(View from downstream)



(3) H. Lamphan Gnai Site
(View from downstream)

Photo A-8 Dak E Meule, H. Lamphan Gnai Rivers

(1) View from Right Bank

(2) View from Upstream

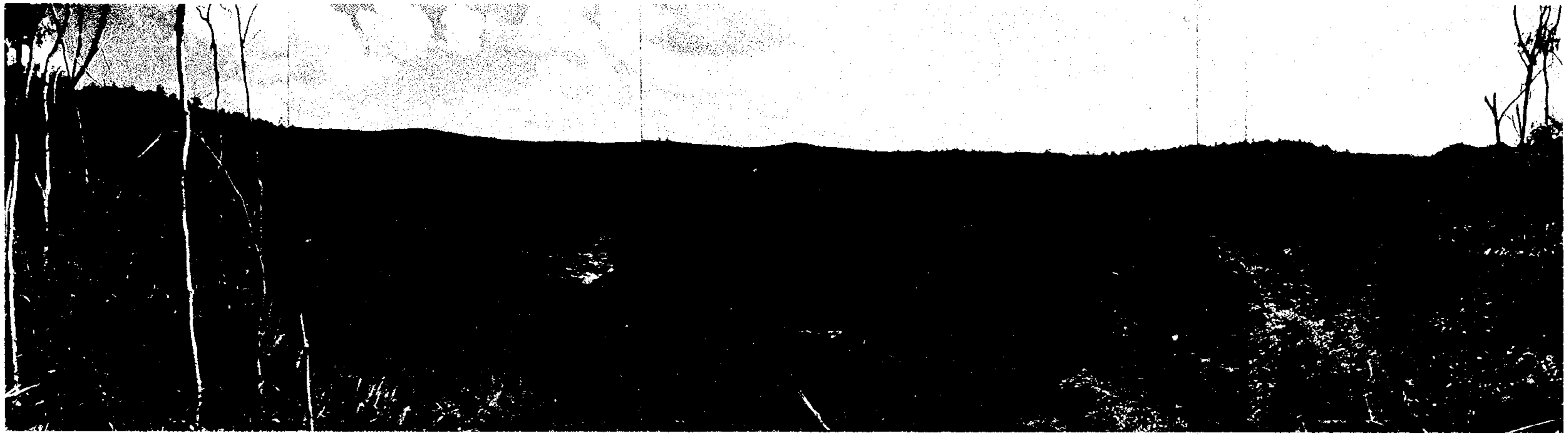
(3) View from Downstream

Photo B-1 Se Kong No.4 Dam Site

(1) View from Downstream

(2) View from Upstream

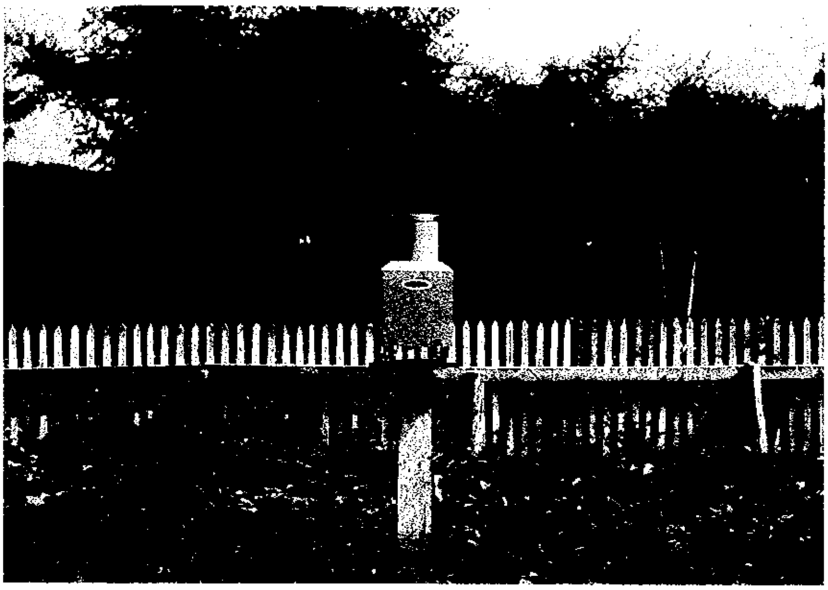
Photo B-2 Xe Kaman No.1 Dam Site



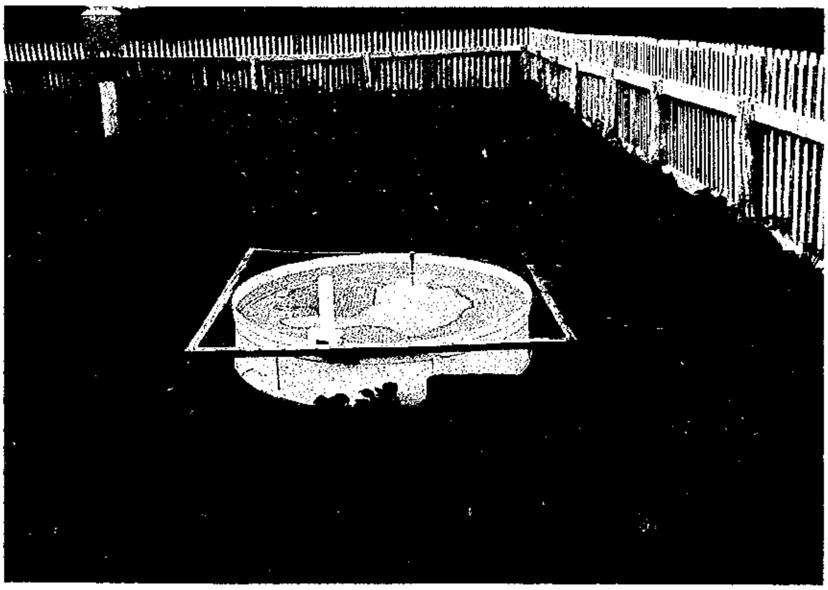
(1) View from Right Bank

(2) View from Downstream Left Bank

Photo B-3 Xe Namnoy Midstream Dam Site



(1) Rain Gauge



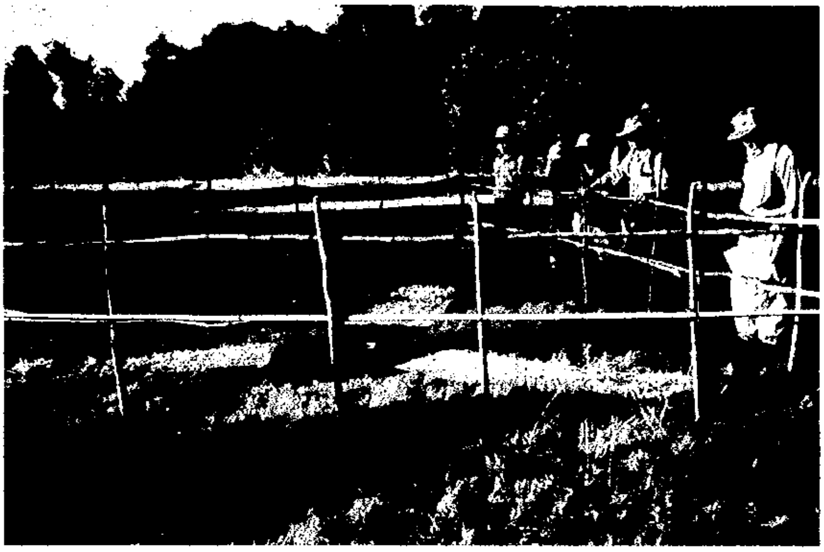
(2) Evaporation Pan

Photo C-1 Meteorological Gauging Station (Sekong Town)

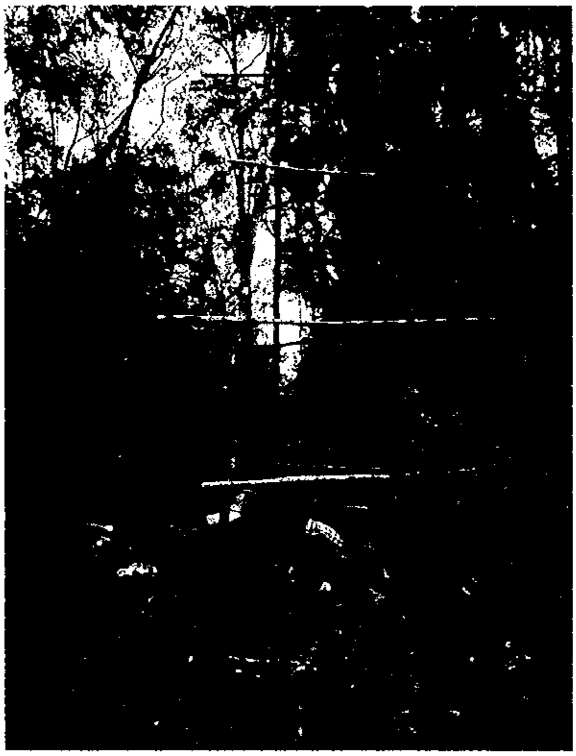
(1) Water Level Gauging Station

(2) Gondla and Winch for Cableway

Photo C-2 Discharge Measurement (B. Latsasin)



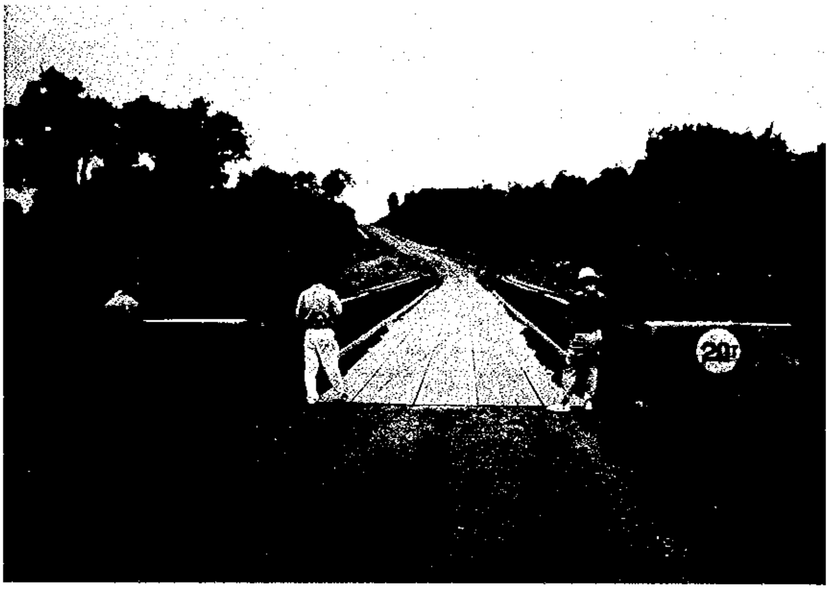
(1) Aerial Photogrammetry



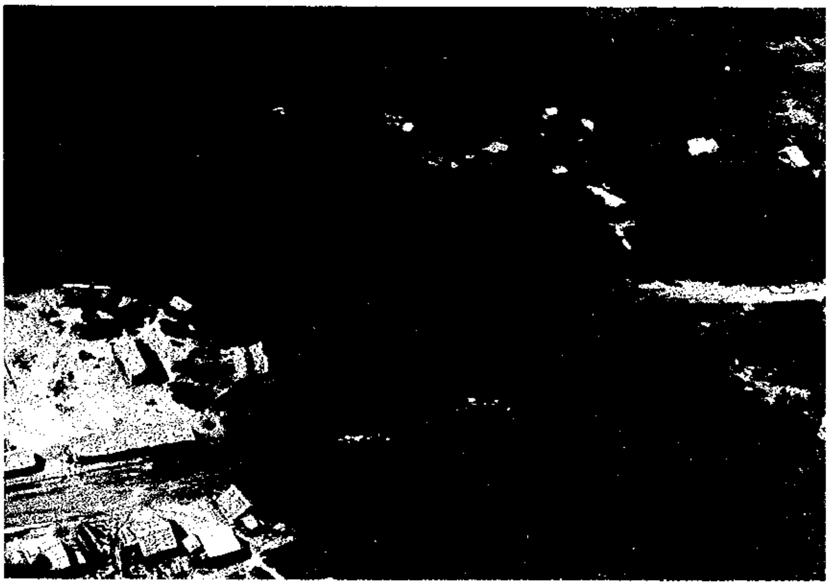
(2) Seismic Prospecting Survey

(3) Core Drilling Work

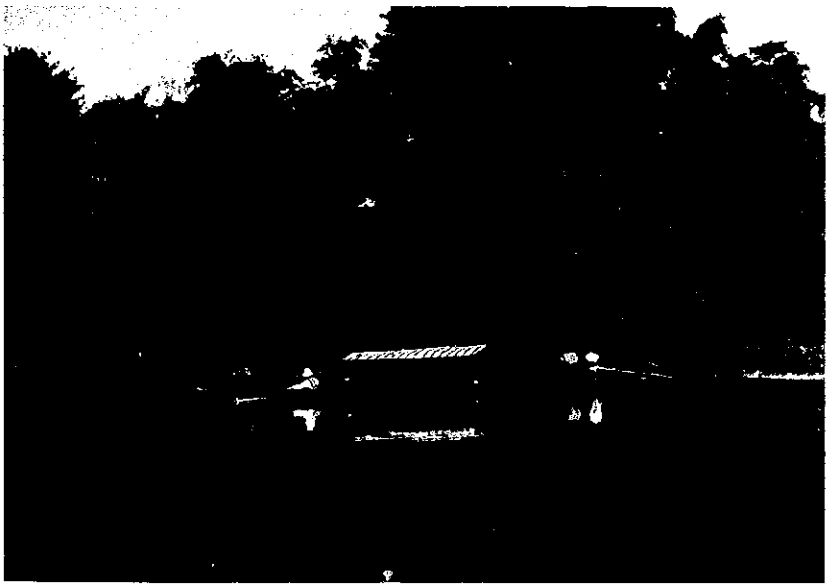
Photo C-3 Field Investigation



(1) Route 20
(at H. Champi)

