LAO PEOPLE'S DEMOCRATIC
REPUBLIC
MINISTRY OF AGRICULTURE
AND FORESTRY

JAPAN INTERNATIONAL
COOPERATION AGENCY
(JICA)

THE STUDY ON THE INTEGRATED AGRICULTURAL AND RURAL DEVELOPMENT PROJECT IN BOLOVEN PLATEAU

VOLUME-II

ANNEXES

September, 1996

NIPPON KOEI CO., LTD.
NAIGAI ENGINEERING CO., LTD.

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PART I MASTER PLAN STUDY

I OBSERVED RECORD

1.1 General

Department of Meteorology and Hydrology, MAF, is responsible to carry out the meteo-hydrological observation and data compilation over the nation. The Department is now operating 93 meteorological stations including rainfall-gauge stations and 108 water level gauging stations. Based on the list of existing meteo-hydrological observatories provided by the Department, observed records on 14 meteorological stations and 8 hydrological stations located in and around the Study area were selected for the study taking the extent of Study area into consideration. Description of the selected stations is as follows;

Meteorological Stations

Station	Code	Lat.	Lon.	Alt.	Type	Period
PATHOUMPHON	M140505	14°46'	105°58'	96m	R	1965 -
CHAMPASAK	M140507	14°54'	105°53'	95m	R	1979 -
NONGHINE	M140604	15°13'	106°21'	1,280m	R	1979 -
ATTAPU	M140605	14°48'	106°50'	105m	M	1980 -
PAKXE	M150504	15°07'	105°47'	102m	M	1960 -
KHONGXEDON	M150506	15°34'	105°48'	200m	M	1989 -
XELABAM	M150508	15°24'	105°50'	96m	R	1972 -
BAN BACHIANG	M150510	15°10'	105°54'	220m	R	1977 -
PAKXONG	M150601	15°10'	106°11'	1,200m	M	1986 -
SALAVAN	M150602	15°41'	106°25'	170m	M	1980 -
KM42	M150603	15°11'	106°10'	1,160m	M	1977 -
BAN LAONGAM	M150604	15°53'	106°15'	500m	M	1989 -
NIKHOM34	M150605	15°11'	106°26'	1,150m	M	1984 -
SEKONG	M150307	15°05'	106°15'	126m	M	1992 -

Type: R;Rain Gauge Station M;Meteorological Station

Hydrological Stations

Station	Code	Lat.	Lon.	Alt.	Type	Period
BAN NANAY	H390101	15°22'	105°49'	117m	H	1988 -
KHONGXEDON	H390102	15°34'	105°48'	122m	Q	1989 -
SALAVAN	H390103	15°42'	106°27'	140m	H	1986 -
SOUVANNAKHILI	H390104	15°23'	105°49'	114m	Q	1988 -
BAN DONXE	H390110	15°19'	105°49'	94m	H	1988 -
H. CHAMPI	H390201	15°11'	106°06'	880m	H	1994 -
NIKHOM 34	H390202	15°10'	106°14'	1,130m	H	1989 -
ATTAPU	H430105	15°48'	106°50'	105m	Q	1987 -

Type: Q;Discharge Data H;Gauge Height Data

Apart from the MAF meteo-hydrological observation network, individual meteo-hydrological observation is made by project basis under the control of governmental agencies such as MCTPC, MIH etc. In the Study area, MIH has been conducted the study on Xe Katam Small-Scale Hydroelectric Power Development Project under the technical cooperation of JICA in 1991. The study covers Xe Namnoy basin where locates the southeast parts of the Study area. Through the study, two (2) automatic water level recorders and five (5) automatic rain gauges have been set up and observation is being continued. Moreover, monthly-basis discharge records of existing hydropower stations, Xe Set and Xelabam, located in and near by the Study area are also available for clarification of runoff phenomenon of rivers related to the Study.

1.2 Meteorological Data

The Study area and its surrounding are classified as savanna climate. Atmospheric dynamics are governed by monsoons, steady winds blow alternately from the northeast and the southwest. These winds are caused by seasonal temperature and the resultant pressure changes over the Central Asia and the Indian Ocean. The southwest monsoon is characterized by heavy and frequent precipitation, high humidityies, maximum cloudiness and tropical temperature. From May to October when the southeast monsoon blows, called the wet season, over 90% of annual rainfall occurs in and around the Boloven Plateau including the Study area. In the remaining period when the northeast monsoon blows, called the dry season, little precipitation occurs, humidity is low, the sky is clear and temperatures are relatively low.

At the meteorological observatories shown in the previous section, observed climatic items are different in each observatory. Most of the observatories, continuous observation is being carried out regarding the rainfall, temperature and relative humidity though many lack of records can be found in the items of evaporation, sunshine hours and wind velocity due to the trouble of observation equipment. The table below summarises the major features of climatic condition within and near the Study area and meteorological items for estimation of potential transpiration are available only these observatories. Pakxe may be considered representative of the west part of lowland area in the Study area and Pakxong for highland area, Salavan for the north part of lowland area.

Station: Pakxe

Item	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Rainfall (mm)													
	2.4	8.5	14.1	59.4	201.3	324.6	376.3	500.5	296.9	116.7	17.5	2.2	1920.4
Temperature (C)													
Max.	32.0	33.5	35.0	35.8	33.8	31.4	30.9	30.6	31.1	31.1	31.1	30.7	32.2
Min.	18.6	21.5	23.7	25.5	25.1	24.6	24.1	24.1	23.8	22.6	20.6	18.3	22.5
Mean	25.3	27.4	29.4	30.7	29.5	28.0	27.5	27.4	27.4	27.0	25.8	24.5	27.5
Relative Humidity (%)													
	61	58	58	63	72	79	81	80	80	75	70	63	70
Sunshine Hours (hours)													
	8.8	7.8	7.5	7.6	7.1	4.2	4.7	4.1	4.7	5.6	7.7	7.9	6.4
Wind Speed (m/s)													
	2.5	2.6	2.9	2.8	2.8	2.4	2.2	2.2	2.0	2.3	2.6	2.7	2.5
Evaporation (mm)													
A-pan	193.3	194.8	224.4	220.7	184.4	120.7	105.9	102.2	122.5	162.9	176.9	191.2	2000.0
Piche	171.5	184.6	218.4	192.7	127.2	78.4	71.1	64.5	65.8	94.8	127.0	153.8	1549.7

Station: Pakxong

Item	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Rainfall (mm)													
	9.8	10.9	104.1	243.8	347.8	457.3	688.4	790.3	427.0	212.5	37.6	14.6	3374.1
Temperature (C)													
Max.	24.2	25.2	25.7	26.4	25.4	23.6	23.1	22.9	24.0	23.9	23.6	23.2	24.2
Min.	10.1	11.8	15.1	17.0	18.0	17.8	17.5	17.2	16.8	16.0	13.6	11.5	15.3
Mean	17.1	18.5	20.4	21.7	21.7	20.7	20.3	20.0	20.4	20.0	18.6	17.4	19.5
Relative Humidity (%)													
	72	71	75	78	83	88	89	90	86	82	75	73	80
Sunshine Hours (hours)													
	7.6	7.1	6.2	6.8	4.5	3.0	2.8	2.4	3.4	4.3	7.6	6.9	5.1
Wind Speed (m/s)													
	2.3	2.7	2.6	2.6	3.0	3.4	3.3	3.2	2.5	3.0	3.1	2.9	2.9
Evaporation (mm) (records at Nikhom34)													
Piche	67.7	54.3	57.4	48.6	44.8	38.8	33.8	33.3	28.6	39.1	47.5	56.6	550.5

Station: Salavan

Item	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Rainfall (mm)													
	3.6	2.0	32.3	51.3	161.6	384.6	325.8	538.2	285.3	123.1	17.7	0.6	1926.1
Temperature (C)													
Max.	30.7	33.5	35.6	35.1	33.7	30.8	30.6	29.7	30.8	30.8	30.4	29.7	31.8
Min.	15.4	19.1	22.7	24.4	24.2	24.4	23.9	23.8	23.5	22.4	19.7	18.0	21.8
Mean	23.1	26.3	29.3	30.2	29..0	27.5	27.3	26.7	27.2	27.0	25.0	23.0	26.8
Relative Humidity (%)													
	65	61	59	63	72	81	80	86	82	79	74	68	73
Sunshine Hours (hours)													
	6.4	8.9	7.4	6.6	6.9	4.4	4.1	3.6	4.9	6.5	8.4	7.4	6.3
Wind Speed (m/s)													
	1.9	1.9	1.9	1.9	1.9	1.7	2.0	1.7	1.6	1.8	2.2	2.2	1.9
Evaporation (mm)													
A-pan	184.3	210.2	243.3	248.5	229.7	139.7	118.0	108.3	105.6	146.0	165.4	173.3	2072.4

Recorded periods in the table are as follows;

Pakxe : 1989 to 1994 for evaporation (A-pan), Others are 1985 to 1994

Pakxong : 1991 to 1994 for sunshine hours, Others are 1986 to 1994

Salavan : 1991 to 1994 for sunshine hours, 1992 to 1994 for evaporation, Others are 1981 to 1994 excluding 1985 to 1989.

(1) Rainfall

Boloven Plateau forms as isolated tableland with elevation of around 1,200m in top portion and surrounded by the plain generated by the rivers such as Nam Khong, Xe Don and Xe Kong. Those topographic conditions closely affects to the dynamics of monsoon and rainfall distribution over the Study area as shown in Fig.1.1.1 of annual isohyetal map. During the wet season, the southwest monsoon hit the southwestern slope of the Plateau and causes large amounts of rainfall reaching up to 3,300mm on an annual average at the southern parts of the Plateau though a tend to decrease of rainfall amounts can be seen with a decent in elevation. Lowland areas surrounding the Plateau ranges 100m to 200m in elevation and annual average rainfall counts from 1,600mm to 2,000mm.

There exists four (4) meteorological and/or rainfall observatories along the route 23 from Lak 42 to Pakxong and the road to Houay Ho damsite from Pakxong in the highland areas. Those observed records on annual total rainfall varies from 2,500mm to 4,700mm. Among the observatories, Pakxong gives the maximum values and the decrease of annual rainfall amount can be seen in other observatories. On the contrary, average annual rainfall in the lowland areas surrounding the Plateau shows at around 2,000mm in the southern part, 1,600 to 1,800mm in the northwestern part and 1,800 to 1,900mm in the northeastern part. The peak of monthly rainfall in and around the Study area takes place in August and accumulates one fourth of annual rainfall within a month. Regarding the rainfall at the beginning of wet season, over 200mm of monthly rainfall occurs in April at the highland areas while noticeable in May at the lowland areas. As for the initial stage of dry season, appearance of less than 100mm of monthly rainfall is dominated in November at entire part of the Study area except the northwestern lowland areas which appears in October. In July, 1983, 533.5mm of daily rainfall had been recorded at Pakxong while 450.3mm and 213mm of daily rainfall at Pakxe and Xerabam observatories, respectinely.

Correlation concerning the monthly distribution of annual rainfall is verified using the average monthly rainfall among the related observatories in and around the Study area. High correlation can be recognized as shown table below and those results mean that the monthly distribution pattern of annual rainfall tends toward same manner over the Study area.

	Xelabam	Khongxedon	Pathoumphon	Pakxe	Sekong	Salavan	Attapu	Pakxong	Laongam
Xelabam	-	0.97223	0.99091	0.95502	0.99153	0.98597	0.98341	0.96628	0.90194
Khongxedon	0.97223	-	0.96801	0.98497	0.98482	0.98701	0.98676	0.99129	0.94721
Pathoumphon	0.99091	0.96801	-	0.93897	0.98874	0.99338	0.98210	0.95717	0.88756
Pakxe	0.95502	0.98497	0.93897	-	0.96320	0.95820	0.97153	0.97095	0.93632
Sekong	0.99153	0.98482	0.98874	0.96320	-	0.99100	0.99429	0.98493	0.92667
Salavan	0.98597	0.98701	0.99338	0.95820	0.99100	-	0.98892	0.97752	0.92196
Attapu	0.98341	0.98676	0.98210	0.97153	0.99429	0.98892	-	0.97988	0.91929
Pakxong	0.96628	0.99129	0.95717	0.97095	0.98493	0.97752	0.97988	-	0.96977
Laongam	0.90194	0.94721	0.88756	0.93632	0.92667	0.92196	0.91929	0.96977	-

Following are the correlation factor of monthly rainfall between Pakxe and other observatories. The value of less than 0.6 indicates a very low correlation under the significant level of 5 % taking the number on a pair of data into account. Salavan can be considered the observatory having high correlation with the Pakxe among the observatories located over the Study area.

Observatory	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Salavan	0.9971	0.9581	0.8546	0.7688	0.7170	0.3368	0.7687	0.7230	0.5494	0.8090	0.6991	0.3139
Xelabam	0.1000	0.8008	0.3713	0.6566	0.6455	0.6444	0.6673	0.7403	0.5353	0.8985	0.3268	0.7212
Laongam	0.9816	0.2297	0.8488	0.7361	0.8314	0.3863	0.7546	0.5112	0.2624	0.3054	0.5869	0.1935
Pakxong	0.7755	0.7928	0.1523	0.5047	0.6232	0.5413	0.4165	0.7424	0.6589	0.3861	0.4558	0.8251
Pathoumphon	0.8463	0.9677	0.2195	0.1122	0.3002	0.1414	0.2171	0.6852	0.5343	0.4550	0.2100	0.4992
Khongxedon	0.9920	0.3109	0.1818	0.7440	0.7719	0.4550	0.2446	0.4463	0.3425	0.8526	0.5451	0.3162
Sekong	0.8490	-	0.1690	0.7790	0.4180	0.9110	0.4320	0.1640	0.8980	0.4240	0.8870	0.5110
Attapu	0.2294	0.2812	0.4933	0.8469	0.1742	0.2588	0.6844	0.3875	0.5983	0.5255	0.2454	0.0183

To contrast the rainfall between highland and lowland areas, correlation factor of monthly rainfall is studied between Pakxong observatory located in the highland areas and the observatory situated in the lowland areas. Results show low and irregular correlation factors as tabulated below. No clear correlation can be found between highland and lowland areas.

Observatory	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Salavan	0.762	0.655	0.201	0.301	0.717	0.733	0.709	0.482	0.729	0.586	0.311	0.017
Xelabam	-	0.220	0.340	0.311	0.665	0.542	0.510	0.796	0.634	0.533	0.194	0.942
Laongam	0.873	0.210	0.368	0.671	0.497	0.937	0.895	0.858	0.355	0.538	0.142	0.189
Pathoumphon	0.863	0.157	0.295	0.409	0.450	0.158	0.434	0.854	0.485	0.267	0.252	0.855
Khongxedon	0.770	0.205	0.959	0.633	0.480	0.297	0.685	0.873	0.597	0.686	0.118	0.246
Sekong	0.842	0.352	0999	0.868	0.061	0.486	0.574	-	0.936	0.968	0.092	0.668
Attapu	0.378	0.154	0.198	0.318	0.500	0.629	0.206	0.160	0.273	0.631	0.234	0.892

For estimation of average annual rainfall in the Study area, nine (9) meteorological observatories were selected in view of location and its data period. With these selected observatories, Thiessen Polygon was delineated as shown in Fig. 1.1.2 and average annual rainfall in the Study area can be estimated at 2,417mm as described below;

Observatory	Data Period (years)	Mean Annual Rainfall(mm)	Areal Ratio (%)	Areal Rainfall(mm)
Pakxe	35	2,060	2.5	51.5
Xelabam	21	1,929	4.2	81.0
Khongxedon	14	1,658	1.1	18.2
Laongam	6	1,856	20.1	373.1
Salavan	28	2,007	7.4	81.0
Sekong	3	1,803	13.7	247.0
Pakxong	16	3,412	31.8	1085.0
Attapu	5	2,153	18.7	402.6
Pathoumphon	16	2,088	0.5	10.4
Total			100.0	2417.3

Probable rainfalls for annual, daily, continuous two-day and three-day are calculated using the observed records of each observatory. Probability of exceedance is basically adopted for calculation though probability of non-exceedance is also examined regarding the annual rainfall. Successive non-rain days is studied during the period from March to June taking the irrigation program into account. Probable no-rain days is tabulated below together with the probable rainfalls stated above;

Unit : mm , Days

Observatory	Item	Return Period (Year)					
		5	10	30	50	100	200
Pakxe	Daily Rainfall	169.8	216.8	302.3	347.5	414.9	489.9
	2-day Rainfall	244.2	307.3	415.0	469.0	547.2	631.1
	3-day Rainfall	284.7	352.3	413.5	517.8	595.0	676.4
	Annual Rainfall (E)	2,358.2	2,552.0	2,816.5	2,928.7	3,073.9	3,212.7
	Annual Rainfall (N)	1,735.3	1,599.4	1,442.4	1,383.9	1,314.1	1,253.1
	No-rain Days	32	39	50	55	62	69
Pakxong	Daily Rainfall	272.1	343.1	464.4	525.5	614.0	709.2
	2-day Rainfall	399.1	484.9	626.0	694.9	792.8	896.0
	3-day Rainfall	466.1	564.7	731.2	814.2	933.7	1,061.4
	Annual Rainfall (E)	4,165.4	4,487.3	4,914.0	5,091.1	5,317.2	5,530.1
	Annual Rainfall (N)	3,068.0	2,813.1	2,510.2	2,394.7	2,255.1	2,131.1
	No-rain Days	21	29	46	56	70	87
Sekong	Daily Rainfall	86.0	108.1	146.5	166.0	194.5	225.4
	2-day Rainfall	88.9	97.3	111.7	118.9	129.3	140.5
	3-day Rainfall	131.5	153.0	196.4	221.2	260.0	305.5
	Annual Rainfall (E)	2,299.4	2,534.8	2,895.2	3,062.0	3,290.7	3,522.8
	Annual Rainfall (N)	1,698.6	1,597.4	1,493.1	1,457.6	1,417.6	1,384.6
	No-rain Days	22	28	38	44	52	62
Khongxedon	Daily Rainfall	181.6	216.4	267.4	290.2	320.8	351.2
	2-day Rainfall	249.3	302.3	381.9	418.2	467.5	517.0
	3-day Rainfall	255.4	313.0	408.6	455.6	522.5	593.3
	Annual Rainfall (E)	2,146.2	2,412.4	2,825.5	3,018.8	3,285.6	3,558.3
	Annual Rainfall (N)	1,485.3	1,377.6	1,268.0	1,231.1	1,189.8	1,156.0
	No-rain Days	33	43	61	70	84	100
Salavan	Daily Rainfall	163.8	191.2	231.9	250.2	275.0	299.7
	2-day Rainfall	212.1	241.6	289.4	312.6	345.2	379.3
	3-day Rainfall	252.4	286.8	339.0	363.0	395.8	428.9
	Annual Rainfall (E)	2,113.4	2,222.9	2,363.0	2,419.6	2,490.7	2,556.4
	Annual Rainfall (N)	1,712.5	1,612.2	1,488.8	1,440.5	1,381.0	1,327.2
	No-rain Days	22	29	41	48	57	69
Laongam	Daily Rainfall	186.0	231.5	305.7	341.6	392.4	445.7
	2-day Rainfall	227.7	263.4	315.7	339.2	370.6	401.7
	3-day Rainfall	248.7	289.7	351.3	379.6	418.0	456.8
	Annual Rainfall (E)	2,066.7	2,189.2	2,353.3	2,421.9	2,510.0	2,593.4
	Annual Rainfall (N)	1,658.0	1,565.1	1,456.0	1,414.7	1,365.0	1,321.2
	No-rain Days	17	20	29	34	42	52
Xelabam	Daily Rainfall	186.9	230.7	327.8	371.0	434.2	502.8
	2-day Rainfall	259.9	317.3	415.3	464.6	535.8	612.3
	3-day Rainfall	304.6	366.5	468.9	519.2	590.9	666.6
	Annual Rainfall (E)	2,351.0	2,678.9	3,147.8	3,354.0	3,627.3	3,895.0
	Annual Rainfall (N)	1,423.5	1,243.4	998.9	924.5	837.8	763.7
	No-rain Days	34	38	44	46	48	51
Pathoumphon	Daily Rainfall	151.1	173.1	204.8	218.7	237.3	255.6
	2-day Rainfall	210.2	235.2	269.7	284.4	303.6	322.0
	3-day Rainfall	252.7	282.8	323.2	340.2	362.0	382.6
	Annual Rainfall (E)	2,652.1	2,950.0	3,338.4	3,497.5	3,699.0	3,887.0
	Annual Rainfall (N)	1,600.8	1,347.7	1,041.8	923.7	779.7	650.6
	No-rain Days	47	54	64	68	74	80
Attapu	Daily Rainfall	143.3	163.9	194.0	207.4	225.5	243.3
	2-day Rainfall	213.6	257.3	325.6	357.6	402.0	447.5
	3-day Rainfall	247.3	300.8	387.2	428.9	487.6	548.8
	Annual Rainfall (E)	2,555.2	2,820.3	3,191.1	3,351.5	3,561.7	3,765.3
	Annual Rainfall (N)	1,746.1	1,579.1	1,391.0	1,322.2	1,241.3	1,171.3
	No-rain Days	28	33	43	48	55	62

Annual Rainfall; (E):probability of exceedance,(N):probability of non-exceedance

(2) Temperature

Generally, the maximum air temperature occurs in the end of dry season, March to April, and minimum is the mid of dry season, January to February. Daily difference of air temperature accounts around 10 C in the wet season and 20 C in the dry season. Because the elevation of Study area ranges from 100m to 1200m, annual average air temperature differs at 7 to 8 C within a Study area. As described in the previous section, recorded air temperature at Pakxong and Pakxe may be considered representative of highland areas of the Plateau and its surrounding lowland areas, respectively. Differences of air temperature and elevation are shown below and difference of air temperature due to elevation can be calculated around 0.7C per 100m.

