Appendix C

Hydro-Meteorology in the Kone River Basin

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Appendix C Hydro-Meteorology in the Kone River Basin

1. HYDRO-METEOROLOGICAL CONDITIONS

1.1 Location and Basin Definition

The Kone river basin is situated in the south central Vietnam between 13°30' to 14°42' north latitude and 108°36' to 109°15' east longitude. The basin is almost entirely situated within the Binh Dinh province. The Kone basin is defined as the basin that discharges into the East Sea through the Quy Nhon Estuary. This basin is composed of the following sub-basins, see also Figure C.1.

- The upper and middle Kone basin, discharging at the Delta apex at Binh Thanh;
- The upper and middle Nui Mot basin located upstream of National Road No. 19;
- The upper and middle Ha Thanh basin located upstream of the National Road No.1;
- The upper and middle La Vi basin located upstream of Phu Cat and north of the Provincial Road 635;
- The lower basin or (flood prone) Delta area, located downstream of Binh Thanh and bordered by Road 635 in the north and Road 19 in the south.

The total basin area amounts to 3,640 km^2 and the sub-basin areas are as follows:

Kone sub-basin upstream Binh Thanh:	2,250 km^2
Nui Mot sub-basin:	180 km^2
Ha Thanh sub-basin:	590 km^2
La Vi sub-basin:	240 km^2
Delta area:	380 km^2
TOTAL BASIN AREA	3,640 km^2

In addition to the division into sub-basins as indicated above, a further sub-division of the upper and middle Kone basin has been made in view of existing (Vinh Son Dam) and anticipated water management structures at Dinh Binh (dam site) and Cay Muong / Van Phong (diversion structure). This subdivision is as follows:

Kone sub-basin upstream Vinh Son:	214 km^2
Kone sub-basin upstream Dinh Binh:	1,040 km^2
Kone sub-basin upstream Cay Muong/Van Phong:	1,677 km^2

Measured along the axis of the Kone River, the distance from the river mouth to its source amounts to some 160 km, climbing from sea level to a maximum elevation of almost 1000 m above sea level.

1.2 Hydro-meteorological Data

Historic runoff data are only available for the Kone sub-basin upstream of Cay Muong (measured at Cay Muong). Runoff series for the other sub-basins are therefor to be generated on the basis of rainfall – runoff modelling in the respective basins. Such modelling requires an accurate assessment of the area rainfall and evaporation in the respective sub-basins. The collection of rainfall data has been focussed on an adequate coverage of all sub-basins. In fact, all available rainfall data over the period 1976 – 2001 with relevance for the estimate of the area rainfall in the respective sub-basins have been collected. Based on availability of data and the requirements of the study, it was decided to use a one-day time step for the runoff analysis. Only for the analysis of floods a shorter time step, i.e. one hour, has been used.

In addition to the runoff related data, also data have been collected related to the sediment loads corresponding with the basin runoff. This information is essential for the estimate of lifetime of proposed reservoirs and the morphological response of river works.

Finally, data on the occurrence of typhoons in or near the project area have been collected in order to analyse the relation between the incidence of this phenomenon and the occurrence of floods.

The following table summarises the hydro-meteorological data that have been collected from the Hydro Meteorological Service of Vietnam. The location of the stations is presented in Figure C.2.

Daily rainfall data

Station	Series	
	from	To
Ba To	Jun 1976	Dec 2001
Gia Vuc	Aug 1977	Dec 2001
Vinh Kim	Aug 1982	Dec 2001
Binh Quang	Jan 1979	Dec 2000
Binh Tuong (Cay Muong)	Jun 1976	Dec 2001
Phu Cat	Jun 1976	Dec 2001
Tan An	Jan 1977	Dec 1988
Quy Nhon	Jan 1976	Dec 2001
An Khe	Jan 1977	Dec 2001
Hoai Nhon	Mar 1978	Dec 2001
Van Canh	Jun 1976	Dec 2001

Daily Evaporation Data

Station	Series	
	from	To
Quy Nhon	Jan 1976	Dec 2000

Daily Discharge Data

Station	Series	
	from	To
Cay Muong	Jan 1976	Dec 2001

The complete list of daily data that have been collected and used in the present study is presented in Annex 1 to this report.

In addition to these daily data, hourly rainfall (Ba To, Hoai Nhon and Quy Nhon) and hourly discharge data (Cay Muong) have been made available of ten mayor flood events, i.e. the years 1978,1980, 1981, 1984, 1987, 1992, 1994, 1996, 1998 and 1999.

1.3 Climate

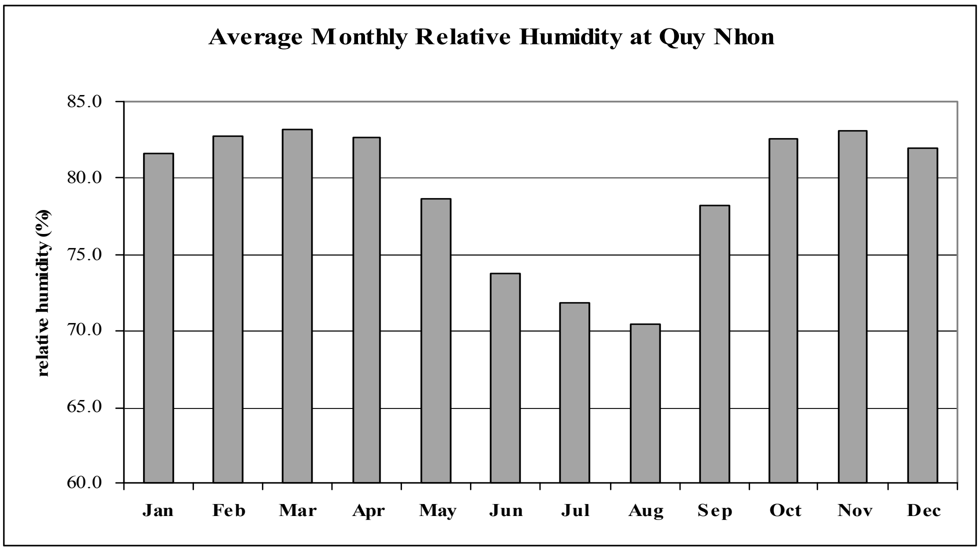
1.3.1 Temperature

The climate in the Kone Basin is characterized by an equable temperature over the year, ranging, in the lower part of the basin, from 23 ^{o}C on the average in January to almost 30 on the average in the period June – August. The day-night fluctuation of the temperature is greatest (7-9 ^{o}C) during the June-August period and smallest (4-6 ^{o}C) during the cooler period December – February.

In the upper part of the basin the temperature is, on the average, 1.5 ^{o}C lower than in the lower part.

1.3.2 Humidity

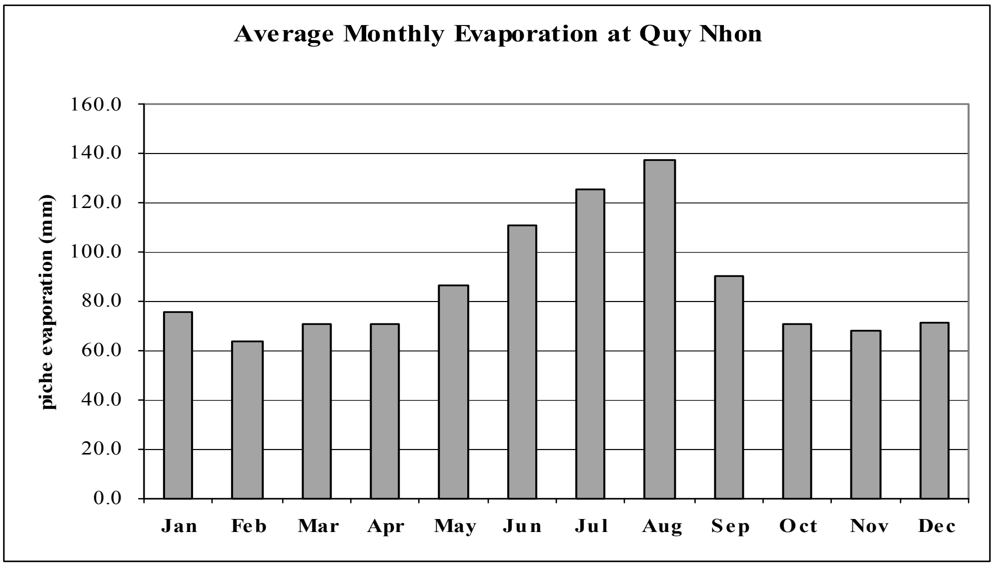
The humidity is lowest in the months with highest temperature (about 70% in July and August) and increases to a level of over 80% in the cooler months.