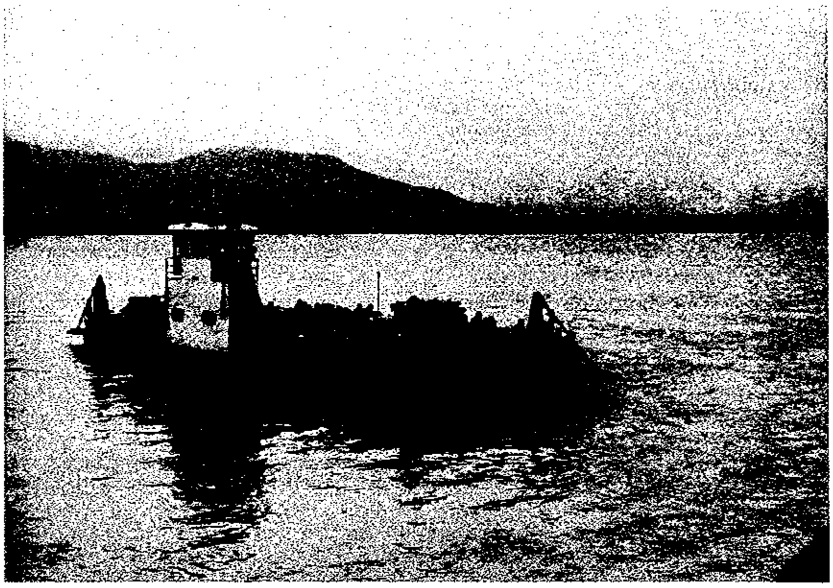


(2) Route 16 B
(at Xe Khampho)

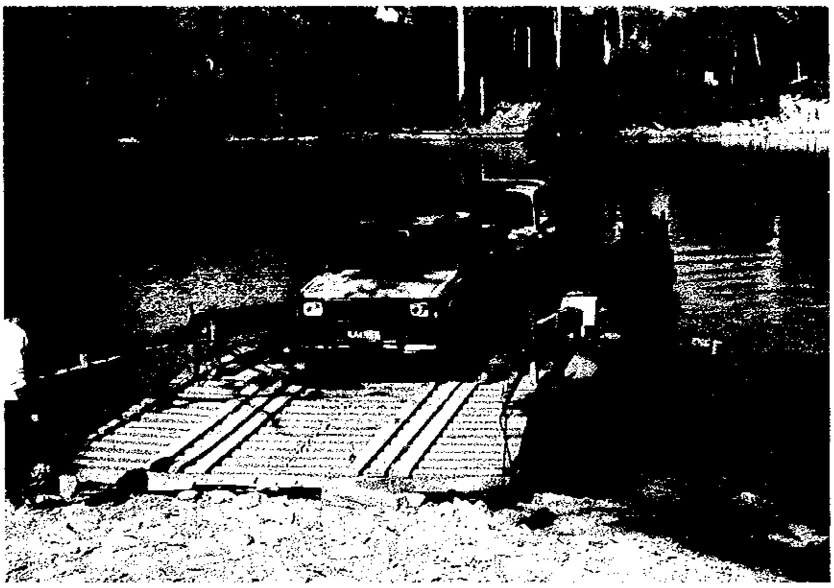


(3) Access to Se Kong No. 4
(by boat)

Photo C-4 Access Survey (1)



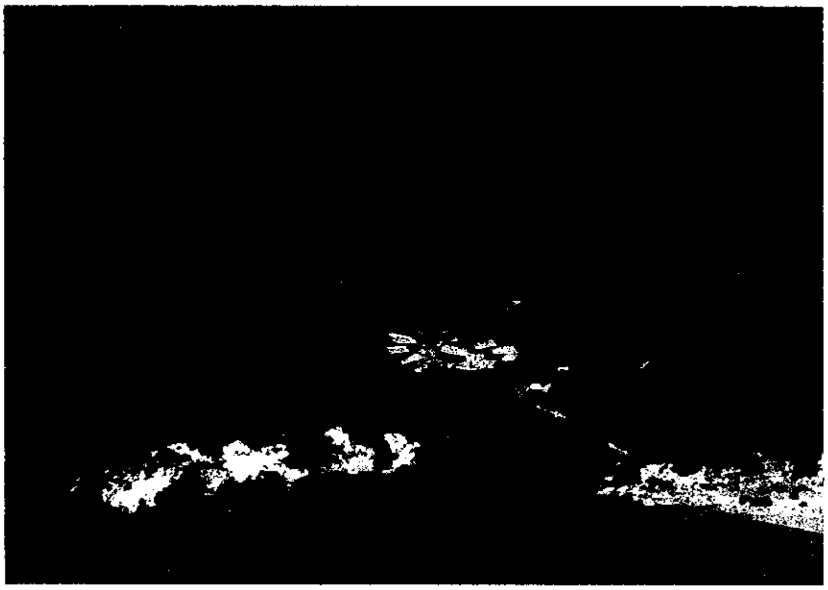
(1) Ferry Boat at Mekong River
(Route 13, Pakse)



(2) Ferry Boat at Xe Namnoy River
(Route 16 A)

(3) Ferry Boat at Se Kong River
(Local road, Attapu)

Photo C-5 Access Survey (2)



(1) Small Village along
Se Kong River

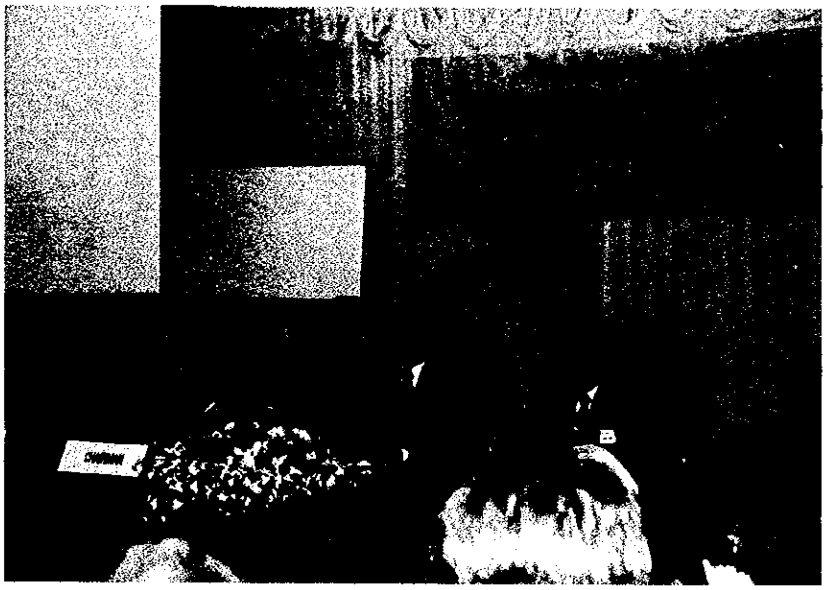
(2) Small Village along
Xe Kaman River

Photo C-6 Environment (1)

(1) Sekong Town

(2) Xe Katam Fall

Photo C-7 Environment (2)



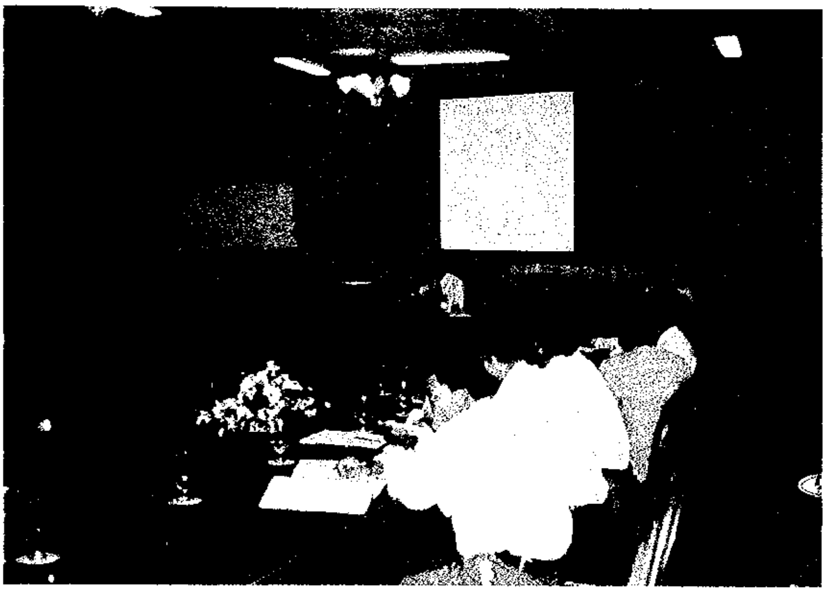


Photo C-8 Technical Transfer
(Seminar on Hydropower Development)

Table of Contents

ABBREVIATION

1. Countries

Lao P.D.R. or Laos	Lao People's Democratic Republic
Cambodia or Kampuchea	Cambodia
China	People's Republic of China
Myanmar	The Union of Myanmar
Thailand	Kingdom of Thailand
Vietnam	Socialist Republic of Viet Nam

2. Domestic Organizations of Lao P.D.R.

MIH	Ministry of Industry and Handicraft
EDL	Electricite du Laos
MCTPC	Ministry of Communication, Transportation, Post and Construction
DGM	Department of Geology and Mines, Ministry of Industry and Handicraft
NGD	National Geographic Department
DHM	Department of Hydrology and Meteorology, Ministry of Agriculture and Forestry
HEC	Hydropower Engineering Consultants

3. International and Foreign Organizations

JICA	Japan International Cooperation Agency
IBRD	International Bank for Reconstruction and Development
ADB	Asian Development Bank
OECF	Overseas Economic Cooperation Fund, Japan
ESCAP	Economic and Social Commission for Asia and the Pacific
Mekong Committee	Mekong Secretariat, or Interim Committee for Coordination of Investigations of the Lower Mekong Basin
UNDP	United Nations Development Programme
EGAT	Electricity Generating Authority of Thailand

3. Technical Terms

C.A.	Catchment area
PMF	Probable Maximum Flood
EL	Elevation(m) above sea level

HWL	High water level
LWL	Low water level
IWL	Intake water level
TWL	Tailrace water level
AC	Alternating current
DC	Direct current
cct	Circuit
GIS	Gas insulated switchgear
EHV	Extra high voltage
HVDC	High voltage direct currency
ACSR	Aluminum conductor steel reinforced
GPS	Global positioning system

4. Economic Terms

GDP	Gross domestic production
B/C	Benefit cost ratio
B-C	Net benefit
EIRR	Economic internal rate of return
FIRR	Financial internal rate of return
ARI	Accounting rate of interest
DSC	Debt service coverage ratio
IDC	Interest during construction
F/C	Foreign currency
L/C	Local currency
BOT	Built operate and transfer

5. Other Terms

S/W	Scope of Work
F/S	Feasibility Study
Pre-F/S	Pre-feasibility Study
PS	Power station
T/G	Turbine and generator
T/L	Transmission line
T/D	Transmission and distribution
O&M	Operation and maintenance

6. Measurement

<u>Length</u>

mm	Millimeter
cm	Centimeter
m	Meter
km	Kilometer
ft	Foot

<u>Area</u>

cm^2	Square centimeter
m^2	Square meter
ha	Hectare
km^2	Square kilometer

<u>Volume</u>

cm^3	Cubic centimeter
l	Liter
kl	Kiloliter
m^3	Cubic meter
MCM	Million cubic meter
m^3/s-d	Cubic meter per second-day (86,400 m^3)

<u>Weight</u>

g	Gram
kg	Kilogram
t /ton	Metric ton

<u>Time</u>

s	Second
min	Minute
h	Hour
d	Day
M	Month
yr	Year

<u>Meteorology</u>

°C	Degree in centigrade
mb	millibar
°K	Degree in kelvin-grade (thermodynamic unit)

Electrical Measures

V	Volt
kV	Kilovolt
A	Ampere
Hz	Hertz (cycle)
W	Watt
kW	Kilowatt (10^3 W)
MW	Megawatt (10^6 W)
GW	Gigawatt (10^9 W)
kWh	Kilowatt hour
MWh	Megawatt hour
GWh	Gigawatt hour
kVA	Kilovolt ampere
MVA	Megavolt ampere
MCM	Mil circular mils

Others

Btu.	British thermal unit
rpm	Round per minute
%	Percent
Lu	Lugeon

7. Currencies

US$ or $	US dollar
M.US$ or M.$	Million US dollar
US¢	US cent
kip	Lao kip
M.kip	Million kip
Baht	Thai baht
¥	Japanese yen

SUMMARY

SUMMARY

List of Tables

List of Figures

List of Drawings

1. Introduction

This Study was undertaken during the period June, 1993 to March, 1995 to formulate the Master Plan Study on the Hydroelectric Power Development in the Se Kong Basin, Lao P.D.R. In the Study, a hydropower potential study in the Se Kong Basin was carried out at first stage. Then pre-feasibility studies were carried out for the three projects selected from the projects in the development plan inventory.

The Study was carried out requested by the Government of Lao P.D.R.. The Scope of Work (S/W) for the Master Plan Study on the project was agreed, and duly signed on March 11,1993 between Ministry of Industry and Handicraft (MIH) of the Lao P.D.R. and Japan International Cooperation Agency (JICA).

In order to promote the Study, JICA selected the consultant firm and awarded the study works to the joint venture consisting of Electric Power Development Co. Ltd. (EPDC, leading firm), NEWJEC Inc. and PASCO International Inc.

The study team, organized in accordance with the above consultancy contract and headed by Mr. T. TEZUKA (EPDC), immediately started study works in June 1993.

The study team first prepared an Inception Report and presented the same to MIH in July, 1993. This Report contained the policy of the study, method of the study and works to be undertaken by the MIH and JICA. In the Report, the study team divided the works into two stages; a hydropower potential study stage and a pre-feasibility study stage.

Secondly, the study team carried out site reconnaissances, a hydropower potential study to prepare hydropower development inventory. Then the three priority projects were selected from the 15 projects in the inventory. These studies were reported in the Interim Report and submitted to MIH in November, 1993.

Thirdly, field investigations such as hydro-meteorological survey, topographic survey by aerial photogrammetry, geological investigation, environmental impact survey were carried out at the three selected project sites. Details of these field investigations were reported in the Progress Report and submitted to MIH in July, 1994.

Finally, pre-feasibility studies were carried out for the three selected projects.

The field works for the study were carried out in cooperation with the team's counterparts from the MIH. During this study, the study team provided technical transfer to their counterparts through the field investigations. In the mean time, JICA invited two counterparts in Japan and provided technical training for them.

The study team also held a technical seminar at Vientiane in July 1994.

All works were completed in March, 1995.