Item	Pakxe	Pakxong	Difference
Mean Max.	32.2 C	24.2 C	8.0 C
Mean Min.	22.5 C	15.3 C	7.2 C
Average	27.5 C	19.5 C	8.0 C
Elevation	100m	1,200m	1,100m

According to the air temperature records at Nikhom 34 observatory located 20km to the east of Pakxong town, 0C and/or close to 0C of minimum air temperature has been observed in several years. Frost has been found at that time and duration counts a few days per year. Appearance of these conditions is limited in Nikhom 34 and its outskirts.

(3) Relative Humidity

According to the records of Pakxong observatories located in highland areas of the Plateau , mean annual relative humidity shows 80%. The value of 70% or more relative humidity is being observed even in the middle of dry season. On the contrary, mean annual relative humidity in the lowland areas comes to 70% in Pakxe and 73% in Salavan and those values decreases upto 60% in the lowland areas during the dry season. The value during the wet season comes around 80% in lowland areas and 90% in highland areas.

(4) Evaporation

Observation records of evaporation are available at Pakxe, Nikhom 34, Salavan, Sekong and Attapu observatories within and adjacent the Study area. Class-A pan evaporator is used at Salavan and Sekong observatories while other observatories are observed by using Piche evaporator. At Pakxe observatory, observation using the Class-A pan had been made from 1967 to 1979 and from 1989 to March 1944, however, observation is now stopped due to trouble of equipment. When the comparison is made by the observed evaporation value of Piche between highland areas of the Plateau and its surrounded lowland areas, following remarks can be pointed out;

- annual total evaporation in highland areas of the Plateau accounts one third of its lowland areas.
- the value during the wet season in highland areas of the Plateau comes half of its lowland areas.
- the value during the dry season in highland areas of the Plateau accounts one third of its lowland areas.
- the value during the wet season comes half of total amount during the dry season in both highland areas of the Plateau and its surrounded lowland areas.

Annual total evaporation by Piche evaporator in the lowland areas represented the observed value of Pakxe and Salavan ranges from 1,400mm to 1,800mm, on the contrary, values on highland areas of the Plateau represented by Nikhom 34 shows around one third of the lowland areas ranging from 500mm to 700mm. Comparison of observed evaporation value is made below between Class-A pan and Piche evaporator using the data of Pakxe observatory.

The value of Class-A pan comes 1.35 times of its Piche on an average.

Unit : mm

Year	Class-A pan (a)	Piche (b)	(a)/(b)
1990	1,817.9	1,518.1	1.20
1991	2,050.3	1,481.1	1.38
1992	1,912.8	1,488.3	1.29
1993	2,055.7	1,432.7	1.43
Average	1,959.2	1,477.8	1.35

(5) Wind

Wind direction over the Study area is governed by monsoons. The northeast winds are prevailed during the dry season though the southwest winds are predominant in the wet season. The existence of the Plateau affects to those prevailing wind directions and generates varied wind directions localy. During the wet season, Pakxe located in the lowland areas and the western side of the Plateau, southeast winds are predominant while the north and/or northeast winds are maily observed in the dry season. At Salavan located in the lowland areas and the northern side of the Plateau, the west and east winds are predominant during the wet season and the north winds added the east winds blow in the dry season. In highland areas of the Plateau, the east and/or the northeast winds are prevailed in the dry season though the west winds are predominant during the wet season.

Wind speeds in the lowland areas are from 2.0 to 2.5 m/sec on an annual average. From 2.5 to 3.0 m/sec on an annual average is observed in the highland areas of the Study area. No clear difference can be observed regarding the wind speeds between the dry and wet seasons.

1.3 Hydrological Data

As stated in the previous section, eight (8) hydrological observatories were selected among the MAF hydrological network as the refference observatories to the Study. Most of selected observatories, however, locates along the river course of Xe Don and Xe Kong having the basin area of over 5,000 km². From the scale of objective river basin in the Study area, river flow records of its basin area of less than 500km² are desirable for clarification of runoff phenomenon. Observed records of H.Champi and Nikhom34 are adequate for the purpose but only water level records are available. As the continuous and long term river discharge records, monthly basis flow regime at Xe Set power station having the river basin of 325 km² is available in the Study area. Flow regime is as follows;

Unit : MCM

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1989	10.5	6.5	5.6	8.8	31.4	58.6	76.6	106.7	119.2	58.6	22.6	14.6	519.6
1990	9.5	4.6	7.1	7.1	17.2	19.7	39.6	53.6	73.0	102.5	53.0	36.2	423.1
1991	10.0	5.6	6.4	7.9	13.9	20.4	93.0	129.3	106.4	88.2	31.0	18.6	530.6
1992	7.9	5.8	5.0	4.6	9.5	38.6	69.8	112.0	74.7	45.5	20.9	13.6	407.8
1993	8.2	5.5	5.5	5.6	13.9	11.9	36.4	71.0	80.6	35.0	17.2	10.5	301.2
1994	6.9	5.0	5.1	13.1	27.4	38.8	72.4	75.5	76.5	45.7	20.9	12.5	396.9
AVERAGE	8.8	5.5	5.8	7.9	18.9	30.8	64.6	91.3	88.4	62.6	27.6	17.7	429.9

During the course of the Phase I Field Study, discharge measurement was carried out at eight (8) sites in six (6) rivers to grasp the river flow phenomenon in a dry season. Measurement results are as follows;

River	Basin Area km2	Date	Q m3/sec	q m3/sec/km2
Xe Pian	14.0	May 04	0.203	0.015
		May 12	0.377	0.027
		May 18	1.085	0.078
		May 30	0.741	0.053
H. Makchan-Gnai(1)	33.0	May 04	0.338	0.010
		May 10	2.173	0.066
H. Makchan-Gnai(2)	56.0	May 04	0.974	0.017
		May 10	3.396	0.061
		May 30	4.186	0.075
H. Champi	51.0	May 04	1.335	0.026
		May 10	1.880	0.037
H. Tapoung(1)	73.0	May 02	0.540	0.007
		May 12	0.726	0.010
		May 16	1.114	0.015
		May 24	0.541	0.007
		May 31	0.532	0.007
H. Tapoung(2)	4.0	May 16	0.196	0.049
H. Namsai	33.0	May 24	0.385	0.012
H. Kapheu	26.0	May 12	0.262	0.010
		May 16	0.278	0.011

In addition to the discharge measurement in the Study area, each three (3) observatories for the rainfall and the river water level measurements were set up by the Study Team within and near the Study area to supplement the continuous river flow data for the Study. Automatic Recorder was equipped for each observatory and stuff gauges were also installed for river water level observatories. The site of new observatories was decided taking into consideration the present distribution of existing observatories, accessibility and the site required for clarification of river flow phenomenon for the project formulation. Locations of each observatories are as follows;

Automatic Water Level Recorder

River	Village	Lat.	Lon.	EL.
Xe Pian	B. Xepian	15°07'	106°18'	1,240m
H. Makchan-Gnai	B. Nongkhung	15°09'	106°25'	1,030m
H. Tapoung	B. Dong	15°23'	106°12'	750m

Automatic Rainfall Gauge

Village	Lat.	Lon.	EL.
B. Xepian	15°07'	106°18'	1,240m
B. Vangkhanan	15°31'	105°59'	302m
B. Kele	14°47'	106°06'	106m

II RIVER RUNOFF

2.1 General

The Study area is surrounded by Nam Khong and its major tributaries, Xe Don and Xe Kong. Hydrological characteristics of those rivers identified by the Mekong Committee are as follows;

River	Drainage Area km2	Annual Rainfall mm	Annual Flow MCM	Annual Runoff mm
Nam Khong at Pakxe	545,000	2,000 at Pakxe	326,730	600
Xe Don	7,170	2,000	7,680	1,070
Xe Kong	28,500	2,250	32,200	1,130

Nine (9) major rivers in the Study area originates outskirts of Pakxong town and flows down in a radial manner to Nam Khong, Xe Don and Xe Kong. River system related to the Study area is shown in Fig. 1.2.1to 1.2.2 and the summaries are as follows;

			Basin Area km2	Length (km)			Elevation (m)			Slope	
				L1	L2	Total	EL.1	EL.2	EL.3	S1	S2
Nam Khong	Xe Don	H.Champi	639	40	28	68	100	400	1,426	0.00750	0.03664
		H.Kapheu	375	41	22	63	110	600	1,288	0.01195	0.03127
		Xe Set	1,129	48	41	89	130	400	1,426	0.00563	0.02502
		H.Namsai	359	24	23	47	195	400	1,521	0.00854	0.04874
	Xe Kong	H .Tay-Un	412	28	25	53	150	500	1,620	0.01250	0.03448
		Xe Namnoy	1,523	16	58	74	140	200	1,086	0.00375	0.01528
		Xe Pian	3,331	106	46	152	80	400	1,422	0.00302	0.02222
		H.Bangliang	505	39	14	53	95	200	1,348	0.00269	0.08200
		H.Touay	368	44	11	55	90	300	1,348	0.00477	0.09527

L1: Within a flat plain L2: Within a mountainous area EL.1: Junction point
EL.2 : Foot of mountainous area EL.3: Highest point S1: (EL.2-EL.1)/L1
S2: (EL3-EL2)/L2

2.2 Basin Rainfall

Basin areal rainfall of stated nine (9) major rivers can be estimated as tabulated below on the basis of Thiessen Polygon, average and probable annual rainfall of the selected observatories. In the column, A, E and N-E mean annual rainfall for average, probability of exceedance and probability of non-exceedance, respectively.

Observatory	Annual Rainfall (mm)			Xe Pian				H. Touay			
		Return period 1/5		Ratio	Rainfall (mm)			Ratio	Rainfall (mm)		
	A	E	N-E	%	A	E	N-E	%	A	E	N-E
Attapu	2,153	2,555	1,746	19.5	420	498	340	-	-	-	-
Pathoumphon	2,088	2,652	1,600	47.7	996	1,265	764	46.7	975	1,238	748
Pakxe	2,060	2,358	1,735	-	-	-	-	-	-	-	-
Xelabam	1,929	2,351	1,423	-	-	-	-	-	-	-	-
Khongxedon	1,658	2,146	1,485	-	-	-	-	-	-	-	-
Laongam	1,856	2,066	1,658	-	-	-	-	-	-	-	-
Salavan	2,007	2,113	1,712	-	-	-	-	-	-	-	-
Sekong	1,803	2,299	1,698	-	-	-	-	-	-	-	-
Pakxong	3,412	4,165	3,068	32.8	1,119	1,366	1,006	53.3	1,819	2,220	1,635
Total				100.0	2,535	3,129	2,110	100.0	2,794	3,458	2,383

Observatory	Annual Rainfall (mm)			H.Bangliang				H. Champi			
		Return period 1/5		Ratio	Rainfall (mm)			Ratio	Rainfall (mm)		
	A	E	N-E	%	A	E	N-E	%	A	E	N-E
Attapu	2,153	2,555	1,746	-	-	-	-	-	-	-	-
Pathoumphon	2,088	2,652	1,600	5.3	111	141	85	-	-	-	-
Pakxe	2,060	2,358	1,735	21.0	433	495	364	8.0	165	189	139
Xelabam	1,929	2,351	1,423	-	-	-	-	44.0	849	1,034	626
Khongxedon	1,658	2,146	1,485	-	-	-	-	-	-	-	-
Laongam	1,856	2,066	1,658	-	-	-	-	-	-	-	-
Salavan	2,007	2,113	1,712	-	-	-	-	-	-	-	-
Sekong	1,803	2,299	1,698	-	-	-	-	-	-	-	-
Pakxong	3,412	4,165	3,068	73.7	2,515	3,070	2,261	48.0	1,638	1,999	1,473
Total				100.0	3,059	3,705	2,710	100.0	2,652	3,222	2,238

Observatory	Annual Rainfall (mm)			H. Kapheu				Xe Set			
		Return period 1/5		Ratio	Rainfall (mm)			Ratio	Rainfall (mm)		
	A	E	N-E	%	A	E	N-E	%	A	E	N-E
Attapu	2,153	2,555	1,746	-	-	-	-	-	-	-	-
Pathoumphon	2,088	2,652	1,600	-	-	-	-	-	-	-	-
Pakxe	2,060	2,358	1,735	-	-	-	-	-	-	-	-
Xelabam	1,929	2,351	1,423	33.3	642	783	474	-	-	-	-
Khongxedon	1,658	2,146	1,485	-	-	-	-	-	-	-	-
Laongam	1,856	2,066	1,658	60.0	1,114	1,240	995	70.5	1,308	1,457	1,169
Salavan	2,007	2,113	1,712	-	-	-	-	4.5	90	95	77
Sekong	1,803	2,299	1,698	-	-	-	-	-	-	-	-
Pakxong	3,412	4,165	3,068	6.7	221	279	206	25.0	853	1,041	767
Total				100.0	1,977	2,302	1,674	100.0	2,251	2,593	2,013

Observatory	Annual Rainfall (mm)			H. Namsai				H. Tay-Un			
		Return period 1/5		Ratio	Rainfall (mm)			Ratio	Rainfall (mm)		
	A	E	N-E	%	A	E	N-E	%	A	E	N-E
Attapu	2,153	2,555	1,746	-	-	-	-	-	-	-	-
Pathoumphon	2,088	2,652	1,600	-	-	-	-	-	-	-	-
Pakxe	2,060	2,358	1,735	-	-	-	-	-	-	-	-
Xelabam	1,929	2,351	1,423	-	-	-	-	-	-	-	-
Khongxedon	1,658	2,146	1,485	-	-	-	-	-	-	-	-
Laongam	1,856	2,066	1,658	21.4	397	442	355	10.3	191	213	171
Salavan	2,007	2,113	1,712	71.4	1,432	1,509	1,223	-	-	-	-
Sekong	1,803	2,299	1,698	-	-	-	-	75.9	1,369	1,745	1,289
Pakxong	3,412	4,165	3,068	7.2	246	300	221	13.8	471	575	423
Total				100.0	2,075	2,251	1,798	100.0	2,031	2,533	1,883

Observatory	Annual Rainfall (mm)			Xe Namnoy				-			
		Return period 1/5		Ratio	Rainfall (mm)			Ratio	Rainfall (mm)		
	A	E	N-E	%	A	E	N-E	%	A	E	N-E
Attapu	2,153	2,555	1,746	50.7	1,077	1,278	873	-	-	-	-
Pathoumphon	2,088	2,652	1,600	-	-	-	-	-	-	-	-
Pakxe	2,060	2,358	1,735	-	-	-	-	-	-	-	-
Xelabam	1,929	2,351	1,423	-	-	-	-	-	-	-	-
Khongxedon	1,658	2,146	1,485	-	-	-	-	-	-	-	-
Laongam	1,856	2,066	1,658	-	-	-	-	-	-	-	-
Salavan	2,007	2,113	1,712	-	-	-	-	-	-	-	-
Sekong	1,803	2,299	1,698	31.7	572	729	538	-	-	-	-
Pakxong	3,412	4,165	3,068	18.3	624	762	561	-	-	-	-
Total				100.0	2,273	2,768	1,973	-	-	-	-

2.3 Basin Runoff

No continuous and long term river flow records are available within and adjacent the Study area except monthly basis flow regime of the Xe Set power station. Estimation of basin runoff regarding the average year, low-water year and high-water year in the Study area is preliminarily carried out using the monthly basis river flow records at Xe Set power station. Low-water year is defined as probability of non-exceedance with return period of 5 (five) years for the annual rainfall in the objective river basin. High- water year is also defined same manner as low-water year, however, the value on probability of exceedance is used instead of non-exceedance value of the low-water year.

Procedures to estimate the basin runoff is as follows;

Using the flow records of Xe Set power station
1) Estimation of average annual flow volume and monthly basis flow ratio,
2) Estimation of annual basin rainfall, and
3) Estimation of average runoff coefficient.

For the respective river basin
1) Estimation of basin areal rainfall for respective river basin,
2) Estimation of annual flow volume using the concerned river basin areal rainfall and the runoff coefficient calculated by the Xe Set basin, and
3) Monthly distribution of the annual flow volume using the flow ratio.

Average annual flow volume with monthly basis and distribution ratio of monthly flow at Xe Set power station are as follows;

Unit : MCM

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
AVERAGE	8.8	5.5	5.8	7.9	18.9	30.8	64.6	91.3	88.4	62.6	27.6	17.7	429.9
Ratio (%)	2.05	1.28	1.35	1.83	4.39	7.17	15.04	21.23	20.57	14.56	6.42	4.11	100.00

Annual basin rainfall and runoff coefficient of the Xe Set basin are as follows;

Year	Basin Rainfall (mm)	Basin Total Volume (MCM)		Coefficient
		Rainfall(a)	River Flow(b)	(b)/(a)
1989	2,223	722.5	519.6	0.72
1990	2,173	706.4	423.1	0.60
1991	2,579	838.3	530.6	0.63
1992	2,378	772.9	407.8	0.53
1993	1,712	556.6	301.2	0.54
1994	2,448	795.8	396.9	0.50
Average	2,252	732.1	429.9	0.59

Annual total flow volume of respective river in the Study area can be estimated by the basin areal rainfall, basin area and runoff coefficient. Runoff coefficient of the Xe Set basin was examined at 0.59 on an average as tabulated above, however, minimum value of 0.50 among the examined values is employed in view of conservative estimation of annual total flow volume in the Study area. Those examined runoff coefficient shows nearly same value of adjacent river basins such as 0.54 of Xe Don and 0.50 of Xe Kong basins. With these basic values, annual total flow of respective river is preliminarily calculated as follows;

River	Basin	Basin Areal Rainfall (mm)			Annual Rainfall Volume of Basin (MCM)			Annual Flow Volume of River (MCM)		
	km2	A	H	L	A	H	L	A	H	L
Xe Pian	3,331	2,535	3,129	2,110	8,444	10,422	7,029	4,222	5,211	3,515
H.Touay	368	2,794	3,458	2,383	1,028	1,272	876	514	636	438
H.Bangliang	505	3,059	3,705	2,710	1,545	1,871	1,368	772	935	684
H.Champi	639	2,652	3,222	2,238	1,693	2,058	1,430	847	1,029	715
H.Kapheu	375	1,977	2,302	1,674	740	863	627	370	431	314
Xe Set	1,129	2,251	2,593	2,013	2,541	2,927	2,272	1,271	1,463	1,136
H.Namsai	359	2,075	2,251	1,798	754	808	645	372	404	323
Xe Namnoy	1,523	2,273	2,768	1,973	3,462	4,215	3,004	1,731	2,107	1,502
H.Tay-Un	412	2,031	2,533	1,883	837	1,043	776	418	521	388
Total/Average	8,641	2,405	2,884	2,086	21,044	25,479	18,027	10,517	12,737	9,015

A : Annual average
H : High-water year (probability of exceedance, return period 5 years)
L : Low-water year (probability of non-exceedance, return period 5 years)

Monthly basis river flow volume of respective river can be generated with the distribution ratio of monthly flow at the Xe Set power station and annual total flow of respective river. Generated results are as follows;

Preliminary estimation results of monthly flow volume in average year Unit : MCM

River	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Xe Pian	86.6	54.1	56.8	77.1	185.3	302.8	634.9	896.8	868.4	614.8	271.0	173.4	4,222.0
H.Touay	10.5	6.6	6.9	9.4	22.6	36.9	77.3	109.2	105.7	74.9	33.0	21.1	514.1
H.Bangliang	15.8	9.9	10.4	14.1	33.9	55.4	116.2	164.1	158.9	112.5	49.6	31.7	772.4
H.Champi	17.4	10.8	11.4	15.5	37.2	60.7	127.3	179.8	174.1	123.3	54.3	34.8	846.7
H.Kapheu	7.6	4.7	5.0	6.8	16.2	26.6	55.7	78.6	76.1	53.9	23.8	15.2	370.2
Xe Set	26.1	16.3	17.1	23.2	55.8	91.1	191.1	269.9	261.3	185.0	81.6	52.2	1,270.7
H.Namsai	7.6	4.8	5.0	6.8	16.3	26.7	56.0	79.1	76.6	54.2	23.9	15.3	372.5
Xe Namnoy	35.5	22.2	23.3	31.6	76.0	121.4	260.3	367.7	356.0	252.0	111.1	71.1	1,730.9
H.Tay-Un	8.6	5.4	5.6	7.6	18.4	30.3	62.9	88.9	86.1	60.9	26.9	17.2	418.4
Total	215.8	134.7	141.5	191.9	461.5	754.3	1,581.0	2,263.2	2,163.2	1,531.5	675.1	432.0	10,517.8

Preliminary estimation results of monthly flow volume in high-water year Uit : MCM

