8.3 Core Drilling Work

8.3.1 General

Core drilling was executed at 3 project sites selected in the hydro power potential study stage. This work was entrusted Lao Company which is advised by a core drilling specialist of JICA Team.

Work Period and Contractor

Work period	:	Commencement	Nov. 21, 1993
	:	Completion	Mar. 15, 1994
Contractor	:	Hydropower Engineering Consultants (HEC) in association with ECAS-Engineering Consultants, Vietiane, Lao P.D.R.	

8.3.2 Location and Quantity of Work

The quantity of works is 12 holes totaling 900 m in length. **(Table 8.3-1)**.

Location of drillhole is shown in **Fig. 8.3-1** to **8.3-3**.

JICA Team visited the sites and decided the detailed location of drillholes in consideration of topography and geology. Steep slopes up to 60° at Xe Kaman dam site provide real difficulties in transporting the drilling machine to the decided point.

The location of drillhole were surveyed from GPS points for topographic mapping and observation points of seismic prospecting line which had been set along the dam axis.

8.3.3 Drilling Works

Core drilling, Lugeon test, measurement of water level in drillhole were executed.

Core drilling was done by rotary drilling machines in order to obtain cores continuously down to the specified bottom of drillhole. The equipments used are shown in **Table 8.3-3**. One of the two drilling machines is Koken KT-100, which is provided by JICA for the Feasibility Study of Xe Katam Small-scale Hydropower Development Project, required supply of spare parts but still available.

Obtained cores are not disturbed in general and provide enough geological information except some sections near the bottom of strongly weathered zone and cracky portion of basalt.

Lugeon tests were executed during drilling work. The length of test section was 5 m long in principal, but it was modified in some sections owing to the condition in drillhole. Injection pressure did not reach 10 kgf/cm² in many sections because of shortage of packers.

The water level of drillhole was measured during drilling.

The drilled cores were arranged in core boxes which contains cores totaling 5 m, and stored in Pakse MIH Office. Some cores were used for laboratory tests such as unconfined compression test.

The records of core drilling and appurtenant works were daily report, log of drillhole, core photograph, result of Lugeon test, result of water level measurement etc. These records were submitted to JICA Team by HEC as Work Report.

Table 8.3-1 List of Core Drilling

Project	Drillhole Number	Length (m)	Coordinates	
			N	E
Se Kong No. 4	SK-1	100	1,715,122	692,132
	SK-2	60	1,715,512	692,112
	SK-3	100	1,715,808	692,102
Xe Kaman No. 1	XK-1	100	1,654,608	732,180
	XK-2	60	1,654,826	732,279
	XK-3	100	1,654,937	732,330
Xe Namnoy Midstream	XN-1	80	1,663,482	673,317
	XN-2	40	1,663,766	673,584
	XN-3	60	1,663,921	673,730
	XN-4	80	1,664,760	672,460
	XN-5	60	1,664,870	672,760
	XN-6	60	1,664,840	672,980
Total	12 holes	900		

Table 8.3-2 List of Equipment

Name	Specification	Quantity	Remarks
Drilling Machine	Koken KT-100	1	with Engine
Drilling Machine	D-900 (Sweden)	1	
Drilling Pump	Koken Mg-5	1	for KT-100
Mono Pump	Australia	2	
Water Supply Pump	Robin MS-410	1	
Derrick	Tripode of ø4 in pip	2 set	H = 5 m
Drill Rod	ø40.5 mm × 3 m	40	for KT-100
Drill Rod	ø40.5 mm × 1.5 m	4	
Drill Rod	NW × 3 m	40	for D-900
Casing Tube	NX × 3 m	4	for KT-100
Casing Tube	NX × 1.5 m	2	
Air Packer	for ø66 mm hole	1 set	
Water Level Detector	100 m reach	2	