2. Power Survey

2.1 Present Situation of Electric Power Industry

(1) Most of electric utilities in Laos are being operated under state or public management. The greater part of them is run by Electricite du Laos (EDL). EDL is now under the control of Ministry of Industry and Handicraft(MIH) which is its supervisory office and conducts integrated management including power generation, transmission and distribution, and electricity export to Thailand.

(2) The total generating capacity in Laos is 210 MW as of 1994 and about 94 % of them are hydroelectric generating equipment. Main power plants include the Num Ngum hydroelectric power plant (150 MW) and Xe Set hydroelectric power plant (45 MW).

(3) As for main power system, Nam Ngum power plant and Vientiane system, Xe Set power plant and the southern system and Thakhek and Savanakhet system where electric power is supplied from Thailand are operated respectively in an isolated system.

2.2 Development Plan and Power Export

(1) According to the latest estimate by EDL, the demand for electric power in Laos is 195 GWh in 1993, 398 GWh in 2000 and 502 GWh in 2003. When only domestic demand considered, the existing facilities are capable of satisfying that demand despite power export to Thailand.

(2) On the other hand, the demand for electric power in Thailand, is increasing by 8% to 9%. Subsequently, Thailand's expectations of Laos for the supply of electric power has increased. On June 1993, both countries agreed that 1,500 MW of the power are to be supply to Thailand by year 2000. Furthermore, more power supply will be expected after year 2000. Recently, investigations and construction of the hydroelectric power projects for the power export to Thailand have been expanded by the private investors.

(3) In Laos, electric power development plan is not basically linked to domestic demand alone. The majority of the nation's power is exported. Assuming construction is carried out as scheduled in the plan, the total capacity will amount to 2,255 MW (8,451 GWh annual power generation) in 2000, 6,279MW (30,797 GWh annual power generation) in 2010.

(4) The Se Kong river basin provides abundant hydropower resources. Therefore, the basin is taken notice of the hydro- electric power development area for the purpose of power export to the neighboring countries.

3. Results of Hydropower Potential Study in the Se Kong Basin

3.1 Field Survey

JICA study team visited Laos six times to carry out the field survey. The surveys were carried out at Vientiane and in the Se Kong basin. Meeting with MIH, data collection, report of the results of the field investigation works to MIH and etc. were carried out at Vientiane. Overall site survey by helicopter, topographic survey and geological reconnaissance at the accessible sites were carried out in the Se Kong basin. Furthermore, meteorological observation stations and water level gauging stations around the basin were improved and advised observation technology by the study team.

On the other hand, the study team visited Mekong Committee Secretariat in Bangkok and EGAT for data collection.

3.2 Selection of Development Plans

(1) Basic Conditions for the Hydropower Potential Study

- The Study covers all the Se Kong river basin of which located within the Lao territory.

- The Study covers hydropower development projects to be developed mainly for the energy export to the neighboring countries..

- The Study covers hydropower development projects to be proposed as a medium to large scale ones with an installed capacity of 10 MW or more..

- The development plan inventory is produced with a purpose to evaluate basin's hydropower potential by proposing a combination of project layouts which provides maximum net benefit.

  However, development plans of each project are studied as independent projects but not as series of incorporated projects.

- Development scales (installed capacities) of each project are so determined to provide a plant factor of approximately 60%.

(2) Basic Data applied in the Study

- The Study was conducted mainly by using 1/50,000 scaled topographic maps which are the largest maps in the existing maps.

- Currently, very little hydrological data is available in the Se Kong basin. It is, therefore, impossible to acquire precise flow data of specific sites throughout the broad reaches in the Se Kong basin. In this study, monthly flow data for the five years from August 1988 to July 1993 at Attapu gauging station were applied. Location of the observation stations are shown in **Fig. 1**.

(3) Review of Development Plans of the Previous Study

Prior to the inventory study, the development plan of the Se Kong basin proposed by the Mekong Committee in 1984, and the development plan of the Xe Namnoy river proposed in the study of Xe Katam Small-Scale Hydroelectric Power Development Project reported by JICA in 1992 were reviewed.

(4) Study of Development Plan Inventory

After reviewed the development plans proposed in the previous studies, 15 development plans which cover the most part of hydropower potential in the Se Kong basin were selected as follows. Location of each development plan is shown in **Fig. 2**.

Se Kong river main stream	3 plans
Xe Kaman river including tributaries	4 plans
Xe Namnoy river including Xe Pian river	2 plans
Nam Kong river	3 plans
Xe Xou river	1 plan
Nam Emun river	1 plan
Houay Lamphan Gnai river	1 plan

(5) Preparation of Development Inventory

Each development plans were studied on the some cases taking into consideration the basin's conditions of topography, geology, environmental impact and other site conditions.

The development inventory in the Se Kong basin was prepared as shown in **Table 1**.

3.3 Selection of Projects to be subjected to Pre-feasibility Study

(1) Evaluation Indexes for Project Ranking

15 plans (projects) listed in the development inventory were ranked based on the following indexes.

- Development scale (MW)
- Annual energy production (kWh)
- Construction cost including transmission line
- Net benefit (B-C)
- Cost benefit ratio (B/C)
- Generation cost (US$/kWh)
- Construction cost per kW

From the results of ranking study, 5 candidate priority development projects were selected as shown in **Table 2**.

(2) Selection of Projects to be Subject to Pre-feasibility Study

Judging from the detailed consideration, the following 3 projects were selected as the projects to be subjected to Pre-feasibility Study.

- Se Kong No.4 Project
- Xe Kaman No.1 Project
- Xe Namnoy Project (including Midstream and Downstream projects)

4. Results of Pre-feasibility Study

4.1 Field Investigation Works

To perform the pre-feasibility study, the following field investigation works were carried out at the 3 selected project sites.

(1) Topographic Survey

Topographic maps were made out by the aerial photogrammetric survey. The aerial photographs were taken at all reservoir area of the three selected sites. Using the photographs, topographic maps of 1/10,000 scale were prepared for the pre-feasibility study purpose. Mapping area and quantity are as follows.

Se Kong No.4	:	80 km^2 for dam site and a part of reservoir area
Xe Kaman No.1	:	80 km^2 for dam site and a part of reservoir area
Xe Namnoy	:	170 km^2 for all project area including the reservoir areas, of Midstream and Downstream projects and the area of Xe Pian Diversion scheme

(2) Seismic Prospecting Survey

Seismic prospecting surveys were carried out along the dam axises at the selected dam sites as follows.

Se Kong No.4	1,000 m (1 line)
Xe Kaman No.1	1,000 m (2 lines)
Xe Namnoy Midstream	1,000 m (1 line)

(3) Core Drilling

Core drilling works were carried out along the dam axises at the selected dam sites as follows.

Se Kong No.4	260 m (3 holes)
Xe Kaman No.1	260 m (3 holes)
Xe Namnoy Midstream	380 m (6 holes)

(4) Survey on Environmental Impact and Compensation

At the selected 3 project sites, environmental impact and compensation were preliminary surveyed. On the environmental impact survey, current status, environmental impacts and their mitigation measures were surveyed. On the compensation survey, compensation cost for the relocation of inhabitants and inundation of the forest caused by the dam construction was preliminary surveyed. Furthermore, surveys needed in future were also studied.

(5) Access Survey

Current status of access to the selected project sites such as ports, airports, existing roads were surveyed by the field reconnaissance.

4.2 Meteorology and Hydrology

(1) Using the data obtained at the existing observation stations and at the stations newly installed in the hydropower potential study stage, monthly discharge, probable flood, evaporation and sedimentation at Se Kong No.4, Xe Kaman No.1 and Xe Namnoy projects were analyzed respectively. Because of short term records of the stations, data for the analysis include some estimated data. Review of the analysis, therefore, will be required adding the data which are continuously observed in future .

(2) The monthly discharge at the dam sites of the projects were calculated from those of nearby stations in proportion to the catchment area. Because of the short term records of the stations, monthly discharge was extended to 10-year period from August 1984 to July 1994 using the regression correlation with the discharge data of the nearby basin.

a) Monthly Discharge at Se Kong No.4

Ten (10) years' monthly discharge at Se Kong Town was firstly estimated by regression correlation study with the daily discharge calculated from the observed water level at the stations of Sekong Town, Attapu Town, and Xe Done River. Then the monthly discharge of Se Kong No.4 was calculated in proportion to the catchment areas of Sekong Town and the Se Kong No.4 dam site.

b) **Monthly Discharge at Xe Kaman No.1**

Ten (10) years' monthly discharge at B.Fangdeng was firstly estimated by regression correlation study with the daily discharge calculated from the observed water level at the stations at B.Fangdeng, B.Hatsaykhao and Attapu. Then the monthly discharge of Xe Kaman No.1 was calculated in proportion to the catchment areas of B.Fangdeng and the Xe Kaman No.1 dam site.

c) **Monthly Discharge at Xe Namnoy Midstream**

Ten (10) years' monthly discharge at B.Latsasin was firstly calculated from the observed water level at the B.Latsasin station, partly supplementing it by using the data at the Xe Set and B.Fangdeng stations. Then the monthly discharge of Xe Namnoy Midstream was calculated in proportion to the catchment areas of the B.Latsasin gauging station and Xe Namnoy Midstream dam site.

d) **Monthly Discharge at Xe Namnoy Downstream**

The available discharge at the Xe Namnoy Downstream dam site consists of the discharge from the downstream drainage area of Xe Namnoy Midstream and Houay Katak Tok (Houay Ho) dam sites as well as from the Xe Katam basin and the power discharge released from the Midstream power plant. The monthly discharge of the downstream drainage area was estimated from the data extended over 10 years of the stations at B.Latsasin and B.Nonghin in proportion to the catchment areas.

e) **Monthly Discharge at Xe Pian Diversion**

Ten (10) years' monthly discharge was estimated from the extended 10 years data of the B.Nonghin station on the Xe Kaman river, which has the basin adjacent to the basin of the Xe Pian river, in proportion to the catchment areas.

(3) The design floods of the each project are estimated by using the data in Laos and neighboring countries and Creager Curve which envelopes PMF at the similar project. The design floods at dam site of each project are estimated as follows.

Se Kong No.4	16,400 m^3/s
Xe Kaman No.1	14,300 m^3/s
Xe Namnoy Midstream	6,000 m^3/s

Xe Namnoy Downstream 9,000 m^3/s

4.3 Geology of Each Project Site

(1) Se Kong No.4 Project

a) Mountain of some 500 m in elevation was cut by the Se Kong river at Se Kong No.4 dam site. At the dam site, river bed is at elevation of 140 m and around 100 m wide. The valley is about 900 m wide at the high water level of the reservoir. The slope of the both banks is relatively gentle.

b) The dam site is underlain by sandstone, shale and andesitic tuff. Sandstone and shale are distributed on the river bed upstream of dam axis. Tuff layer accompanied by tuff breccia and limestone blocks are distributed on both banks of the dam site and river bed downstream of the dam axis. Tuff layers are overlain by conglomerate. The recent river deposits are inferred to be 10 m deep in maximum from abundant outcrops of tuff on the river bed downstream of the dam axis. Surface deposits such as talus deposits and recent river deposits are thin. This dam site will not provide any serious geotechnical problems, because of shallow surface deposits and weathering and limited limestone distribution.

c) Upstream reservoir area is characterized by narrow valley and steep slopes. While, in midstream and downstream of the reservoir area, valley are widened and with gentle slopes. There is no distinct landslide topography, large scale slope failure. The reservoir area is mainly underlain by shale and sandstone. Limestone distribution is judged from topography to be so limited and discontinuous that it will not cause any problem on reservoir watertightness. Coal seams distributed in the vicinity of B. Chakeui are reported but details are unknown.

It seems like that the reservoir area has few problems on stability for the surrounding slopes and watertightness.

(2) Xe Kaman No.1 Project

a) The dam site is located on the second downstreamost gorge of Xe Kaman river. River bed is at elevation of about 130 m, and 80 m wide. Valley is about 500 m wide at the high water level of the reservoir. The slopes below an elevation of

some 240 m have an average gradient 40° on the left bank and 50° on the right bank. The slopes above that elevation are gentle.

b) The dam site is underlain by sandstone and intercalating conglomerate and shale. Sandstone is fresh and medium to coarse grained and some times get coarser to conglomerate. Talus deposits are limited on the upper slope of the damsite. Recent river deposits are inferred to be some 5 m thick by the outcrops on the river bed at the dam site.

c) Valleys are generally narrow and V shaped in the upstream reservoir area, some basin separated by short gorge appear in the downstream reservoir area. Any distinct landslide topographies and large slope failures are not observed. Close to the backwater of the reservoir, high white cliffs are continued along the Xe Kaman river and seems to be composed by limestone, but typical karst topographies are not found.

Geology in the reservoir area is underlain mainly by sandstone and shale. It seams that the reservoir area is generally watertight.

(3) Xe Namnoy Midstream Project

a) Midstream dam site is located on the Bolaven Plateau where elevation of the mountains are about 800 m and that of Xe Namnoy river is from 700 to 720 m. The valleys of that river system are shallow but large in density. At the dam site, river bed is about 80 m wide and the width of the valley at high water level is about 900 m. Xe Namnoy river has many rapids and waterfalls between 650 m in elevation 4 km of downstream of the dam site and 300 m in elevation near the junction of Xe Katam river where about 2 km upstream of the power station site.

b) The dam site is underlain by sandstone, shale and basalt. Sandstone and shale distribute on the river bed, right bank and upper slope on the left bank. Basalt is distributed on the left bank its bottom is lower than recent river bed. This basalt is characterized by cooling joints and porous in some horizons. Lower part of the basalt shows low ground water level and high permeability. Talus deposits, recent river deposits are thin and limited in distribution.

c) The reservoir area covers upstream of Xe Namnoy river and surrounded by the gentle mountains of 1,000 m in elevation. Basalt is limited to the narrow area near

the dam site. The basalt at the dam site will be treated so as to stop the leakage from the reservoir to downstream. Then the watertightness of the reservoir will be achieved.

d) The headrace tunnel route is located on the right bank of Xe Namnoy river. The tunnel will penetrate same sandstone and shale that is distributed at the dam site. Both sandstone and shale are supposed to be massive and fresh.

4.4 Environmental Impact and Compensation

(1) Outline

Preliminary field surveys on environmental impact and compensation were carried out from November, 1993 to March, 1994 by the Hydropower Engineering Consultants (HEC) entrusted JICA study team.