River	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Xe Pian	106.8	66.7	70.3	95.4	228.8	373.6	783.7	1,106.3	1,071.9	758.7	334.5	214.2	5,210.9
H.Touay	13.0	8.1	8.6	11.6	27.9	45.6	95.7	135.0	130.8	92.6	40.8	26.1	635.8
H.Bangliang	19.2	12.0	12.6	17.1	41.0	67.0	140.6	198.5	192.3	136.1	60.0	38.4	934.8
H.Champi	21.1	13.2	13.9	18.8	45.2	73.8	154.8	218.5	211.7	149.8	66.1	42.3	1029.2
H.Kapheu	8.8	5.5	5.8	7.9	18.9	30.9	64.8	91.5	88.7	62.8	27.7	17.7	431.0
Xe Set	30.0	18.7	19.8	26.8	64.2	104.9	220.0	310.6	300.9	213.0	93.9	60.1	1462.9
H.Namsai	8.3	5.2	5.5	7.4	17.7	29.0	60.8	85.8	83.1	58.8	25.9	16.6	404.1
Xe Namnoy	43.2	27.0	28.4	38.6	92.5	151.1	316.9	447.3	433.4	306.8	135.3	86.6	2107.1
H.Tay-Un	10.7	6.7	7.0	9.5	22.9	37.4	78.4	110.6	107.2	75.9	33.4	21.4	521.1
Total	261.1	163.1	171.9	233.1	559.1	913.3	1,915.7	2,704.1	2,620.0	1,854.5	817.6	523.4	12,736.9

Preliminary estimation results of monthly flow volume in low-water year Unit : MCM

River	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Xe Pian	72.1	45.0	47.5	64.3	154.3	252.0	528.6	746.2	723.0	511.8	225.7	144.5	3,514.9
H.Touay	9.0	5.6	5.9	8.0	19.2	31.4	65.9	93.1	90.2	63.8	28.1	18	438.4
H.Bangliang	14.0	8.8	9.2	12.5	30.0	49.1	102.9	145.3	140.8	99.6	43.9	28.1	684.4
H.Champi	14.7	9.2	9.7	13.1	31.4	51.3	107.5	151.8	147.1	104.1	45.9	29.4	715.0
H.Kapheu	6.4	4.0	4.2	5.7	13.8	22.5	47.2	66.7	64.6	45.7	20.2	12.9	314.0
Xe Set	23.3	14.5	15.3	20.8	49.9	81.5	170.9	241.2	233.7	165.5	73.0	46.7	1,136.3
H.Namsai	6.6	4.1	4.4	5.9	14.2	23.1	48.6	68.5	66.4	47.0	20.7	13.3	322.8
Xe Namnoy	30.8	19.2	20.3	27.5	66.0	107.7	226.0	319.0	309.0	218.7	96.5	61.7	1,502.4
H.Tay-Un	8.0	5.0	5.2	7.1	17.0	27.8	58.4	82.4	79.8	56.5	24.9	15.9	388.0
Total	184.9	115.4	121.7	164.9	395.8	646.4	1,356.0	1,914.2	1,854.6	1,312.7	578.9	370.5	9,016.2

From the table mentioned above, water resources in the Study area depending entirely on the nine (9) major rivers can be summarized as follows;

Major 9 (nine) rivers: Total basin area is 8,641 km2

Year	Basin Rainfall (mm)	Annual Total Flow (MCM)			Annual Total Runoff (mm)		
		Total	Wet Season	Dry Season	Total	Wet Season	Dry Season
Average	2,610	10,517	8,754	1,763	1,217	1,013	204
Low-water	2,087	9,016	7,479	1,576	1,043	866	177
High-water	2,949	12,736	10,566	2,170	1,473	1,223	250

Wet Season : From May to October Dry Season : From November to April

In accordance with the MIH's development plans, water resources related to Xe Pian and Xe Namnoy are scheduled to use for new hydropower development projects among the major rivers in the Study area. Available water resources of the rivers in the Study area excluding Xe Pian and Xe Namnoy, therefore, can be estimated as follows;

Major 7 (seven) rivers: Total basin area is 3,787 km2

Year	Basin Rainfall (mm)	Annual Total Flow (MCM)			Annual Total Runoff (mm)		
		Total	Wet Season	Dry Season	Total	Wet Season	Dry Season
Average	2,811	4,564	3,786	778	1,205	900	205
Low-water	2,111	3,998	3,317	681	1,056	876	181
High-water	2,863	5,419	4,495	924	1,431	1,187	244

Wet Season : From May to October Dry Season : From November to April

2.4 River Runoff at Selected Site

(1) Monthly Flow Volume

Through the overall basin study of the Project, sixteen (16) potential sites for irrigation development were proposed. Available water resources in such specified river basins is preliminarily calculated using the estimated monthly flow of major rivers in the Study area. River flow regime on average, low-water and high-water years at the intake sites of the proposed irrigation project is as follows;

Monthly flow volume in average year Unit : MCM

Proposed Project	River basin	Basin Area	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1. Upper Champi	H.Champi	37km2	1.01	0.63	0.66	0.90	2.15	3.52	7.38	10.41	10.09	7.14	3.15	2.02	49.04
2. Upper Tapoung	Xe Set	4km2	0.09	0.06	0.06	0.08	0.20	0.32	0.68	0.96	0.93	0.66	0.29	0.19	4.50
3. Lower Xe Pian	Xe Pian	43km2	1.12	0.70	0.74	1.00	2.39	3.91	8.20	11.57	11.21	7.94	3.50	2.24	54.50
4. Upper Makchan	Xe Namnoy	31km2	0.72	0.45	0.48	0.64	1.55	2.53	5.30	7.48	7.25	5.13	2.26	1.45	35.23
5. Middle Xe Katam	Xe Namnoy	174km2	4.05	2.53	2.67	3.62	8.68	14.18	29.74	41.99	40.68	28.79	12.70	8.13	197.76
6. Middle Namlang	Xe Namnoy	51km2	1.19	0.74	0.78	1.06	2.54	4.16	8.72	12.31	11.92	8.44	3.72	2.38	57.97
7. Lower Makchan-Gnai	H Makchan-gnai	65km2	1.51	0.95	1.00	1.35	3.24	5.30	11.11	15.68	15.20	10.76	4.74	3.04	73.88
8. Lower Champi	H.Champi	249km2	6.77	4.22	4.46	6.04	14.49	23.66	49.64	70.07	67.89	48.06	21.19	13.57	330.05
9. Upper Kapheu	H. Kapheu	24km2	0.49	0.30	0.32	0.43	1.04	1.70	3.56	5.03	4.87	3.45	1.52	0.97	23.68
10. Middle Tapoung	Xe Set	59km2	1.36	0.85	0.90	1.22	2.92	4.76	9.99	14.10	13.66	9.67	4.26	2.73	66.42
11. Lower Tapoung	Xe Set	103km2	2.38	1.48	1.57	2.12	5.09	8.31	17.44	24.62	23.85	16.88	7.44	4.77	115.95
12. Lower Xe Set	Xe Set	325km2	7.50	4.68	4.94	6.70	16.06	26.23	55.03	77.68	72.56	53.27	23.49	15.04	365.88
13. Lower Namsai	H. Namsai	160km2	3.40	2.12	2.24	3.03	7.28	11.89	24.94	35.20	34.10	24.14	10.64	6.81	165.79
14. Upper Thon	H. Namsai	42km2	0.89	0.56	0.59	0.80	1.91	3.12	6.55	9.24	8.95	6.34	2.79	1.79	43.52
15. Middle Lamphan	H. Tay-Un	147km2	3.06	1.91	2.01	2.73	6.55	10.69	22.43	31.66	30.68	21.71	9.57	6.13	149.14
16. Upper Tay-Un	H. Tay-Un	22km2	0.46	0.29	0.30	0.41	0.98	1.60	3.36	4.74	4.59	3.25	1.43	0.92	22.32

Monthly flow volume in low-water year — Unit : MCM

Proposed Project	River basin	Basin Area	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1. Upper Champi	H.Champi	37km2	0.85	0.53	0.56	0.76	1.82	2.97	6.23	8.79	8.52	6.03	2.66	1.70	41.40
2. Upper Tapoung	Xe Set	4km2	0.08	0.05	0.05	0.07	0.18	0.29	0.61	0.85	0.83	0.59	0.26	0.17	4.03
3. Lower Xe Pian	Xe Pian	43km2	0.93	0.58	0.61	0.83	1.99	3.25	6.82	9.63	9.33	6.61	2.91	1.86	45.37
4. Upper Makchan	Xe Namnoy	31km2	0.63	0.39	0.41	0.56	1.34	2.19	4.60	6.49	6.29	4.45	1.96	1.26	30.58
5. Middle Xe Katam	Xe Namnoy	174km2	3.52	2.20	2.32	3.14	7.54	12.31	25.82	36.44	35.31	24.99	11.02	7.05	171.65
6. Middle Namtang	Xe Namnoy	51km2	1.03	0.64	0.68	0.92	2.21	3.61	7.57	10.68	10.35	7.33	3.23	2.07	50.31
7. Lower Makchan-Gnai	H Makchan gnai	65km2	1.31	0.82	0.87	1.17	2.81	4.60	9.64	13.61	13.19	9.34	4.12	2.64	64.12
8. Lower Champi	H.Champi	249km2	5.71	3.57	3.76	5.10	12.23	19.98	41.90	59.15	57.31	40.57	17.89	11.45	278.61
9. Upper Kapheu	H. Kapheu	24km2	0.41	0.26	0.27	0.37	0.88	1.41	3.02	4.27	4.13	2.93	1.29	0.83	20.09
10. Middle Tapoung	Xe Set	59km2	1.22	0.76	0.80	1.09	2.61	4.26	8.93	12.61	12.22	8.65	3.81	2.44	59.38
11. Lower Tapoung	Xe Set	103km2	2.13	1.33	1.40	1.90	4.55	7.43	15.59	22.01	21.32	15.09	6.66	4.26	103.67
12. Lower Xe Set	Xe Set	325km2	6.71	4.19	4.42	5.99	14.36	23.45	49.20	69.45	67.29	47.63	21.00	13.44	327.11
13. Lower Namsai	H. Namsai	160km2	2.95	1.84	1.94	2.63	6.32	10.32	21.64	30.54	29.59	20.95	9.24	5.91	143.87
14. Upper Thon	H. Namsai	42km2	0.77	0.48	0.51	0.69	1.66	2.71	5.68	8.02	7.77	5.50	2.42	1.55	37.77
15. Middle Lamphan	H. Tay-Un	147km2	2.84	1.77	1.87	2.53	6.08	9.93	20.82	29.39	28.48	20.16	8.89	5.69	138.44
16. Upper Tay-Un	H. Tay-Un	22km2	0.42	0.27	0.28	0.38	0.91	1.49	3.12	4.40	4.26	3.02	1.33	0.85	20.72

Monthly flow volume in high-water year — Unit : MCM

Proposed Project	River basin	Basin Area	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1. Upper Champi	H.Champi	37km2	1.22	0.76	0.80	1.09	2.62	4.27	8.96	12.65	12.26	8.68	3.83	2.45	59.58
2. Upper Tapoung	Xe Set	4km2	0.11	0.07	0.07	0.09	0.23	0.37	0.78	1.10	1.07	0.75	0.33	0.21	5.18
3. Lower Xe Pian	Xe Pian	43km2	1.38	0.86	0.91	1.23	2.95	4.82	10.12	14.28	13.84	9.79	4.32	2.76	67.27
4. Upper Makchan	Xe Namnoy	31km2	0.88	0.55	0.58	0.78	1.88	3.08	6.45	9.10	8.82	6.24	2.75	1.76	42.89
5. Middle Xe Katam	Xe Namnoy	174km2	4.93	3.08	3.25	4.41	10.57	17.26	36.20	51.11	49.52	35.05	15.45	9.89	240.72
6. Middle Namtang	Xe Namnoy	51km2	1.45	0.90	0.95	1.29	3.10	5.06	10.61	14.98	14.51	10.27	4.53	2.90	70.56
7. Lower Makchan-Gnai	H Makchan-gnai	65km2	1.84	1.15	1.21	1.65	3.95	6.45	13.52	19.09	18.50	13.09	5.77	3.70	89.92
8. Lower Champi	H.Champi	249km2	8.22	5.13	5.41	7.34	17.60	28.75	60.31	85.13	82.48	58.38	25.74	16.48	400.97
9. Upper Kapheu	H. Kapheu	24km2	0.57	0.35	0.37	0.50	1.21	1.98	4.15	5.86	5.67	4.02	1.77	1.13	27.58
10. Middle Tapoung	Xe Set	59km2	1.57	0.98	1.03	1.40	3.36	5.48	11.50	16.23	15.73	11.13	4.91	3.14	76.45
11. Lower Tapoung	Xe Set	103km2	2.74	1.71	1.80	2.44	5.86	9.57	20.07	28.34	27.46	19.43	8.57	5.49	133.47
12. Lower Xe Set	Xe Set	325km2	8.63	5.39	5.69	7.71	18.49	30.20	63.34	89.41	86.63	61.32	27.04	17.31	421.15
13. Lower Namsai	H. Namsai	160km2	3.69	2.30	2.43	3.30	7.90	12.91	27.08	38.23	37.04	26.22	11.56	7.40	180.06
14. Upper Thon	H. Namsai	42km2	0.97	0.60	0.64	0.86	2.07	3.39	7.11	10.03	9.72	6.88	3.03	1.94	47.26
15. Middle Lamphan	H. Tay-Un	147km2	3.81	2.38	2.51	3.40	8.16	13.33	27.96	39.46	38.24	27.07	11.93	7.64	185.89
16. Upper Tay-Un	H. Tay-Un	22km2	0.57	0.36	0.38	0.51	1.22	1.99	4.18	5.91	5.72	4.05	1.79	1.14	27.82

(2) Flood Discharge

Estimation of flood discharge of the river is made with return period of 5 and 10 years taking the design condition of project facilities into account. As for the H. Lamphan, return period 200 years is also estimates because the site has possibility to construct the dam facilities as the intake. Due to the lack of historical flood records, Rational formula is employed for estimation of flood discharge at the proposed intake site. In the formula, following condition is applied ;

Runoff coefficient : 0.5
Arrival time of flood : Rziha's formula
Rainfall intensity within an arrival time of flood : $(R24/24)(24/T)^{0.5}$
R24 : Probable daily rainfall
T : Arrival time of flood

Estimated results are as follows;

Peak flood discharge at the selected site

Project Site	Probable Daily Rainfall mm/day			Arrival Time of Flood Hour			Rainfall Intensity mm/hour			Peak Flood Discharge m3/sec		
	1/5	1/10	1/200	L (km)	H (km)	T (hr)	1/5	1/10	1/200	1/5	1/10	1/200
1. Upper Champi	226.4	283.5	-	12	0.19	2.0	32.7	41.0	-	168.3	210.7	-
2. Upper Tapoung	206.5	257.6	-	3	0.02	0.8	48.5	60.5	-	27.0	33.6	-
3. Lower Xe Pian	189.3	227.1	-	18	0.38	2.5	24.3	29.2	-	145.3	174.3	-
4. Upper Makchan	148.7	179.0	-	10	0.20	1.5	25.1	30.3	-	108.3	130.4	-
5. Middle Xe Katam	148.7	179.0	-	29	0.72	3.7	15.8	19.0	-	381.4	459.1	-
6. Middle Namtang	148.7	179.0	-	18	0.31	2.9	17.9	21.6	-	127.2	153.1	-
7. Lower Makchan-Gnai	148.7	179.0	-	27	0.47	4.3	14.7	17.7	-	132.7	159.7	-
8. Lower Champi	226.4	283.5	-	46	1.21	2.6	19.4	24.3	-	670.9	840.1	-
9. Upper Kapheu	192.1	238.7	-	15	0.36	2.0	28.1	34.9	-	93.5	116.2	-
10. Middle Tapoung	206.5	257.6	-	16	0.42	2.0	30.1	37.5	-	246.6	307.6	-
11. Lower Tapoung	206.5	257.6	-	26	0.69	3.2	23.7	29.5	-	338.4	422.2	-
12. Lower Xe Set	206.5	257.6	-	45	0.98	6.2	16.9	21.1	-	764.1	953.1	-
13. Lower Namsai	176.3	210.8	-	31	1.34	2.8	21.4	25.6	-	475.1	568.1	-
14. Upper Thon	176.3	210.8	-	12	0.44	1.2	32.7	39.1	-	190.7	228.1	-
15. Middle Lamphan	122.0	153.2	314.9	20	0.60	2.3	16.5	20.7	42.6	337.3	423.5	870.6
16. Upper Tay-Un	122.0	153.2	-	13	0.58	1.2	23.1	29.0	-	70.6	88.7	-

The 100-year return period flood discharge at the Xe Set power station has been calculated as 1,000 m^3/sec with drainage area of 325 km^2. Also, 840 m^3/sec of flood discharge has been estimated at the Xe Katam Project under the condition of return period 100-year and drainage area of 290 km^2. The H. Lamphan basin in the Study area, those flood discharge with return period 100-year comes 754 m3/sec with drainage area of 147 km^2.

III WATER QUALITY

3.1 Water Sampling

Establishment of improvement plan of rural infrastructure as well as agricultural development plan is the main purpose of the Study to elevate the standard of living of the rural habitants. Drinking water supply for the rural area is one of the major component of the improvement plan. With these basic consideration, the location of water sampling for the water quality analysis is selected at the present source of drinking water and the possible site for the water source in the improvement plan. Twenty-one (21) sites of water sampling mentioned below were conducted in May 18 and 19, 1995 and those quality analysis entrusted to the Laboratory of Water Quality Analysis, MAF in Vientiane.

No.	Village	Water Source	No.	Village	Water Source
1	Pakxong	Dug well without pump	12	Nkh L. 4	H.Sai
2	Pakxong	H.Champi upstream	13	B.SiXiangmai	H.Kapheu
3	B.Lak 40	Tributary of H.Hin	14	B.Kengkia	H.Kapheu
4	B.Lak 38	Tributary of H.Champi	15	B.Houakhua	Xe Set
5	B.Lak 30	H.Koy (H.Bangliang)	16	B.Nonglao-lum	H.Phan
6	Nkh L. 34	H.Makchan-Gnai	17	B.Iaomgam	H.Tapoung
7	B. Houaykong	H.Makchan-Gnai	18	B.Palai	H.Palai
8	B.Xe Pian	Xe Pian	19	B.Bachiang	H.Champi
9	B.Tongset	Borehole with handpump	20	B.Thateng	H.Namsai
10	B.mai	Borehole with handpump	21	B.Khamkok	Spring, H.Tit basin
11	B.Katouat	Tributary of Xe Set	-	-	-

3.2 Water Quality Analysis

Items analyzed at the laboratory are; pH, electric conductivity (EC), suspended sediment (S.S.), coliform group, chemical oxygen demand (COD) and chemical analysis for NO3-N, Ca2+, Mg2+, Mn2+, Fe2+, Cu,Cl- . Results of analysis and MAF standard for drinking water are shown below;

Sample No.	pH	EC mS/m	S.S. mg/l	Coliform col./100ml	COD mg/l	NO3-N mg/l	Ca2+ meq/l	Mg2+ meq/l	Mn2+ mg/l	Fe2+ mg/l	Cu mg/l	Cl- meq/l
1	5.56	4.30	0	2	0.156	1.354	0.124	0.213	0.030	0.086	0.024	0.062
2	6.58	4.60	9	107	1.407	0.003	0.151	0.218	0.030	0.264	0.030	0.008
3	6.61	2.00	1	7	0.801	0.317	0.117	0.049	0.030	0.178	0.004	0.019
4	5.80	1.22	3	0	2.502	0.081	0.032	0.080	0.030	0.515	0.028	0.014
5	5.78	1.39	6	0	0.657	0.025	0.093	0.024	0.082	0.426	0.023	0.017
6	7.06	5.40	4	2	1.673	0.367	0.221	0.267	0.030	0.302	0.027	0.009
7	7.06	4.72	6	0	5.446	0.010	0.186	0.223	0.030	0.167	0.032	0.007
8	6.90	4.21	3	13	1.407	0.001	0.131	0.281	0.060	0.157	0.034	0.021
9	5.78	6.52	7	0	0.078	1.508	0.203	0.301	0.030	0.183	0.034	0.076
10	6.26	17.7	5	0	0.129	0.004	0.878	0.829	0.384	1.128	0.040	0.009
11	6.36	7.63	0	4	1.016	0.258	0.268	0.402	0.030	0.205	0.014	0.020
12	6.99	5.8	4	17	2.260	0.005	0.280	0.238	<0.001	0.281	<0.001	0.009
13	6.87	4.6	5	0	1.161	0.004	0.174	0.208	0.030	0.162	0.006	0.025
14	6.97	6.7	8	9	2.182	0.053	0.301	0.257	<0.001	0.736	<0.001	0.016
15	7.00	4.75	7	0	2.483	0.041	0.203	0.202	<0.001	0.210	<0.001	0.027
16	7.02	14.9	13	12	5.063	0.193	0.566	0.741	<0.001	0.400	0.001	0.057
17	7.15	8.7	6	0	1.650	0.054	0.320	0.395	0.030	0.389	<0.001	0.019
18	7.09	4.5	1	0	2.189	0.070	0.202	0.148	<0.001	0.162	<0.001	0.020
19	7.04	4.4	1	19	2.162	0.007	0.211	0.139	<0.001	0.373	<0.001	0.023
20	7.12	9.9	4	0	5.173	0.075	0.471	0.415	0.030	0.232	<0.001	0.006
21	6.20	7.9	1	0	1.099	0.152	0.285	0.507	<0.001	0.076	0.022	0.027
Standard	5.8-8.6	-	2	100	-	10	15(*1)	24.7(*2)	0.3	0.3	1.0	5.8(*3)

(*1) : 200ppm=(200/35.45)=5.8 meq/l
(*2) : 300ppm=(300/20.04)=15 meq/l
(*3) : 300ppm=(300/12.16)=24.7 meq/l

Following are the results of analysis for the sampled water. In the analysis, water utilization not only drinking water but also irrigation purpose is verified.