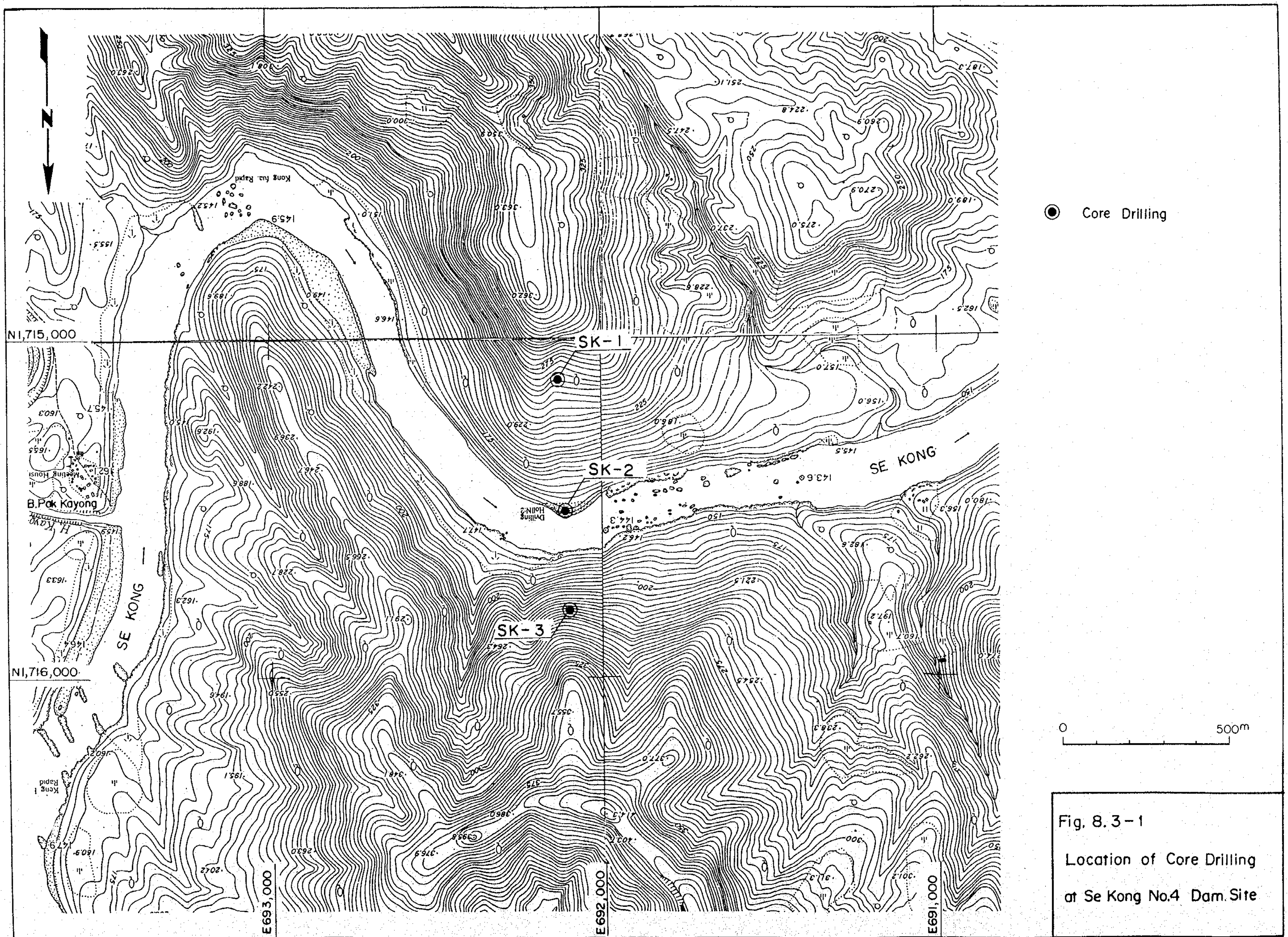

Fig. 8.3-1

Location of Core Drilling

at Se Kong No.4 Dam Site

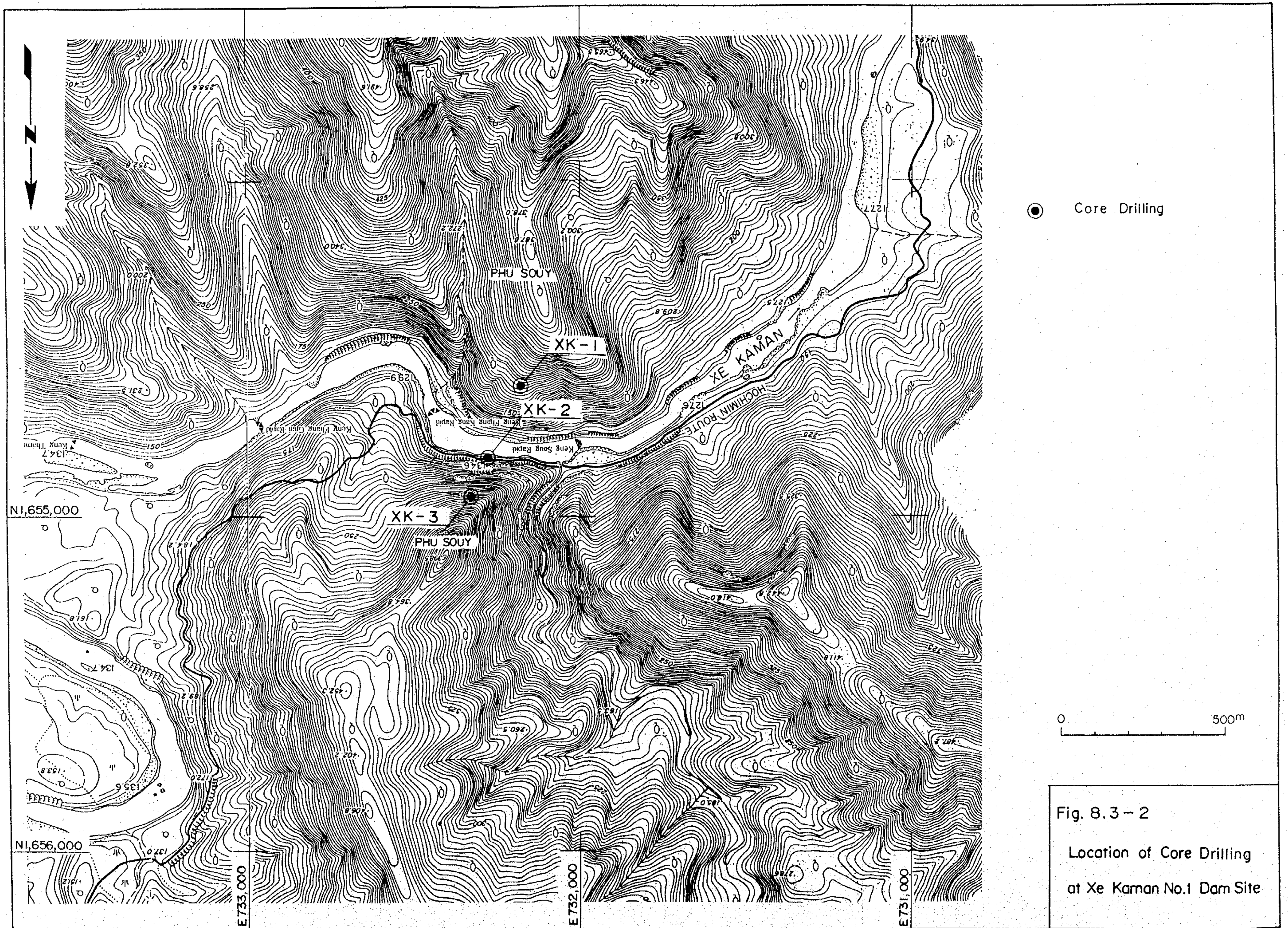

Fig. 8.3 - 2

Location of Core Drilling at Xe Kaman No.1 Dam Site

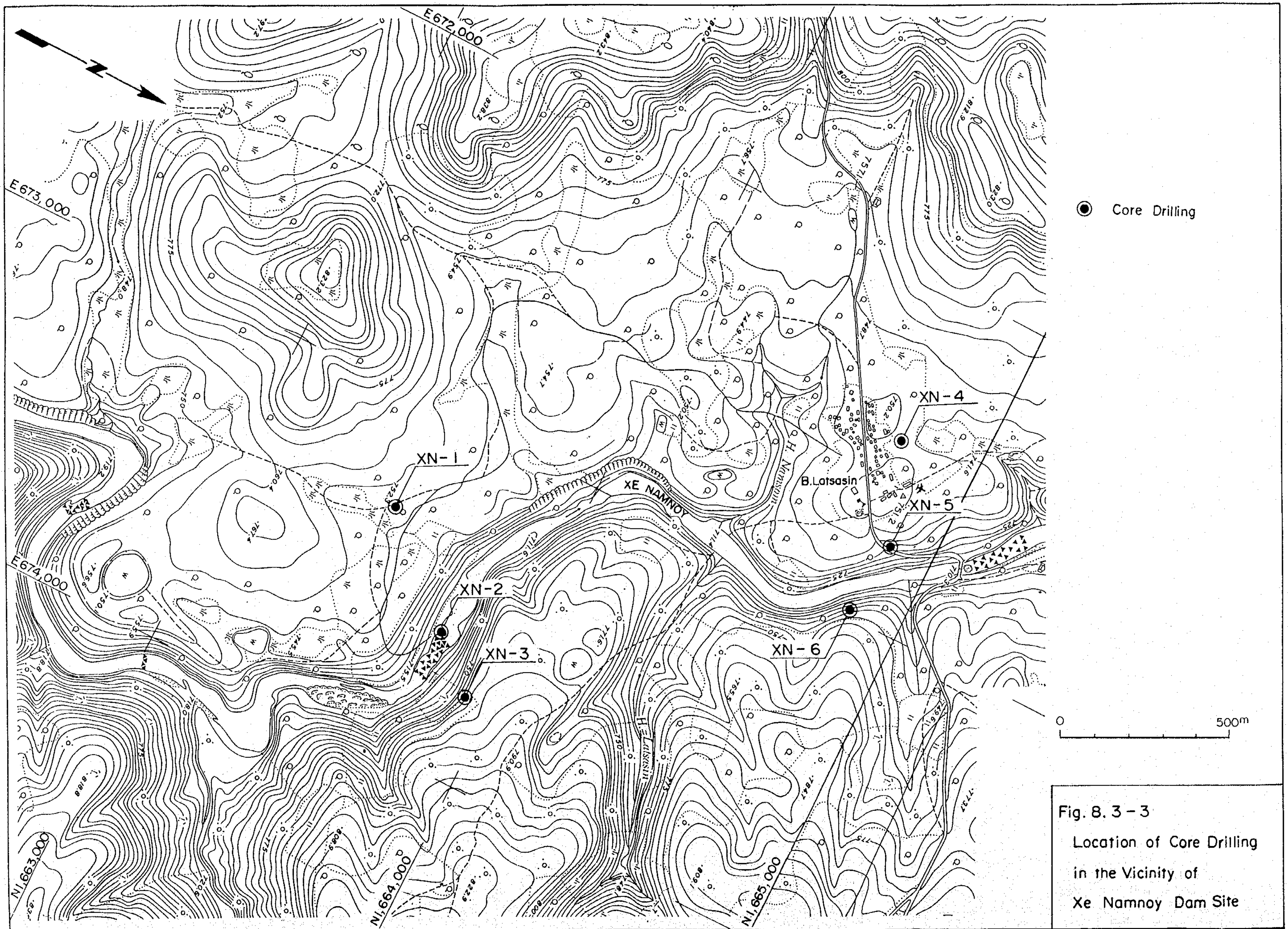

Fig. 8.3-3
Location of Core Drilling in the Vicinity of Xe Namnoy Dam Site

8.4 Preliminary Survey on Environmental Impact and Compensation

8.4.1 Outline

Preliminary field survey on environmental impact and compensation for the selected three projects; Se Kong No.4, Xe Kaman No.1 and Xe Namnoy were carried out by the local Consultant shown below.

Consultant : Hydropower Engineering Consultants (HEC), Vientiane, Lao P.D.R

Work Period : From November 1993 to March 1994

8.4.2 Methodorogy of Survey

The field survey were carried out mainly data collection collaborated with Lao experts and organization. Furthermore, some of the items were on the field survey including interview with the local authorities and the local peoples.

Based on the field survey results, initial environmental examination, measure to alleviate impacts, survey items needed in future, and survey of example in similar reservoir in Laos were carried out.

8.4.3 Survey Items

(1) Environmental Impact Survey

(a) Social Environment

- Population and communication
- Industry and economy
- Utilization of land
- Utilization of water area
- Infrastructures and transportation
- Sanitation
- Land scape
- Cultural assets

(b) Natural Environment

- Topography and soil condition
- Water phenomena and condition
- Flora and fauna
- Air, noise and vibration

(2) Compensation

- Compensation costs related to the project

8.4.4 Results

Data of the field survey has been reported by the HEC as "Report on Environmental Impact and Compensation".

The results of the survey are described in Chapter 11.

8.5 Survey on Access to Project Sites

8.5.1 Usable Port and Airport

Since Laos has no sea board, import materials and equipment will be transported through Thailand. Pakse city which is center point in southern Laos is to be transportation base for the hydropower construction in the Se Kong river basin.

Pakse city faces to the Mekong River, and connected road from Thailand by a ferry boat at the Mekong River. Capacity of the ferry boat at present are as follows:

Capacity tonnage :	100 ton, 1 boat
	50 ton, 1 boat
Loading capacity or 100 ton boat :	6 tracks or 12 cars

At Pakse city, there is a domestic airport and daily flight from Vientiane has been operated. Furthermore, there is weekly flight from Vientiane at Saravane airport in the Saravane province.

8.5.2 Existing Roads

There are national roads and local roads to approach from Pakse to the Se Kong river basin as existing roads.