1.3.3 Evaporation

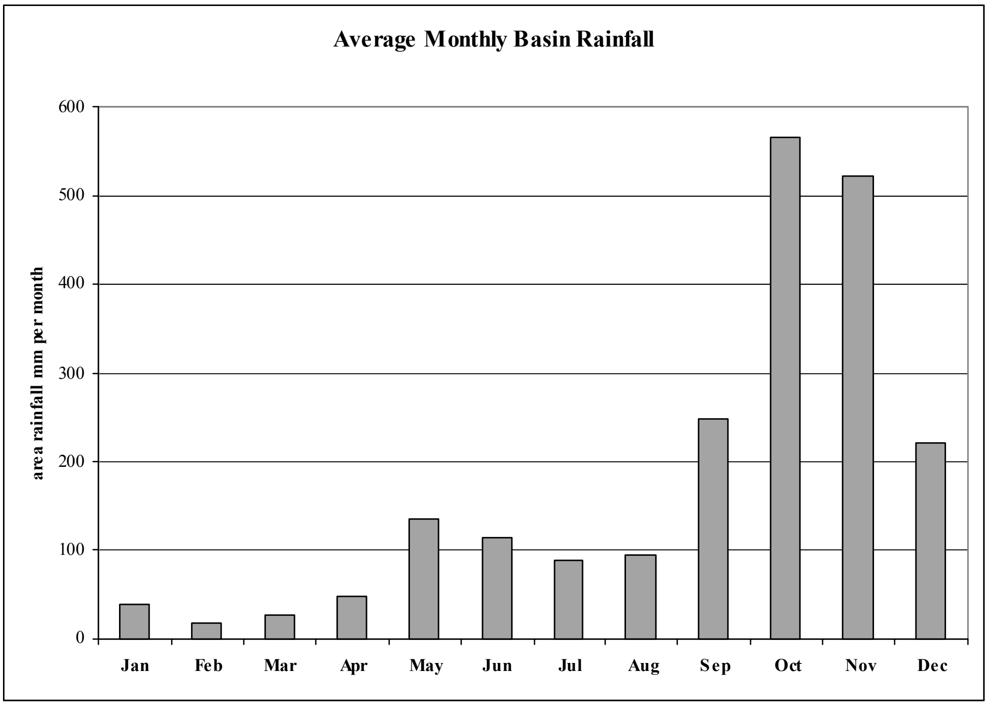
The annual evaporation in the lower basin, measured at Quy Nhon with "Piche",over the period 1976 - 2000 amounts to 1041 mm on the average. A substantial variation in yearly evaporation has, however, been observed, from 776 mm in 1988 to 1,319 mm in 1997. The monthly variation is on the average as shown in the figure below, with highest values in the dry and hot July-August period. During the "winter" months the monthly evaporation can be as low as half the monthly values during the "summer"months.

On the basis of the 24 year of rainfall-runoff simulation, that has been carried out in this study, it is found that the actual basin wide evapotranspiration amounts to some 565 mm per year on the average.



1.3.4 Precipitation

The yearly basin rainfall, averaged over the last 25 years (1977 – 2001) amounts to 2,120 mm. From this amount some 63%, or 1,333 mm falls on the average in the period September – November. The average monthly basin rainfall is as follows:



The spatial distribution of the rainfall in the Kone basin indicates that the rainfall increases from the lower delta area to the upper area upstream of Binh Dinh. The yearly average precipitation in the Delta area amounts to 1,857 mm, while in the upper catchment the rainfall is as high as 2,590 mm per year on the average.

In Chapter 2, a detailed analysis of the rainfall intensities and spatial distribution in the Kone basin is presented.

1.3.5 Typhoons and Tropical Depressions

An inventory has been made of typhoons and tropical storms that made landfall during the period 1976 – 2000 at or near the Kone basin (between Na Trang and Da Nang or between 12^{o}N and 16^{o}N). A summary of this inventory is presented in the table overleaf. The inventory was made for the mentioned period in order to evaluate the coincidence of these storms with the occurrence of floods in the Kone basin.

A total number of 34 relevant storms were identified, of which 28 toke place during October-November, two during the Minor flood season (May – June) and four during the Early flood season in September.

Although there is a clear (and obvious) indication that there is a relation between the occurrence of the tropical storms and the occurrence of floods, it is also clear that not all storms that were identified caused exceptional peak discharges. About 50% of the identified storms created peak discharges with a yearly probability of exceedance of 90% or less. The other 50% of these storms did not have an exceptional effect on the Cay Muong discharges. On the other hand, yearly peak discharges in Cay Muong coincided in only 8 years out of the 25 with the occurrence of a typhoon or tropical storm. That is to say that the observed yearly maximum discharges are not related to typhoons or tropical storms (at least not the identified ones) in some 70% of the cases.

Coincidence of landfall of Typhoons and Tropical Depressions and Area Rainfall anf flood discharges in the Kone basin

Storm	date	PA1day	prob.	PA2days	prob.	PA3days	prob.	QdayCM	prob.	Qpeak	prob.	Qmaxyear
no 26	30-Oct-78	43		75		77		256				
no 27	03-Nov-78	128		160		173		812		1475	0.8	1475
no 19	15-Oct-79	187	0.4	242		295		1050		1780	0.8	2380
no 22	02-Nov-80	172	0.5	330	0.2	362	0.3	1390				4280
no 23	14-Oct-81	137		226		235		1020				4140
no 12	09-Oct-83	94		136		146		353				2770
no 20	12-Oct-84	212	0.2	311	0.2	317	0.4	995		1380	0.8	3480
no 23	01-Nov-84	85		144		221		771				3480
no 24	07-Nov-84	91		179		181		2040	0.3	3480	0.2	3480
no 25	25-Nov-85	181	0.4	219		224		1020		2450	0.5	2450
no 22	22-Oct-86	132		161		166		612		1410	0.8	2850
no 23	11-Nov-86	38		68		82		77				2850
no 21	18-Nov-87	228	0.05	289	0.3	348	0.3	4010	0.02	6340	0.016	6340
no 25	09-Oct-88	148		243		256		800				2050
no 30	06-Nov-88	81		108		205		1020		1680	0.8	2050
no 22	03-Oct-90	156		193		205		598				3210
no 24	18-Oct-90	171	0.5	192		202		1360				3210
no 26	12-Nov-90	175	0.5	311	0.2	334	0.4	1540	0.5	2840	0.4	3210
	20-Oct-94	175	0.5	266	0.4	276		1270		2330	0.6	2330
Yvette	26-Oct-95	172	0.5	186		197		989		2560	0.5	2690
Zack	01-Nov-95	67		77		113		932		2690	0.4	2690
Abel	17-Oct-96	49		92		138		189				3460
Linda	01-Nov-97	151		204		327	0.4	1210		2480	0.5	2480
	11-Nov-98	192	0.3	315	0.2	366	0.3	1520	0.5			4350
	19-Nov-98	177	0.4	300	0.3	402	0.2	2460	0.17	4350	0.11	4350
	24-Nov-98	139		165		165		1970	0.3			4350
	16-Oct-99	82		155		172		1110		2100	0.6	3680
	15-Dec-99	95		102		111		753				3680
Minor Flood	**date**	**PA1day**	**prob.**	**PA2days**	**prob.**	**PA3days**	**prob.**	**QdayCM**	**prob.**	**Qpeak**	**prob.**	**Qmaxyear**
no 5	30-Jun-78	58	0.2	94	0.1	94	0.17	60	0.6	77	0.6	77
no 1	10-Jun-84	97	0.016	127	0.02	131	0.035	312	0.026	763	0.006	763
Early Flood	**date**	**PA1day**	**prob.**	**PA2days**	**prob.**	**PA3days**	**prob.**	**QdayCM**	**prob.**	**Qpeak**	**prob.**	**Qmaxyear**
no 12	25-Sep-77	162	0.005	282	0.003	307	0.0035	778	0.004	978	0.008	978
no 16	06-Sep-82	22	0.9	32	0.9	42	0.9	48	0.7	55	0.8	55
no 14	28-Sep-84	26	0.8	36	0.8	48	0.8	30	0.8			37
Fritz	25-Sep-97	108	0.05	165	0.07	192	0.06	110	0.56	212	0.5	212