(1) pH

Analyzed pH ranges from 7.15 to 5.56. Those value show from neutrality to weak acidity. Among the samples, shallow well , spring and surface water of H.Champi basin indicate weak acidity. Because the desired level of pH for drinking water is from 5.8 to 8.6 according to the MAF Standard, shallow well and surface water in the surrounding area of Pakxong town shown at 5.56 to 5.78 of pH values are lower than the Standard value. However, utilization of those water source without treatment for drinking water is not a subject taking into account the time of sampling which is the end of the dry season and the insignificant difference of value between the Standard and the analyzed results. Monitoring will, however, be required to clarify the transition of pH values for utilization as the water source. As for the irrigation use, desirable pH of irrigation water ranges from 5.5 to 7.5 on an average. Therefore, no treatment of water will be required for irrigation use.

(2) Electric Conductivity (E.C.)

E.C. values ranges from 4.4 to 17.7 mS/m. Generally, irrigation water having more than 30 mS/m of E.C. value arises a decrease of agricultural productivity. Being within the limit of E.C. value, all sampled water can be used for irrigation purpose.

(3) Suspended Sediments (S.S.)

An allowable extent of suspended sediment in water is less than 2 mg/l for drinking water in the Standard. Analyzed values of S.S. ranges 0 to 13 mg/l and most of surface flow exceeds the Standard value. Those results show the requirement of stilling basin for the intake facility in case that the surface flow is used as the drinking water source. On the contrary, an allowable value for irrigation is less than 50 mg/l. No special consideration is required for utilization regarding the suspended sediments of river flow.

(4) Coliform Group

Desired level of coliform group in the MAF Standard is less than 100 colonies/ml. Only one site, upstream of H. Champi, exceeds permissible level of coliform group among the analyzed samples. Water sampling at upstream of H.Champi is made at the reservoir of micro-hydropower station at Pakxong. Washing and taking a bathe are practiced by the rural habitants in the reservoir and those activities are being progressed the contamination of reservoir water especially in the dry season.

(5) Chemical Oxygen Demand (COD)

No desirable level of COD is mentioned in the MAF Standard. Generally, suspended sediment shows volume index of inorganic substance in the unit quantity of water and COD is a quantity of organic substance. An allowable extent of COD is less than 6 mg/l for irrigation use and analyzed results of all samples shows lower values such an allowable extent.

(6) Chemical Analysis

From the analyzed results of dissolved ions, around half of water samples exceed the Standard for iron ion of drinking water. Shallow well in B.Mai exceeds the Standard value of both iron and manganese ions. When surface and well water in the Study area utilize as the water source of drinking water within a desired level of the Standard, iron and/or manganese removal will be required according to the location of intake site. Individual or combination facilities among the pre-chlorination, aeration, chemical precipitation and filtration will be required as the removal facility for iron and manganese.

As the summary of the water quality in the Study area, both surface and well water can basically be used for irrigation and drinking purpose. However, some well and surface water exceed allowable extent of the Standard for drinking water regarding the coliform group, dissolved ions especially iron and manganese and treatment will be required when those water utilize as the drinking water source.

VI GROUNDWATER

4.1 General

Ministry of Health is now carrying out the Study on Groundwater Development for Champasak and Salavan Provinces under the technical cooperation of JICA. Purpose of the study is to formulate a groundwater development plan for village water supply in Champasak and Salavan provinces. The study includes observation of groundwater level, test boring and evaluation of groundwater potential. To grasp the groundwater potential of the Boloven Plateau and its adjacent areas, interim results of the study are quoted for the Study.

During the course of the Phase I field study of the Project, shallow wells located in the Pakxong town were selected as the bench mark well to confirm the seasonal water level fluctuation in the highland areas of the Plateau. Water level observation of selected wells is being continued and results will be analyzed during the succeeding Phase III field study of the Project.

4.2 Quantity and Quality

Geological feature of the Study area is characterized by basalt lava flows underlain by Jurassic shale. Basaltic rocks of Tertiary and Quaternary ages are sporadically distributed in Boloven Plateau. Rocks consisting of alkali basalt lava were formed during volcanic activities in Pliocene to Pleistocene age.

Based on the topography and geology, ten (10) hydrogeologic units and four (4) ranks of qualitative groundwater potential are set up in the study area. Table below shows those hydrogeologic units and the rank of groundwater potential.

Unit	Topography and Geology	Aquifer	I GL -m	II m3/day/m	III A to D
Qf	Flood plain, Accumulation terrace. Sand, Silt & Clay, Jurassic shales.	Quaternary sand. Jurassic sandstone.	6-13	14-128 -	A
Qt	Alluvial fan, Talus slope Sand, Silt, Jurassic shales.	Sand. Jurassic sandstone.	7-8	- -	C
Ba1	Basalt slope. Basalt lava flows, Ash, Loam, Lava.	N-Q Basalt lava. Weathered basalt lava.	20-35	3-20 -	B-C
Ba2	Basalt slope. Basalt lava flows.	N-Q Basalt lava. Autobrecciated lava.	13-24	- 1700-1900	A
Ba3	Basalt slope. Basalt lava flows, Jurassic shales.	Pg Basalt lava. Jurassic sandstone.	4-12	- 19.1	B
Ep	Erosional plain. Jurassic red shale, Sandstone.	Jurassic sandstone. Sandyshale.	7-12	3-166	B
Eh	Erosional hill. Jurassic red shale, Sandstone.	Jurassic sandstone. Conglomerate.	9-20	1-17.3	B-C
Et1	Erosional terrace. Triassic acidic welded tuff, Dacite.	Fissured aquifer.	8-15	4.6 -	B-C
Et2	Erosional terrace. Paleozoic slate, Sandstone	Fissured aquifer.	8-17	36.9	B
P	Plateau, High plain. Jurassic Creta, Sandstone, Shale.	Sandstone. Locally fissured aquifer.	Low	-	C
M	Mountains. Metasediments, Plutonic rocks.	Fissured aquifer. Sand, Silt in Valleys.	Low-High	-	C-D

I : Groundwater Level II : Specific Capacity
III : Groundwater Potential (A : high, B : medium, C : low D : no potential)

Entire part of the plateau, Pakxe, Batiang and the eastern part of Laongam belongs to Ba1 of hydrogeologic unit in the Study area. As the other hydrogeologic units distributed in the Study area, Ba2 is the western part of Laongam, Ba3 is Thateng, Ep is Salavan and P for the Xe Namnoy basin. Hydrogeologic map of the study area is shown in Fig. 1.4.1.

Detailed information of each hydrogeologic unit is as follows;

Ba1 : Unit if underlain by thick volcanic ash and mudflow with boulders. The groundwater table is deep. Unconfined water or perched water exists in the sediments.

Ba2 : Thin volcanic deposits cover the surface. Unconfined or perched water exist in the sediments. The basalt lava constitutes the hydrogeologic basement, however confined groundwater may exist in the lower basalt lava.

Ba3 : No surface deposition is found on the slope. Groundwater may exist in the fissure. Underlying Jurassic shale may have confined groundwater.

Ep : Unit is an erosion plain with no surface deposition. Jurassic shale crops out on the surface. The weathered zone of shale constitutes an aquifer. Groundwater table is shallow. Confined groundwater may exist in deeper layers.

P : Unit consists of gently undulated plain, and in higher elevation, it is composed of hard formation. Groundwater may exist in the fissure.

Water quality analysis has been made at 50 points in the Study on Groundwater

Development for Champasak and Salavan provinces. Around half of sampled water exceeds the Standard regarding the chemical components of iron(Fe), manganese (Mn) and nitrate (No3). In biological components, analyzed value of coliform group and bacteria exceed the Standard value especially in the wet season.

PART 2 FEASIBILITY STUDY

I CLIMATE

1.1 General

Through the Master Plan study of the project , five (5) areas were selected as the priority areas to execute the feasibility study on the agricultural and rural development in the study area. Prior to settle the such priority areas, meteorological observation network in and around the study area, observed meteorological items and its recording periods were clarified to set up the representative meteorological observatories for the study and to provide basic data for the formulation of various schemes of the project.

1.2 Climatic Condition

(1) Application of meteorological data for the selected priority area

Meteorological items such as temperature, relative humidity, sunshine hours and wind speed are essential to estimate the potential evapo-transpiration of crops. Also rainfall data are indispensable for estimation of irrigation demand. Taking these basic requirements and data availability into account, representative meteorological stations of the project area were selected at Pakxe, Salavan and Pakxong in and around the study area. For each selected priority area, application of the meteorological data excluding rainfall data is made with the stand points of elevation, slope direction of the plateau and location in the Thiessen Polygon. Applied meteorological observatory for the priority area is as follows;

Priority Area	Meteorological Observatory
Upper Champi Project area	Pakxong Observatory
Upper Tapoung Project area	Pakxong Observatory
Upper Kapheu Project area	Salavan Observatory
Lower Xe Set Project area	Salavan Observatory
Upper Tay-un project area	Salavan Observatory

(2) Pakxong Observatory

Pakxong observatory locates central part of the plateau and its elevation is 1,200 m in MSL. Observation is started in 1986 and observed items are temperature, relative humidity, dew point, rainfall, duration of sunshine, wind direction and speed. Reflecting the topographical condition such as top of plateau and high elevation, general climate surrounding areas of Pakxong is characterized as the cool weather and much rainfall. Mean annual temperature is 19.5 °C and over 3,000 mm of rainfall is observed during the rainy season. Annual mean sunshine hours is 5.1 hours, however, less than 3 hours a day continues at the mid rainy season in July and August. General features of the climatic condition of Pakxong observatory are shown in a section of Master Plan study.

Since no evaporator is available at Pakxong observatory, simplified A-pans have been manufactured at Pakxe and set in the Pakxong and KM42 observatories during the Master Plan study of the project. Observation by the staff of observatory has been started June 12, 1995. Monthly basis measured values are as follows;

Unit: mm

Station	Evaporator	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Pakxong	A-pan	87.8	86.8	68.5	76.6	90.1	107.9	87.5	101.4	118.3
KM42	- do -	71.2	77.1	60.8	67.1	66.5	94.1	65.1	71.9	105.5
Pakxe	- do -	-	-	-	-	-	-	162.0	179.7	197.2
Pakxe	Piche	70.7	76.8	60.3	83.1	117.2	169.3	176.7	193.4	242.1
Nikhom34	- do -	43.8	39.1	33.2	45.6	29.5	57.6	56.2	69.2	79.8
KM42	- do -	10.7	11.6	8.8	14.2	17.4	21.3	25.2	23.7	28.9

Compared with the A-pan values of Pakxe observatory located in the lowland area, monthly basis evaporation values of Pakxong show around 55 % and 40 % in KM42.

(3) Salavan Observatory

Salavan observatory locates northern part of the plateau and its elevation is around 200 m in MSL. Observation is started in 1980 and observed items are temperature, relative humidity, dew point, rainfall, duration of sunshine, evaporation, wind direction and speed. Because observatory locates in a flat flood plain developed by Nam Khong, mean annual temperature is 26.8 °C and around 2,000 mm of rainfall is observed during the rainy season. Annual mean sunshine hours is 6.3 hours, however, more than 7 hours a day continues at the mid dry season in February and March. General features of the climatic condition of Salavan observatory are shown in a section of Master Plan study.

(4) Other Reference Observatories for Meteorological Data

In connection with the selected priority areas, following meteorological observatories can be positioned as the reference observatories taking its location and elevation into account. Observed meteorological items of those observatories are limited such as rainfall, temperature and humidity.

Priority Area	Reference Meteorological Observatory
Upper Champi Project area	KM 42 Observatory
Upper Tapoung Project area	-
Upper Kapheu Project area	Laongam Observatory
Lower Xe Set Project area	Laongam & Thateng Observatories
Upper Tay-un project area	Thateng Observatory

Average observed values of reference observatories are as follows;

Observatory : KM42 EL.: 1,160 m (Data Period: 1983 to 1995)

Item	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Rainfall (mm)													
Ave.	8.9	10.2	83.6	205.6	344.1	569.3	580.3	873.2	467.1	247.4	87.0	12.8	3489.4
Temperature (℃)													
Mean	20.1	21.7	22.7	23.3	22.7	21.7	21.4	21.0	21.5	21.2	20.3	19.7	21.4
Relative Humidity (%)													
Mean	67	70	74	80	84	90	89	91	88	83	77	71	80

Observatory : Laongam EL.: 500 m (Data Period: 1992 to 1994)

Item	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Rainfall (mm)													
Ave.	10.7	3.3	43.5	77.9	245.8	247.5	358.7	366.7	281.8	145.8	6.6	1.9	1790.1
Temperature (℃)													
Mean	22.1	25.1	27.1	27.6	27.0	25.9	24.9	24.8	25.0	23.9	22.9	21.5	24.8
Relative Humidity (%)													
Mean	62	58	60	59	71	77	81	84	83	77	70	68	71

Observatory : Thateng EL.: 800 m (Data Period: 1993 to 1995)

Item	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Rainfall (mm)													
Ave.	0.5	21.5	45.8	145.4	416.0	252.7	439.4	368.3	303.8	103.5	13.2	13.2	2123.2
Temperature (℃)													
Mean	18.8	20.2	23.8	25.8	25.4	25.8	24.9	25.3	25.5	23.8	22.5	21.4	23.6
Relative Humidity (%)													
Mean	72	73	77	74	83	86	93	89	89	92	87	84	83

1.3 Rainfall

(1) Application of rainfall data for the selected priority area

In the calculation of irrigation water requirement, estimated amounts of the effective rainfall in the objective irrigation areas influences noticeably to the total irrigation demands of the objective areas. Since the selected priority areas distribute in the central, north-western and northern parts of the plateau, rainfall amounts and its patterns differ with the elevation, slope direction of the plateau, etc. To estimate irrigation demands more accurately, rainfall data should be selected with the extents reflected the configurations of objective area because rainfall observation network in and around the plateau is constructed densely compared with the meteorological observation network. Taking these conditions into account, area division delineated by the Thiessen Polygon is applied for the selection of rainfall data on the irrigation area of each priority area. Application of rainfall observatory for the selected priority area is as follows;

Priority Area	Meteorological Observatory
Upper Champi Project area	Pakxong observatory
Upper Tapoung Project area	Pakxong observatory
Upper Kapheu Project area	Laongam observatory
Lower Xe Set Project area	Laongam observatory
Upper Tay-un project area	Sekong observatory

Average monthly rainfall in recent five years (1991 to 1995) of the selected rainfall stations is as follows;

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Packing													
	13.7	19.9	122.9	210.0	295.3	491.9	790.5	774.7	425.7	139.7	32.8	32.6	3349.7
Laongam													
	11.1	4.5	23.4	57.6	208.4	246.9	362.8	393.1	310.7	136.0	4.6	1.1	1760.0
Sekong													
	13.9	43.9	135.3	106.1	206.0	225.6	270.3	311.0	242.3	158.2	149.1	82.5	1620.3

(2) Other Reference Observatories for Rainfall Data

The same observatories for the meteorological data as described in the previous section are employed for the reference observatories of rainfall records related to the selected priority areas. The observed rainfall value is also shown on the table in the previous section.

II RIVER RUNOFF

2.1 Basic Data

Due to insufficiency of the river flow record in and around the study area, water resources of the specified river basin in the study area have been evaluated preliminarily based on the mean monthly flow records of Xe Set power station during the Master Plan Study of the project. Taking these data availability and required runoff data for the further study into consideration, water level observation and discharge measurement on three rivers in the study area have been started by the study team at the end phase of Master Plan Study of the project.

Five (5) priority project sites were proposed to execute the feasibility study through the overall basin study of the project for agricultural and rural development. Hydrological aspects in the feasibility study is focused to prepare the long term river discharge record in these priority project sites to clarify the available water resources for the project.

During the Feasibility Study stage, observed water level records and discharge record to construct the H-Q curve were thoroughly checked and prepared continuous runoff record for the respective rivers. In addition to these observation records, daily inflow data at the intake site of the Xe Set power station were obtained through the analysis of daily power generating records at the station. With these continuous river discharge records available in the study area, construction of the runoff model and reproduction of runoff were made on the respective rivers for the project formulation.

2.2 Runoff Model

The purpose of the construction of runoff model is the reproduction of river runoff in the selected priority area. To meet these requirements, Sugawara's Tank Model Method is employed to construct the basic rainfall-runoff model of the project.

Taking the location of rivers having available continuous discharge records and the objective priority area, two runoff models were constructed and the application of these models for the objective priority area is as follows;

Model A : runoff model calibrated using the discharge record at H.Tapoung
basin area : 73.0 km^2
basin areal rainfall : Pakxong 56%, Laongam 44%
priority area to be applied
Upper Champi Project area .... H. Champi
Upper Tapoung Project area .... H. Tapoung
Upper Kapheu Project area .... H. Kapheu

Model B : runoff model calibrated using the discharge record at Xe set power station
basin area : 325.0 km^2
basin areal rainfall : Pakxong 68%, Laongam 32%
priority area to be applied
Lower Xe Set Project area .... downstream catchment area
Upper Tay-Un project area .... H. Tay-Un & H. Thong

For model calibration, rainfall and discharge data were used from May, 1995 to January, 1996 for the model A and from January to December in 1995 for the model B. The calibration was focused to suit on the recession curve of the hydro-graph of annual runoff and the annual total runoff volume of the observed records. Constructed model and its multiplier are shown in Fig.2.2.1 and calibration results with the daily basis are shown in Fig. 2.2.2. Correlation factors between observed and estimated discharges are as follows;

Model A	cumulative discharge	....	0.9139
	daily basis discharge	....	0.9979
Model B	cumulative discharge	....	0.9443
	daily basis discharge	....	0.9987

2.3 Flow Regime of Rivers in the Selected Priority Area

Using the constructed run-off model and the basin areal rainfall, reproduction of river runoff related to the priority area is made with daily basis. The duration of reproduction is ten (10) years from 1986 to 1995.

Following areal ratio of point rainfall is used for the river basin of priority area on the basis of Thiessen Polygon delineated in and around the study area.

Priority Area	River	Basin Area	Areal Ratio (%)		
		(km^2)	Pakxong	Laongam	Sekong
Upper Champi	H. Champi (47)	16.0	100	-	-
	H. Champi (43)	36.0	100	-	-
Upper Tapoung	H. Tapoung	4.0	100	-	-
Upper Kapheu	H. Kapheu	24.0	75	25	-
Lower Xe Set	Xe Set (dam)	325.0	68	32	-
	Xe Set (down)	88.0	-	100	-
Upper Tay-Un	H. Tay-Un	21.0	-	57	43
	H. Thong	8.0	-	25	75

Mean monthly rainfall values for each river basin at the intake site are shown in Table 2.2.1 from 1986 to 1995. When the point rainfall data are missing and/or nothing in the objective periods, these data were compensated with the correlation equation constructed by the rainfall data of neighboring observatories. Average values are as follows based on the point rainfall and areal ratio mentioned above;

Unit: mm

	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
H.Champi 47 & 43, H. Tapoung	10.7	23.5	101.0	237.3	343.3	467.0	679.8	757.3	412.2	209.2	31.2	18.4	3,291.0
H. Kapheu	10.4	20.5	86.6	204.9	320.6	415.3	600.9	671.5	375.4	197.1	25.4	14.2	2,942.6
Xe Set	10.1	17.8	74.2	177.0	301.0	370.8	533.2	597.8	343.8	186.7	20.3	10.7	2,643.3
H. Tay-Un	9.5	20.1	66.1	125.0	248.2	264.1	352.5	414.1	264.8	168.7	41.2	19.4	1,993.8
H. Thong	9.7	26.6	83.2	138.0	245.2	267.2	343.7	414.0	264.7	174.7	66.0	32.5	2,065.4

Runoff calculation results for objective rivers are shown in Table 2.2.2 with monthly mean discharge basis. Summary of the calculation results are shown below. In the column, droughty, low-water, ordinary discharges mean that the discharge occurs more than 355, 275 and 185 days in a year, respectively.

H. Champi (Lak 47)   A= 16.0 km²

Unit : m³/sec

Discharge	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Average
Droughty	0.118	0.117	0.155	0.091	0.104	0.102	0.125	0.093	0.123	0.170	0.120
Low-water	0.243	0.262	0.314	0.230	0.229	0.272	0.226	0.194	0.309	0.277	0.256
Ordinary	0.602	0.528	0.579	0.622	0.546	0.651	0.464	0.357	0.701	0.438	0.549

Upper Champi Project area

H. Champi (Lak 43)   A= 36.0 km²

Unit : m³/sec

Discharge	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Average
Droughty	0.266	0.263	0.349	0.205	0.234	0.230	0.281	0.209	0.277	0.382	0.270
Low-water	0.547	0.590	0.706	0.518	0.515	0.612	0.508	0.436	0.695	0.623	0.575
Ordinary	1.354	1.188	1.303	1.400	1.228	1.465	1.044	0.803	1.577	0.986	1.235

Run-of-river type mini-hydro power station is now operating on the river course of H. Champi at Pakxong town (3 km upper stream reach of Lak 47). During the dry season (from December to April), power operation is performed with 25 KVA generator. Operation hours are limited for 8 to 12 o'clock in the morning and 6 to 10 or 12 o'clock in the evening. From the effective water head (Max. 9.2m, Min. 5.2m) and installed capacity (25 KVA in the dry season, 87 KVA in the rainy season) of the power station, outflow from the power station during the operation can roughly be estimated from 0.35 m³/sec to 0.60 m³/sec in the dry season and from 1.20 m³/sec to 2.10 m³/sec in the rainy season.