These surveys were mainly for the collection of data. Some surveys were done in the field including interviews with local authorities and residents. The data of these field surveys was prepared by the HEC in its "Report on Environmental Impact and Compensation".

(2) Summary of Environmental Impact Survey

As this is a preliminary survey at the pre-feasibility study stage, it does not adequately determine the current status of the environment, for which reason some matters must wait until future surveys. However, an overall consideration on the basis of the results of the survey together with other information to date suggests that implementing appropriate measures to alleviate impacts will forestall the occurrence of environmental impacts that would hinder these projects.

The major items of the survey results and the surveys needed in the future are summarized below;

a) Impacts on Local Societies, Inhabitants and Agriculture by Submersion Relocation

The population in the reservoir area is estimated at approximately 3,600 people at Se Kong No.4, 600 people at Xe Kaman No.1 and 900 people at Xe Namnoy Midstream. The greatest impact by these projects on the inhabitants and local

societies will be the submersion of their dwellings, settlements, farmlands and other elements of their livelihood, and the relocation of these.

Almost all the inhabitants of the reservoir areas are minorities who practice slash-and-burn agriculture, and who still pursue a traditional lifestyle. They also prefer living in small, dispersed settlements.

On the other hand, while the government's scheme to move these people is to encourage them to cultivate low lying farmland and abandon slash-and burn agriculture, any attempt to follow this scheme would mean that, in order to ensure the investment, the resettlement areas would have to be large, intensive settlements located on flatlands. In view of this, it is anticipated that the resettled people's lifestyles will change considerably.

It will be necessary to conduct on-site surveys of the reservoir areas and their peripheries to check the inhabitants awareness and desires with regard to resettlement and other matters. Consideration is also needed to ensure the resettlement plan lessens the burden on the inhabitants as much as possible.

b) Infectious Water Area

Construction of a dam reservoir could result in water-related epidemics through the creation of new stagnant water areas that would serve as a habitat for mosquitoes and other disease vectors. With this, different a living environment and various other attendant changes will place a large mental burden on the resettled people.

Detailed surveys on the state of health and hygiene of the people in the project areas, and on matters including past instances of epidemics will be necessary in the future. Also, countermeasures such as those for the prevention of epidemics, the maintenance of hygiene and adequate guidance for the construction personnel will be very necessary.

c) Impact of Dam Construction on Water Transportation, Water Area Utilization and Fishing

Water transportation is the only means of transportation linking the settlements upstream from the project location with either Sekong Town or Attapu Town, which constitute the primary part of the downstream areas. As a large population in the

upstream area will remain in-place after project completion, upstream to downstream transportation will continue to be of great importance and the construction of a dam will hinder such movement. An alternative means of transportation will have to provided.

The construction of these hydropower projects offers hope of favorable effects, especially wherein that in the downstream regions the river flow will increase in the dry season, and that less flooding will occur in the rainy season. On the other hand, during peak use when daily plant operation and shut down are repeated, it is possible that rising downstream water levels during operation start-up and output changes will present danger to people in boats, who are fishing, bathing, doing laundry, and the like. The requisite future surveys and studies may indicate a need for measures to deal with this situation, such as installing discharge warning devices to be activated when danger is anticipated.

It is possible that changes engendered by dam construction, such as in flow characteristics including water depths and current velocity, as well as in water quality, bottom material, and the like, will affect the aquatic organisms.

While it is difficult to clearly predict what those impacts will be, for migratory fish the dam will affect spawning by hindering the passage of fish which presently traverse the rivers. The project may, therefore, bring about a decline in their numbers. It is also reported that, although rarely, local inhabitants see river dolphins in the Se Kong River. On the other hand, in the case of the Nam Ngum, the dam construction would greatly increase the number of fish inhabiting the reservoir area.

More detailed surveys will be needed on the current state of fish stocks together with careful assessment of the total project impact in the future.

d) Impacts on Fauna

It is reported that many species of irreplaceable animals, including those rarely seen and those seen only in the past, exist in the project areas. Conceivable project impacts on animals include the submersion of forest lands which provide habitats and food, and the blockage of migratory routes by the reservoirs. It would perhaps be effective to provide wildlife protection areas on the peripheries of the reservoirs in order to compensate for the submersion of such habitats.

More detailed surveys will be needed to determine the current state of flora and fauna and the existence of irreplaceable species.

e) **Impacts on the Inter-basin Diversion and River Flow Decrease**

The Se Kong No.4, Xe Kaman No.1 and Xe Namnoy projects will decrease the downstream river water by peak power generation for a limited time in the dry season. Xe Pian river also decrease at the downstream from the intake dam, by the Xe Pian Diversion plan. Therefore, each project are considered a constant river flow discharge throughout a day (24 hours) to the downstream from the dam or powerhouse.

It will be necessary to conduct detailed surveys and investigations concerning these potential problems and institute, in accordance with the need, remedial measures such as releasing the amount of water needed as the water flow to maintain the river.

(3) Summary of Compensation

Compensation for submerged dwellings, farmland and other assets would consist in offering resettled people compensation "in kind" at their new locations. One group resettlement plan with one resettlement area per one project was planned.

Compensation costs were calculated according to the following guidelines and preconditions;

- Land in new settlements would be provided free of charge by the government.
- One (1) ha. of land would be prepared as the property of each household.
- An average per-household budget of 750,000 kip would be set aside as living costs and food aid for the first two years after resettlement.
- The following basic infrastructures would be built. Although apparently the settlements within the reservoir areas have almost no infrastructures such as this, items would be constructed because the settlement areas will be large due to group location, and because it would provide the inhabitants an incentive to resettle.
  Meeting halls, temples, schools, medical care facilities, government offices, markets, wells, electric power, irrigation equipment, roads (unpaved).

The compensation costs estimated above are approximations only and include many assumptions. They will have to be reassessed after conducting surveys of the populations, assets (including houses and farmland), social capital, type of ethnic groups and other matters regarding all the settlements in and around the reservoir areas, and surveys covering the perceptions, hopes, and other feelings, of the inhabitants concerning resettlement, as well as after incorporating the opinions of the central and local government authorities.

At present, only those settlements lying within the reservoir areas are planned for relocation. However, future surveys of inter-settlement interchanges and other circumstances within these areas may indicate the need to relocate the peripheral resettlements as well.

4.5 Operation Plan

In the operation plan, a review of the electric power development programs, transmission line plan, and operation plan of the reservoir and power plant facility are studied.

(1) Review of Electric Power Development Programs

- Laos is blessed with many tributaries to the Mekong River, offering plentiful hydropower potential. However, as population is low and domestic industrial structure is mainly defined by primary industries, domestic demand for electric power is far below the supply potential.
- Medium and large hydroelectric power projects in Laos are not developed solely for domestic supply, but with export to neighboring countries as their primary purpose. And, some areas around Laos have a large and rapidly increasing electric power demand. Taking advantage of these conditions, future strategy for economic growth of Laos will center on the development of domestic hydropower potentials for export.
- For the hydropower development in the Se Kong River Basin, clarification as source of domestic electricity supply and that as electric power export are studied.

(2) Transmission Line Plan

- Current status of transmission line expansion plan in Laos is studied.
- Electric power generated at the projects in the Se Kong basin will be connected to the B. Houaykong substation located in the Bolaven Plateau. From this substation, the

electric power will be transmitted to the neighboring countries by an international power system.

- Comparative studies of the transmission line cost up to the Thai border are carried out as follows:

  Case 1: Allocated transmission line

  Case 2: Independent transmission line

- Transmission line routes for each project and an international linkage line plan are preliminary studied.

(3) Operation Plan of Reservoir and Power Plant

- To guarantee stable supply, hydroelectric power developments in the Se Kong basin will require a holding reservoir. Also, in the plan of operation, it is necessary to place high emphasis on minimizing the unit cost of electric power production.

- Rivers in areas affected by Asian tropical monsoons generally have vast differences in flow volumes from the dry to rainy seasons, and there are also significant differences from one year to the next. In order to take full advantage of the hydropower potentials of a river with wide variances in its flow volumes, it is necessary to fabricate an enough storage capacity of reservoir and thus regulate the natural inflow.

- The hydropower development plan carried out in the pre-feasibility study is referred the recent daily demand load curve of Thailand. Peak power duration of 8 hours is applied in the project scale optimization study.

- In consideration of the effects on the environment, it is necessary to maintain a river flow to the downstream of the dam. In this study, in principle, a condition that two-thirds of monthly mean discharge during the driest month should be maintained at the project downstream throughout a day (24 hours) for maintaining rivers functions is applied power plant operation of each project.

4.6 Selection of Optimum Development Plan

(1) An optimum development study is carried out for the three selected projects in the hydropower potential study. The following basic conditions are applied in the selection of the optimum development plan;

a) **Basic Data**

- 1/10,000 scale and 1/50,000 scale topographic maps are used in the study.
- Estimated monthly discharge of the 10-year period, 1984-94 are used.
- Reservoir evaporation, design flood, reservoir sedimentation are calculated and used as basic data.

b) **Reservoir Operation Rule**

- A reservoir operation rule which regulates a series of reservoir inflow over years (carry-over operation) is applied for reservoir type projects.
- Firm discharge is determined for an effective storage capacity by the mass curve calculation with series of inflow data for a 10-year period.

c) **Power Plant Operation Condition**

- 8 hours is applied as a peak power duration for reservoir type projects.
- As a rule, two-thirds of the river flow during the driest month is conditioned to be maintained as the river retaining flow.

d) **Conditions for Estimation of Construction Cost**

- Costs of the preparatory works, civil works, hydraulic equipment, electro-mechanical equipment, compensation, engineering fees, administration and etc. are estimated, but the transmission line cost is not included in this study.
- Preliminary work quantities and unit prices are applied in this study.

e) **Economic Evaluation Index**

- In the economic evaluation, energy cost per kWh (E/C), which is calculated dividing annual cost (C) by annual energy (E), is used as the primary index.
- Addition to the (E/C), benefit cost ratio (B/C), net benefit (B-C) and unit construction cost per kW are calculated and correctly employed.

(2) Se Kong No.4 Project

a) Selection of Basic Project Layout

- The dam site of the Se Kong No.4 Project selected in the study of the development plan inventory is reviewed and selected, using 1/10,000 scale topographic maps.
- A concrete faced rockfill dam is tentatively selected, taking into consideration the topography and dam scale.
- As for layout of the waterway and powerhouse, the power intake is planned at the right bank with the powerhouse downstream from the dam and connected by a headrace tunnel and penstock.

b) Selection of Optimum Development Plan

The following optimum development plan of the Se Kong No.4 Project is selected after the case study, which is a change in the high water level and reservoir capacity, based on the basic conditions and the layout described above.

Reservoir HWL	290.0 m
Reservoir LWL	275.4 m
Effective storage capacity	1,700 MCM
Firm discharge	143 m^3/s
Minimum outflow	30 m^3/s
Peak power duration	8 hours
Maximum discharge	370 m^3/s
Rated intake water level	285.1 m
Rated tail water level	145.0 m
Rated effective head	137.0 m
Installed capacity	443 MW
Firm peak capacity	406 MW
Annual energy	1,816 GWh

(3) Xe Kaman No.1 Project

a) Selection of Basic Project Layout

- The dam site of the Xe Kaman No.1 Project is selected using 1/10,000 scale topographic maps.
- A concrete gravity dam is selected taking into consideration the topography of dam site and the prevalent geology.
- For the waterway and powerhouse, the power intake is planned at the left bank with the powerhouse being downstream from the dam and connected by a headrace tunnel and penstock.

b) Selection of Optimum Plan

The following optimum development plan of the Xe Kaman No.1 Project is selected after the case study, which is a change in the high water level and reservoir capacity, based on the basic condition and the layout described above.

Reservoir HWL	260.0 m
Reservoir LWL	253.2 m
Effective reservoir capacity	1,270 MCM
Firm discharge	89 m^3/s
Minimum outflow	20 m^3/s
Peak power duration	8 hours
Maximum discharge	228 m^3/s
Rated intake water level	257.7 m
Rated tail water level	125.0 m
Rated effective head	129.9 m
Installed capacity	256 MW
Firm peak capacity	245 MW
Annual energy	1,137 GWh

(3) Xe Namnoy Project

The Xe Namnoy River has many rapids in its midstream section and presents potential for a high head hydropower development plan by using the head of approximately 500m. In

the development plan inventory, the Xe Namnoy Project was proposed as a two stage development plan which incorporates the Midstream Project and Downstream Project.

a) Selection of Basic Project Layout

a-1) Xe Namnoy Midstream Project

- The dam site of the Xe Namnoy Midstream Project selected in the inventory is reviewed with alternative sites, using a 1/10,000 scale map and a more suitable site is selected, taking the topography and geology into consideration.
- A zone type rockfill dam is selected in accord with the topographic conditions at the site.
- The Midstream Project is planned as the Xe Pian Diversion to increase the water from Xe Pian River basin. Two intake dams on the Xe Pian River basin and a diversion channel connecting the intake dams and the Xe Namnoy Midstream reservoir are planned.
- The power intake is selected in the right bank tributary located immediately upstream of the dam site. The powerhouse site is selected at the right bank of the Xe Namnoy River. The intake and powerhouse are connected by a headrace tunnel.

a-2) Xe Namnoy Downstream Project

- The dam site of the Xe Namnoy Downstream Project is selected at downstream of the powerhouse of the Midstream Project which is located immediately downstream at the confluence of the Houay Katak Tok River.
- The dam is planned as a regulating pond with daily flow regulation.
- A concrete gravity dam is selected taking into consideration the topography, dam scale and design flood.

b) Selection of Optimum Development Plan

The following optimum development plans of the Xe Namnoy Project are selected based on the basic conditions and layout described above. For the Xe Namnoy Midstream Project, a comparative study is also carried out with and without the Xe Pian diversion.