Sources 1976-1990 : Tropical Cyclone Tracks in the Western North Pacific, Japan Meteorological Agency, 1992
1991-2000 : Annual Tropical Cyclone Report, Naval Pacific Meteorology and Oceanography Centre / Joint Typhoon Warning Centre
: Hydro-Meterology Forecast Centre of Binh Dinh

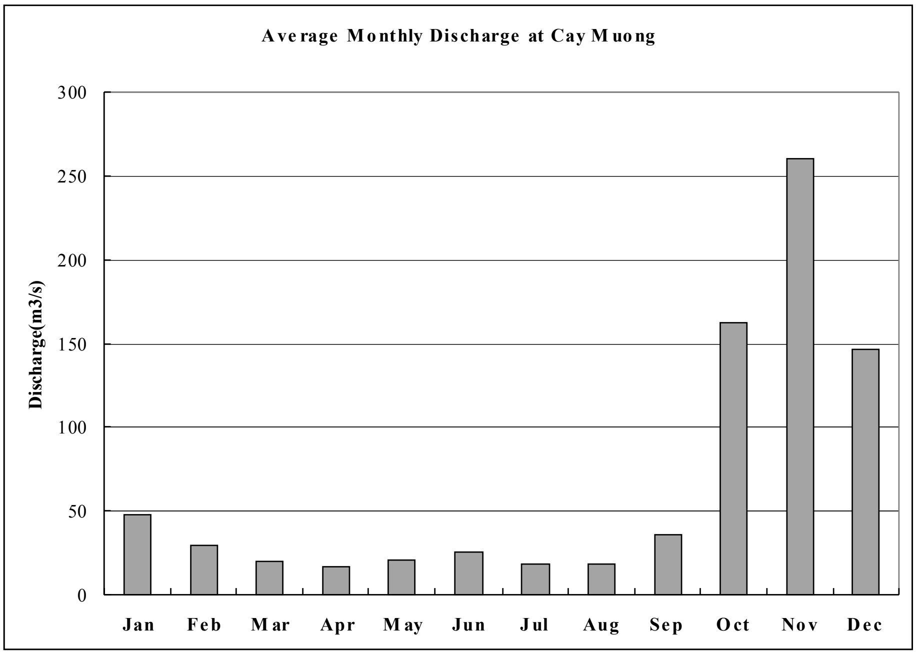
1.4 Hydrology

1.4.1 Natural Runoff

Long series of discharge observations are available at Cay Muong only. This hydrological station covers 1677 km2, or 46%, of the total basin area that discharges at the Quy Nhon estuary. Moreover, the observed runoff at Cay Muong refers to the runoff of surface water only. It is estimated that the surface runoff corresponds with about 70% of the total basin runoff, including the subsurface flow. This estimate is based on the results of the rainfall-runoff simulation in the basin.

From the 1976 – 2001 daily discharge data at Cay Muong, it is derived that the average runoff at that location amounts to 68.2 m3/s. This corresponds to 1283 mm on a yearly basis or 54% of the average yearly rainfall, calculated at 2368 mm for the area upstream of Cay Muong.

The average monthly discharges at Cay Muong are as follows:



In Chapter 2, a comprehensive analysis is presented of the basin runoff and the runoff of the different sub-basins.

1.4.2 Flood Runoff

In the Kone basin a distinction is made between the Main Floods, Early Floods, Minor Floods and Late Floods. Main floods occur in the period October-November or, exceptionally, in December. These floods are often the result of tropical depressions, tropical storms or typhoons that land at the Vietnamese coast near the Kone Basin causing high rainfall intensities in the order of 200 – 400 mm in one day. An early arrival of storms, generally with lower intensities in the order of 50 – 100 mm in one day may cause the so-called Early Floods during the months August - September. Minor Floods may occur in the months May – June, corresponding with rainfall that is similar to the Early Flood rainfall. Late floods are floods that may occur in December after the main floods have passed, these floods tend to go together with rainfall intensities in the order 200 mm in one day.

From the analysis of historical floods at Cay Muong it is learned that the duration of the Main Floods varies between one and four days, and go together with area rainfalls in the order of some 300 mm in two days up to 500 mm in three days. The maximum yearly flood volumes (in the order of 200 – 400 Mm3) correspond, on the average, with about 65% of the rainfall volumes. The floods have a flashy character, reaching the peak discharge normally within 12 hours.

The highest discharge at Cay Muong has been observed in 1987 and amounted to 6,340 m3/s. This peak discharge has an estimated return period of about 100 years (113 years when a Pearson3 distribution is assumed and 77 years only when a Gumble distribution is assumed). The estimated probable peak discharges of the various floods are indicated below:

Annual Peak Discharges at Cay Muong

(m^3/s)

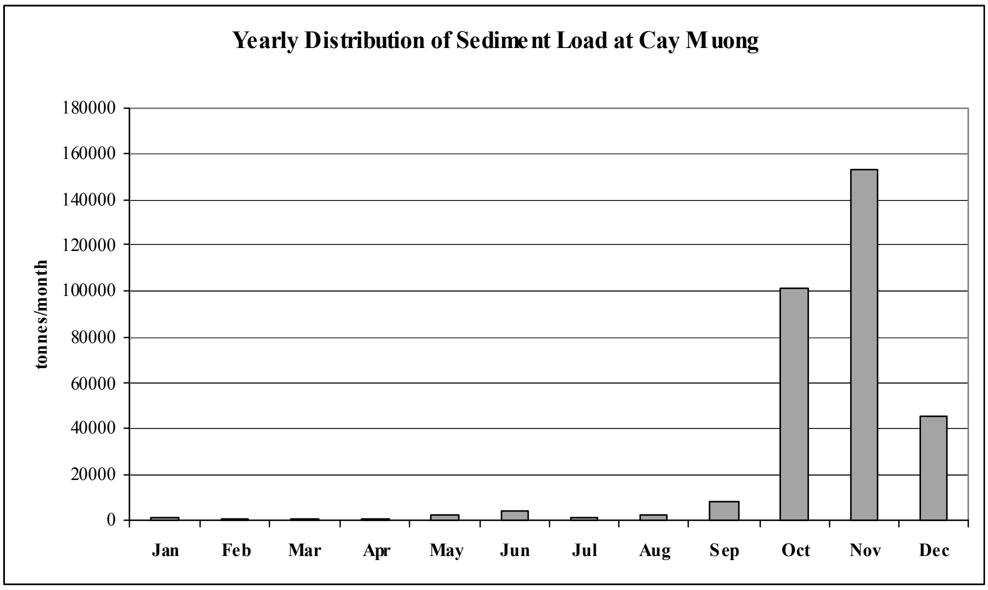
	Probability (% per year)					
	50%	20%	10%	5%	2%	1%
Main Flood Peak Discharge	2,530	3,700	4,400	5,020	5,750	6,270
Late Flood Peak Discharge (December)	250	900	1,530	2,200	3,330	4,380
Minor Flood Peak Discharge (May – June)	120	250	360	460	610	720
Early Flood Peak Discharge (August –September)	180	360	500	660	880	1,070

In Chapter 2, a comprehensive analysis of the flood runoff of the different sub-catchments of the Kone Basin are presented.

1.4.3 Sediments

The runoff of sediments is measured at Cay Muong only. Daily data on the concentration of suspended sediments at that location have been collected for the period 1980 – 2000. These data are compiled in the Appedix 1 to this report.

Sediment concentrations at Cay Muong vary from practically zero in the low flow period to values of over 500 – 1,000 gr/m^3 (ppm) during the floods in October – November. As a consequence most of the sediment load occurs during the flood season. The distribution of the average suspended load of some 320,000 tonnes per year is shown in the figure below:



Almost 80% of the transport of suspended sediments take place during October – November.