Upper Tapoung Project area

H. Tapoung   A= 4.0 km²

Unit : m³/sec

Discharge	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Average
Droughty	0.030	0.029	0.039	0.023	0.026	0.026	0.031	0.023	0.031	0.042	0.030
Low-water	0.061	0.066	0.078	0.058	0.057	0.068	0.056	0.048	0.077	0.069	0.064
Ordinary	0.150	0.132	0.145	0.156	0.136	0.163	0.116	0.089	0.175	0.110	0.137

Upper Kapheu Project area

H. Kapheu   A= 24.0 km²

Unit : m³/sec

Discharge	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Average
Droughty	0.151	0.149	0.197	0.120	0.156	0.101	0.161	0.106	0.146	0.197	0.148
Low-water	0.326	0.346	0.401	0.317	0.343	0.300	0.293	0.242	0.353	0.334	0.325
Ordinary	0.804	0.682	0.770	0.847	0.818	0.770	0.617	0.456	0.857	0.540	0.716

Lower Xe Set Project area

Dam   A= 325.0 km²

Downstream catchment area   A= 88.0 km²

Unit : m³/sec

Discharge	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Average
Droughty	1.916	2.107	2.760	1.831	1.673	2.373	1.916	2.090	1.588	1.894	2.015
Low-water	3.877	4.565	4.756	4.010	3.107	3.798	3.300	3.116	3.487	3.128	3.714
Ordinary	15.850	10.140	12.486	14.451	10.173	10.057	5.886	5.412	9.447	5.990	9.987

In case of Lower Xe Set project area, runoff at the intake site consists of outflow from the power station and the runoff from the downstream catchment area of Xe Set dam. Calculation using the runoff model was, therefore, made only for the downstream catchment area. Outflow records from the power station were employed for setting up the available discharge at the intake site. According to the operation record of Xe Set power station, entire inflow to the reservoir consumes for the power generation within a same day. During the dry season, however, inflow to the reservoir is stored (Max. volume 0.37 MCM) in day-time and used for power generation in night-time. Operation hours for such cases are limited within 3 to 5 hours in a day. Taking these operation procedures of the power station into account, construction of the regulating pond will be required to deliver the irrigation water continuously.

Upper Tay-Un project area

H. Tay-Un A= 21.0 km^2

Unit : m^3/sec

Discharge	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Average
Droughty	0.166	0.164	0.176	0.122	0.097	0.153	0.164	0.113	0.099	0.019	0.127
Low-water	0.254	0.284	0.277	0.221	0.170	0.204	0.237	0.170	0.160	0.111	0.209
Ordinary	0.607	0.405	0.470	0.489	0.359	0.386	0.300	0.374	0.260	0.210	0.386

H. Thong A= 8.0 km^2

Unit : m^3/sec

Discharge	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Average
Droughty	0.070	0.070	0.075	0.053	0.050	0.076	0.072	0.046	0.050	0.017	0.058
Low-water	0.106	0.118	0.114	0.092	0.081	0.108	0.091	0.066	0.071	0.048	0.078
Ordinary	0.245	0.166	0.192	0.202	0.150	0.182	0.121	0.201	0.107	0.097	0.166

From the calculation results, occurrence of droughty discharge varies from February to May depending on the rainfall amount in the last wet season and/or rainfall during the dry season. River basins consisting hyetal region of Pakxong observatory such as H.Champi, H.Tapoung and H.Kapheu, show stable and high specific discharge during the dry season compared with the river basins consisting hyetal region except Pakxong observatory.

During the course of the field survey, discharge measurements has been carried out at the each intake site of the priority area and those results are shown below;

River	Basin Area km2	Date	Q m3/sec	q m3/sec/km2
H.Tay-Un	21.0	Feb.12,1996	0.015	0.001
		Feb.20,1996	0.016	0.001
		Feb.26,1996	0.019	0.001
H.Thong	8.0	Feb.12,1996	0.039	0.005
		Feb.20,1996	0.030	0.004
		Feb.26,1996	0.064	0.008
H.Kapheu	24.0	Feb.13,1996	0.309	0.013
		Feb.21,1996	0.336	0.014
		Feb.27,1996	0.265	0.011
H.Tapoung	4.0	Feb.13,1996	0.053	0.013
		Feb.21,1996	0.083	0.021
		Feb.27,1996	0.053	0.013
H.Champi (Lak.47)	16.0	Feb.13,1996	0.237	0.015
		Feb.21,1996	0.240	0.015
		Feb.27,1996	0.271	0.017
H.Champi (Lak.43)	36.0	Feb.13,1996	0.480	0.013
		Feb.21,1996	0.669	0.019
		Feb.27,1996	0.804	0.022

From the comparison between mean monthly value of the estimated discharge by the constructed runoff model and the observed discharge at the intake site, both discharges can be recognized in a same extent except the value of H. Tay-Un. To verify the such discharge differences of H. Tay-Un, runoff calculation for January and February in 1996 were carried out additionally using the constructed runoff model for Xe Set basin. As the results, mean monthly discharges were estimated at 0.070 m³/sec for January and 0.020 m³/sec for February. Thus, the same discharge extent on estimation and observation values were obtained at the intake site of H. Tay-Un reflecting the little rainfall during the last rainy season and no rainfall in the succeeding dry season.

2.4 Flood Discharge

2.4.1 Flood discharge at the intake site

Flood discharge at the intake site of selected priority areas is estimated by the rational formula. Probable daily rainfall is employed for setting up the rainfall intensity during the arrival time of flood. From the point rainfall records and the Theissen Polygon, daily rainfall of the priority area in each probable year is as follows;

Intake Site	Area Ratio (%)			Probable Daily Rainfall (mm/day)					
	Pakxong	Laongam	Sekong	1/5	1/10	1/30	1/50	1/100	1/200
H. Champi(47)	100	-	-	272.1	343.1	464.4	525.5	614.0	709.2
H. Champi(43)	100	-	-	272.1	343.1	464.4	525.5	614.0	709.2
H. Tapoung	100	-	-	272.1	343.1	464.4	525.5	614.0	709.2
H. Kapheu	75	25	-	250.6	315.2	424.7	479.5	558.6	643.3
Xe Set (dam)	68	32	-	244.5	307.4	413.6	466.7	543.1	624.9
Xe Set (down)	-	100	-	186.0	231.5	305.7	341.6	392.4	445.7
H. Tay-Un	-	57	43	143.0	178.4	237.2	266.1	307.3	351.0
H. Thong	-	25	75	111.0	139.0	186.3	209.9	244.0	280.5
Point Rainfall	Pakxong			272.1	343.1	464.4	525.5	614.0	709.2
	Laongam			186.0	231.5	305.7	341.6	392.4	445.7
	Sekong			86.0	108.1	146.5	166.0	194.5	225.4

Arrival time of flood and rainfall intensity during the flood time are estimated by using Rziha's formula, and the presumed equation quoted from the arrival time of flood and daily rainfall. Calculated results are tabulated below.

Intake Site	Arrival Time (hour)			Rainfall Intensity (mm/hr)					
	L (km)	H (km)	T (hr)	1/5	1/10	1/30	1/50	1/100	1/200
H. Champi(47)	9	0.15	1.5	46.00	58.00	78.50	88.83	103.79	119.88
H. Champi(43)	12	0.19	2.0	39.23	49.46	66.95	75.76	88.51	102.24
H. Tapoung	3	0.02	0.8	60.52	76.31	103.29	116.88	136.57	157.74
H. Kapheu	15	0.36	2.0	36.60	46.04	62.04	70.05	81.60	93.97
Xe Set (dam)	50	0.78	8.4	17.19	21.61	29.08	32.81	38.18	43.93
Xe Set (down)	24	0.60	3.0	21.74	27.06	35.74	39.94	45.87	52.11
H. Tay-Un	12	0.56	1.0	28.51	35.58	47.30	53.05	61.27	69.98
H. Thong	7	0.20	0.8	25.01	31.31	41.98	47.29	54.97	63.20

Peak flood discharge estimated by the Rational formula is as follows on the basis of the above mentioned rainfall intensity and the basic data shown in the column.

Intake Site	Basic Data		Peak Flood Discharge (m^3/sec)					
	Area(km^2)	Runoff Coeffi.	1/5	1/10	1/30	1/50	1/100	1/200
H. Champi(47)	16.0	0.5	102.2	128.9	174.5	197.4	230.7	266.4
H. Champi(43)	36.0	0.5	196.1	247.3	334.8	378.8	442.6	511.2
H. Tapoung	4.0	0.5	33.6	42.4	57.4	64.9	75.9	87.6
H. Kapheu	24.0	0.5	122.0	153.5	206.8	233.5	272.0	313.3
Xe Set (dam)	325.0	0.5	776.2	975.6	1312.8	1481.1	1723.7	1983.3
Xe Set (down)	88.0	0.5	265.8	330.8	436.8	488.1	560.7	636.9
H. Tay-Un	21.0	0.5	83.2	103.8	138.0	154.7	178.7	204.1
H. Thong	8.0	0.5	27.8	34.8	46.6	52.6	61.1	70.2

2.4.2 Drainage Requirement

Estimation method of the drainage water requirement for the selected priority area is divided into two i.e. paddy and upland fields. For the paddy field, such requirement is estimated to evacuate the surplus rain water with the drainage period of 3 days by using the probable daily rainfall which has a probability of once in a 5-years. Besides, Rational formula is applied for the upland field to estimate the drainage water requirement with a probability of once in a 5-years. Drainage period of four (4) hours for vegetable field and one day for other upland crops are considered. Estimated results are as follows;

Priority Project Area	Probable Daily Rainfall (mm/day)	Paddy Field	Upland Field	
		q (lit./sec/ha)	r, (mm/hr)	q (lit./sec/ha)
Upper Champi	272.1	10.5	27.8	38.6
Upper Tapoung	272.1	10.5	27.8	38.6
Upper Kapheu	186.0	7.2	7.8	10.8
Lower Xe Set	186.0	7.2	7.8	10.8
Upper Tay-Un	86.0	3.3	3.6	5.0

III WATER QUALITY

3.1 Water Sampling

To clarify the water quality at the intake sites of the priority area, water sampling for water quality analysis has been carried out at the following seven (7) sites in six (6) rivers on Feb. 20&21,1996.

Selected priority area	River	Sampling Site
1 Upper Champi Area	H. Champi	Lak. 47 intake site
2 - do -	H. Champi	Lak. 43 intake site
3 Upper Tapoing Area	H. Tapoung	intake site
4 Upper Kapheu Area	H. Kapheu	intake site
5 Lower Xe Set Area	Xe Set	intake site
6 Upper Tay-Un Area	H. Tay-Un	intake site
7 - do -	H. Thong	intake site

Analysis of those sampled water was entrusted to the Laboratory of Water Quality Analysis, MAF in Vientiane. Items to be analyzed at the laboratory are; pH, electric conductivity (EC), suspended sediment (S.S.), fecal coliform, chemical oxygen demand (COD) and chemical analysis for NO3-N, Ca2+, Mg2+, Mn2+, Fe2+, Cu and Cl-.

3.2 Analyzed Results

Analyzed results of the sampled water and the MAF standard for drinking water are shown below;

Sample No.	pH	EC mS/m	S.S. mg/l	Coliform col./100ml	COD mg/l	NO3-N mg/l	Ca2+ meq/l	Mg2+ meq/l	Mn2+ mg/l	Total Fe mg/l	Cu mg/l	Cl- meq/l
1	7.68	7.5	1	4	1.029	0.011	0.309	0.314	0.029	0.123	0.022	0.026
2	7.76	6.1	1	3	1.667	0.007	0.314	0.203	0.028	0.196	0.022	0.037
3	6.59	2.3	1	1	4.570	0.002	0.109	0.107	0.020	0.923	0.005	0.061
4	7.33	4.5	5	0	1.846	0.004	0.221	0.191	0.024	0.292	0.004	0.039
5	7.90	7.6	2	0	4.570	0.009	0.356	0.329	0.027	0.192	0.010	0.024
6	7.31	6.0	1	0	1.029	0.037	0.296	0.209	0.001	0.731	0.001	0.026
7	7.73	16.3	2	1	1.057	0.004	0.764	0.755	0.107	0.201	0.031	0.056
Standard	5.8-8.6	-	2	100	-	10	15(*1)	24.7(*2)	0.3	0.3	1.0	5.8(*3)

(*1) : 200ppm=(200/35.45)=5.8 meq/l
(*2) : 300ppm=(300/20.04)=15 meq/l
(*3) : 300ppm=(300/12.16)=24.7 meq/l

(1) pH

All sampled water shows weak alkalinity except the sample taken from H. Tapoung intake site. Since desirable level of pH for drinking water is from 5.8 to 8.6 in the MAF standard and analyzed results show 6.59 to 7.90 of pH values, all sampled water is suitable for drinking water regarding the pH values. On the contrary, desirable level of pH values for irrigation use is 6.0 to 7.5 for paddy cultivation and same extent of its paddy rice is the upper limit of desirable pH ranges for upland crops. Some of the samples exceed such desirable extent of pH. The pH value of surface water is closely related to activation of photo-synthesis of water grasses and seasonal changes are easily occurred due to degree of river flow, water and/or air temperature, sunshine hours, etc. When the origin of strong alkalinity and/or acidity pH values causes by the existence of pollution due to disuse alkali and acid, natural sulfate acid flow, countermeasures are required to use such water for the specific purposes. No particular origin of alkali and acid is found in the river basins of selected priority areas. Therefore, treatment procedures to adjust the pH values will be required for irrigation use.

(2) Electric Conductivity (EC)

Desirable EC values for irrigation water is less than 30 mS/m for paddy cultivation in general. In case of upland crops, salt-tolerant varies crop by crop. For instance, beans, cabbage, eggplant, etc. have low salt-tolerant and cotton sugarcane, potatoes, etc. have high salt-tolerant compared with paddy rice. Because EC values of sampled water ranges from 2.3 mS/m to 16.3 mS/m, all sampled water can be used for irrigation purpose in view of EC values.

(3) Suspended Sediments (SS)

An allowable extent of the suspended sediments is less than 2 mg/l for drinking water in the MAF standard. For the irrigation use, such index is required less than 100 mg/l in general. Among the sampled water, H. Kapheu sample shows 5 mg/l and others are the less than 2 mg/l. Based on this result, stilling basin together with the intake facility and/or filtration pond is required for drinking water use in case of H. Kapheu site to suit the standard.

(4) Coliform Group

All sampled water exists in a desirable extent of MAF standard.

(5) COD

COD is the index of the water pollution expressed by the dissolved oxygen demand of water. Generally, 6 mg/l is the upper limit value for irrigation water though no limitation is mentioned in the MAF standard.. All analyzed results of sampled water show lower values than that of limitation.

(6) Chemical Analysis

Analyzed results of surface water at the intake site on the selected priority area varies in an allowable extent for drinking and irrigation water use regarding the concentration and composition of dissolved ions except item of the total iron. An allowable concentration of the total iron is 0.3 mg/l for drinking water and 0.6 mg/l is desirable for irrigation water. Water samples exceeded the standard values of the total iron were taken from H. Tapoung and H. Tay-Un sites, and those values are 0.923 mg/l and 0.731 mg/l, respectively. Problems containing excessive iron are the unpleasant odor and color of water but harmlessness for health in case of sampled water. For removal of ions to use within an allowable containing, treatment is required such method as pre-chlorination, aeration, chemical precipitation and filtration.

As the summary of the water quality of river flow at the intake site of the selected priority area, all surface water can basically be used for irrigation and drinking purposes. For drinking use, however, removal facilities of iron may be required to suit the standard value of drinking water. To finalize the processing method of river flow, monitoring of water quality throughout the year is required to clarify the quality transition since sampling of analyzed water has been made only one time at the mid of dry season.

Tables

Table 2.2.1 Mean Monthly Rainfall in Each River Basin (1/2)

River Basin : H.Champi (47, 43) , H.Tapoung

UNIT : mm

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
1995	1.7	34.7	145.5	183.1	291.3	289.9	690.8	454.8	268.5	179.6	20.1	54.9	2624.9
1994	0.6	48.4	318.2	292.1	374.7	500.9	1213.8	594.9	606.2	181.8	53.7	67.2	4252.5
1993	0.0	4.1	40.2	150.6	335.5	251.0	522.5	758.4	392.4	57.9	80.2	8.9	2601.7
1992	45.0	11.8	41.0	130.2	211.2	866.7	566.6	835.8	373.3	125.3	9.6	23.8	3241.3
1991	21.4	0.3	69.5	294.0	264.0	551.1	958.6	1218.7	488.2	153.7	0.2	8.4	4028.1
1990	0.0	0.0	105.6	135.0	355.1	514.7	404.4	797.4	494.1	271.9	34.5	0.0	3112.7
1989	11.4	0.0	96.2	379.0	374.9	361.4	705.1	524.2	472.1	238.8	64.8	1.1	3229.0
1988	27.3	118.6	38.0	346.3	414.1	368.0	436.4	566.6	338.8	358.2	13.2	0.0	3025.5
1987	0.0	0.0	58.1	284.7	285.6	575.3	642.8	945.4	318.3	238.8	0.0	0.0	3350.0
1986	0.9	17.3	97.8	177.9	526.9	391.4	656.9	865.0	370.0	285.7	35.5	19.4	3443.8
AVERAGE	10.7	23.5	101.0	237.3	343.3	467.0	679.8	757.3	412.2	209.2	31.2	18.4	3291.0

River Basin : H.Kapheu

UNIT : mm

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
1995	1.3	29.1	111.0	143.4	253.6	274.4	607.6	404.9	255.7	174.3	18.1	41.2	2314.5
1994	0.5	36.7	255.1	253.2	335.6	447.1	1025.6	508.5	532.0	163.9	41.3	50.4	3649.8
1993	0.0	3.7	39.5	124.0	316.9	194.8	454.2	663.2	392.5	55.4	61.8	6.7	2312.7
1992	47.5	10.3	30.8	111.8	212.0	758.7	507.6	765.8	363.1	118.3	7.2	17.9	2950.9
1991	16.2	0.3	53.6	227.1	250.0	478.3	822.7	1054.3	441.5	181.8	0.2	7.7	3533.5
1990	0.1	0.2	110.7	119.2	325.9	462.3	376.3	689.9	428.9	258.6	31.5	0.0	2803.7
1989	13.3	0.0	87.6	330.2	391.3	319.3	629.5	461.5	400.6	211.3	48.8	0.8	2894.1
1988	25.0	108.4	34.8	316.7	378.4	336.8	399.1	518.0	309.9	327.6	12.1	0.0	2767.0
1987	0.0	0.0	53.3	260.4	260.1	524.1	586.9	859.8	291.3	218.7	0.0	0.0	3054.6
1986	0.0	15.9	89.4	162.7	481.8	356.7	600.0	789.4	338.5	260.8	32.5	17.8	3145.5
AVERAGE	10.4	20.5	86.6	204.9	320.6	415.3	600.9	671.5	375.4	197.1	25.4	14.2	2942.6

River Basin : Xe Set (Dam)

UNIT : mm

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
1995	1.2	27.5	101.4	132.3	243.0	270.1	584.3	388.1	252.1	172.8	17.5	37.3	2227.6
1994	0.4	33.5	237.5	242.3	324.7	432.0	972.9	484.3	511.2	158.9	37.9	45.7	3481.1
1993	0.0	3.6	39.3	116.6	311.7	179.1	435.0	636.6	392.6	54.6	56.6	6.1	2231.7
1992	48.2	9.8	27.9	106.7	212.2	728.5	491.1	745.9	360.2	116.3	6.5	16.2	2869.6
1991	14.7	0.3	49.1	208.3	246.0	457.9	784.6	1008.2	428.5	189.7	0.2	7.5	3394.9
1990	0.2	0.3	112.2	114.7	317.8	447.6	368.4	659.8	410.6	254.9	30.7	0.0	2717.1
1989	13.8	0.0	85.1	316.5	395.8	307.5	608.3	444.0	380.6	203.6	44.3	0.7	2800.3
1988	24.4	105.6	33.9	308.5	368.4	328.1	388.6	504.4	301.9	319.1	11.8	0.0	2694.6
1987	0.0	0.0	51.9	253.6	253.0	509.8	571.2	835.6	283.8	213.1	0.0	0.0	2971.9
1986	0.0	15.5	87.1	158.5	469.2	346.9	584.1	768.2	329.7	253.8	31.7	17.3	3062.0
AVERAGE	10.3	19.6	82.5	195.8	314.2	400.8	578.9	647.5	365.1	193.7	23.7	13.1	2845.1

River Basin : Xe Set (Downstream)