The national roads have good road condition in general. The roads have width of 6 m-10 m and partly tarred. The roads have steel bridges (20 t) and passable even during the rainy season. However, the greater part of Route 16 located in Se Kong-Attapu-Pakse have narrow width (approximately 6 m), unpaved road, no bridges, and very difficult to pass by car during the rainy season. These national roads are progressing improvement now by the ADB finance.

The local roads have narrow width (4 m) and steep slope in general. The roads are unpaved and very few bridges. It is very difficult to pass during the rainy season.

Results of the existing roads survey done by the study team in 1993 are summarized in **Table 8.5-1**. The road map in the Se Kong basin and surroundings is as shown in **Fig. 8.5-1**.

As shown in **Table 8.5-1**, distance from Pakse to Sekong town which is a base for Se Kong No.4 is estimated 153 km, from Pakse to Attapu town which is a base for Xe Kaman No.1 is estimated 233 km, and from Pakse to B.Latsasin which is a base for Xe Namnoy is estimated 110 km.

Of the existing roads mentioned above, improvement of roads and reinforcement of wooden bridges will be required for the transportation of heavy equipment such as construction machines and ele-mecha equipment. Furthermore, special barges will be required at the ferry boat sections.

8.5.3 Construction Roads

Other than the roads described in 8.5.2, there are no roads approach to the project sites. In the pre-feasibility study stage, new construction roads connecting from the existing roads to the dam sites are planned as described in Chapter 14. Improvement of the existing roads also planned.

Table 8.5-2 shows summary of new construction roads planned in the study.

Table 8.5-1 Existing Roads

Route No.	Section	Distance	Width	Description
R-10	Thai border - Pakse	40 km	6-8 m	Tarred road Ferry boat (Mekong River) Steel bridges 20t, 15t (B=3 m, 4 m)
R-13	Vientiane - Pakse	700 km	8-10 m	Tarred, earthen road
	Pakse - B. Pathoumphen	45 km	6-8 m	Earthen road
R-16A	B. Thateng - B. Phon	40 km	6 m	Earthen road Wooden bridges 5t
	B. Phon - Sekong	7 km	6 m	Earthen road Wooden bridges 5t
	Sekong - Attapu	80 km	6 m	Earthen road Wooden bridges 10t No bridges at Xe Namnoy
R-16B	Attapu - B. Pathoumphen	120 km	6 m	Earthen road No bridge at Xe Pian Riv.
R-20	B. Houayhe - B. Beng	70 km	10 m	Tarred, earthen road Steel bridges 20t
R-23	Pakse - B. Houayhe	16 km	10 m	Tarred road
	B. Houayhe - Paksong	30 km	8 m	Earthen road
	Paksong - B. Thateng	-	6 m	Earthen road
	B. Thateng - B. Beng	20km	6-8 m	Earthen road Steel bridges 20t
	B. Beng - Saravane	-	10 m	Tarred road
Local roads	B. Phon - B. Nava Nua (Se Kong No. 4)	2 km	3 m	Earthen road Wooden bridges 5t
	Paksong - B. Latsasin (Xe Namnoy)	65 km	3-6 m	Earthen road Wooden bridges 5t
	Attapu - Xe Kaman (Xe Kaman No. 1)	54 km	3-6 m	Earthen road Ferry boat (Se Kong River) No bridges near site
Total distance from Pakse				
	Pakse - Sekong	153m		
	Pakse - Attapu (North route)	233m		
	Pakse - Attapu (South route)	165 km		
	Pakse - B. Latsasin (Xe Namnoy)	111 km		