2. RUNOFF ANALYSIS

2.1 Natural Runoff

2.1.1 Objectives of the Runoff Analysis

The formulation of a comprehensive river basin plan for the Kone Basin requires an accurate assessment of the water resources potential of this basin. The water resources potential is defined as the volume of water, with an adequate quality, that can be made available for satisfying water demands. These demands can be related to agricultural, domestic and industrial water requirements but also to hydropower, navigation, wetland development and conservation, fish and wildlife, recreation and waste assimilation.

The formulation of the comprehensive plan for the Kone Basin essentially considers only the availability of surface water resources within the basin. Two other potential sources that could be considered are: (i) groundwater and (ii) the import of surface water from neighbouring basins.

An estimated 20% of the rainfall volume on the basin runs off via groundwater flow. The potential use of this groundwater is limited as a consequence of the absence of subsurface aquifers from where this water could be subtracted in an cost-effective way. For the supply of drinking water to urban areas in the basin, other sources then groundwater are being sought to safeguard the satisfaction of future demands.

The transfer of water from the projected An Khe reservoir in the Ba basin towards the Kone river is a promising option to increase the availability of water in the Kone basin. This option, however, is considered as a potential supplement to the available Kone basin waters, rather then as an alternative for the use of Kone basin waters. The basin plan will, therefor, primarily be based on the available resources in the Kone basin itself.

For the formulation of the comprehensive basin plan the natural flow regime of the Kone basin will be taken as starting point. The plan will consider the construction of reservoirs for several purposes: (i) storage for satisfying demands under natural low flow conditions, (ii) retention of flood waves and (iii) hydro-power. The water balance, will be an essential tool in the assessment of the need for such storage capacity.

The principal objective of the runoff analysis is to provide the input for detailed water balance studies and to allow the assessment in terms of time and location of the availability of surface water in the several sub-catchments of the Kone basin.

In view of the location of the areas with potential water demands and potential storage reservoirs, the runoff analysis should assess the availability of water at the following locations in the basin:

- at Dinh Binh / Vinh Thanh, where the creation of storage capacity is envisaged and the supply of water for the Vinh Tanh irrigation scheme;
- at Cay Muong / Van Phong, where the supply of water for the Van Phong scheme is envisaged;
- at Binh Than (the apex of the Kone Delta), where the distribution of water over the several branches takes place;
- at the river mouth, where a minimum discharge is to be maintained.

In addition to these control points along the main stem of the Kone river, also the runoff of the Nui Mot, La Vi and Ha Thanh sub-basins should be known for the assessment of the water balance within these sub-basins.

The irrigation water demand is by far the most important demand in quantitative terms. Since this demand is normally expressed in the demand per decade of days, also the water availability should be known with the same time step.

2.1.2 Methodology

Previous water balance studies that have been carried out for the Kone basin (IWRP, 1997-1998 and HEC-1, 2000) made use of the observed runoff series. After a statistical analysis of the runoff characteristics ("flow modules" in $m^3/s/km^2$) of this series, these characteristics were used for the assessment of the probable runoff of other sub-catchments in the basin. The yearly flow distribution, either in months or decades was, derived from the "typical" distribution at Cay Muong station. In this way, typical (synthetic) runoff years with a certain probability of occurrence (50%, 75%, 80%, 85%, 90%) were generated and used in the water balance analysis.

In the present study, preference is given to the generation of runoff series for each of the control points, on the basis of historical rainfall and runoff data, and to use these series in the water balance studies. Carrying out the water balance studies by simulation with the help of historical series gives a more factual picture of the probability that a certain demand can be satisfied. A period of 25 years or more of historical information is considered adequate for this approach.

The most reliable and extensive runoff data of the Kone basin come from the Cay Muong discharge series observed since 1976. Discharge data of this station that are collected prior to 1976 are reported to be inadequate. A full picture of the rainfall in the Kone basin can be obtained from the 9 rainfall stations that are mentioned in the Section 2.3 of this report. Full coverage of rainfall data in these stations is available as from September 1977. Hence, the best estimate of the area rainfall on the several sub-catchments can be made as from the end of the dry season of 1977. Based on these considerations it has been decided to generate the runoff series at the respective control points for the period September 1977 – December 2001.

Sufficient information is available for an adequate modelling, calibration and verification of the rainfall – runoff process in the Cay Muong sub-basin. With the help of such model, the runoff series can be generated. For the estimate of the area rainfall, the Thiessen method has been applied. From the measurement of the respective areas belonging to a certain rainfall station, the following area weights have been derived:

Area Weights (%) used in the Calculation of Area Rainfall according to Thiessen											
Catchment	km2	BaT	G V	V K	B Q	B T	P C	Q N	AnK	V C	
u/s VinhSon Dam	(214)	0.0	41.0	59.0	0.0	0.0	0.0	0.0	0.0	0.0	100
u/s Dinh Binh	(1040)	6.4	34.7	58.9	0.0	0.0	0.0	0.0	0.0	0.0	100
u/s CayMuong	(1677)	4.3	23.6	48.7	15.3	7.1	0.0	0.0	0.9	0.0	100
u/s Binh Thanh	2250	3.2	17.6	36.4	13.8	20.9	4.0	0.0	0.7	3.4	100
NuiMot	180	0.0	0.0	0.0	0.0	13.7	20.7	11.0	0.0	54.7	100
LaVi	240	0.0	0.0	0.0	0.0	0.0	100	0.0	0.0	0.0	100
HaThanh	590	0.0	0.0	0.0	0.0	0.0	0.0	31.9	0.0	68.1	100
Delta	380	0.0	0.0	0.0	0.0	0.0	55.0	45.0	0.0	0.0	100
	3640										

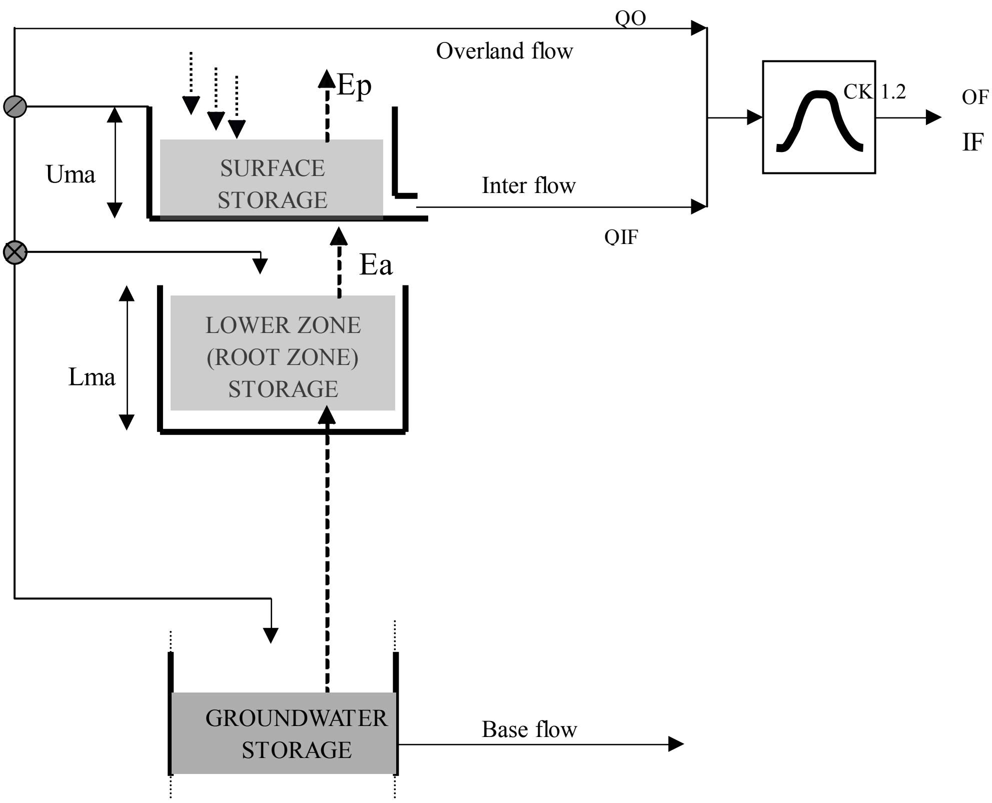
NuiMot Catchment area: upstream of National Road No.19
LaVi Catchment area: upstream of Railway bridge
HaThanh Catchment area: upstream of National Road no.1
GV: GiaVuc, VK: VinhKim, BQ: BinhQuang, BT: BinhTuong (CayMuong), PC: PhuCat, QN: Quy Nhon (Qui Nhon), VC: Van Canh

The Terms of Reference of the present study call for the use of the MIKE 11 modelling system for the simulation of the rainfall – runoff process. In the present study the NAM module of this system is used for the generation of runoff series. Also the TANK model has been used in order to examine whether this model would give a better reproduction of the rainfall – runoff process in the Kone basin.