UNIT : mm

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
1995	0.0	12.2	7.6	24.3	140.4	227.9	358.1	225.1	217.3	158.5	12	0	1383.4
1994	0.0	1.7	65.9	136.4	218.3	285.7	461.0	249.2	309.2	110.2	4.2	0.0	1841.8
1993	0.0	2.5	37.4	44.2	261.1	26.3	249.2	377.7	392.9	47.7	6.5	0.0	1445.5
1992	54.9	5.6	0.1	56.7	214.3	434.8	330.7	552.8	332.5	97.3	0.0	0.0	2079.7
1991	0.4	0.3	5.8	26.3	207.8	259.8	414.9	560.9	301.5	269.2	0.1	5.5	2049.5
1990	0.5	0.8	126.1	71.7	238.4	305.0	292.0	357.4	233.2	218.8	22.6	0.0	1876.5
1989	18.8	0.0	61.6	183.6	440.3	193.1	402.7	273.5	186.1	128.7	0.8	0.0	1889.2
1988	18.1	77.9	25.3	228.0	271.4	243.3	287.0	372.3	223.3	235.9	8.8	0.0	1991.5
1987	0.0	0.0	38.7	187.4	183.8	370.6	419.0	600.0	210.4	158.4	0.0	0.0	2168.4
1986	0.0	11.5	64.3	117.2	346.7	252.4	429.3	562.5	243.9	186.2	23.7	12.9	2250.6
AVERAGE	9.3	11.3	43.3	107.6	252.2	259.9	364.4	414.1	265.0	160.8	7.9	1.8	1897.6

River Basin : H. Tay-Un

UNIT : mm

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
1995	0.0	7.2	4.3	51.9	226.4	231.0	369.1	197.4	185.1	137.8	11.0	8.6	1429.7
1994	0.0	1.0	67.7	117.8	197.3	293.0	399.1	362.4	280.7	97.3	3.2	2.1	1821.6
1993	7.5	17.3	70.0	95.2	241.1	147.0	223.2	344.3	401.5	118.0	130.0	78.5	1873.7
1992	50.5	22.9	57.4	89.1	181.8	305.3	263.3	427.2	310.0	109.6	61.2	39.6	1917.9
1991	3.4	58.7	158.1	38.2	190.3	212.4	360.4	457.7	229.2	265.1	128.2	51.6	2153.3
1990	0.3	0.5	104.9	83.0	246.6	333.8	291.2	446.8	285.2	209.3	23.8	0.0	2025.4
1989	14.3	0.0	65.3	220.7	365.9	220.7	440.3	316.4	251.4	146.9	20.8	0.3	2063.1
1988	18.9	81.0	26.4	237.2	282.0	253.3	298.4	387.0	232.3	245.4	9.2	0.0	2071.0
1987	0.0	0.0	40.4	194.9	190.1	383.4	434.8	618.3	219.1	165.0	0.0	0.0	2245.0
1986	0.0	12.0	66.9	121.9	360.5	261.2	445.7	583.2	253.7	193.1	24.7	13.5	2336.5
AVERAGE	9.5	20.1	66.1	125.0	248.2	264.1	352.5	414.1	264.8	168.7	41.2	19.4	1993.8

Table 2.2.1 Mean Monthly Rainfall in Each River Basin (2/2)

River Basin : H. Thong

UNIT : mm

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
1995	0.0	3.4	3.9	72.5	290.3	233.2	377.3	176.7	161.1	122.4	10.3	15.1	1464.2
1994	0.0	0.4	69.1	104.0	181.7	298.5	353.0	446.7	259.6	87.7	2.4	3.6	1806.6
1993	13.1	28.4	94.3	133.1	226.3	236.8	203.8	319.5	407.9	170.3	222.0	136.9	2192.4
1992	47.2	35.8	100.1	113.2	157.6	208.9	213.1	333.7	293.2	118.8	106.8	69.2	1797.6
1991	5.7	102.2	271.4	47.1	177.2	177.2	319.8	380.9	175.4	264.3	223.5	86.0	2230.5
1990	0.1	0.2	89.1	91.4	252.7	355.2	290.6	506.0	323.9	202.2	24.7	0.0	2136.1
1989	11.0	0.0	68.0	248.3	310.6	241.2	468.4	348.3	299.9	160.4	35.6	0.6	2192.5
1988	19.5	83.3	27.2	244.0	289.8	260.7	306.9	397.9	239.0	252.4	9.5	0.0	2130.2
1987	0.0	0.0	41.7	200.5	194.8	393.0	446.5	631.9	225.5	169.9	0.0	0.0	2303.7
1986	0.0	12.4	68.8	125.4	370.7	267.8	457.9	598.7	261.1	198.3	25.4	13.9	2400.4
AVERAGE	9.7	26.6	83.2	138.0	245.2	267.2	343.7	414.0	264.7	174.7	66.0	32.5	2065.4

Table 2.2.2 Monthly Mean Discharge (1/2)

H.Champi (lak 47)
Basin Area 16 km2

UNIT : m3/sec

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	AVERAGE
1986	0.334	0.213	0.143	0.147	0.451	0.665	1.032	1.403	1.436	1.150	0.888	0.585	0.704
1987	0.334	0.209	0.134	0.158	0.341	0.691	1.116	1.553	1.390	1.150	0.813	0.506	0.702
1988	0.322	0.239	0.182	0.265	0.413	0.735	0.693	1.196	0.999	0.975	0.726	0.448	0.600
1989	0.267	0.161	0.103	0.180	0.471	0.726	0.929	1.179	1.205	1.018	0.803	0.530	0.631
1990	0.306	0.189	0.128	0.111	0.288	0.531	0.702	1.071	1.389	1.178	0.870	0.550	0.609
1991	0.331	0.209	0.135	0.130	0.379	0.624	1.209	2.164	1.912	1.512	1.015	0.649	0.856
1992	0.410	0.272	0.175	0.139	0.177	0.636	1.146	1.517	1.401	1.116	0.760	0.480	0.686
1993	0.306	0.189	0.113	0.115	0.230	0.311	0.612	1.153	1.144	0.863	0.613	0.400	0.504
1994	0.237	0.157	0.238	0.353	0.543	0.764	1.517	1.796	1.726	1.412	0.961	0.701	0.867
1995	0.389	0.255	0.184	0.227	0.362	0.425	0.776	0.943	0.978	0.792	0.574	0.368	0.523
AVERAGE	0.323	0.209	0.153	0.186	0.365	0.611	0.973	1.398	1.357	1.117	0.802	0.522	0.668

H.Champi (lak 43)
Basin Area 36 km2

UNIT : m3/sec

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	AVERAGE
1986	0.751	0.478	0.322	0.330	1.015	1.496	2.323	3.157	3.231	2.588	1.998	1.316	1.584
1987	0.751	0.471	0.301	0.445	0.767	1.554	2.511	3.495	3.106	2.588	1.830	1.140	1.580
1988	0.724	0.539	0.409	0.597	0.928	1.654	1.559	2.692	2.249	2.194	1.634	1.008	1.349
1989	0.601	0.363	0.232	0.405	1.059	1.633	2.089	2.654	2.712	2.790	1.806	1.193	1.420
1990	0.688	0.425	0.288	0.250	0.648	1.195	1.579	2.410	3.125	2.650	1.957	1.237	1.371
1991	0.744	0.470	0.304	0.292	0.853	1.404	2.719	4.870	4.303	3.402	2.283	1.461	1.925
1992	0.921	0.611	0.393	0.313	0.398	1.431	2.578	3.412	3.152	2.510	1.710	1.080	1.542
1993	0.688	0.426	0.255	0.258	0.517	0.701	1.377	2.594	2.573	1.942	1.380	0.900	1.134
1994	0.533	0.353	0.535	0.795	1.221	1.719	3.413	4.041	3.882	3.178	2.162	1.577	1.951
1995	0.876	0.575	0.414	0.510	0.814	0.956	1.746	2.122	2.201	1.782	1.293	0.828	1.176
AVERAGE	0.728	0.471	0.345	0.420	0.822	1.374	2.189	3.145	3.053	2.513	1.805	1.174	1.503

H. Tapoong
Basin Area 4 km2

UNIT : m3/sec

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	AVERAGE
1986	0.083	0.053	0.036	0.037	0.113	0.166	0.258	0.351	0.359	0.288	0.222	0.146	0.176
1987	0.083	0.052	0.033	0.049	0.085	0.173	0.279	0.388	0.345	0.288	0.203	0.127	0.176
1988	0.080	0.060	0.045	0.066	0.103	0.184	0.173	0.299	0.250	0.244	0.182	0.112	0.150
1989	0.067	0.040	0.026	0.045	0.118	0.181	0.232	0.295	0.301	0.254	0.201	0.133	0.158
1990	0.076	0.047	0.032	0.028	0.072	0.133	0.175	0.268	0.347	0.294	0.217	0.137	0.152
1991	0.083	0.052	0.034	0.032	0.095	0.156	0.302	0.541	0.478	0.378	0.254	0.162	0.214
1992	0.102	0.068	0.044	0.035	0.044	0.159	0.286	0.379	0.350	0.279	0.190	0.120	0.171
1993	0.076	0.047	0.028	0.029	0.057	0.078	0.153	0.288	0.286	0.216	0.153	0.100	0.126
1994	0.059	0.039	0.059	0.088	0.136	0.191	0.379	0.449	0.431	0.353	0.240	0.175	0.217
1995	0.097	0.064	0.046	0.057	0.090	0.106	0.194	0.236	0.245	0.198	0.144	0.092	0.131
AVERAGE	0.081	0.052	0.038	0.047	0.091	0.153	0.243	0.349	0.339	0.279	0.201	0.130	0.167

H.Kaphea
Basin Area 24 km2

UNIT : m3/sec

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	AVERAGE
1986	0.459	0.268	0.167	0.184	0.576	0.877	1.369	1.870	1.936	1.553	1.197	0.779	0.940
1987	0.459	0.284	0.177	0.251	0.439	0.899	1.480	2.069	1.864	1.554	1.090	0.671	0.936
1988	0.420	0.307	0.232	0.329	0.531	0.970	0.917	1.589	1.341	1.303	0.973	0.591	0.792
1989	0.369	0.219	0.136	0.211	0.628	0.982	1.224	1.557	1.537	1.323	1.023	0.656	0.822
1990	0.459	0.284	0.192	0.166	0.432	0.796	1.053	1.606	2.083	1.767	1.304	0.825	0.914
1991	0.405	0.245	0.145	0.126	0.406	0.719	1.479	2.654	2.447	1.999	1.352	0.854	1.072
1992	0.557	0.366	0.228	0.175	0.228	0.801	1.470	1.998	1.872	1.516	1.030	0.639	0.907
1993	0.400	0.242	0.138	0.123	0.262	0.380	0.739	1.394	1.505	1.152	0.798	0.506	0.637
1994	0.309	0.196	0.243	0.396	0.643	0.945	1.851	2.211	2.167	1.801	1.217	0.862	1.070
1995	0.501	0.321	0.218	0.237	0.398	0.516	0.945	1.190	1.274	1.053	0.754	0.467	0.656
AVERAGE	0.434	0.275	0.190	0.220	0.454	0.789	1.253	1.817	1.803	1.502	1.074	0.685	0.875

H.Thong
Basin Area 8 km2

UNIT : m3/sec

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	AVERAGE
1986	0.124	0.099	0.079	0.075	0.185	0.290	0.432	0.587	0.615	0.437	0.297	0.162	0.282
1987	0.124	0.098	0.077	0.097	0.147	0.270	0.488	0.602	0.601	0.437	0.246	0.140	0.277
1988	0.116	0.099	0.085	0.115	0.182	0.323	0.279	0.499	0.407	0.374	0.240	0.127	0.237
1989	0.099	0.076	0.058	0.070	0.211	0.332	0.345	0.487	0.451	0.356	0.233	0.128	0.237
1990	0.098	0.074	0.059	0.051	0.116	0.202	0.298	0.391	0.544	0.459	0.272	0.131	0.225
1991	0.098	0.078	0.127	0.151	0.107	0.167	0.202	0.345	0.347	0.319	0.285	0.246	0.206
1992	0.112	0.091	0.078	0.073	0.095	0.127	0.175	0.258	0.324	0.297	0.194	0.130	0.163
1993	0.081	0.061	0.050	0.047	0.091	0.172	0.221	0.252	0.366	0.352	0.290	0.250	0.186
1994	0.098	0.074	0.055	0.053	0.064	0.161	0.281	0.337	0.443	0.336	0.154	0.095	0.183
1995	0.071	0.049	0.030	0.019	0.103	0.145	0.274	0.261	0.247	0.176	0.087	0.053	0.126
AVERAGE	0.102	0.080	0.070	0.075	0.130	0.219	0.300	0.407	0.434	0.354	0.230	0.146	0.212

Table 2.2.2 Monthly Mean Discharge (2/2)

H.Tay-Un
Basin Area 21 km²

UNIT : m3/sec

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	AVERAGE
1986	0.303	0.235	0.187	0.177	0.447	0.719	1.081	1.476	1.552	1.099	0.741	0.401	0.702
1987	0.303	0.236	0.183	0.231	0.355	0.669	1.226	1.519	1.524	1.100	0.611	0.348	0.692
1988	0.280	0.235	0.203	0.275	0.445	0.801	0.690	1.241	1.014	0.933	0.591	0.311	0.585
1989	0.239	0.178	0.134	0.152	0.546	0.887	0.859	1.193	1.028	0.832	0.490	0.245	0.569
1990	0.210	0.151	0.125	0.102	0.274	0.471	0.722	0.913	1.243	1.086	0.636	0.299	0.519
1991	0.244	0.189	0.188	0.179	0.192	0.359	0.591	1.050	1.123	1.037	0.744	0.489	0.532
1992	0.297	0.239	0.194	0.166	0.232	0.354	0.672	0.995	1.087	0.909	0.534	0.309	0.501
1993	0.235	0.177	0.139	0.118	0.196	0.374	0.478	0.612	0.997	0.847	0.570	0.387	0.427
1994	0.210	0.151	0.107	0.100	0.177	0.428	0.754	0.993	1.098	0.843	0.383	0.233	0.456
1995	0.163	0.109	0.062	0.030	0.166	0.292	0.576	0.615	0.672	0.507	0.238	0.130	0.297
AVERAGE	0.248	0.191	0.152	0.153	0.303	0.538	0.765	1.061	1.134	0.919	0.554	0.319	0.528

Xe Set
Basin Area 413 km²

UNIT : m3/sec

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	AVERAGE
1986	4.342	3.093	2.359	2.932	13.452	20.907	31.838	42.477	43.245	28.347	17.592	7.621	18.184
1987	4.700	3.356	2.375	5.227	10.117	19.964	36.460	43.495	43.119	28.616	13.797	6.285	18.126
1988	4.617	4.055	3.263	6.720	12.652	23.616	19.351	36.227	27.757	25.135	14.233	5.747	15.281
1989	4.165	2.908	2.067	3.950	16.249	25.600	24.947	35.910	30.890	22.948	13.289	5.907	15.736
1990	3.856	2.608	2.177	1.748	8.159	15.253	21.775	27.903	39.424	31.124	16.314	6.118	14.705
1991	4.186	3.174	3.036	3.145	6.090	11.287	32.820	41.872	41.718	37.298	17.599	9.791	17.668
1992	3.790	3.406	2.415	2.335	4.350	15.746	30.036	45.900	34.843	21.523	10.355	5.820	15.043
1993	4.020	2.972	2.540	2.562	6.087	5.680	14.550	26.724	34.571	17.182	7.985	4.616	10.791
1994	3.089	2.331	2.030	5.268	11.050	15.650	29.721	30.923	36.667	19.884	9.506	5.851	14.331
1995	3.952	2.872	2.370	2.290	5.561	5.850	13.036	21.574	25.043	17.586	9.378	5.226	9.562
AVERAGE	4.072	3.077	2.463	3.618	9.377	15.955	25.453	35.301	35.726	24.954	13.005	6.298	14.943