	Midstream Project	Downstream Project
Reservoir HWL	765.0 m	270.0 m
Reservoir LWL	747.7 m	266.7 m
Effective reservoir capacity	335 MCM	2.0 MCM
Firm discharge	20.8 m^3/s	24.0 m^3/s
Minimum discharge	1 m^3/s	-
Peak power duration	8 hours	6 hours
Maximum discharge	60 m^3/s	96 m^3/s
Rated intake level	758.6 m	268.4 m
Rated tail water level	270.0 m	180.0 m
Rated effective head	463.0 m	81.0 m
Installed capacity	238 MW	67 MW
Firm peak capacity	230 MW (8 hr)	66 MW (6 hr)
Annual energy	1, 052 GWh	332 GWh

4.7 Preliminary Design of Main Structures

(1) Se Kong No.4 Project

a) The preliminary design of the main structures for the Se Kong No.4 Project is carried out based on the optimum development plan described in 4.6 (2).

b) **Civil Structures**

- Topographically around the dam site, the river is approximately 160m wide with relatively gentle slops on each side. The dam crest is expected to be about 900m long at HWL. Considering this topography, a fill dam is recommended. Minimizing the dam volume should be considered to allow faster construction method. To meet these requirements, a concrete facing rockfill dam (CFRD) is selected.

- A design flood of 16,400 m^3/s at the dam site is estimated from the hydrological analysis. To discharge the flood safely, a chute type spillway is adopted at a location separate from the dam and excavated at the left bank. The spillway structure is 136m wide and provides 8 sets of radial gates. The muck excavated from the spillway will be used as embankment material on the dam.

- The power intake is planned at the right bank. Two lanes of 6.2 m dia. headrace tunnels and two lanes of 5.4m dia. penstock are planned. Each penstock is branched and connected to the four turbines.

- The topography recommends the adoption of a semi-underground type powerhouse.

- It is necessary to construct a new road from the end of the existing road to the dam site as an access road. A 14-km access road which requires both improvement and new construction has been planned.

c) **Generators and Components**

- The output of the Se Kong No.4 power plant is planned to be 443 MW.

- It is conditioned that 30 m^3/s of river retaining flow is considered for the selection of the turbine size.

- Four turbine/generator units being 2 large Francis turbine/generators (125 m^3/s) and 2 small Francis turbine/generators (60 m^3/s) are selected in consideration of the river retaining flow. The river retaining flow is equivalent to a 50% flow for the small units. It should be operate with no cavitation or vibration problems.

- A vertical 3-phase AC synchronous generator is appropriate for direct connection to the turbine.

- Conventional switchgear is planned at the switchyard.

d) **Transmission Line**

- A 80 km long, 230 kV, 1 cct transmission line route from the powerhouse to the B.Houaykong substation is planned.

- Comparative studies of the transmission line up to the Thai border are carried out.

- A 22 KV, 2cct transmission line is also planned for domestic power supply.

e) The salient features of the Se Kong No.4 Project are summarized in 4.12. Outline of the Project is shown in **DWG. 1 and 2.**

(2) Xe Kaman No.1 Project

a) The preliminary design of the main structures for the Xe Kaman No.1 Project is carried out based on the optimum development plan described in 4.6 (3).

b) **Civil Structures**

- Around the dam site, the river is approximately 60m wide with steep sloping banks on either side with gradients of 40 to 45 degrees. The site is more suitable for a concrete dam and no specific problem with geological features are seen from the investigations carried out in this study.

  A 143m high RCC dam (roller compacted concrete dam) with a 440m long crest was finally selected.

- The design flood of 14,300 m^3/s at the dam site is estimated from hydrological analysis. To discharge the flood safely, a center overflow type spillway is adopted on the dam crest. 7 sets of large spillway gates are provided at the dam crest to control the flood.

- The power intake is planned at the left bank. Two lanes of 4.8m dia. headrace tunnels and two lanes of 4.2m dia. penstock are planned.

- In consideration of the topographic conditions, a semi- underground powerhouse is adopted.

- It is necessary to improve and/or construct an access road from Attapu Town to the dam site. It is planned to improve 23 km of the existing road and construct 22 km of new road.

c) **Generators and Components**

- The output of the Xe Kaman No.1 Power Plant is planned to be 256 MW.

- It is conditioned that 20 m^3/s of river retaining flow is considered for selection of turbine size.

- Four turbine/generators units (57 m^3/s) and a Francis turbine are selected in consideration of the river retaining flow. The river retaining flow is equivalent to a 35 % flow.

- A vertical 3-phase AC synchronous generator is appropriate for direct connection to the turbine.

- Conventional switchgear is planned at the switchyard.

d) **Transmission Line**

- A 140 km long, 230 kV, 1cct transmission line from the powerhouse to the B.Houaykong substation is planned.

- Comparative studies of the transmission line up to the Thai border are carried out.

- A 22 kV, 2 cct transmission line from the powerhouse to Attapu Town is planned for domestic power supply.

e) The salient features of the Xe Kaman Project are summarized in 4.12. Outline of the Project is shown in **DWG. 3** and **4**.

(3) Xe Namnoy Project

a) The preliminary design of the main structures for the Xe Namnoy Project including the Downstream Project is carried out based on the optimum development plan described in 4.6 (4).

b) **Civil Structures**

b-1) Xe Namnoy Midstream Project

- Topographically around the dam site, the river is approximately 80m wide with gentle sloping banks on both sides. A dam, 69m high with a 780m long crest is

planned. Taking the consideration topographical/geological conditions into consideration, a zone type rockfill dam is selected.

- As a wide distribution of highly permeable basalt is present in the left bank at the dam site, further investigation will be required to determine the method and area for the dam foundation treatment.

- A design flood of 6,000 m^3/s at the dam site is estimated from hydrological analysis. To discharge the flood safely, a chute type spillway is adopted at a location separate from the dam and excavated at the left bank. The spillway structure is 114m wide and 550m long.

- The power intake is planned at the right bank. A 9,000m long, 4.5m dia. headrace tunnel is planned The headrace tunnel is connected to a surge tank, penstock and the powerhouse.

- A semi-underground powerhouse is planned at the right bank of the Xe Namnoy River.

- An outlet facility with a 1 m^3/s capacity is planned at the dam to discharge the river retaining flow to the downstream area.

- 40 km of new roads leading to the dam site and powerhouse site are planned as access roads.

b-2) Xe Pian Diversion

- To make the Midstream Project a more effective development, it is planned to divert water from the Xe Pian River, which lies next to the Xe Namnoy River, to the Xe Namnoy reservoir.

- Two small intake dams, 17m and 10m in height are planned in the Xe Pian basin.

- A 7,200m long open channel and a 900m long tunnel are planned to connect the Xe Pian River to the Xe Namnoy reservoir.

- 6 km of new road is planned for the Xe Pian Diversion work.

b-3) **Xe Namnoy Downstream Project**

- The dam site is located 4 km downstream from the junction of the Xe Namnoy and Xe Katam rivers.

- The dam site is selected from a 1/10,000 scale map. A 33m high concrete gravity dam with a 350m long crest is planned.

- The design flood of 9,000 m^3/s at the dam site is estimated from hydrological analysis. The flood is discharged by the dam center spillway.

- The power intake is planned at the right bank. A 3,680m long, 5.8m dia. headrace tunnel, surge tank and penstock are planned.

- A semi-underground type powerhouse is planned at the right bank of the Xe Namnoy River.

c) **Generators and Components**

c-1) **Xe Namnoy Midstream Project**

- The output of the Xe Namnoy Midstream power plant is planned at 238 MW.

- River retaining flow by turbine/generator is not considered because the flow is maintained by the dam outlet facility.

- Two turbine/generator units are adopted taking their technical reliability and the economical viewpoint into consideration. Although the Pelton turbine is applicable due to a high head, the Francis turbine is adopted because of a large 30 m^3/s discharge for one unit and there being two units.

- A vertical 3-phase AC synchronous generator is appropriate for direct connection to the turbine.

- Conventional switchgear is adopted at the switchyard.

c-2) Xe Namnoy Downstream Project

- The output of the Xe Namnoy Downstream power plant is planned at 67 MW.

- Two turbine/generator units are adopted. The Francis turbine was adopted in this study. As the effective head is 81m, a Deriaz turbine which provides a broad operation range is also applicable.

- A vertical 3-phase AC synchronous generator is appropriate for direct connection to the turbine.

- Conventional switchgear is adopted at the switchyard.

d) Transmission Line

d-1) Xe Namnoy Midstream Project

- A 10 km long, 230 kV, 1 cct transmission line from the powerhouse to the B.Houaykong Substation is planned.

- Comparative studies of the transmission line up to the Thai border are carried out.

- A 22 kV, 2 cct transmission line is planned for domestic power supply.

d-2) Xe Namnoy Downstream Project

- A 10 km long, 230 kV, 1 cct transmission line from the powerhouse to the Midstream powerhouse is planned.

e) The salient features of the Projects are summarized in 4.12. Outline of the Projects are shown in **DWG. 5, -6, -7 and -8**.

4.8 Construction Plan and Schedule

(1) Construction Plan

a) Conditions Common to All Projects

- The transportation of construction equipment and materials will be made via Thailand and Pakse. Paske, a center in southern Laos, is considered to be the transportation base. National roads will be used from Pakse to as near each site as possible. Some part of the roads, however, may require improvement and barges are required at the river crossing for the transportation of heavy construction equipment and generating equipment. Improvements to the local roads leading to the sites may be required in all sections. New roads leading from the end of the existing roads to the dam sites will be required.

- The construction plan includes preparation works such as that for construction roads and construction facilities.

- The number of monthly working days for the open work is assumed as 20 days, and that for underground work assumed as 25 days.

- Construction power is supplied by diesel power plants as there are no adequate power stations in the vicinity of the project sites.

- The necessary concrete plants including an aggregate plant will be provided.

- Telecommunication facilities such as a radio communication system between the project sites and the base camp will be required.

- Other facilities such as compressed air supply, water supply, a drainage system and a ventilation system will be required.

b) **Construction Plan of the Main Structures for Each Project**

- The construction method and schedule for the diversion tunnel and cofferdam are planned for the river diversion works.

- The construction method and schedule for the dam are planned based on the calculated quantities of the excavation, concrete or embankment.

- The construction method and schedule for the spillway, power intake, headrace tunnel, penstock, powerhouse and etc. are planned.

- The site installation schedules for the hydraulic equipment and electro-mechanical equipment and transmission line are planned.

(2) **Construction Schedule of Each Project**

a) **Se Kong No.4 Project (Fig. 3)**

- The dam construction work is planned as requiring approximately 8 years including for the preparatory works such as that for roads, the river diversion and the spillway.

- The waterway work and the powerhouse work will require 4.5 years. These works will be completed within the dam construction work.

- The hydraulic equipment, the electro-mechanical equipment and the transmission line will be completed within the dam construction work.

- The reservoir impounding will be require 8 months.

- The total construction period, including the running test of the power plant is planned as requiring 8.3 years (99 months).

b) **Xe Kaman No.1 Project (Fig. 4)**

- The dam construction is planned as requiring approximately 5.5 years. This includes the preparation works such as that for the access road and river diversion.

- The waterway work and powerhouse work will be require 3.5 years. These works will be completed within the dam construction work.

- The hydraulic and electro-mechanical equipment will be completed within the dam construction work.

- The transmission line work is planned to require 4 years.

- The reservoir impounding will require 30 months.

- The total construction period, including that for the running test of the power plant is planned as requiring 6.3 years (75 months).

c) Xe Namnoy Projects (Fig. 5)

c-1) Xe Namnoy Midstream Project

- The dam construction work is planned to require 4 years, including the preparation work such that for the access roads, the river diversion and the spillway.

- The waterway, including the headrace tunnel will require 3.8 years. Completion of this work will be delayed by the dam construction.

- The Xe Pian diversion work and the powerhouse will be completed within the dam construction work.

- The hydraulic and electro-mechanical equipment and the transmission line will be completed within the waterway construction work.

- The total construction period, including that for the running test of the power plant is planned as requiring 5 years(59 months).

c-2) Xe Namnoy Downstream Project

- The construction schedule of the Xe Namnoy Downstream Project is planned to be completed within the period of the Xe Namnoy Midstream Project.

- The total construction period, including that for the running test of the power plant is planned as requiring 40 months.

4.9 Construction Cost

(1) Basic Consideration

- Construction cost is estimated for the three projects carried out in the pre-feasibility study.

- The construction cost of the each project is roughly estimated as the stage of the pre-feasibility study.

- The work quantities of the major items are calculated based on the preliminary design.

- The unit prices of the civil work are referred by the prices of similar projects in Laos and neighboring countries.

- The costs of the hydraulic equipment, electro-mechanical equipment and the transmission line are estimated referring by the cost in the neighboring countries.

- The cost estimation for the project is based upon 1994 levels and no cost escalation is considered.

- The interest during construction is not included.

(2) Construction Cost Components

The construction cost of each project consists of the following items. The each item is divided into foreign currency and local currency.

	Foreign currency (%)	Local currency (%)
Preparatory work	0	100
Civil work	85	15
Hydraulic equipment	90	10
Electro-mechanical equipment	90	10
Transmission line	90	10
Compensation cost	0	100
Engineering fee	90	10
Administration cost	0	100
Contingency	90	10

(3) Construction Cost of Each Project

a) Se Kong No.4 Project

1) Base Case (including cost of T/L up to B. Houaykong substation)

Foreign portion	US$ 542,216,000
Local Portion	US$ 101,393,000
Total	US$ 643,609,000

2) Case 1 (Base case + B. Houaykong substation and 500kv T/L up to the Thai border)

Foreign portion	US$ 586,174,000
Local Portion	US$ 107,378,000
Total	US$ 693,552,000

3) Case 2 (Independent 230kv T/L up to the Thai border)

Foreign portion	US$ 583,283,000
Local Portion	US$ 106,986,000
Total	US$ 690,269,000

b) Xe Kaman No.1 Project

1) Base Case (including cost of T/L up to B. Houaykong substation)

Foreign portion	US$ 342,443,000
Local Portion	US$ 61,607,000
Total	US$ 404,050,000

2) Case 1 (Base case + B. Houaykong substation and 500kv T/L up to the Thai border)

Foreign portion	US$ 367,861,000
Local Portion	US$ 65,069,000
Total	US$ 432,930,000

3) Case 2 (Independent 230kv T/L up to the Thai border)

Foreign portion	US$ 375,934,000
Local Portion	US$ 66,168,000
Total	US$ 442,102,000

c) Xe Namnoy Projects

c-1) Xe Namnoy Midstream Project

1) Base Case (including cost of T/L up to B. Houaykong substation)

Foreign portion	US$ 237,578,000
Local Portion	US$ 44,229,000
Total	US$ 281,807,000

2) Case 1 (Base case + B. Houaykong substation and 500kv T/L up to the Thai border)

Foreign portion	US$ 267,880,000
Local Portion	US$ 48,355,000
Total	US$ 316,235,000

3) Case 2 (Independent 230kv T/L up to the Thai border)

Foreign portion	US$ 262,996,000
Local Portion	US$ 47,690,000
Total	US$ 310,686,000

c-2) Xe Namnoy Downstream Project

For Xe Namnoy Downstream Project, it will be developed together with of after Xe Namnoy Midstream Project. Therefore, the construction costs in the Case 1 and 2 are the same as the Base case.