Table 8.5-2 Plan of Construction Roads

Project	Distance	Width	Description
Se Kong No. 4			
New Construction	14 km	6 m	Earthen road Steel bridges
Improvement	14 km	6 m	
Xe Kaman No. 1			
New construction	22 km	6 m	Earthen road Steel bridges
Improvement	23 km	6 m	
Xe Namnoy Mid-stream includes Downstream			
New Construction	29 km	6 m	Earthen road Steel bridges
Improvement	34 km	6 m	

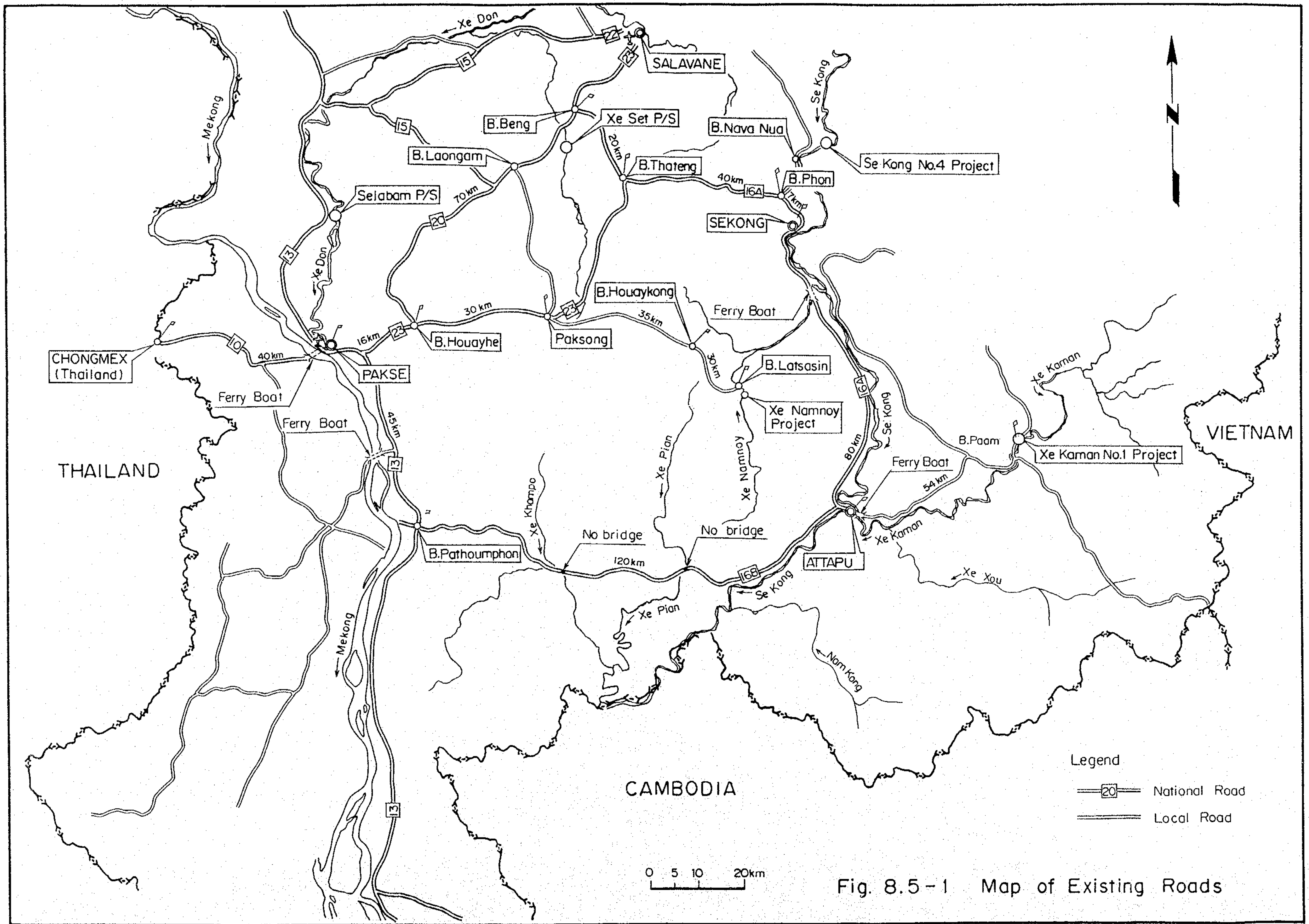

Fig. 8.5-1 Map of Existing Roads

9. Meteorology and Hydrology

9. Meteorology and Hydrology

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9. Meteorology and Hydrology

9.1 Outline

Monthly discharges and provable floods of three hydropower projects were analyzed and presented in this chapter. The analyses were based on the observed meteorological and hydrological data which have been compiled at the newly established stations in the project basin since the end of 1993.

Se Kong No.4, Xe Kaman No.1 and Xe Namnoy hydropower projects were squeezed from fifteen candidates in the Hydropower Potential Study Stage as reported in Chapter 7.

In the Hydropower Potential Study Stage, the observed daily water level records at the stations in Sekong Town, B.Fangdeng and B.Latsasin could not be used though 5, 2 and 3 year records are retained, respectively. The water level could not be converted to discharge because no stage discharge relation was identified due to lack of discharge measurement record at the stations.

In 1993 October, cableways crossing the river to measure the river discharge with the current meter provided by JICA were installed by MIH at the three stations. The flow velocity can be measured from the river bank even in flood period through the steel wire and a manual type winch. Because of small river, a gondola was furnished at the station in B.Latsasin and a observer can directly measure the flow velocity from the gondola.

The discharge measurement to get stage discharge relation at the stations has been carried out by four times a month and records are sent to MIH in Vientiane.

The monthly discharges for the study of three projects were calculated based on the daily discharges converted from daily water level records through the newly established stage discharge relation. The probable floods for sizing the diversion work during construction of the projects were also studied based on the daily discharges obtained from the stations.

The latest rain and evaporation records sent from the stations were introduced in the study presented in this chapter. The three new rainfall gauges with automatic recorder and the three class A evaporation pans were supplied by JICA and installed by MIH at the staions in Sekong Town, B.Fangdeng and B.Latsasin in 1993.

9.2 Monthly Discharge

The monthly discharges of the projects were calculated from those of nearby stations in proportion to the catchment area. Because of short term records of the stations, monthly discharges were extended to longer records using regression correlation of the nearby basin.

It is generally said that reliable streamflow record for 10 to 20 years is essential for the plan of hydropower projects. In this study, it was aimed that period of monthly discharges of three projects should be 10 years.

The stage discharge relation in high water period is not yet made because discharge measurement was began to carry out from the end of 1993 which was the end of last wet season. The stage discharge relation in high range of water level was estimated by uniform flow depth or non-uniform flow calculation of the stream at the stations, and daily water level records were converted to daily discharge records.

The stage discharge relation used in this study is just for tentative use, therefore, the relation should be updated in the future as soon as discharge measurement records covering the unknown range of water level are available.