Figures

Fig. 1.1.1 Annual Isohyetal Map

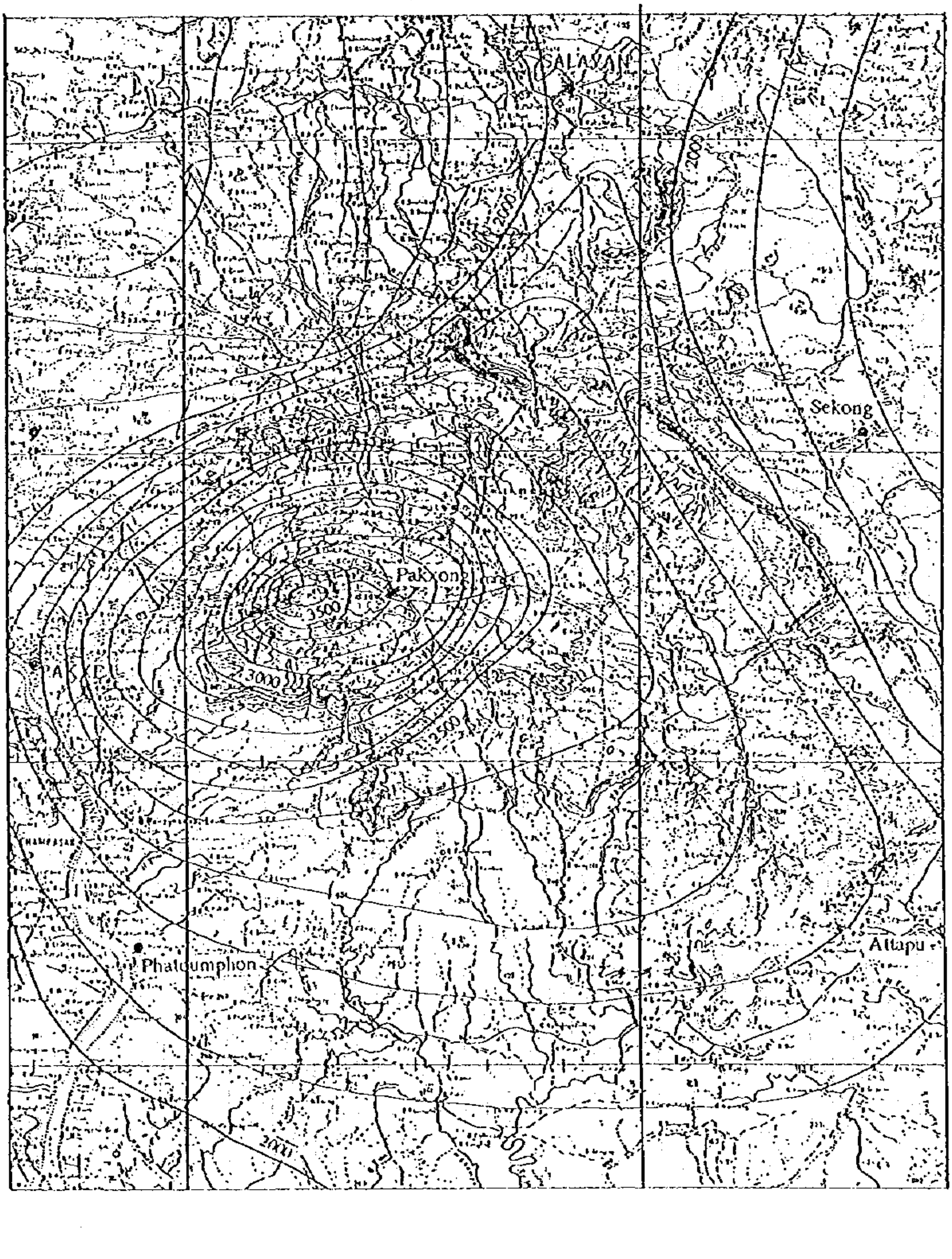


Fig. 1.1.2 Thiessen Polygon

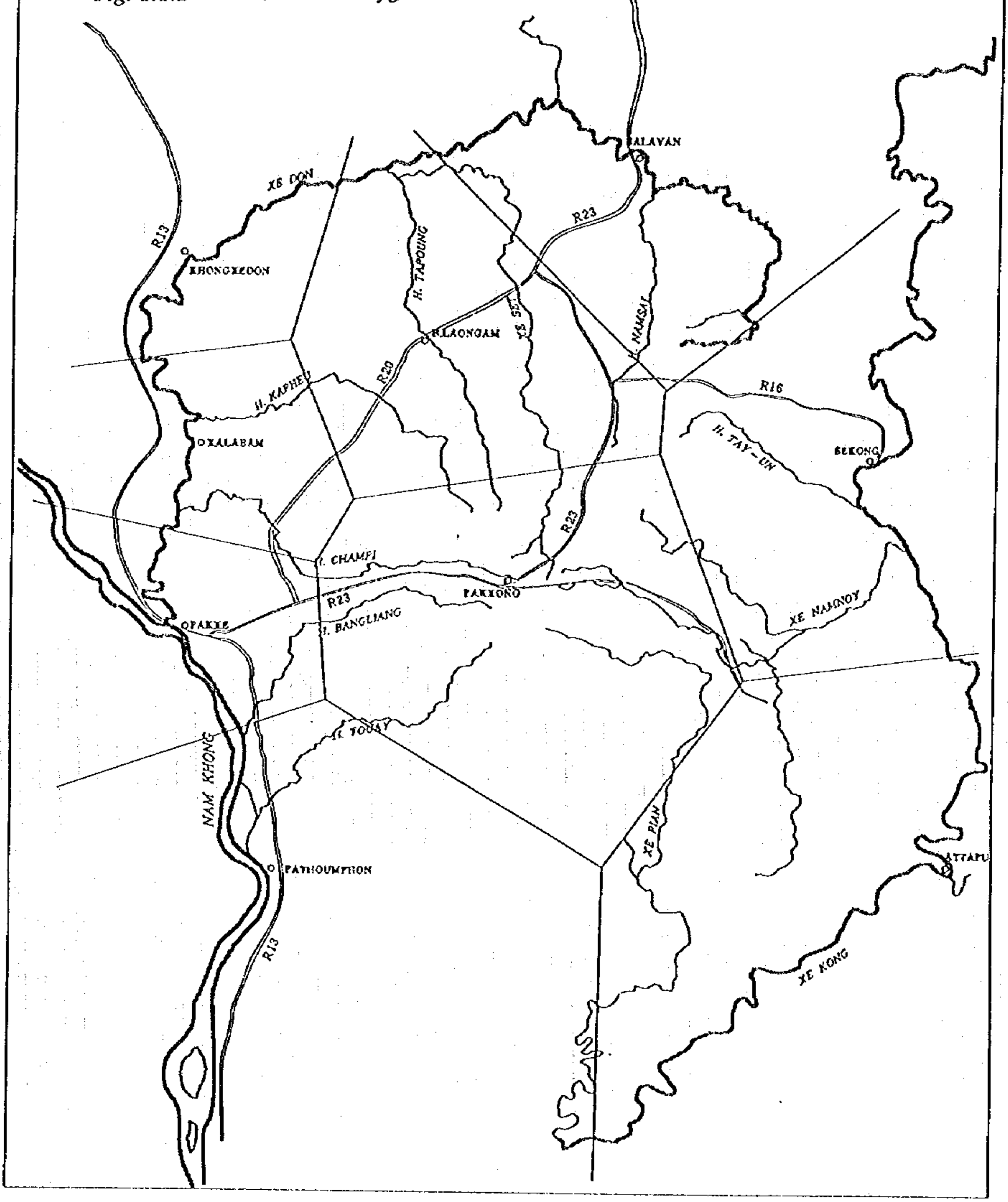


Fig. 1.2.1 River System

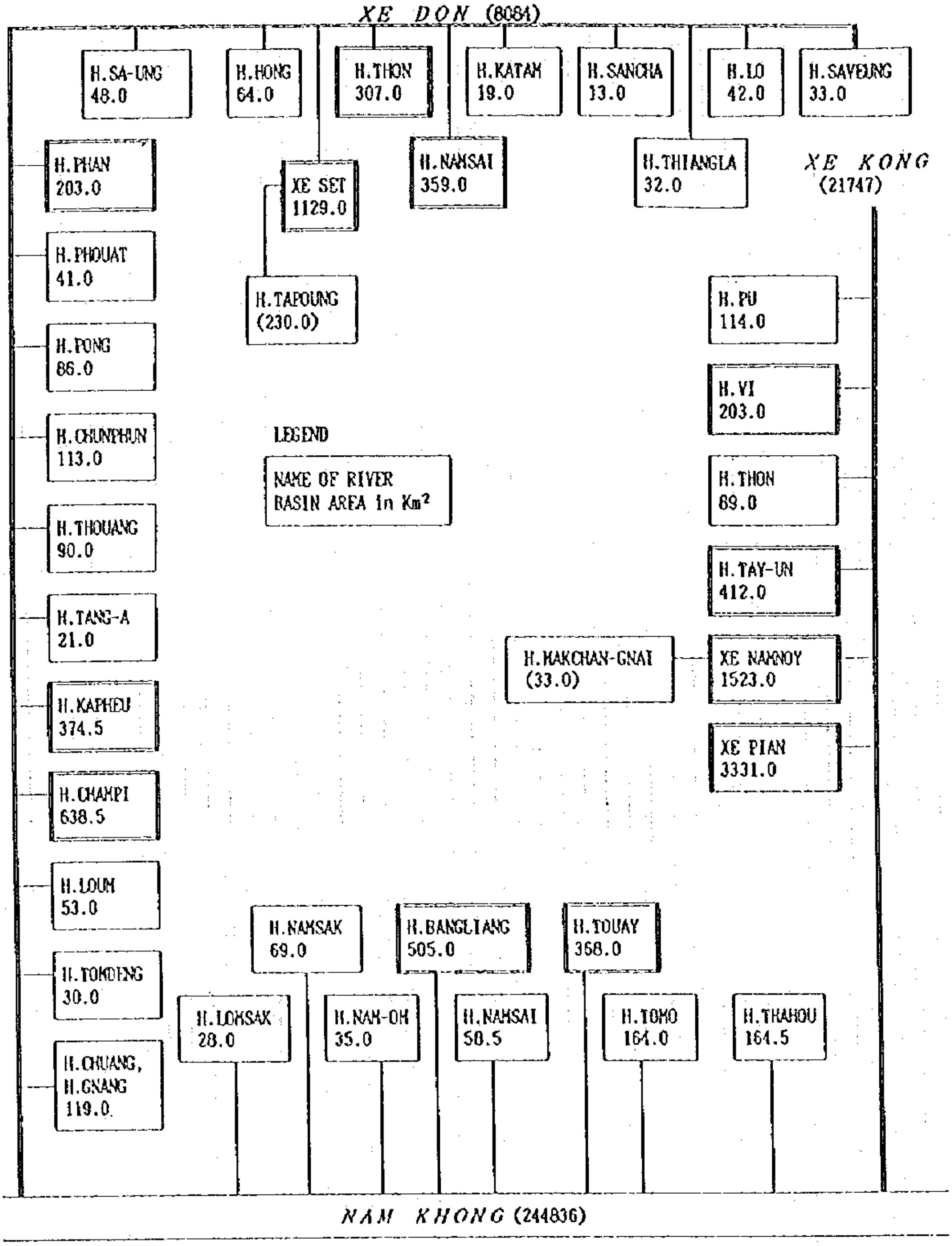


Fig. 1.2.2 Basin Area in the Study Area

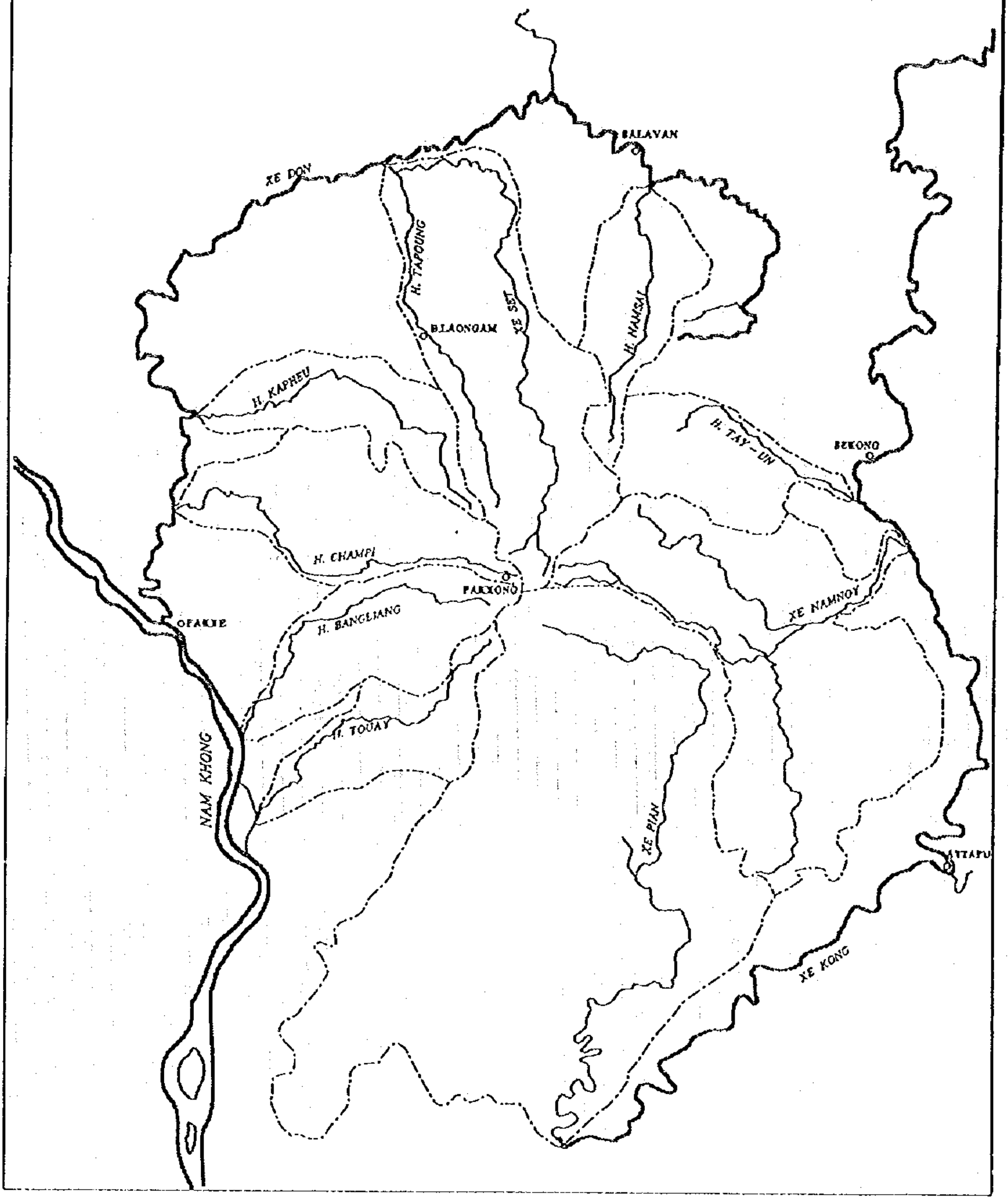


Fig. 1.4.1 Hydrogeologic Map of the Study Area

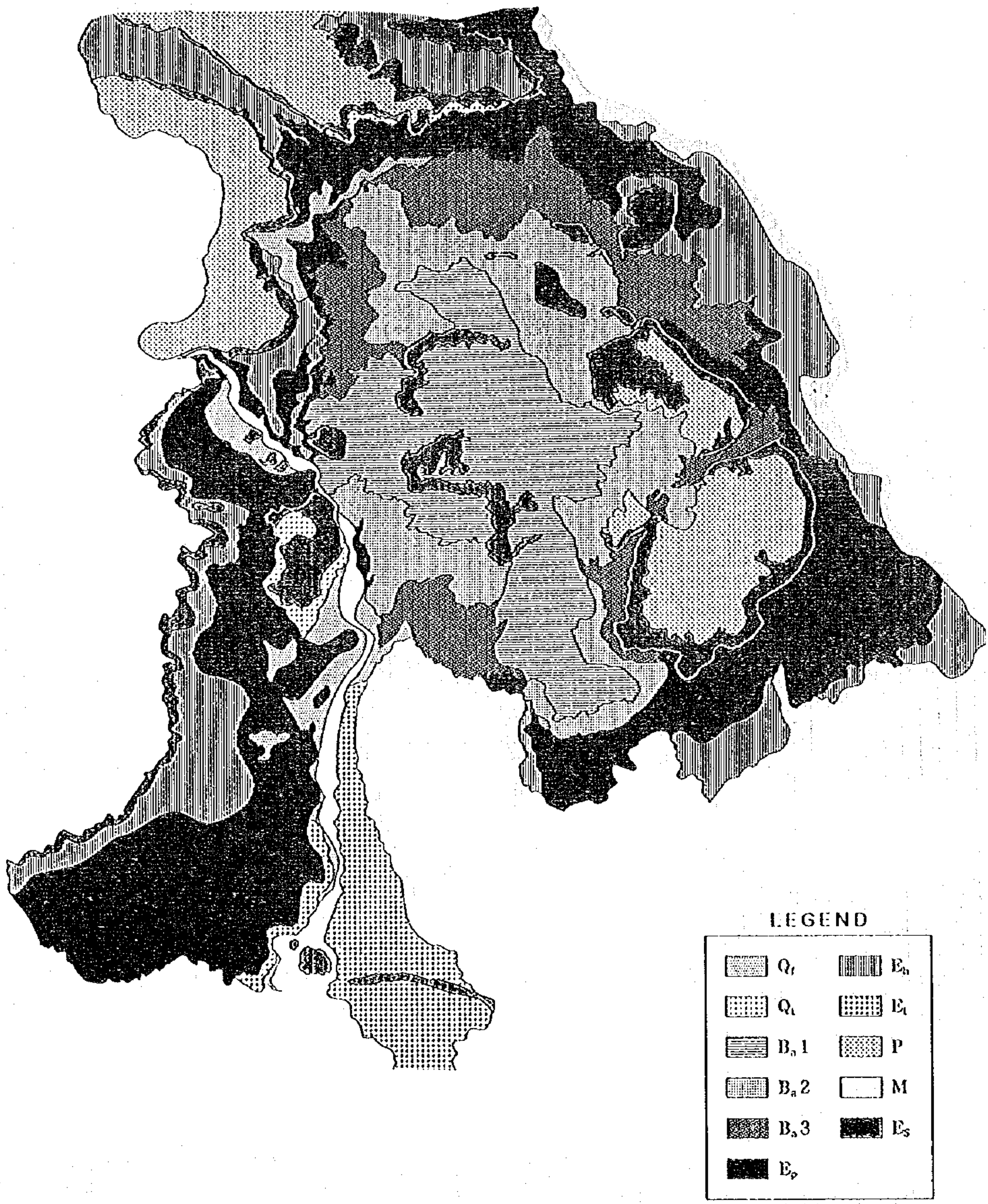
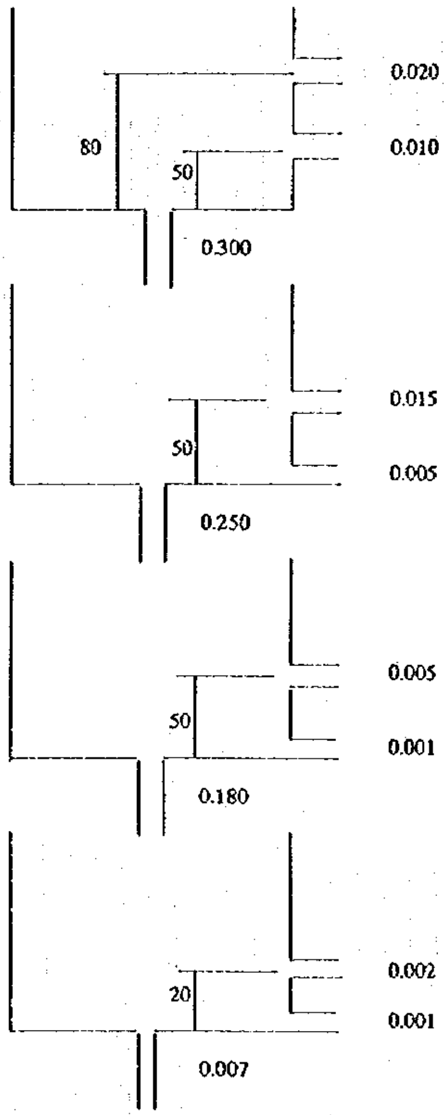


Fig. 2.2.1 Constructed Tank Model and Multiplier

(1) Model A



(1) Model B

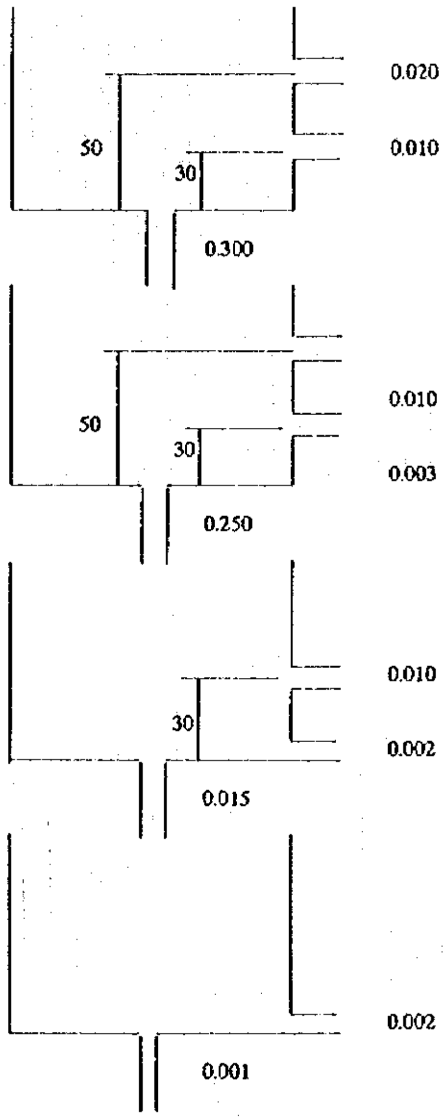
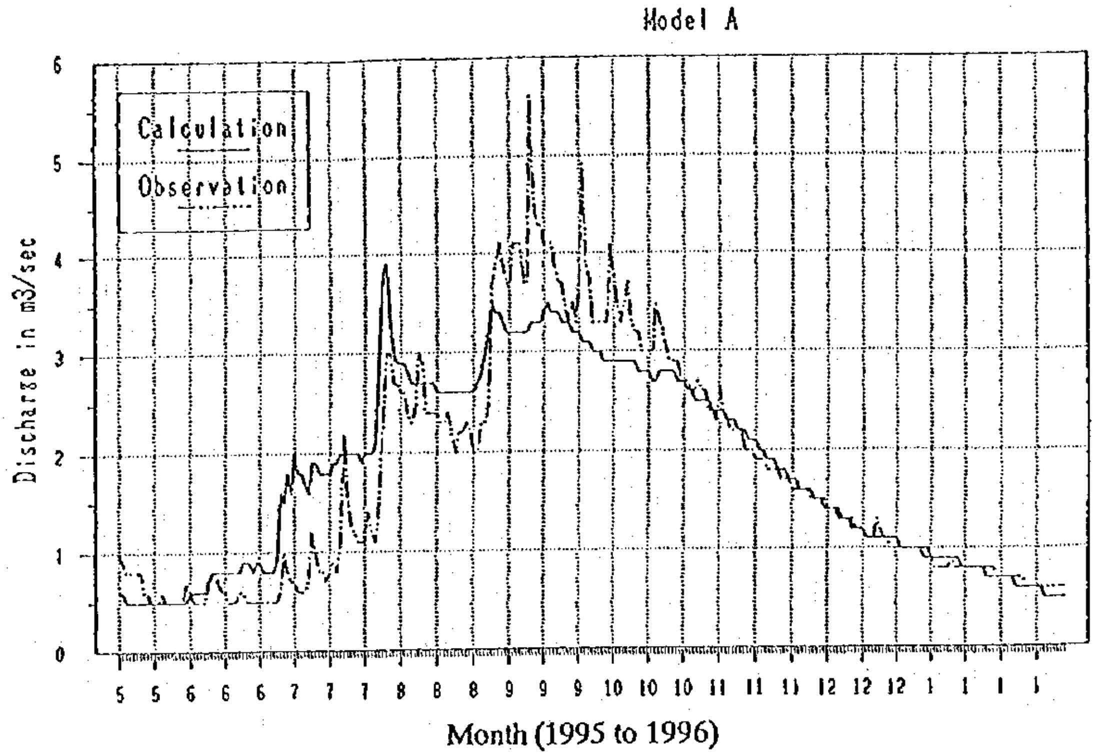
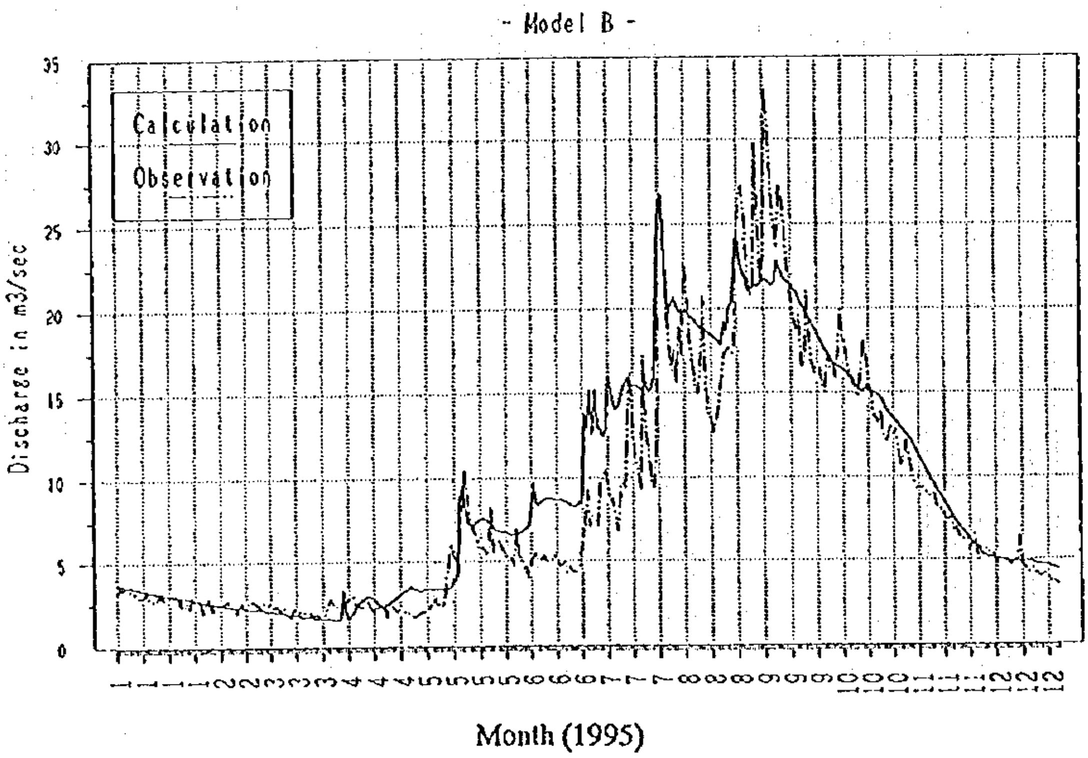


Fig. 2.2.2 Tank Model Calibration Results'





ANNEX II

SOIL AND LAND USE

ANNEX II SOILS AND LAND USE

PART I THE MASTER PLAN

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ANNEX II SOILS AND LAND USE

PART I THE MASTER PLAN

I GENERAL

The present studies (phase I) on soil and land classification aim at determining soil units and their distribution in the study area to evaluate the land resources and to estimate the possibility of land development.