Foreign portion	US$ 129,514,000
Local Portion	US$ 21,903,000
Total	US$ 151,417,000

4.10 Economic Analysis

(1) Methodology of Economic Analysis

Economic analysis is to be carried out by using "with and without" method. "With" means the project and "Without" means an alternative power plan equipped with an equivalent kW and kWh at Sending-out (powerhouse Exit) with those of the project. A combined cycle power plant is selected as an alternative power plant to be compared with the relevant project in respect to evaluating the economic performance of the projects based on the discussion with MIH.

The economic preference of the project is to be valued by using the Economic Internal Rate of Return (EIRR). Common conditions for economic analysis is shown in **Table 3**.

Economic performance of alternative plans of transmission line up to the Thai border are also verified for the Case 1 (allocated transmission line system) and the Case 2 (independent transmission line) because the transmission line in the basic condition is assumed to be constructed up to Ban Houaykong Substation.

(2) Se Kong No.4

a) Basic Conditions

The project consists of the following characteristics.

- Installed Capacity ··············· 443 MW
- Firm Capacity ·················· 406 MW
- Sending-out Energy ·············· 1,797.8 GWh
- Project Cost ···················· 643.61 M.US$

b) Result of Economic Analysis

The EIRR for the basic conditions resulted in 10.81%. Since the EIRR exceeds ARI (10%), the project is deemed to be economically feasible. The EIRR for the Sekong No.4, however, gives the lowest value among the three project sites (four plans).

Transmission Line up to the Thai Border

Case	Construction Cost	EIRR (%)
Base Case	1,585 $/kW (643.6 M.US$)	10.81
Case 1 (Allocated)	1,704 $/kW (691.6 M.US$)	10.01
Case 2 (Independent)	1,700 $/kW (690.3 M.US$)	10.03

(3) Xe Kaman No.1 Project

a) Basic Conditions

The project consists of the following characteristics.

- Installed Capacity ··············· 256 MW
- Firm Capacity ·················· 245 MW
- Sending-out Energy ·············· 1,125.6 GWh
- Project Cost ···················· 404.05 M.US$

b) Result of Economic Analysis

The EIRR for the basic conditions resulted in 11.78%. The Xe Kaman No.1 Project is deemed to be economically feasible.

Transmission Line up to the Thai Border

Case	Construction Cost	EIRR (%)
Base Case	1,649 $/kW (404.1 M.US$)	11.78
Case 1 (Allocated)	1,780 $/kW (436.2 M.US$)	10.74
Case 2 (Independent)	1,805 $/kW (442.1 M.US$)	10.57

(4) Xe Namnoy Project

(4.1) Xe Namnoy (Midstream + Downstream)

a) Basic Conditions

The project consists of the following characteristics.

- Installed Capacity ··············· 305 MW
- Firm Capacity ·················· 296 MW
- Sending-out Energy ············· 1,370.2 GWh
- Project Cost ···················· 433.22 M.US$

b) **Result of Economic Analysis**

The EIRR for the basic conditions resulted in 16.67%. The Xe Namnoy (Mid + Down) Project is expected to be good economic return.

Transmission Line up to the Thai Border

Case	Construction Cost	EIRR (%)
Base Case	1,464 $/kW (433.2 M.US$)	16.67
Case 1 (Allocated)	1,575 $/kW (466.3 M.US$)	14.89
Case 2 (Independent)	1,561 $/kW (462.1 M.US$)	15.10

(4.2) Xe Namnoy (Midstream)

a) **Basic Conditions**

The project consists of the following characteristics.

- Installed Capacity ··············· 238 MW
- Firm Capacity ·················· 230 MW
- Sending-out Energy ············· 1,041.5 GWh
- Project Cost ···················· 281.81 M.US$

b) **Result of Economic Analysis**

The EIRR for the basic conditions resulted in 21.83%. The EIRR gives the highest value among the three project sites (four plans). The project can be expected excellent return.

Transmission Line up to the Thai Border

Case	Construction Cost	EIRR (%)
Base Case	1,225 $/kW (281.8 M.US$)	21.83
Case 1 (Allocated)	1,369 $/kW (314.9 M.US$)	18.18
Case 2 (Independent)	1,351 $/kW (310.7 M.US$)	18.58

4.11 Financial Analysis

(1) Methodology of Financial Analysis and Conditions

a) Methodology

In this chapter, Debt Service Coverage Ratio (DSC) is used as an index for judging financial soundness of the project. Furthermore, Financial Internal Rate of Return (FIRR) is also calculated to evaluate the rate of profit return.
According to IBRD's guide line, more or equal to 1.5 is desirable as DSC value.

b) Conditions

i) Materializing Method of the Project

Two (2) materializing methods for the projects are assumed as follows.

Materialized by the Lao Government (Case-A)

- The Lao Government (EDL) will materialize the project by their own finance and by official loan such as ADB's loan, IBRD's loan and OECF's loan.
- Common conditions for financial analysis in Case-A is shown in **Table 4**.

Materialized by BOT (Build-Operate-Transfer) (Case-B)

- The Lao Government will establish the subsidiary (Lao PDR)
- Private company will joint the project.
- Both parties will establish the new electricity company.
- Common conditions for financial analysis in Case-B is shown in **Table 5**.

ii) **Treatment of Transmission Line**

Other additional two (2) cases concerning the transmission line up to the Thai border are also incorporated in this chapter. Case 1 and Case 2 are called "allocated transmission line system" and "independent transmission line" respectively.

(2) **Se Kong No.4 Project**

a) **Basic Conditions**

The project consists of following characteristics.

- Installed Capacity ··············· 443 MW
- Firm Capacity ·················· 406 MW
- Salable Energy ·················· 1,616.2 GWh
- Construction Cost ··············· 643.61 M.US$

b) **Results of Financial Analysis**

Case-A

The results are shown below.

Case	DSC	FIRR	Levelized Financial Generation Cost
Base	1.61	24.55%	56.93 $/MWh
Case 1	1.46	22.75%	61.33 $/MWh
Case 2	1.47	22.86%	61.04 $/MWh

DSC and FIRR almost satisfy the feasible conditions, say 1.5 point for DSC and 6.0% for FIRR. The project is expected good return.

Case-B

The results are shown below.

Case	DSC	FIRR	Levelized Financial Generation Cost	FIRR for BOT Period (25 years)
Base	0.85	-9.85%	78.15 $/MWh	8.03%
Case 1	0.78	-19.25%	83.79 $/MWh	6.88%
Case 2	0.78	-18.26%	83.42 $/MWh	6.96%

DSC and FIRR indicate that the project to be proceeded by BOT method cannot expect financially sound and good return over the repayment period. The conditions proposed by MIH does not provide project feasibility by BOT method.

(3) **Xe Kaman No.1 Project**

a) **Basic Conditions of Xe Kaman No.1**

The project consists of following characteristics.

- Installed Capacity ··············· 256 MW
- Firm Capacity ·················· 245 MW
- Salable Energy·················· 1,011.9 GWh
- Construction Cost ··············· 404.05 M.US$

b) **Results of Financial Analysis**

Case-A

The results are shown below.

Case	DSC	FIRR	Levelized Financial Generation Cost
Base	1.55	27.49%	54.95 $/MWh
Case 1	1.42	25.37%	58.85 $/MWh
Case 2	1.38	24.73%	60.10 $/MWh

Even though FIRR becomes better than that of Se Kong No.1, DSC becomes slightly lower than that of Se Kong No.4. The project can be expected good return for the base case.

Case-B

The results are shown below.

Case	DSC	FIRR	Levelized Financial Generation Cost	FIRR for BOT Period (25 years)
Base	0.83	-13.68%	74.67 $/MWh	7.97%
Case 1	0.76	-31.25%	79.61 $/MWh	6.83%
Case 2	0.74	N/A	81.19 $/MWh	6.48%

The conditions proposed by MIH does not provide project feasibility by BOT method.

(4) Xe Namnoy Project

(4.1) Xe Namnoy (Midstream + Downstream)

a) Basic Conditions of Xe Namnoy (Midstream + Downstream)

The project consists of following characteristics.

- Installed Capacity ··············· 305 MW
- Firm Capacity ·················· 296 MW
- Salable Energy·················· 1,231.8 GWh
- Construction Cost ··············· 433.22 M.US$

b) **Results of Financial Analysis**

Case-A

The results are shown below.

Case	DSC	FIRR	Levelized Financial Generation Cost
Base	1.75	37.28%	46.51 $/MWh
Case 1	1.59	34.12%	50.19 $/MWh
Case 2	1.61	34.62%	49.60 $/MWh

DSC and FIRR indicate that the project will be run financially sound well.

Case-B

The results are shown below.

Case	DSC	FIRR	Levelized Financial Generation Cost	FIRR for BOT Period (25 years)
Base	0.93	-6.58%	63.06 $/MWh	10.33%
Case 1	0.85	-13.31%	67.64 $/MWh	8.84%
Case 2	0.86	-12.06%	66.90 $/MWh	9.07%

Although DSC and FIRR have slightly improved in comparison with those of the preceding two (2) project, the both indicators are still less than feasible conditions. FIRR for the BOT period has just cleared 10% for the base case. The project to be implemented by BOT method is deemed to be difficult from the financial viewpoint, especially from the short term view point.

(4.2) Xe Namnoy (Midstream)

a) **Basic Conditions of Xe Namnoy (Mid Stream)**

The project consists of following characteristics.

- Installed Capacity ··············· 238 MW
- Firm Capacity ················· 230 MW
- Salable Energy················· 936.3 GWh

- Construction Cost ··············· 281.81 M.US$

b) **Results of Financial Analysis**

Case-A

The results are shown below.

Case	DSC	FIRR	Levelized Financial Generation Cost
Base	2.12	43.45%	39.86 $/MWh
Case 1	1.84	38.75%	44.71 $/MWh
Case 2	1.88	39.46%	43.92 $/MWh

DSC and FIRR indicate the highest values among the three (3) project sites (four plans). The project is expected excellent return.

Case-B

The results are shown below.

Case	DSC	FIRR	Levelized Financial Generation Cost	FIRR for BOT Period (25 years)
Base	1.11	2.76%	54.80 $/MWh	13.60%
Case 1	0.97	-3.73%	60.83 $/MWh	11.15%
Case 2	0.99	-2.62%	59.86 $/MWh	11.51%

Although DSC and FIRR indicate the highest performance among the all, the both indicators are still less than feasible conditions. It seems to be difficult to conclude whether the BOT method is feasible or not under the proposed conditions by MIH.

4.12 Salient Features of Projects

Of the results on the pre-feasibility study, salient futures of the three projects are summarized as follows.

(1) Se Kong No.4 Project (DWG.1 and 2)

Reservoir	
Catchment area	5,400 km^2
Annual inflow	5,721 million m^3
High water level	EL 290.00 m
Low water level	EL 275.40 m
Available depth	14.60 m
Effective capacity	1,700 million m^3
Reservoir area	130 km^2
Dam	
Type	Concrete faced rockfill dam
Dam height	164 m
Crest length	910 m
Dam volume	14,400,000 m^3
Spillway	
Type	Chute type
Width, length, gate	136 m, 680 m, 8 sets
Maximum design flood	16,400 m^3/s
Headrace tunnel	
Diameter	6.20 m
Length	315 m / 365 m
Number of tunnel	2 lanes
Penstock	
Diameter	5.40 m
Length	442 m
Number of penstock	2 lanes, 4 branches
Powerhouse	
Type	Semi-underground type
Width, length	20 m, 80 m
Number of unit	Large size 2 units
	Small size 2 units

Turbine	Francis type
	Large size 150 MW
	Small size 71.5 MW
Generator	3 phase, alternative current, synchronous
Power generation plan	
Peak power duration	8 hours
Maximum discharge	370 m^3/s
Effective head	137.00 m
Installed capacity	443 MW
Firm peak capacity (8 hours)	406 MW
Annual energy	1,816 GWh
Plant factor	47 %
Access road	
New construction	14 km
Improvement	14 km
Transmission line (powerhouse-B.Houaykong substation)	
Capacity	230 KV, 1 cct
Length	80 km

(2) Xe Kaman No.1 Project (DWG.3 and 4)

Reservoir	
Catchment area	3,800 km^2
Annual inflow	4,245 million m^3
High water level	EL 260.00 m
Low water level	EL 253.20 m
Available depth	6.80 m
Effective capacity	1,270 million m^3
Reservoir area	193 km^2
Dam	
Type	Concrete gravity dam
Dam height	143 m
Crest length	440 m
Dam volume	1,670,000 m^3
Spillway	
Type	Dam overflow type
Width, length	122 m, 203 m
Maximum design flood	14,300 m^3/s
Headrace tunnel	
Diameter	4.80 m
Length	315 m/322 m
Number of tunnel	2 lanes
Penstock	
Diameter	4.80 m
Length	317 m
Number of penstock	2 lanes, 4 branches
Powerhouse	
Type	Semi-underground type
Width, length	18 m, 64 m
Number of unit	4 units
Turbine	Francis type, 64 MW
Generator	3 phase, alternative current, synchronous

Power generation plan	
Peak power duration	8 hours
Maximum discharge	228 m^3/s
Effective head	129.90 m
Installed capacity	256 MW
Firm peak capacity (8 hours)	245 MW
Annual energy	1,137 GWh
Plant factor	51%
Access road	
New construction	22 km
Improvement	23 km
Transmission line(powerhouse-B.Houaykong)	
Capacity	230 kV, 1 cct
Length	140 km

(3) Xe Namnoy Project (DWG. 5, 6, 7, 8)

a) Xe Namnoy Midstream with Xe Pian Diversion

Reservoir	
Catchment area	
Xe Namnoy	531 km^2
Xe Pian	223 km^2
Annual inflow	1,042 million m^3
High water level	EL 765.00 m
Low water level	El 747.70 m
Available depth	17.30 m
Effective capacity	250 million m^3
Reservoir area	21.8 km^2
Dam	
Type	Rockfill dam
Dam height	69 m
Crest length	780 m
Dam volume	1,253,000 m^3
Spillway	
Type	Chute type
Width, Length	114 m, 550 m
Maximum design flood	6,000 m^3/s
Headrace tunnel	
Diameter	4.5 m
Length	9,010 m
Number of tunnel	1 lane
Penstock	
Diameter	4.0 ~ 3.5 m
Length	780 m
Number of penstock	1 lane
Powerhouse	
Type	Semi-underground type
Width, length	18 m, 50 m
Number of unit	2 units
Turbine	Francis 119 MW
Generator	3 phase, alternative current, synchronous