The Rainfall- Runoff module NAM of the MIKE-11 software is a lumped conceptual rainfall-runoff model, that simulates overland flow, interflow and base flow as a function of the moisture content in each of four mutually interrelated storages. In the absence of snow storage, the following three storages are relevant for the modelling of the runoff in the Huong Basin, as shown below schematically:

- Surface storage
- Lowe zone or root zone storage

The NAM Model



The model allows to add a second groundwater storage to enable a more accurate description of the base flow, consisting of a “fast” responding component and a “slow” responding component. This feature appeared to be essential for a proper simulation of the receding runoff after the flood season.

Since Cay Muong is the sole station with adequate discharge series, the model calibration could only be done for the catchment upstream of this station. A five year series (September 1982 – August 1987) with full coverage of discharge and rainfall data has been used for model calibration. In the calibration process emphasis was put on the calibration of the recession part of the hydrograph after the flood season. An accurate calibration of this part is decisive for a correct reproduction of the low flow conditions.

For the generation of the runoff series in the respective sub-basins of the Kone basin area rainfall series have been compiled for the period September 1977 – December 2001 on the basis of the daily rainfall data described before.

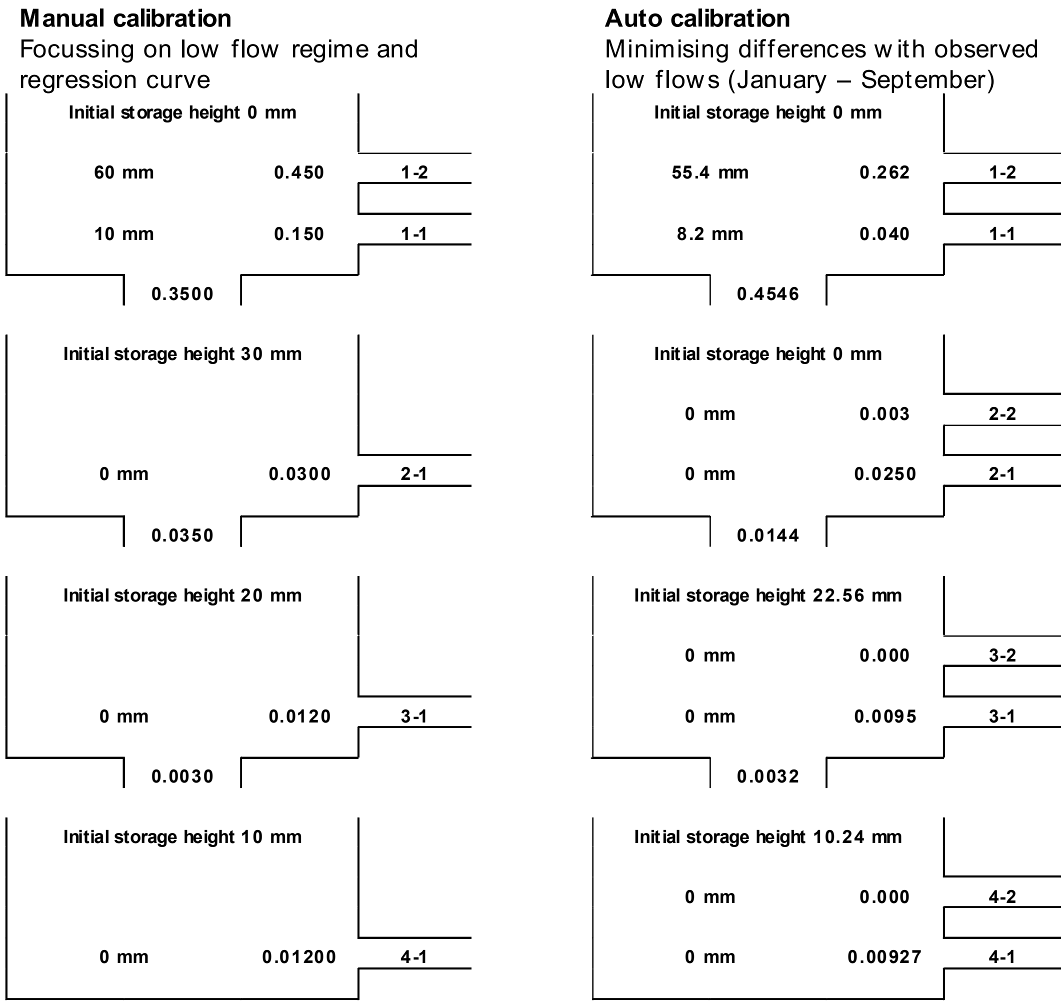
Potential evapo-transpiration data of Quy Nhon according to the Hydrological Atlas were used for the entire basin for model calibration as well as for the generation of the runoff series.

The calibration was carried out with the auto-calibration option of MIKE-11, with the objective functions ‘Overall Root Mean Square Error’ and ‘Low Flow RMSE’. With these 2 objectives checked, the calculated run-off corresponds best with the measured discharges. The values for the model parameters of the lower groundwater reservoir were not optimised by the auto-calibration function of MIKE-11. The values are primarily taken from a recession analyses and manually adjusted based on comparison between the calculated run-off and the measured discharges at Cay Muong.

The calibrated parameters are summarised in the table below.:

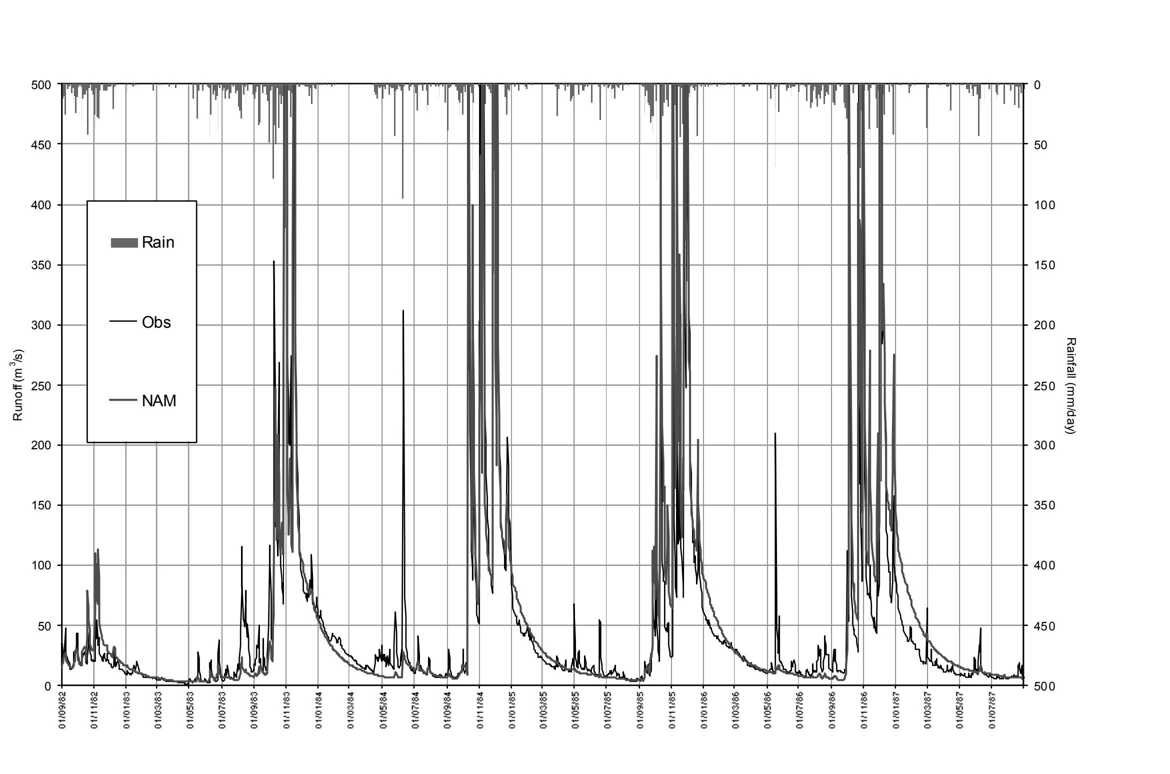
Model Part	Parameter	Unit	Initial input values	Value from autocalibration
Surface Rootzone	Umax	mm	10	10.4
	Lmax	mm	100	123
	CQOF	-	0.5	0.511
	CKIF	hour	500	415.1
	CK1,2	hour	5	24.5
	TOF	-	0	0.716
	TIF	-	0	1.6exp-7
Ground water	TG	-	0	0.197
	CKBF	hour	500	967.7
	Cqlow	percent	25	25
	Cklow	hour	4500	4500
Initial Conditions	U/Umax	-	0.5	
	L/Lmax	-	0.5	
	QOF	m^3/s	0	
	QIF	m^3/s	0	
	BF	m^3/s	10	
	BF low	m^3/s	5	