Soil and land use survey was carried out in three kinds of procedure, that is, analysis of existing data, field survey, and soil chemical analysis. Existing topographical maps and the results of previous soil examination which has been done by the related authorities of Lao PDR are referred to for the present study. Soil classification of the study area was made by using the system of FAO/UNESCO (1974) and land evaluation was done by using the system of USDA (1961) taking both systems of USBR (1967) and FAO (1976) into consideration.

II SOILS

2.1 Methods of Soil Survey

On the basis of the data obtained by soil survey, properties and distribution of soils are known, the soils are classified into several sorts and soil classification maps are prepared. As the same time, the land is evaluated by rating its capability and /or suitability and land capability and/or suitability maps are produced. Moreover, present land use state is observed on the way of soil survey and the results obtained are illustrated on the map and estimated in every category of land use. In this way, practice of soil survey is indispensable for carrying forward a scheme to reconcile agricultural development (e.g. increase in crop production) and environmental conservation (e.g. decrease in erosion risk) of the project area. Therefore, the techniques to be utilized for soil survey, land evaluation, and land use examination must be ones which have been backed by authorized methodologies.

2.1.1 Data Collection

Certain existing data relating to soils and present and proposed land use in Lao PDR were collected from the Ministry prior to investigation and reviewed to execute efficiently this study.

According to FAO's information, in the step of master plan, the type of land resource survey belongs to intermediate one between exploratory and reconnaissance and its content is summarized as follows:

Types of land resource survey

	Exploratory survey	Reconnaissance survey
Aim and level	Resource inventory Project location Prefeasibility	Prefeasibility Regional planning Project location
Site intensity and survey method	Free survey of variable intensity usually much < 1% 100 ha	Free survey of variable intensity usually < 1%100 ha
Preferred scales: Aerial photos	≦1: 60 000 ≦1: 100 000	1: 40 000 to 1: 20 000
: Final map	Variable	≦1: 50 000

Source: Extracted from Table 2.1 in "BOOKER TROPICAL SOIL MANUAL" ed. by J.R. Landon (1991).

Furthermore, the mapping units used before this in land resource survey are selected and summarized as follows:

Mapping units used in land resource survey

	Exploratory survey	Reconnaissance survey
Final mapping unit	1.Physiographic units/ land systems 2.Potential development areas	1.Physiographic units/ land systems 2.Soil associations 3.Land capability units 4.Potential development areas
Landscape component		
: Geomorphology	Major relief units	Relief units, major landforms
: Soil	The highest level of soil classification to association	Associations
: Vegetation	Soil/climate-related types	Soil/climate-related types, plant associations
: Land use	Agro-ecological groups	Land use system, cultivation density

Source: Extracted from Table 2.2 in "BOOKER TROPICAL SOIL MANUAL" ed. by J.R. Landon (1991).

General topographic maps (1: 1 000 000 in scale) and the reports on soils and land use which were published for each of provinces and districts in the study area were used fully. Furthermore, 1: 20 000 scale aerial photographs that were taken on some parts of the study area were utilized for checking the present land use.

2.1.2 Field Survey

Field survey for soils and land use in the study area, 654 050 ha, which corresponds to almost of "Boloven Plateau" was carried out in collaboration with the counterpart provided by the Ministry. The field work including landscape, topography and vegetation survey, institution of soil mapping units by boring with soil auger, pit preparation and its profile observation, soil description, soil sampling, etc.was enforced.

(1) Boring spot test with soil auger

In the first, boring spot test was done by using the soil auger. In practice, the work was made in two steps, that is, in first step thirty one spots were cored by a narrow shaped auger to know an outline of soil distribution in the study area, and in second step sixty nine spots were bored by a jarret type of auger to examine individual soil column. The boring spots were distributed in 100 sites in total. As a result of the work, texture, consistency, color, contents of big fragments such as gravel or stone, effective depth, etc., of soils were realized. Furthermore, slope of land surface, biological state, drainage condition, degree of humidity, aspects of erosion and erodibility were observed.

(2) Preparation of excavating pits and observation of soil profiles in excavating pits

The observation of soil profiles ere executed in excavating pits. Sites of the pits were selected in consideration of land topography using the maps of 1:00,000 in scale. The size of the pits was fundamentally one hundred twenty centimeters, two hundred centimeters and one hundred twenty centimeters in depth, long and wide, respectively. However, at he place where rock bed lies in relatively shallow situation, digging couldn't but be ceased at very thin horizon. The procedure of soil description was mostly done in accordance with the Guidelines for Soil Profile Description (FAO, 1977) and the Soil Survey Manual (USDA, 1951). Twenty five pits were dug, and on each profile, horizon sequence, effective depth, texture, structure, consistency, plasticity, gravel and stone content, color, hardness, ground water level, root spread, drainage, etc. were observed and recorded. Furthermore, landscape, land slope and vegetation were recorded. The sites of boring spot test and master pits are shown in Figure I-1.

(3) Sample collection

Seventy three bulky samples of the soils were taken from the representative horizons on the profile of each excavating pit.

2.1.3 Laboratory Analysis of Soil Samples

The soil samples taken from excavating pits were analyzed on chemical properties by using a set of simplified soil testing apparatus at the provisional laboratory in Pakxong. The items of chemical analysis were: pH(H20), pH(KCl), ammonia nitrogen, nitrate nitrogen, available phosphorus, exchangeable potassium, exchangeable calcium, exchangeable magnesium, available iron and exchangeable manganese. These constituents except for pH were extracted from each soil sample with unified solution (Morgan's solution) and estimated by colorimetry or turbidimetry.

2.2 Physiography

2.2.1 Topography and Geology

The study area belongs to the physiographic region named the Boloven Plateau. The altitude at the top of the area is about one thousand and two hundred meters or more. The slope of the plateau is relatively gentle in western and northern parts while it is considerably steep in eastern and southern sides.

The geology of the area is so-called Kontum massif that consists of the stratigraphic units in the period from Mesozoic to present, and the weathered lava flows of basalt covers in wide area on the basal massif.

2.2.2 Soil Formation Process

Under the tropical conditions of high temperature and high rainfall that is often seasonal, the soil development from its parent material, in general, rapidly progresses. The parent rocks quickly collapse, and alkalis and alkaline earths which are important constituents are removed fast in solution.

Iron tends to move with rainfall after oxidation.

Under the condition that parent materials are poor in alkaline constituents or relatively shallow and soil reaction is strongly acid by severe leaching, red yellow podsolic soils and reddish brown lateritic soils which are expressed as Orthic Acrisols on the FAO-UNESCO Soils Map of the World develop dominantly. The fertility of these is generally low.

On the other hand, under the environment that parent materials are rich in alkaline contents like basalt and their layer is relatively deep, well-structured clay loam which is signed as Dystric Nitosols extends in wide area. The fertility of these is relatively high.

2.3 Results of Field Survey and Laboratory Analysis

The results obtained by preliminary boring test and by regular boring test are given in Tables I-1 and I-2, respectively. The results obtained on pit profile observation together with pH values and chemical analysis data are are shown shown in Tabls I-3 and I-4, respectively.

2.4 Soil Classification

The soils extend in "Boloven Plateau" are divided roughly into three sorts depending on mainly geological origin, that is, 1. Alluvial soils, 2. Soils derived from sand stones and clay stones, and 3. Soils derived from basalt rock. Among those sorts, the soil that is distributed in most wide area, used for agriculture, and there by regarded as representative one is basaltic soil. Incidentally, soil classification was practiced based on the FAO-UNESCO system for soil classification because that for the Soil Taxonomy system the detailed data concerning physical and chemical analysis are insufficient.

2.4.1 Alluvial Soils

(1) Soil code 1: Orthic Acrisoils (Dystric Cambisols and Fluvisols)

Characteristics of these soils are as follows: Color is light yellowish brown; effective depth is medium (30-75 cm); texture is coarse (sand to loamy sand) to medium (sandy loam to clay loam); reaction is strongly acid to acid; and fertility is low.

These soils are distributed in small area (520 ha; 0.08 %) in southern part of Pakxong District. The land is used for paddy rice.

(2) Soil code 2: Gleyic Acrisols (Eutric and Dystric Gleysols)

Characteristics of these soils are as follows: Color is light yellowish brown; effective depth is deep (>75 cm); texture is medium (sandy loam to clay loam), reaction is acid; fertility is medium to high; and hydromorphic properties appear.

These soils are distributed in small area (310 a; 0.05 %) in Pakxong District. The land is utilized as paddy field.

(3) Soil code 3: Orthic Acrisols (Ferric Acrisols)

Characteristics of these soils are as follows: Color is yellowish brown; effective depth is shallow (<25 cm) to medium (30-75 cm); texture is medium (sandy loam to clay loam): reaction is strongly acid; and fertility is low.

These soils are distributed in Salavan Province, Sekong Province and Champasak Province. However, they don't occur in the study area.

2.4.2 Soils Derived from Sand Stone and Clay Stone

(1) Soil code 4: Orthic Acrisols (Dystric Cambisols)

Characteristics of these soils are as follows: Color is pale brown; effective depth is medium (30-75 cm); texture is coarse (sand to loamy sand) to medium (sandy loam to clay loam): reaction is very strongly acid to strongly acid; and fertility is low.

These soils are distributed in the areas of 2,280 ha in Pakxong District, 840 ha in Salavan District and 1,180 ha in Bachiang District. Total area is 4,930 ha (0.75 %).

(2) Soil code 5: Lithic Acrisols (Lithosols)

Characteristics of these soils are as follows: Color is light gray; effective depth is shallow (<25 cm); texture is coarse (sand to loamy sand) to medium (sandy loam to clay loam); reaction is strongly acid and fertility is low.

These soils are distributed in the areas of 150,630 ha in Pakxong District, 1,05 ha in Laongam District, 5,220 ha in Salavan District, 4,220 ha in Thateng District and 460 ha in Bachiang District. Total area is 161,580 ha (25.70 %). The land is mostly utilized as steep forest one.

2.4.3 Soils Derived from Basalt Rock

(1) Soil code 6: Dystric Nitosols

Characteristics of these soils are as follows: Color is dark brown, dark yellowish brown or dark reddish brown; texture is medium (sandy loam to clay loam) to fine (clay to silty clay loam); reaction is strongly acid to acid; fertility is medium.

These soils are distributed in the areas of 100,620 ha in Pakxong District, 16,790 ha in Salavan District, 64,120 ha in Laongam District, 12,190 ha in Thateng District and 44,990 ha in Bachiang District. Total area is 238,710 ha (36.50 %).

(2) Soil code 7: Dystric Nitosols (Lithic Nithosols)

Characteristics of these soils are as follows: Color is dark brown, dark yellowish brown or dark reddish brown; effective depth is medium (30-75 cm); texture is medium (sandy loan to clay loam) to fine (clay to silty clay loam); reaction is acid to slightly acid; and fertility is medium to high.

These soils are distributed in the areas of 43,220 ha in Pakxong District, 4,900 ha in Laongam District, 160 ha in Salavan District and 12,300 ha in Thateng District. Total area is 60,580 ha (9.26 %).

(3) Soil code 8: Lithic Nitosols (Lithosols)

Characteristics of these soils are as follows: Color is dark brown, dark yellowish brown or dark reddish brown; effective depth is shallow; texture is fine (clay to silty clay loam); reaction is slightly acid to neutral; and fertility is high.

These soils are distributed in the areas of 48,620 ha in Pakxong District, 28,950 ha in Laongam District, 9,000 ha in Salavan District, 1,490 ha in Thateng District and 1,490 ha in Bachiang District. Total area is 88,200 ha (13.49 %).

2.4.4 Others

(1) Soil code 9: Steep Land Soils

Characteristics of these soils are as follows: These are soils on the land with slopes over than 60 % .

These soils extend in the areas of 60,400 ha in Pakxong District, 19,870 ha in Laongam District, 7,570 ha in Thateng District, 16340 ha in Salavan District and 11,380 ha in Bachiang District. Total area is 99,220 ha (15.17 %).

Area and distribution pattern of the soil units in the study are given in Table I-5 and Fig. I-1, respectively.

III LAND CLASSIFICATION

3.1 Land Classification System

Land evaluation of the study area was made from the points of view of the land capability and the land suitability. It is not easy to distinguish between 'capability' and 'suitability'. According to McRAE & BURNHAM, "Suitability and Capability have often been confused or even regarded as synonymous. This book (p.3) draws a distinction between *suitability* for a single clearly defined, reasonablly homogenous purpose or practice, e.g. carrot production or mole drainage, and *capability* for a broader use such as agriculture or urban development. Thus *suitability* assessment has a sharp focus, looking for sites possessing the positive features associated with successful production or use, whereas *capability* must be vaguer, and is often defined in terms of negative limitations, which hinder or prevent some or all of the individual activities being considered.".

3.2 The Capability Class and the Suitability Class

(1) The Capability Class

Land evaluation for capability was made by using procedure for land capability classification prepared by USDA (1961). Major items of land characteristics and qualities used in classification were effective depth, natural drainage, rockiness, stoniness, textural appreciation, slope, and erosion hazard. A system of land capability classes is usually numbered from I (the least limited) to VIII (land with severely restricted use) that a brief description for the classes follows. In practice, for land capability classification of the study area, the degrees of effective depth, slope and rockiness were regarded as important items.

Class I. Soils have few limitations that restrict their uses.

Class II. Soils have some limitations that reduce the choice of plants or require moderate conservation practices.

Class III. Soils have severe limitations that reduce the choice of plants, require special conservation practices, or both.

Class IV. Soils have very severe limitations that restrict the choice of plants,

	or both. Land Limited in Use - Generally Not Suited for Cultivation.
Class V.	Soils have little or no erosion hazard, but have other limitations impractical to remove the limit their use largely to pasture, range, woodland, or wildlife food and cover.
Class VI.	Soils have severe limitations that make them generally unsuited to cultivation and limit their use largely to pasture or range,woodland, or wildlife food and cover.
Class VII.	Soils have severe limitations that make them unsuited to cultivation and that restrict their use largely to pasture or range, woodland, or wildlife.
Class VIII.	Soils and land forms have limitations that preclude their use for commercial plant production and restrict their use to recreation, wildlife, or water supply, or to esthetic purpose.

(2) The Suitability Class

The FAO Framework for Land Evaluation by a system of land suitability classification is well-known. Land Suitability Classes are numbered according to decreasing degrees of suitability. Three Suitable Classes and two Not Suitable Classes are recommend as below:

Class S1	High Suitable Land having no significant limitation to sustained application of a given use, or only minor limitations that will not significantly reduce productivity or benefits and will not raise input above an acceptable level.
Class S2	Moderately Suitable Land having limitations which in aggregate are moderately severe for sustained application of a given use; the limitations will reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will be appreciably inferior to that expected on Class S1 land.
Class S3	Marginally Suitable Land having limitations which in aggregate are severe for sustained application of a given use and will so reduce productively or benefits, or increase required inputs, that this expenditure will be only marginally justified.
Class N1	Currently Not Suitable Land having limitations which may be surmountable in time but which cannot be corrected with existing knowledge at currently acceptable cost; the limitations are so severe as to preclude successful sustained use of the land in the given manner.
Class N2	Permanently Not Suitable Land having limitations which appear so severe as to preclude any possibilities of successful sustained use of land in the given manner.

The system of the land suitability classification for irrigation which has been produced by USBR (1953) is thought highly. In the system of USBR, the irrigation suitability classification is expressed by using the symbols of land class, soil deficiency, topographic deficiency, drainage deficiency, risk of flooding, need for leveling, land use code, relative productivity level code, relative land development costs code, farm water requirement code and land drainability code.

An instance of the criteria used in assessing soil suitability for crops are given in the following table.

Mayor criteria used in assessing soil suitability for crops in Malaysia (Extract)

Crop	Maximum Slope (%)	Soil depth (cm)	Texture	Drainage	Water release (months)	pH
Soyabean	10.5	25	Not C	W-I	GS	5.5-6.5
Vegetables	10.5	25	Not C	W-I	GS	4.5-6.5
Tea	36	100	Not S or C	W-I	12	4.0-6.0
Grass(cut)	21	25	Not LS or coarser	W-P	12	4.3-7.0
Citrus	36	125	Not S or C	W-I	12	5.0-7.0
Pineapple	10.5	25	All	W-I	12	4.5-5.5
Banana	21	125	Not LS or coarser	W-I	12	4.0-7.0
Cashew	36	100	Not C	W-I	9	4.0-7.3
Coffee	21	125	Not S	W-I	12	4.5-6.5
Coconut	10.5	100	Not LS or coarser	W-I	12	4.5-7.5
Maize	10.5	50	Not S or C	W-I	GS	>5.0
Sorghum	10.5	50	Not S	W-I	GS	>5.0
Groundnut	10.5	25	Not S or C	W-MW	GS	5.5-7.0
Paddy rice	0.4	25	SCL or finer	Controlled	Dry at harvest	>4.0

LS-Loamy sand: SL-Sandy loam: C-Clay: S-Sand: SCL-Sandy clay Loam; W-Well drained: MW-Moderately well drained: I-Imperfectly drained: P-Poorly drained; GS-Growing season.
Source: Extrated from Table 4.2 in Land evaluation" & C.D. BURNHAM (1981)

In this study, land evaluation for suitability was done by the system of USDA, especially, on the base of the relation between altitude of land and crop suitability, the effective depth, the slope and the rockiness.

3.3 Results of Land Classification

Results of land capability and land suitability were shown in Table I-6 to I-7 and Fig. I-2.

IV LAND USE

4.1 Present Land Use

4.1.1 Total Study Area

Present land use in the study area was investigated by the existing data, field survey and aerial photographs.

The results obtained are as follows: plants which are cultivated covering the wide or small area are coffee, tea, sugar cane, cereal crops such as rice and maize, leguminous plants such as mungbean, groundnut and soybean, spice food plants such as cardamom land chili, etc.

Fruit trees and crops such banana, papaya, dorian, mango, pineapple, jack fruit, etc. are also planted. Vegetables such as cabbage, chinese cabbage, cucumber, etc. are cultivated in scattered land.

Besides, grassland is used for livestock in considerably wide area.

The forest land extends largely. Deep forest which grows thickly on steep land in wild state in considerable wide area, while a part of forest land is used for timber logging and shifting cultivation even in the area with a steep slope. The results obtained approximately is indicated in Table I-8 and Fig. I-3.

4.1.2 Tentatively Selected Priority Development Areas

Present land use in sixteen areas which are tentatively selected as Priority Development Areas was examined. The result obtained approximately is given in Table I-9.

4.2 Optimum Prospective Land Use

4.2.1 Total Study Area

Taking the existing data relating to optimum prospective land use plan and the knowledge obtained from field survey into consideration, a draft for land use plan of the study area in the future was prepared. The results obtained are given in Table I-10 and Fig. I-4.

4.2.2 Tentatively Selected Priority Development Areas

The future plan of the tentatively selected priority development areas is undertaken in other part of this report.

4.3 Soils and Soil Erosion

The results obtained through environmental studies with Geographical Information System (GIS) technology state clearly that the erosion risk in Lao PDR is divided into three classes and these classes are effected by seven factors, that is, 1. Population density, 2. Cattle density, 3. Ethnic groups, 4. Slope, 5. Geology, 6. Soil, and 7. Climate.

Among those factors, geology is a item closely relating to soil. According to the hydrogeology map of the Mekong Atlas published by the Mekong Secretariat, 1968, erosion risk classes which are influenced by geology are arranged as follows:

Erosion risk class 1:	a)	Sandy alluvium
	b)	Limestone
Erosion risk class 2:	a)	Basalt
	b)	Gneiss, Schist, Quartzite, Granite and Gabbro
Erosion risk class 3:	a)	Sedimentary rocks
	b)	Shale

From such a point of view, it may be thought that erosion risk is considerably heavy because that the parent material of major soils in "Boloven Plateau" is basalt rock. According to the engineering soil map (scale 1:2,000,000) of the Mekong Atlas Published by Mekong Secretariat 1968, erosion risk classed that are influenced are as follows:

Erosion risk class 1: Highly plastic clay

Erosion risk class 2:	a)	Poorly graded sand and silty sand
	b)	Interbedded silt, sand, clay on poorly drained alluvial plains
	c)	Sand, clay and silt on mountains, hills and dissected

plains

Erosion risk class 3: a) Silty sand and clayey sand
b) Clayey silt

Major soil extending in "Boloven Plateau" is equivalent to highly plastic clay soil. Therefore, the soil is easily eroded.

Conclusively, the soil erosion risk in "Boloven Plateau" is ranged in medium class. Referring further, the erosion risk is medium in central region, low in forest land in eastern and southeastern regions, and high in the belt like region from center to south edge, of "Plateau".

In practice, the shallow soils are distributed in the area of 310,360 ha (47.48 %) in the study area. Especially, in most part of Pakxong and Laongam Districts, sand stone, clay stone or basalt rock which is parent materials of the soil crops out on the land surface.

In such a case, if the land surface is rough, a great mass of soil is easily eroded by heavy rainfall (around 2917.3 mm/year in the average of 11 years'record).