9.2.1 Monthly Discharge at Se Kong No.4 Project Site

The water level has been recorded since January 1989 in Sekong Town which sits on the flat area between the Bolaven Plateau and Annam Ranges and is located 40 km downstream from the Se Kong No.4 dam site along the river. There exists no more water level station along the Se Kong River except for Attapu Town sitting 90 km downstream from Sekong Town.

The catchment area covered by the station in Sekong Town is 6,200 km^2.

(1) Observation Data

The observation data at the station in Sekong Town utilized in this section are listed as follows.

Water Level Record	Jan. 1989		to	June 1994
	Breakdown			
		1989 Jan - Nov.	: Nov.,Dec. incomplete	
		1990 Jan - Dec	: Oct. incomplete	
		1991 Jan - Dec.	: complete	
		1992 Jan - Dec.	: Dec. incomplete	
		1993 Jan - Dec.	: March, May,Jun., Aug. incomplete	
		1994 Jan. - June		
	Total	64 months , 5.3 years		
		Range of record	: 0.88 - 14.48 m	
		Mean W.L	: 2.3 m	
Discharge Measurement Records	November 6, 1993		to	June 29, 1994
	Number of record		: 30 times	
	Range of record		: 1.09 - 3.14 m	

(2) Estimation of Rating Curve

Two station rating curves showing stage discharge relation in Sekong Town were determined and shown in **Fig. 9.2-4**.

One is the curve for low water level range and another is the curve for high water level range. The latter was estimated using uniform flow depth to substitute the insufficient number of discharge measurement record.

a) The rating curve in low water level range was determined by least square method using 29 data of 30 observed discharge measurement data which are tabulated in **Table 9.2-1**.

b) The uniform flow depths of the stream flow at the station were calculated in the following cases and the most fitted case to the observation data was selected. The river cross section surveyed by MIH engineers in January 1994 for uniform flow depth calculation is shown in **Fig. 9.2-1**.

i) i = 1/5,000	ii) i = 1/2,500	iii) i = 1/1,250
n = 0.04	n = 0.04	n = 0.04
= 0.05	= 0.05	= 0.05
= 0.06	= 0.06	= 0.07
= 0.07	= 0.07	= 0.08

where, i : riverbed slope

n : coefficient of roughness

c) The rating curve for high water level range was finally determined by least square method using calculated uniform flow depth in case of river slope : 1/1,250 and coefficient of roughness : 0.07.

d) These two curves were connected at the crossing point of 1.69 m in terms of the water level.

(3) Monthly Discharge

The daily discharges were converted from stage observation records by the said two rating curves and monthly records for 57 months from June 1989 to June 1994 excluding December 1989, October and November 1990 at the station in Sekong Town were compiled.

(4) Substitution of Monthly Discharge Data

Regression analysis was introduced to extend period of monthly discharges in Sekong Town to 10 years.

a) from record at Attapu in Se Kong River basin

16 months of monthly discharge, from June 1988 to May 1989 and December 1989, October and November 1990, and July 1994, were supplemented from those of Attapu using regression correlation. The results of regression analysis of monthly discharges between Sekong Town and Attapu show a good correlation having the coefficient of 0.91 from 56 monthly discharge data of both stations.

b) from record at B.Nanay of Xe Done River basin

Monthly discharges for 21 years at B.Nanay of Xe Done River are presented in the feasibility study report "XE DONE 2 HYDROELECTRIC PROJECT April 1991, by NIPPON KOEI". Using this record, some 19 year monthly discharges in Sekong Town, which are for 2 years from 1960 to 1961, 12 years from 1964 to 1975, 4 years from 1978 to 1981, and 1 year and 5 months from January 1987 to May 1988, were developed by regression analysis with the correlation coefficient of 0.86 in all seasons and 0.95 in dry seasons.

c) from record at Souvannakhili of Xe Done River basin

5 monthly discharges from August to December in 1986 were supplemented by those of Souvannakhili. The correlation coefficient from regression analysis is 0.8 using all monthly discharge data from June 1988 to December 1993 and 0.7 using the data in dry season.

Consequently, the period of monthly discharge record in Sekong Town was extended to around 25 years based on the record of 5 year monthly discharges converted from water level records.

(5) Monthly Discharge of Se Kong No.4 Project Site

The projects other than Se Kong No.4 finally have 10 year monthly discharges from August 1984 to July 1994 for their study as reported in the following sections. In order to get same period of discharge data, monthly discharges from August 1984 to July 1986 in Sekong Town were arranged as follows.

a) The average discharges for 8 years from August 1986 to July 1994 and 10 years, namely all data, at the station in B.Fangdeng were calculated and the ratio of both average was also calculated.

b) The average discharge for 8 years of the same period as above (a) in Sekong Town was calculated. The average discharge of 2 years in Sekong Town was derived from the ratio of 8 and 10 year average of B.Fangdeng assuming that the ratio in both stations was same.

c) Series of 2 year monthly discharge were selected among 25 year monthly discharges in Sekong Town so as to close to the average discharge of 2 years obtained in above (a).

Consequently, the monthly discharges from August 1969 to July 1971 in Sekong Town were replaced to those of 1984 and 1986. The monthly discharges of Se Kong No.4 were calculated from 10 year monthly discharges of Sekong Town in proportion to the catchment area as shown in **Table 9.2-5** and **Fig. 9.2-9**.

9.2.2 Monthly Discharge at Xe Kaman No.1 Project Site

B.Fangdeng sitting in the right bank of the Xe Kaman River is the village located 10 km to the east of Attapu Town and there exists a water level station maintained by the Department of Hydrology and Meteorology in Attapu. No more water level station was found along the Xe Kaman River. Water discharge measurement, however, has not been conducted by them.

In October 1993, MIH installed a cableway in B.Hatsaykhao located 3 km upstream from B.Fangdeng with financial support of JICA to make a station rating curve at B.Fangdeng.

Xe Kaman No.1 project sits in the west end of Annam Ranges and is located 50 km to the east of B.Fangdeng along the river.

(1) **Observation Data**

The observation data utilized in this section are listed as follow.

a) B.Hatsaykhao	Water Level Record	Nov. 1993 to May 1994
	Discharge Measurement	Oct. 1, 1993 to May 29, 1994
	Number of record	: 28 times
	Range of record	: 0.36 - 1.72 m
b) B.Fangdeng	Water Level Record	Nov. 1991 to May 1994
		(April 1992, April 1993 incomplete)
	Range of record	: 0.3 - 6.22 m

(2) Catchment Area of B.Fangdeng

The catchment area coverd by the station in B.Fangdeng is 4,570 km^2.

The downstream drainage area of 770 km^2 from the Xe Kaman No.1 dam site was measured by the 1 to 100,000 scale topographic map and the catchment area of B.Fangdeng was calculated.

(3) Water Level Relation between B.Fangdeng and B.Hatsaykhao

Water levels of both stations at the same day were depicted in **Fig. 9.2-3** and linear relation was found. Using this relation, water level records of the new station in B.Hatsaykhao were converted to those in B.Fangdeng and discharge measurement records were utilized as those in B.Fangdeng.