Power generation

Peak power duration	8 hours	
Maximum discharge	60 m^3/s	
Effective head	463 m	
Installed capacity	238 MW	
Firm peak capacity (8 hours)	230 MW	
Annual energy	1,052 Gwh	
Plant factor	50%	

Access road

New construction	26 km
Improvement	34 km

Transmission line(powerhouse-B.Houaykong)

Capacity	230 kV, 1 cct
Length	10 km

Xe Pian diversion scheme

Intake dam

Type	Concrete gravity dam
Dam height	10 m

Diversion waterway

Type	Open Channel	Tunnel
Width	5.0 m	4.0 m
Length	7.2 km	900 m

Maximum diversion capacity 20 m^3/s

b) Xe Namnoy Downstream Project

Reservoir

Catchment area	1,475 km^2
Direct	1,252 km^2
Indirect	223 km^2
Annual inflow	2,109 million m^3
High water level	EL 270.00 m
Low water level	EL 266.7 m
Effective capacity	2 million m^3 (daily regulating)
Reservoir area	0.7 km^2

Dam	
Type	Concrete gravity dam
Dam height	33 m
Crest length	350 m
Dam volume	133,200 m^3
Spillway	
Type	Dam overflow type
Width	158 m
Maximum design flood	9,000 m^3/s
Headrace tunnel	
Diameter	5.80 m
Length	3,670 m
Number of tunnel	1 lane
Penstock	
Diameter	5.60 ~ 5.40 m
Length	450 m
Number of penstock	1 lane
Powerhouse	
Type	Semi-underground type
Width, length	18.00 m, 50.00 m
Number of unit	2 units
Turbine	Francis 33.5 MW
Generator	3 phase alternative current, synchronous
Power generation	
Peak power generation	6 hours
Maximum discharge	96 m^3/s
Effective head	81 m
Installed capacity	67 MW
Firm peak capacity (6 hours)	66 MW
Annual energy	332 GWh
Plant factor	57%
Access road	
New construction	23 km
Transmission line (powerhouse-B.Houaykong substation)	
Capacity	230 kV, 1 cct
Length	10 km

Summary of Plans proposed in Hydropower Potential Study and Pre-feasibility Study

Description	Potential Study		Pre-feasibility Study	
1. Basic conditions				
Scale of topographic maps	1/50,000		1/10,000	
Discharge data period	5 years		10 years	
Reservoir operation	Annual operation		Carry-over operation	
Peak power duration	12 hours		8 hours	
2. Proposed Plans				
Se Kong No.4				
Reservoir HWL	300	m	290	m
Effective Storage Capacity	1,287	MCM	1,700	MCM
Regulated Firm Discharge	144	m^3/s	143	m^3/s
Maximum Discharge	288	m^3/s	370	m^3/s
Rated Effective Head	140	m	137.0	m
Installed Capacity	346	MW	443	MW
Plant Factor	63	%	47	%
Xe Kaman No. 1				
Reservoir HWL	280	m	260	m
Effective Storage Capacity	833	MCM	1,270	MCM
Regulated Firm Discharge	93	m^3/s	89	m^3/s
Maximum Discharge	186	m^3/s	228	m^3/s
Rated Effective Head	159	m	129.9	m
Installed Capacity	255	MW	256	MW
Plant Factor	61	%	51	%
Xe Namnoy Midstream				
Reservoir HWL	760	m	765	m
Effective Storage Capacity	255	MCM	250	MCM
Regulated Firm Discharge	25	m^3/s	20.8	m^3/s
Maximum Discharge	50	m^3/s	60	m^3/s
Rated Effective Head	446	m	463.0	m
Installed Capacity	192	MW	238	MW
Plant Factor	69	%	50	%
Xe Namnoy Downstream				
Reservoir HWL	280	m	270	m
Firm Discharge	33.4	m^3/s	24.0	m^3/s
Maximum Discharge	100	m^3/s	96.0	m^3/s
Rated Effective Head	74	m	81.0	m
Installed Capacity	63	MW	67	MW
Plant Factor	61	%	57	%

Notes: 1) Location of projects in the potential study is shown in Fig.2.
2) Location of projects in the pre-feasibility study is shown in the beginning of the Report.

Table 1 Summary of Development Plan Inventory of Se Kong Basin

No.	Project	River	Catchment Area (km^2)	HWL (m)	TWL (m)	Rated Net Head (m)	Maximum Discharge (m^3/s)	Installed Capacity (MW)	Firm Capacity (MW)	Annual Energy (GWH)	Plant Factor (%)	Construction Cost (M$)	B-C (M$)	B/C (-)	Unit Energy Cost (US¢/KWH)	Const. Cost/KW (US$/KW)
1	Se Kong No. 3	Se Kong	9710	160	95	59	588	298	265	1603	61	691.1	5.5	1.07	4.74	2315
2	Se Kong No. 4	Se Kong	5400	300	160	140	288	346	331	1925	63	754.9	17.6	1.21	4.31	2182
3	Se Kong No. 5	Se Kong	2600	500	300	186	158	253	225	1353	61	574.6	5.7	1.09	4.67	2275
4	Xe Kaman No. 1	Xe Kaman	3800	280	118	159	186	255	250	1354	61	520.7	29.6	1.52	4.23	2045
5	Xe Kaman No. 2	Xe Kaman	1770	380	280	86	72	53	38	302	64	308.3	-21.3	0.37	11.20	5768
6	[1] Xe Kaman No. 3	Xe Kaman	665	790	380	385	24	79	79	441	63	118.5	12.1	1.93	2.95	1491
7	Xe Kaman No. 4	Xe Kaman	381	1080	380	644	21	115	113	597	59	450.4	-16.0	0.68	8.30	3908
8	Xe Namnoy	Xe Namnoy	[3]1273	-	-	520	-	255	[2]228	1499	67	429.6	24.5	1.52	3.15	1685
8-1	Midstream	Xe Namnoy/Xe Pian	[3] 749	760	280	446	50	192	186	1161	69	313.6	23.2	1.67	2.97	1637
8-2	[1] Downstream	Xe Namnoy	[3]1273	280	200	74	100	63	63	338	61	116.0	8.9	1.70	3.78	1828
9	Houay Katak Tok	Xe Namnoy (Houay Katak Tok)	199	880	100	730	16.7	105	104	550	60	137.6	15.7	2.03	2.75	1312
10	Nam Kong No. 1	Nam Kong	1250	340	160	163	75	105	91	518	56	233.0	1.9	1.07	4.95	2223
11	Nam Kong No. 2	Nam Kong	850	460	340	108	32	30	27	184	71	124.9	-5.1	0.63	7.48	4209
12	Nam Kong No. 3	Nam Kong	600	540	460	74	32	21	19	112	62	100.5	-5.2	0.53	9.87	4859
13	Xe Xou	Xe Xou	1480	180	120	55	73	35	33	184	60	142.1	-5.8	0.63	8.48	4081
14	Dak E Meule	Nam Emun	446	-	-	575	-	138	136	660	55	393.2	-3.8	0.91	6.60	2844
14-1	Upstream	Nam Emun	230	960	760	170	16	23	22	115	56	122.6	-6.9	0.49	11.80	5256
14-2	Midstream	Nam Emun	446	770	380	405	33	115	114	545	54	270.6	3.1	1.10	5.50	2354
15	Houay Lamphan Gnai	Houay Lamphan Gnai	195	840	160	629	16	87	84	500	66	182.1	5.6	1.28	4.00	2103
	Total / Average		[3]16460	-	-	-	-	2175	[2]2023	11782	62	5161.5	-	-	4.82	2373

1) Planned as daily regulation type with 6 hours peak power duration. (All the others are planned applying 12 hours peak power duration.)
2) Figures obtained by adjusting firm capacities of daily regulation projects to the figures for 12 hours peak power duration.
3) Includes 223 km^2 of the Xe Pian diversion scheme.

Table 2 Profile of Candidate Projects

Description	Unit	Se Kong No. 4	Xe Kaman No. 1	Xe Kaman No. 3	Xe Namnoy			Houay Katak Tok
					Midstream	Dwnstream	Total	
Hydrology								
Catchment Area	km^2	5,400	3,800	655	(529+220) 749	1252+220-199) 1,273	-	199
Annual Inflow Volume	$10^6 m^3$	6,444	4,177	758	1,151	2,209	-	299
Average Inflow	m^3/s	204	132	24	36	70	-	9
Project Structure								
Dam Height × Crest Length	m	155 × 880	170 × 410	30 × 150	50 × 920	30 × 230	-	65 × 260
Tunnel Length	m	–	–	5,000	9,350	3,500	12,850	6,000
Open Channel Length	m	–	–	–	1,400	–	1,400	–
Penstock Length	m	870	580	950	1,390	220	1,610	900
Reservoir								
High Water Level	m	300	280	790	760	280	-	880
Low Water Level	m	291	276	788	741	278	-	869
Gross Storage Capacity	$10^6 m^3$	7,776	16,208	1.5	323	16	-	316
Effective Storage Capacity	$10^6 m^3$	1,287	833	Daily Regulation	255	Daily Regulation	-	142
Regulation Ratio	%	20	20	–	22	–	-	47
Regulated Firm Flow	m^3/s	144	93	6.0	25.0	33.4	-	8.4
Power Generation Plan								
Tail Water Level	m	160	118	380	280	200	-	100
Maximum Gross Head	m	145	162	410	480	80	560	780
Net Head	m	140	159	385	446	74	520	730
Maximum Discharge	m^3/s	288	186	24	50	100	-	16.7
Installed Capacity	MW	346	255	79	192	63	255	105
Peak Power Duration	Hours	12	12	6	12	6	12	12
Firm Peak Capacity[2)]	MW	331	250	79	186	63 (42)[3)]	228	104
Annual Energy	GWH	1,925	1,354	441	1,161	338	1,499	550
Plant Factor	%	63	61	63	69	61	67	60
Project Economy								
Construction Cost[1)]	10^6\$	754.9	520.7	118.5	313.6	116.0	429.6	137.6
Net Benefit (B-C)[2)]	10^6\$	17.6	29.6	12.1	23.2	8.9 (1.3)[3)]	24.5	15.7
Benefit Cost Ratio (B/C)[2)]	–	1.21	1.52	1.93	1.67	1.70 (1.11)[3)]	1.52	2.03
Energy Cost	¢/kWh	4.31	4.23	2.95	2.97	3.78	3.15	2.75
Construction Cost per kW	\$/kW	2,182	2,045	1,491	1,637	1,828	1,685	1,312

1) Including transmission line cost and excluding interest during construction cost.
2) Calculated applying the peak power duration of each project.
3) Figures evaluated with the condition of 12 hours peak power duration.

Table 3 Common Conditions for Economic Analysis

Items	The Project	The Alternative	Remarks
Power Source	Hydro Power	Combined Cycle	according to the discussion with MIH.
Construction Cost	up to the projects	744.17 US$/kW *	* as of 1994 Price Level
Construction Period	up to the projects	3 years * 25, 32.5, 42.5 %	* F/C : L/C = 75 : 25
Planned Maintenance Days	6 days/year	63 days/year	
Forced Outage Rate	1.0 %	9.0 %	
Plant Available Factor	97.4 %	75.3 %	PA=(1-PO/365)(1-FO)
Station Use	1.0 %	5.0 %	
T/D Loss	10 %	10 %	
O/M Cost	1.5 %	2.5 %	of the Const. Cost
Fuel Cost	0.0 $/MWh	18.43 $/MWh	LNG , 1 US$ =26 Baht
Fuel Escalation	-	2.0 % per annum	assumed 3% increase in real term for crude oil
Life Time	50 years *	25 years	* according to the discussion with MIH

Table 4 Common Conditions for Financial Analysis
(Case-A: Materialized by the Lao Government)

Items	Value and Conditions
Financing Proportion a/	Own Finance 10 % Official Loan 80 % Bilateral Loan 10 %
Loan Conditions a/	6.0 % for interest rate and 25 years repayment period
Graced Period	During Construction
Project Life Time	50 years
Initial Fixed Asset a/	Construction Cost after escalation + IDC
Depreciation Method	Constant Value Method
Income Tax	20 %
Export/Domestic a/	100/0 (All salable energy will be allocate for export provisionally.)
Export Tariff in year 0 b/	52.41 US$/MWh (39.00x(1+0.03)^10=52.41)
Export Tariff Escalation	1.0 % per year
Domestic Tariff in Year 0 c/	34.33 US$/MWh (28.17 x (1+0.02)^10=34.33)
Domestic Tariff Escalation a/	1.0 % per year
Increase of Domestic Consumption a/	0.0 % per year
Price Escalation	F/C: 2.8 % (IBRD's projection as of 1990) L/C: 4.5 % (Thailand 1990-1993 average)

Note: a/ JICA's assumption or estimate

b/ According to Nam Thuen1-2, tariff escalation up to 3 %/year is accepted by EGAT.

c/ JICA's estimate 20 kip/kWh at 1994 (1 US$ = 710 kip) equals to 28.17 US$/MWh.