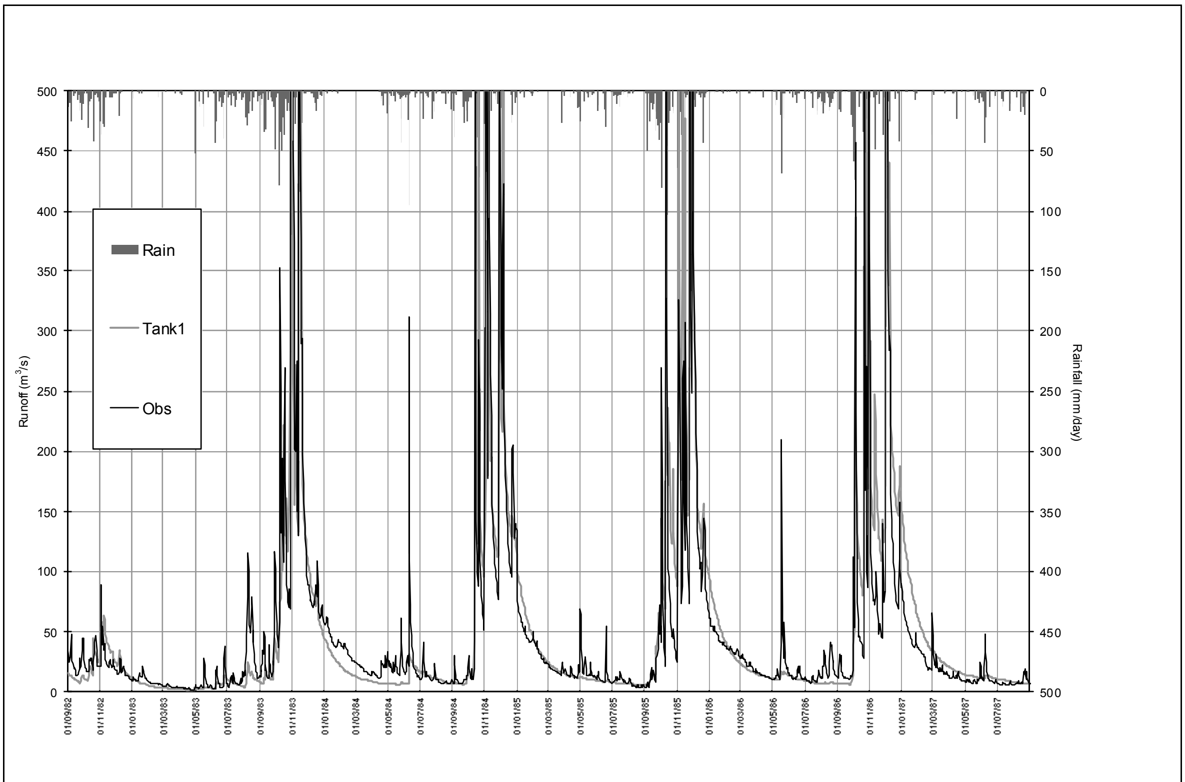
In the process of calibration of the TANK model for the Cay Muong catchment area, the following parameters have been found for the calibration period September 1982 – August 1987



Comparison of the two TANK calibrations revealed better results for the manual calibration.

The calibration results of both the NAM and the TANK model are shown in the figures overleaf. The results are quite similar and no clear preference for the use of one of the models can be derived from these results. Both models describe satisfactorily the recession curve after the rainy season and give an acceptable reproduction of the low flow conditions. Based on these results it was concluded that it is possible to describe satisfactorily the rainfall- runoff process in the area under study with the help of both models. Wit reference to the greater familiarity that the MARD has with MIKE11-NAM model, it has been decided to use the results of this model in the further analysis.





The reproduction of the runoff at Cay Muong on a yearly basis is quite accurate, as is shown in the following table:

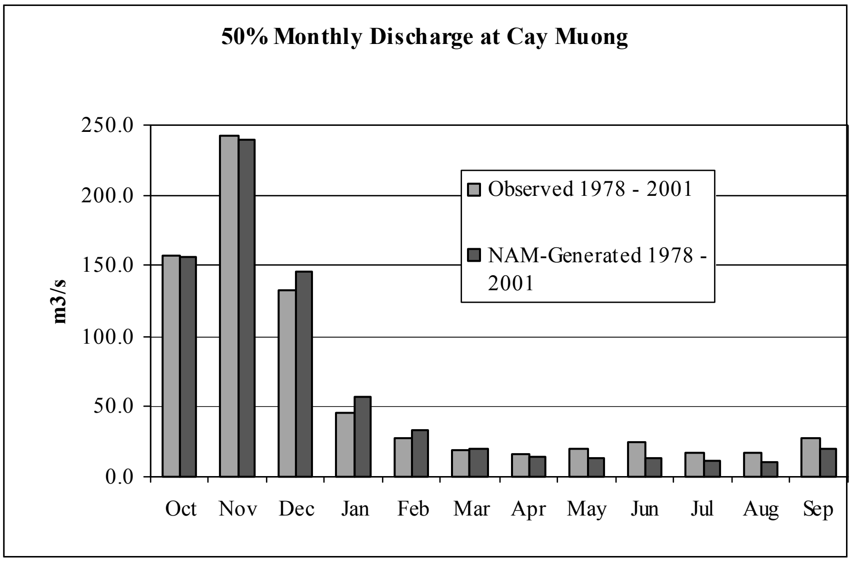
Average Yearly Runoff at Cay Muong (m^3/s)

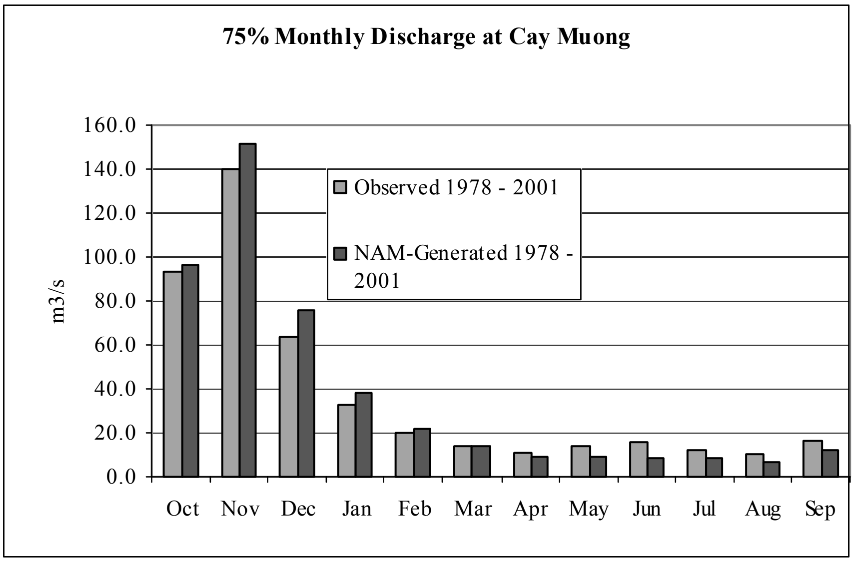
Probability of Exceeding (assuming LN3 distribution)	50%	75%	90%
Historic Series 1978 - 2001	66.4	46.5	31.0
Generated Series 1978 - 2001	65.4	45.6	29.3