(4) Estimation of Rating Curve

The records of discharge measurement cover the range from 0.36 to 1.72 in water level at B.Fangdeng as shown in **Table 9.2-2** though the maximum water level of 6.22 m was recorded. The measurement was started from the end of 1993 last year. This is the same situation as that in Sekong Town.

Therefore, the data in high water level were substituted by uniform flow depth in addition to 28 observation data. The rating curve was decided by least square method using those data as shown in **Fig. 9.2-5**. The parameters such as riverbed slope and coefficient of roughness of the river to calculate uniform flow depth were considered by several combination shown below. The river cross section for the calculation of uniform depth is shown in **Fig. 9.2-2**.

i) i = 1/5,000	ii) i = 1/2,500	iii) i = 1/1,250	iv) i=1/1,000
n = 0.03	n = 0.03	n = 0.03	n= 0.04
= 0.04	= 0.04	= 0.04	
	= 0.05	= 0.05	

where, i : riverbed slope
n : coefficient of roughness

The combination of slope : 1/2,500 and roughness : 0.03 was selected. Calculated water levels from the uniform flow depths which were computed using these parameters, give the closest position to the observation data.

(5) **Monthly Discharge**

The daily water level records at the station in B.Fangdeng were converted to daily discharge records by estimated rating curve and monthly discharges for 29 months from November 1991 to May 1994, excluding April 1992 and April 1993, were compiled.

(6) **Substitution of Monthly Discharges**

Period of 2.5 years of monthly discharges compiled from daily discharges were extended to 10 years by regression analysis as follows.

a) from record at Attapu

The monthly discharges for 6.5 years, from June 1988 to October 1991, in B.Fangdeng was extended from those of Attapu by regression analysis. The correlation coefficient from regression analysis shows good correlation ; 0.95 by all monthly discharge data and 0.90 by the data in dry season.

b) from record at Kontum

The monthly discharges at Kontum of the Dak Bla River basin whose drainage borders on that of the Xe Kaman River were introduced to extend 6.5 year monthly discharges to 10 years period. The correlation coefficient of 0.86 was given from regression analysis using 19 month records of both stations.

Finally, monthly discharges for 10 years from August 1984 to July 1994 in B.Fangdeng were obtained.

(7) **Monthly Discharge of Xe Kaman No.1 Project**

Monthly discharges at the project site in the Xe Kaman River basin were calculated from extended 10 year discharge in B.Fangdeng in proportion to the catchment area as shown in **Table 9.2-6 and Fig. 9.2-10**.

9.2.3 Monthly Discharge at Xe Namnoy Midstream Project Site

B.Latsasin is situated 2 km downstream from the Xe Namnoy Midstream Project dam site and there is an automatic water level recorder which was installed by JICA in 1991 and has been maintained by MIH. No more station was found along the Xe Namnoy River other than this station.

At the station discharge in the dry season have been measured. Because of no gondola facility, discharge in rainy season could not measured, discharges have been measured just during low flow period. In October 1993, MIH constructed cableway crossing the river at the 300 m upstream from existing water level gauging station with financial support of JICA and a gondola was furnished to measure the flow velocity directly from it even in flood period.

(1) Observation Data

The observation data at the station in B.Latsasin are listed as following.

Water Level Record	Feb. 1991 to July 14, 1994
Range of record	: 0.45 - 5.12 m
Discharge Measurement	May 17, 1991 to Jul. 12, 1994
Number of record	: 65 times
Range of record	: 0.47 - 4.36 m

(2) Evaluation of Observation Data

A temporary bridge for access to Houay Katak Tok (Houay Ho) project site was constructed at the end of 1993 and the bridge was replaced to permanent one according to the JICA Study Team members who visited site in the end of July 1994.

The bridge crosses the Xe Namnoy River at 100 m downstream of the existing water level gauging station. The river cross sectional area at this point is decreased because of piers of the bridge and dumped soil materials from the construction work. The streamflow might be affected and backwater from the bridge may extend to the gauging station.

The data which are affected by this backwater, therefore, should be compiled separately from the previous data to make rating curves of both cases.

The discharge measurement records, which are shown in **Fig. 9.2-6** and **Table 9.2-3**, were evaluated from that point of view as stated above and followns.

a) Discharge measurement record from May 1991 to April 1992

The measurement in this period was conducted by JICA Study Team of Xe Katam Small Hydropower Project.

Though discharge measurement was carried out in only dry season during this period, the record shows stage discharge relation clearly before backwater influence as seen in **Fig. 9.2-6**.

b) Discharge measurement record from October 1993 to January 1994

Discharge measurement was carried out, using the newly constructed cableway during this period.

After this period, some errors of measurement caused by the current meter were found. The error is that the current meter had indicated excessive flow velocity when the discharge was small and actual velocity was small. Because the river section at the cableway is rather big comparing to the small streamflow in dry season, flow velocity becomes too small and that may be out of measurement rage of the current meter.

It is deemed that the record includes not only such errors but also backwater influence, and the record seems not to be reliable as scattered in **Fig. 9.2-6**.

The record in this period, therefore, was neglected.

c) Discharge measurement record from February 1994 to May 1994

To solve this phenomena, the JICA Study Team gave their suggestions during site reconnaissance conducted in February 1994. It is that the discharges should be measured at the place where stream flows with appropriate velocity measurment by the current meter.

The record seems to include backwater influence comparing to the record of item (a) as shown in **Fig. 9.2-6.**

d) Discharge measurement record from June 1994 to July 1994

The discharge measurement records during this period apparently include backwater influence judging from the recorded date.

It was intended that a rating curve before construction of the bridge could be substituted by the curve made from the records of this period because substituted curve shows smaller streamflow than actual one for the water level records before the end of 1993 and moreover the record in this period covers enough high water level to determine a rating curve.

However, the annual runoff amount calculated by the said substituted rating curve became bigger than the amount of annual rainfall observed in nearby stations below.

Station	Annual	1991	1992	1993	1994***
B.Latsasin	Runoff [mm]	3,858	2,010	1,977	1,221
B.Latsasin	Rainfall [mm]	2,774	* 1,232	1,892	** 171
B.Namkong	Rainfall [mm]	3,449	** 537	2,197	1,006

* : missing few ** : missing many *** : record up to middle of July

It was judged, therefore, that this substitution of the rating curve was not proper, because it is not rational that annual runoff is bigger than annual rainfall in the basin.

The water level records in wet season from May to July 1994 were neglected, because there is no way to translate this record into water discharge.

(3) Estimation of Rating Curve

The available data to make rating curves at the station in B.Latsasin are 26 data measured by JICA Study Team of Xe Katam Small Hydropower Project and 15 data measured during February and May in 1994. By the former data, the rating curve for low flow range was decided by least square method and the latter were used for decision of the curve when the water level was affected by the back water.

The discharge measurement record covers the range of 0.47 to 1.78 m in water level though the daily stage observation was recorded from 0.45 to 5.12 m. Therefore, the rating curve in high water level was estimated by non-uniform flow calculation using river cross sections made from 1 to 10,000 scale topographic map which was made by JICA Study Team for this project.

(4) Monthly Discharge

The daily water level were translated into the daily discharge by the three rating curves which are figured in **Fig.** 9.2-7 and monthly discharge for 39 months from February 1991 to April 1994 were obtained.