Table 5 Common Conditions for Financial Analysis
(Case-B: Materialized by BOT)

Items	Value and Conditions
Share of Equity	Lao PDR : Private = 25:75
Debt/Equity	70/30
Royalty	10 % of Sales Revenue Payment will be made from the first year of the commercial operation.
Interest Rate	10 % for IDC and onwards
Graced Period	During Construction
Repayment Period	10 years
Project Life Time	50 years
Initial Fixed Asset a/	Construction Cost after escalation + IDC
Depreciation Method	Constant Value Method
Income Tax	20 %
Export/Domestic a/	100/0 (All salable energy will be allocate for export provisionally.)
Export Tariff in year 0 b/	52.41 US$/MWh (39.00x(1+0.03)^10=52.41)
Export Tariff Escalation	1.0 % per year
Domestic Tariff in Year 0 c/	34.33 US$/MWh (28.17 x (1+0.02)^10=34.33)
Domestic Tariff Escalation a/	1.0 % per year
Increase of Domestic Consumption a/	0.0 % per year
Price Escalation	F/C: 2.8 % (IBRD's projection as of 1990) L/C: 4.5 % (Thailand 1990-1993 average)

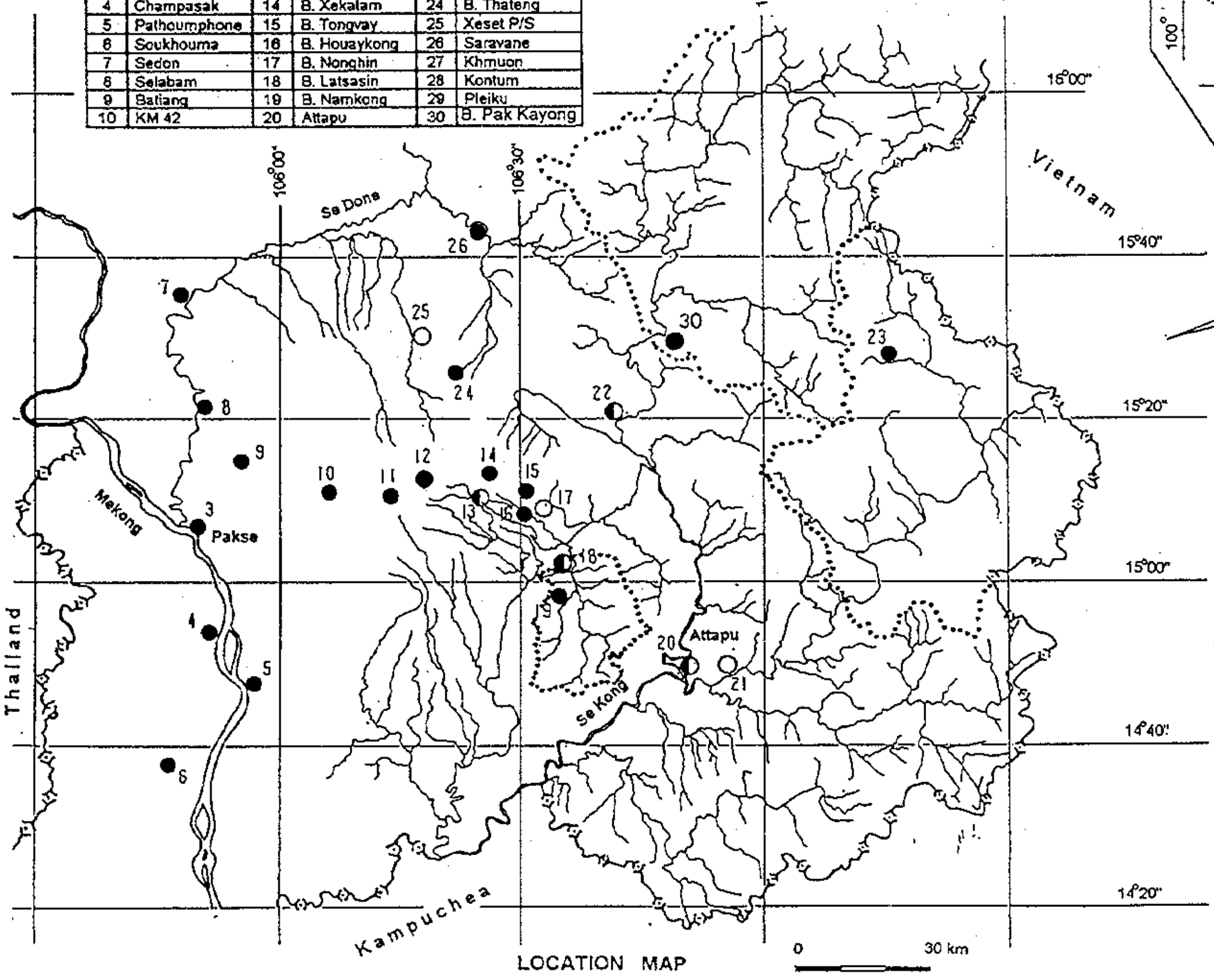
Note: a/ JICA's assumption or estimate

b/ According to Nam Thuen1-2, tariff escalation up to 3 %/year is accepted by EGAT.

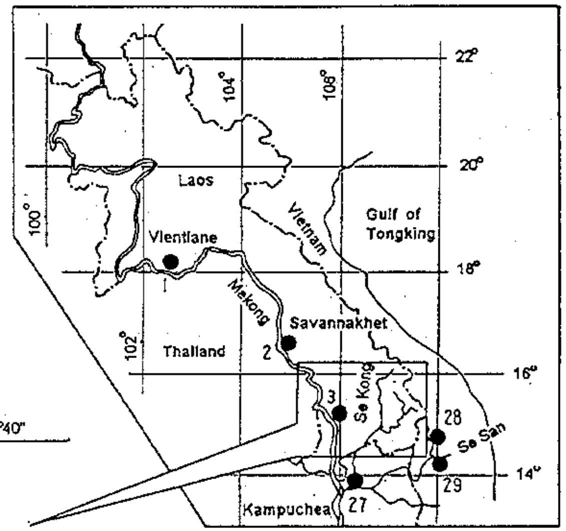
c/ JICA's estimate 20 kip/kWh at 1994 (1 US$ = 710 kip) equals to 28.17 US$/MWh.

Hydrological and Meteorological Stations

No.	Station	No.	Station	No.	Station
1	Vientiane	11	Paksong	21	B. Fangdeng
2	Savannakhet	12	Nonghin	22	Sekong Town
3	Pakse	13	Nikhom 34	23	B. Dakchung
4	Champasak	14	B. Xekatam	24	B. Thateng
5	Pathoumphone	15	B. Tongvay	25	Xeset P/S
6	Soukhouma	16	B. Houaykong	26	Saravane
7	Sedon	17	B. Nonghin	27	Khmuon
8	Selabam	18	B. Latsasin	28	Kontum
9	Batiang	19	B. Namkong	29	Pleiku
10	KM 42	20	Attapu	30	B. Pak Kayong



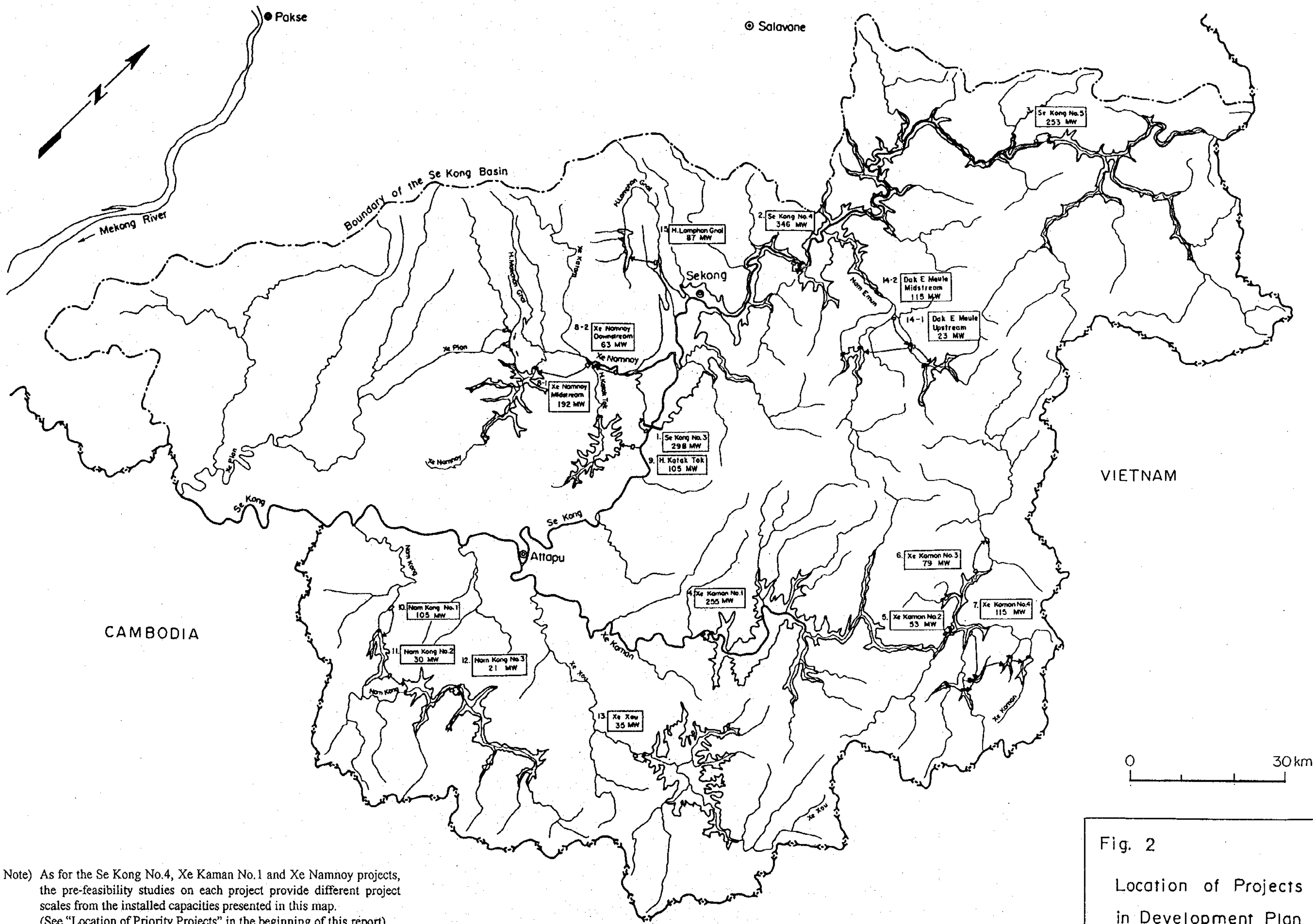
LOCATION MAP



KEY MAP

● : Rainfall Station
○ : Water Level Gauging Station
◐ : Rainfall and Water Level Gauging Station
International Boundary
Catchment Boundary

Fig. 1 Location Map of Hydrological and Meteorological Stations



Note) As for the Se Kong No.4, Xe Kaman No.1 and Xe Namnoy projects, the pre-feasibility studies on each project provide different project scales from the installed capacities presented in this map. (See "Location of Priority Projects" in the beginning of this report)

Fig. 2

Location of Projects in Development Plan Inventory

Fig. 3 Construction Schedule of Se Kong No.4 Project

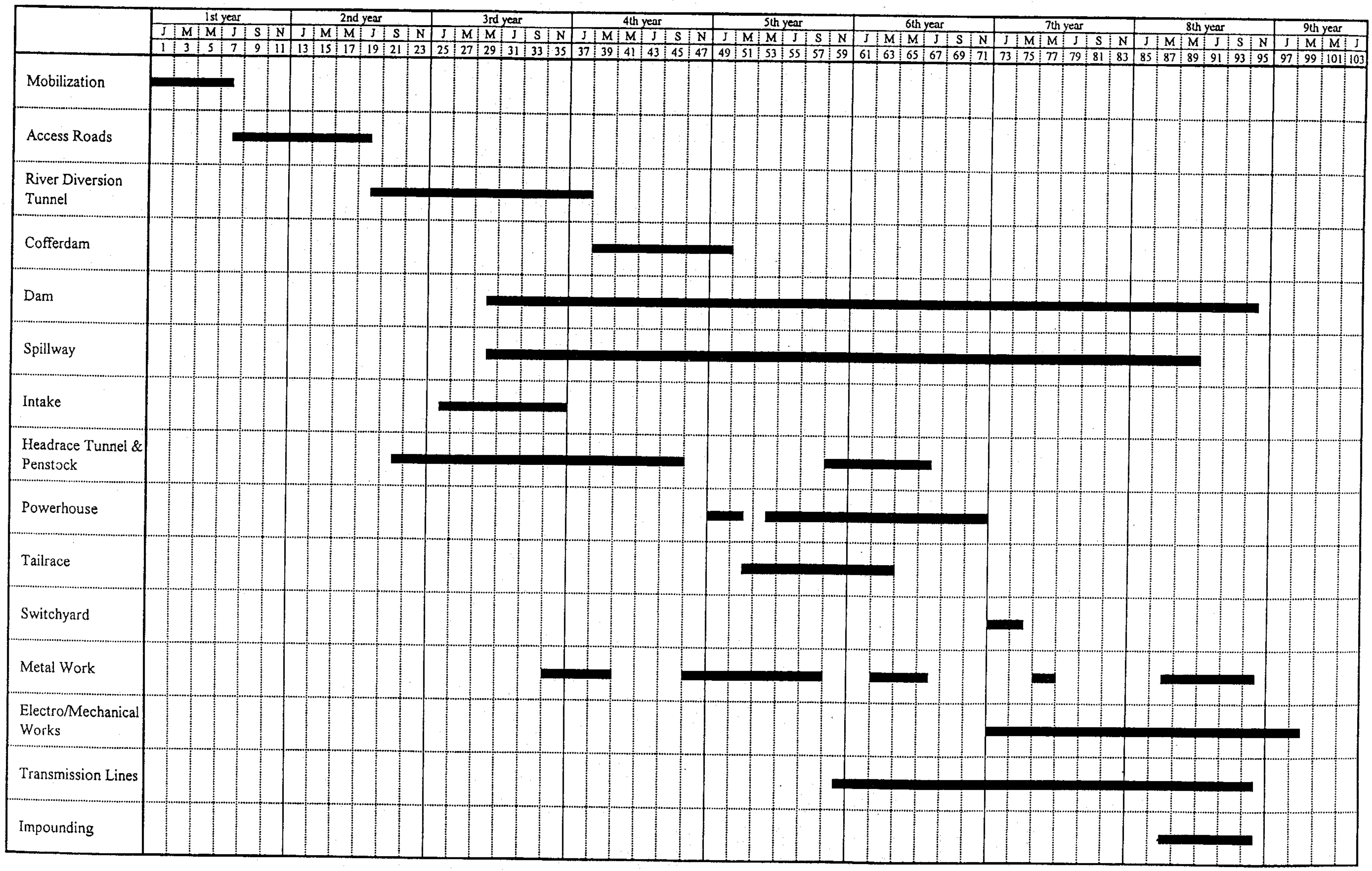


Fig. 4 Construction Schedule of Xe Kaman No.1 Project