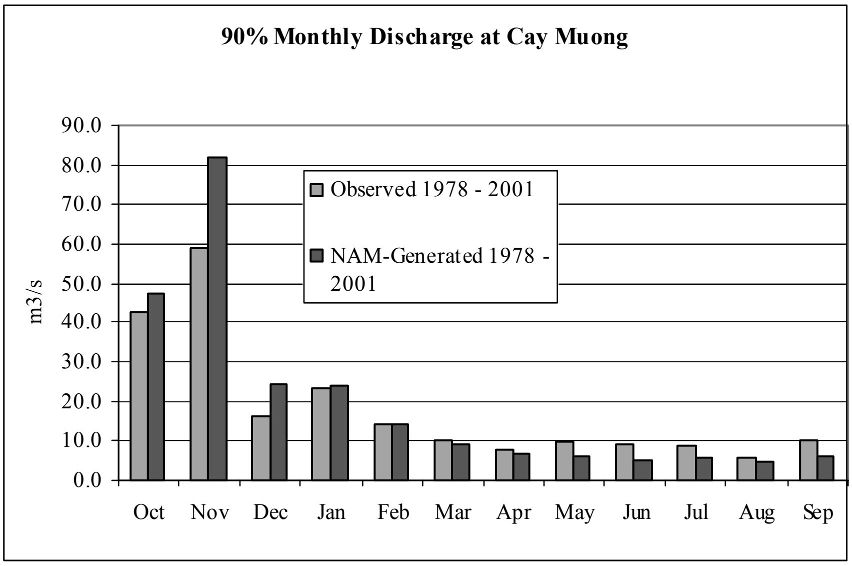
It is noted that the minor floods that tend to occur in the May – June period are not well reproduced by neither of the models. This phenomena is most probably caused by the fact that in running the models, use has been made of the daily area rainfall data. These minor floods are likely to be the result local intensive storms of short duration. Spreading such short intensive rain over a full day hardly generates a noticeable peak runoff.

These minor floods, however, have a noticeable impact on the average monthly or decade runoff. This impact is not reproduced adequately in the models. As a consequence, the average monthly or decade discharges generated by the models show an underestimate of the natural runoff during especially the months May and June. Therefor, the discharges generated for the months of May and June from the sub-catchments have been corrected in accordance with the deviation between the observed runoff and the generated runoff at Cay Muong during the months May and June. This deviation is presented in the figures overleaf.

In the absence of available runoff data and corresponding rainfall data of other (sub-) catchments in the Kone basin, it has not been possible to validate the calibration results of the Cay Muong catchment in other catchments. Therefore, the assumption that the Cay Muong calibration results can be used for the generation of runoff series in the different control points and sub-catchments could not be verified.


50% Monthly Discharge at Cay Muong
250.0
200.0
150.0
100.0
50.0
0.0
m3/s
Observed 1978 - 2001
NAM-Generated 1978 - 2001
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep


75% Monthly Discharge at Cay Muong
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
m3/s
Observed 1978 - 2001
NAM-Generated 1978 - 2001
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep


90% Monthly Discharge at Cay Muong
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
m3/s
Observed 1978 - 2001
NAM-Generated 1978 - 2001
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep

2.1.3 Result of the Runoff Analysis

In the present study, the water balance in the respective sub-catchment areas is analysed on the basis of the 25 years of historic 10-days runoff series. These series have been generated in accordance with the methodology described in the previous section and are presented in the Table C.1.

The results have been summarised for the relevant low flow months for all control points in Figure C3 and C.4.

2.2 High Flow Analysis

2.2.1 Objectives of the High Flow Analysis

Flood damage mitigation is one of the main subjects in the preparation of the comprehensive management plan for the Kone basin. A proper description of the natural flood phenomena in the basin is essential for the formulation of measures for the mitigation of the flood damages. Moreover, regulation works for water management, like dams, weirs, dikes, etc, need to be designed in such a way that they are safe under most, if not all, flood conditions.

From the point of view of the mitigation of flood damages, it is essential that a flood protection level is adopted that is optimal from the socio-economic and environmental point of view.

Actually, the MARD is applying the following flood protection criteria for the Kone basin:

- protection against the once in 10 years main flood, and
- protection against the once in 100 years early flood.

The MARD distinguishes the following types of flood in the Kone basin:

- the main flood: occurring during October – November;
- the late flood : occurring during December – January;
- the minor flood: occurring during May – June;the early flood: occurring during August – September.

The Binh Dinh provincial authorities tend to accept the occurrence of the main flood, provided that the late floods occurring just after the October-November main flood season will not damage the newly planted winter-spring crop. A protection level of 5% (once in the 20 years on the average) is aimed at.

The present flood analysis aims at the assessment of peak discharges and the corresponding flood volumes for the flood events with return periods of 2 years, 5 years, 10 years, 20 years, 50 years and 100 years in the different flood periods. These flood events need to be estimated at the locations where the implementation of flood control measures are envisaged, as well just upstream of the flood prone area.

The implementation of flood control measures upstream of the flood prone area is envisaged at:

- Dinh Binh (reservoir)
- Cay Muong (retarding basin)

The flood prone area has been defined as follows:

The lower basin or Delta area, located downstream of Binh Thanh (Apex) and bordered by Road 635 in the north and Road 19 in the south.

Consequently, flood runoff of the following sub-basins is to be estimated:

- The upper and middle Kone basin, discharging at the Delta apex at Binh Thanh;
- The upper and middle Nui Mot basin located upstream of National Road No. 19;
- The upper and middle Ha Thanh basin located upstream of the National Road No.1;
- The upper and middle La Vi basin located upstream of Phu Cat and north of the Provincial Road 635;

In this report a distinction is made between probable floods and design floods. Probable floods are the floods that have been derived on the basis of a frequency analysis of historic events, considering the validity of certain probability distribution functions.

Design floods are the floods to be used in designing the hydraulic works and that, therefor, include a certain safety margin as compared to the estimated probable floods. This distinction is made since the Vietnamese practice tend to assess the so-called probable floods with a safety margin included that is related to the length of the series and the standard deviation the observed extreme events. As a consequence, the so-called probable floods as assessed by the Vietnamese parties is always at the higher side than the probable floods calculated with the help of an accepted probability distribution function.

2.2.2 Methodology of the High Flow Analysis

For the assessment of the flood runoff at the various locations in the Kone basin, two different approaches have been followed. Both based on the available historical hydro-meteorological data of the basin. The first method aiming at a reliable and detailed description of rainfall-runoff relations, allowing the conversion of the (abundantly available) rainfall series into runoff series. The second method seeks the estimation of flood runoff from the statistical analysis of runoff data and empirical methods for the construction of the flood hydrograph and its conversion from one sub-basin to another.

As has been mentioned already before, discharges in the Kone basin are observed in Cay Muong only. The discharge measurements that have been initiated in the framework of the present project at Dinh Binh have not yet produced sufficient results for the compilation of a rating curve that could serve for the conversion of observed water levels at Dinh Binh into discharges. Discharges observed at Vinh Son, Nui Mot and Thuan Ninh refer to reservoir releases and cannot be considered as natural runoff from the respective sub-basins.

Available rainfall data allow for an accurate estimate of the area rainfall on the respective sub-catchments in the basin. These rainfall data, however, are generally available on a daily basis only. The absence of sufficient hourly rainfall information hampers seriously an accurate calibration of rainfall-runoff relations under flood conditions. The very rapid response of the various sub-basins on the occurrence of storms, (in the order of a few hours) makes it necessary that very accurate hourly area rainfall information is required for calibration and verification of rainfall-runoff models for the simulation of flood runoff of the different sub-catchments. The hourly rainfall data within the Kone basin is only available at Quy Nhon, at the downstream edge of the basin. At the upstream side of the basin, the nearest by station with hourly rainfall data is at Ba To. In the coastal area between these two stations hourly rainfall data were obtained from Hoai Nhon. The geographical spacing of these stations does not allow, however, to assess accurately the hourly distribution of the area rainfall on the several sub-catchments of the Kone basin.