(5) Substitution of Monthly Discharge Data

Period of 2.5 years of monthly discharges compiled from daily discharges were extended to 10 years by regression analysis as follow.

a) from record of Xe Set River

The streamflow record at the power station of the Xe Set River, whose basin borders on that of Xe Namnoy River, were employed to investigate the correlation between two rivers. Good relation was found with the correlation coefficient of 0.98 by 29 monthly discharges.

The Xe Set River has the 4 year record from 1985 to 1990 excluding 1987 and 1988. These 2 years were supplemented by the record at B.Nanay of the Xe Done River. Then, 6 years monthly discharges of the Xe Namnoy from January 1985 to January 1991 were converted through regression correlation.

b) from B.Fangdeng

The rest of 10 years, namely August to December in 1984 and May to July in 1994, were supplemented by the record at B.Fangdeng of the Xe Kaman River. The results of regression analysis show that the correlation coefficient is 0.88 by 39 monthly discharges of both rivers.

It is deemed that the characteristic of both basin would not be similar because B.Fangdeng is located 40 km far from B.Latsasin and is not on the Bolaven Plateau. However, the period supplemented is so short that affection to the total amount of runoff will be negligible.

(6) Monthly Discharge of Xe Namnoy Midstream Project

Monthly discharge at the project site in the Xe Namnoy River basin was calculated from extended 10 year discharge in B.Latsasin in proportion to the catchment area.

The results are shown in **Table 9.2-7** and **Fig. 9.2-11**.

9.2.4 Monthly Discharge at Xe Namnoy Downstream Project Site

The available discharge of the Xe Namnoy Downstream Project is the water from the downstream drainage area of the Xe Namnoy Midstream Project and Houay Katak Tok (Houay Ho) project as well as Xe Katam basin, and discharge from Xe Namnoy Midstrem Project power station through the headrace tunnel.

The streamflow from the downstream drainage area of the two projects could be calculated from the estimated monthly discharge at B.Latsasin, and the monthly discharge of Xe Katam River was calculated based on the observation data at B.Nonghin as below.

(1) Monthly Discharge of Xe Katam River

The JICA Study Team of the Xe Katam Small Hydropower Project installed a water level gauge with an automatic recorder at B.Nonghin in 1991 and discharges have been measured with the current meter since then.

The rating curve was determined by the least square method based on those data as shown in **Fig. 9.2-8**.

a) Observation data

Water Level Record		Jan.24, 1991 to Sep.30, 1993
		Jan. 1, 1994 to May 31, 1994
	Range of record	: 0.20 - 1.51 m
Discharge Measurement		May. 3, 1991 to Mar.21, 1993
	Number of record	: 151 times
	Range of record	: 0.26 - 1.48 m

b) Rating curve at B.Nonghin

The 151 recorded data are depicted in **Fig. 9.2-8** as well as the determined rating curve by the least square method. The 7 points of 151 data did not contribute to determination of the curve.

The discharge measurement record at the station in B.Nonghin is shown in **Table 9.2-4**.

c) Monthly Discharge

The daily water level was converted to the daily discharge by the rating curve and monthly discharge for 38 months from January 1991 to May 1994 were obtained.

d) Substitution of Monthly Discharge

The period of 3 years compiled on monthly discharge basis was extended to 10 years by regression analysis in the following procedure.

i) from record of Xe Set River

The period of 6 years was extended from the monthly discharge of the Xe Set River with the correlation coefficient of 0.98 obtained from the regression analysis using 29 month records from January 1991 to June 1993.

ii) from B.Latsasin

9 monthly discharges at B.Nonghin, from August to December 1984, October to December 1993, and June and July 1994, were extended from those of B.Latsasin. The correlation coefficient from regression analysis is 0.87 by the 36 discharges in all seasons and 0.93 by the 15 discharges in dry season.

Finally, monthly discharges for 10 years from August 1984 to July 1994 at B.Nonghin of the Xe Katam River were obtained, as shown in **Table 9.2-8** and **Fig. 9.2-12**.

(2) Available Streamflow for Xe Namnoy Downstream Project

The downstream drainage area of 721 km^2 from the Midstream Project consists of the sub-drainage areas ; 290 km^2 of the Xe Katam River and the rest ; 431 km^2 of the Xe Namnoy River.

The streamflows from the former and the latter were calculated from those at B.Nonghin (drainage area : 171 km^2) and B.Latsasin (drainage area : 537 km^2), respectively, in proportion to the catchment area.

The results are shown in **Table 9.2-9** and **Fig. 9.2-13.**

9.2.5 Monthly Discharge of Xe Pian Diversion Scheme

10 year streamflows at B.Nonghin of the Xe Katam River, whose basin borders on the drainage area of the Xe Pian River, were calculated in previous Section 9.2.4. These streamflows were employed to estimate monthly discharges of the Xe Pian River Diversion Scheme because there exists no water level gauging station in the basin.

(1) Drainage Area

Two intakes are planed in the Xe Pian basin to divert the water to the Xe Namnoy Midstream Project and the drainage area of 223 km^2 was obtained the 1 to 50,000 scale topographic map.

(2) Monthly Discharge

The monthly discharge of Xe Pian Diversion Scheme was calculated from that of B.Latsasin in proportion to the catchment area.

The results are shown in **Table 9.2-10** and **Fig. 9.2-14.**

9.3 Flood

9.3.1 Design Flood

The probable maximum floods (PMF) to determine the scale of dam spillway were estimated by the Creager curve which envelopes the recorded maximum discharges and design floods of hydropower projects in Laos and adjacent countries as presented in Section 6.3.

The following design floods are applied for the pre-feasibility study.

Se Kong No. 4	16,400 m^3/sec
Xe Kaman No. 1	14,300 m^3/sec
Xe Namnoy Midstream	6,000 m^3/sec
Xe Namanoy Downstream	9,000 m^3/sec

9.3.2 Probable Flood

The probable floods to determine the scale of diversion work for the projects are introduced in this Section. Those floods were calculated based on the daily discharge records collected from the new stations in the project basin.

The probable floods are generally derived from observed annual maximum discharges through statistical procedure.

However, the available discharges for the study are the discharges translated from the observed water level for 5, 2 and 3 years at the stations in Sekong Town, B.Fangdeng and B.Latsasin, respectively. Moreover, no maximum discharge is recorded, and only periodical measurement have been done. The Year Book published by Mekong Secretariat also have no maximum discharge record of the 3 rivers except for that of the Se Kong River at Attapu in which 3 years discharges were recorded.

After substitution of the annual maximum discharge data at the stations as stated below, the probable floods of three projects were given by frequency analysis using log-normal distribution.

(1) **Relation between Peak Discharge and Mean Daily Discharge**

The ratio of recorded annual maximum discharges to daily discharges of the same day and catchment area of the rivers were depicted in **Fig. 9.3-1**. In this figure, a parabola enveloping all records was drown. It was assumed that the relation was expressed by this curve.

The records, which include the data at Attapu (Se Kong River), Souvannakhili (Xe Done River), B.Nanay (Xe Done River), Kontum (Dac Bla River) and other 14 stations in Laos, are quoted from the Year Books in 1988, 1989 and 1990.

(2) **Estimation of Maximum Discharges**

Because there are 5, 2 and 3 years recorded annual maximum discharges in the three stations, the maximum discharges of 1 year in Sekong Town, 4 years at B.Fangdeng , 3 years at B.Latsasin are substituted from the records at Attapu, Sekong Town and Sekong Town respectively in proportion to the catchment area.

(3) **Probable Floods of Projects**

The probable floods of three projects were given by frequency analysis. The analysis was done using annual maximum discharges which were converted from those of the three stations in proportion to the catchment area. Results of the analysis are shown below.

The probable floods of three projects are depicted in **Fig. 9.3-2** to **9.3-4** and that of Attapu is shown in **Fig. 9.3-5.**

The flood discharges of 100 year return period of each projects and Attapu can be laid close to the envelope curve which are proposed by ECAFE as presented in **Fig. 6.3-6.**

Although the number of data was limited, the results show quite the reliable value at this moment.

a) Se kong No.4 (Catchment area : 5,400 km^2)

The design flood discharge of 20 year return period for diversion work is 5,400 m^3/s as shown below.

Return Period [year]	Probable Flood [m³/s]	Flood per sq. km [m³/s/km²]
5	3,524	0.65
10	4,454	0.82
20	5,404	1.00
50	6,718	1.24
100	7,767	1.44
200	8,870	1.64

b) **Xe Kaman No.1 (Catchment area : 3,800 km^2)**

The design flood discharge of 5 year return period for diversion work is 3,212 m^3/s as shown below.

Return Period [year]	Probable Flood [m³/s]	Flood per sq. km [m³/s/km²]
5	3,212	0.85
10	3,917	1.03
20	4,615	1.21
50	5,550	1.46
100	6,276	1.65
200	7,023	1.85

c) **Xe Namnoy Midstream Project (Catchment area : 531 km^2)**

The design flood discharge of 20 year return period for diversion work is 950 m^3/s as shown below.

Return Period [year]	Probable Flood [m³/s]	Flood per sq. km [m³/s/km²]
5	594	1.12
10	758	1.43
20	927	1.75
50	1,162	2.19
100	1,351	2.54
200	1,551	2.92

d) Xe Namnoy Downstream Project
(Catchment area : 1,451 km^2 including H.Katak Tok)

The diversion tunnel will be designed by the probable flood of 5 year return period because a concrete gravity type dam is planning in the Xe Namnoy Downstream Project.

The Creager curve for the probable floods of 5 year return period can be drown in parallel with the Creager curve of 100 year return period. The flood discharge, 1,350 m^3/s of 5 year return period for the Downstream Project was calculated from the curve as shown below.

$$q = 0.149A^{(1.8A^{-0.05} - 1)}$$

Where,

q : specific flood discharge of 5 year return period [$m^3/s/km^2$]
A : drainage area [km^2]

9.4 Evaporation

Annual evaporation of the three projects are presented in Section 6.3.5.

To seek the monthly evaporation, the ratio of each monthly evaporation to annual evaporation were calculated from the observation data at the nearby stations. The data recorded by the new evaporation pan installed in the three stations in the project basin for the study were also refereed.

9.4.1 Data List

The data recorded by the new everporation pans are listed below. Those were distributed at the below stations in the Project basin .

(1)	Attapu	(Jan.	to	Nov.	1989	by Pitcher)
		(Jan. 1990	to	Dec.	1991	by Pitcher)
		Oct. 1993	to	May	1994	by Class A Pan
(2)	Sekong Town	Oct. 1993	to	Jun.	1994	by Class A Pan
(3)	B.Latsasin	Oct. 1993	to	Jun.	1994	by Class A Pan

9.4.2 Observed Evaporation at the nearby Stations

The distribution of the observed monthly evaporation at the meteorological station in Pakse and Nikhom 34 can be seen by the said ratio in **Fig. 9.4-1** and **Fig. 9.4-2**. The same figure in Attapu is also seen in **Fig. 9.4-3.** This is made based on daily evaporation which were observed by the pitcher for 3 years. The ratio of the calculated monthly evaporation to annual evaporation is also shown in the same figures. These calculated monthly evaporation are derived from the observed humidity and temperature records presented in Section 6.3.

In Pakse, the peak of monthly evaporation is recorded in March and the minimum one appears from June to September in wet season.

In Nikhom 34, though the peak of monthly evaporation appears in February and evaporation fluctuates gently, the pattern is similar to that in Pakse.

In Attapu, observation data show random pattern because of short term record. However, both observed and calculated monthly evaporation ratios show a peak in March and there seems to be a bottom between June and September. This is the similar trend of other two locations.

The ratio based on the observation data in February, November, and December are rather big comparing to the calulated monthly evaporation ratio. On the contrary, the former ratio is rather small in April.

The trend of calculated monthly evaporation ratio is similar to one in Pakse.

9.4.3 Monthly Evaporation of the Projects

(1) Se Kong No.4

Evaporation has been recorded since October 1993 by the class A pan which was newly installed at the meteorological station in Sekong Town.

The observed daily data for about 9 months seem to have some errors in wet season because the amount of daily evaporation, taking the amount of rainfall into consideration, shows sometimes negative value or scale of several tens millimeters. Then, the records of October 1993 and April to June 1994 were abandoned and observed evaporation were adopted as shown in **Fig. 9.4-4**.

According to **Fig. 9.4-4**, evaporation in November and December tends to increase and the peak of monthly evaporation will take place in March. It may say that the trend of monthly evaporation in Sekong town is similar to that in Pakse. Therefore, monthly evaporation of the Se Kong No.4 is estimated from the annual evaporation based on the monthly ratio of Pakse.

(2) Xe Kaman No.1

The same type pan as that in Sekong Town was installed at the meteorological station in Attapu in 1993 for the Study and the records from October 1993 are available. The record in May was abandoned due to the same reason as stated about Sekong Town.

Because of few data, it is not easy to define the tendency from the data in **Fig. 9.4-5**. However, the amount of evaporation in November and December is larger than that in January and February, and that is similar to the tendency of the monthly evaporation measured by the pitcher in the same town as shown in **Fig. 9.4-3**.

Therefore, monthly evaporation of the Xe Kaman No.1 is estimated from the annual evaporation based on the monthly ratio of the observed data by pitcher in Attapu.

(3) Xe Namnoy

Fig. 9.4-6 was made by the same procedure described above based on the 4 month record of 9 month record from middle of October 1993 to June 1994 in B.Latsasin. Namely, following data were neglected because of insufficient reliability.

October 1993

March, April, and May 1994

Moreover, evaporation record in June 1994 was neglected because no rainfall record in this month was available.

It is deemed that no specific trend is interpreted from **Fig. 9.4-6**.

Then, monthly evaporation of the Xe Namnoy Project was estimated from the annual evaporation based on the monthly ratio of Nikhom 34 because Nikhom 34 is also located on the Bolaven Plateau.

The monthly evaporation of each project are shown in **Table 9.4-1**.