Nevertheless, an attempt has been made to reproduce a number historical floods with the help of the Sacramento model. The results of this exercise are described in the Annex 2 to this report. An acceptable model calibration could be achieved.

However, it would be rather arbitrary to apply the model for the generation of designs floods without a profound analysis of the probability of occurrence of certain storm events with certain time (hours) and spatial distribution. Such a profound analysis, however, is only possible with adequate time series of hourly rainfall within the Kone basin and its respective sub-basins. Such time series were not available in the present study.

> During the Phase-1 hydrological studies of the present project, similar problems were encountered in the flood analysis in the Huong Basin. In that basin a better spatial distribution of hourly rainfall information allowed for a reasonably accurate reproduction of the response of the different sub-basins to the storms. However, the definition of a design storm appeared to be critical . A different hourly distribution of the same peak daily rainfall can generate peak flows that can easily differ from each other by 30%.
> For the Kone basin, the 1987 flood and corresponding hourly rainfall distribution has been used to estimate tentatively the 10% and 1% flood hydrographs at Binh Dinh. The results are given in Annex 1 and indicate that these results are consistent with those obtained with the synthetic hydrograph approach that is presented below.

It is concluded that insufficient data is available in the Kone basin for a proper calibration and subsequent use of an advanced rainfall-runoff model for the different sub-catchments of the Kone basin. Hence, it is considered a proper approach to derive from the historical observed flood events an appropriate synthetic hydrograph that can be used for the different sub-catchment areas.

The approach that has been followed for the generation of the flood hydrographs to be used in the formulation and subsequent design of the flood protection measures starts from the basic principle: “a p% flood is generated by a p% (area) rainfall”

Basic (single peak) synthetic hydrograph is given by: $Q_t = Q_p \left(\frac{t}{T_p} \right)^m * e^{m(1- t/T_p)}$ (1)

where:	Q_t	=	Runoff at time t [m^3/s]
	Q_p	=	Peak runoff [m^3/s], at time T_p
	t	=	time elapsed [h]
	T_p	=	time to peak of hydrograph [h]
	m	=	determines the shape of the hydrograph. For m = 3, this hydrograph matches the USDA SCS dimensionless hydrograph closely.(In physical terms, m = the number of reservoirs in the so-called Nash reservoir cascade)

Thus, for each catchment, Q_p,T_p, and m are to be determined, such that:

a) Q_p equals the observed, or statistically determined peak flow

b) T_p matches the observed times to peak during historical floods

c) m is selected such that the synthetic hydrograph shape is similar to the observed ones

d) the total runoff during the flood period, V_a, is the same as that of the corresponding catchment rainfall, P_a, times an average runoff factor, C_a, times the catchment area, F_a.

Or $V_a = P_a C_a F_a$ (2)

where:	V_a	=	total runoff volume during flood, including baseflow [m³/s]
	P_a	=	catchment rainfall [mm], determined by averaging weighted rainfall from a number of rainfall gauges in the catchment by the Thiessen method
	C_a	=	runoff co-efficient, calculated from observed flood situations [-]
	F_a	=	catchment area [km²]

The transposing of flood peaks and base flows from the gauged (Cay Muong) catchment to the ungauged catchment is carried out as follows, with the associated catchment rainfall being derived using the Thiessen method.

1) determine the transpose coefficient at the gauged catchment as follows:

$$Q_{\max,p} = A_p F_a^{(1-n)} \qquad (3)$$

$$\text{Or } A_p = \frac{Q_{\max,p}}{F_a^{(1-n)}} \qquad (4)$$

where:	$Q_{max,p}$	=	Flood peak with an associated probability of p%, including baseflow [m³/s]
	A_p	=	Corresponding transpose factor [-]
	F_a	=	Gauged catchment area [km²]
	n	=	Regionalised factor determined by experience, for Southern Central Region of Vietnam, n = 0.35 [-]. A "n" value of 0.55 would give similar results as the Creager Formula (giving the envelop for maximum peak discharges).

2) The flood peak at the ungauged location is calculated using (3), with A_p calculated in the previous step, F_a being the ungauged catchment area, for n an intermediate value between 0.35 and 0.55.has been assumed at 0.45.

3) The baseflow at the ungauged catchment is calculated as:

$$Q_{b,u} = \frac{F_{a,u}}{F_{a,g}} Q_{b,g} \tag{5}$$

where Q and F are baseflow and catchment area respectively and indices u and g refer to ungauged and gauged catchments respectively.

For Cay Muong the average baseflow during flood periods is taken as the 10% wet season (oct-dec) flow, calculated at: 324 m^3/s

2.2.3 Historical Floods

(1) Main Floods

The maximum yearly (instantaneous) peak discharges at Cay Muong have been analysed for the different periods that are considered relevant for the flood damage assessments.

The straightforward approach has been followed in which a number of distribution functions have been tried out to find the distribution function that best fits the series of 26 observed instantaneous peak discharges. That distribution function has subsequently been used to estimate the peak discharges with return periods up to 100 years.

The *main flood* is, according to the MARD definition, the flood that occurs in the months October – November. Out of the 26 years of observation three annual maximum discharges took place, however, in December and one in September. These "late and early floods" have been included in the analysis of the probability distribution of main floods.

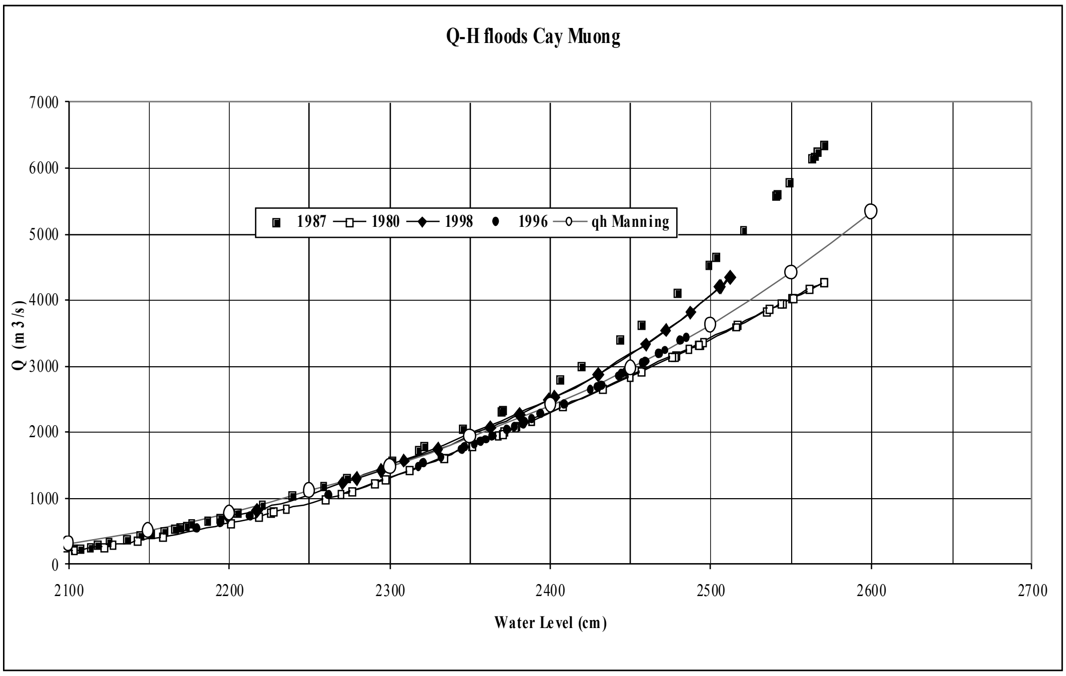
The following instantaneous main flood peak discharges have been identified:

Historical Instantaneous Main Flood Peak Discharges (m^3/s)

Year	Peak Discharge	Date
1976	1,466	November 14
1977	2,751	November 10
1978	1,475	November 4
1979	2,280	November 18
1980	4,280	November 17
1981	4,140	November 9
1982	106	November 4
1983	2,770	October 30
1984	3,480	November 8
1985	2,450	November 25
1986	2,860	December 3
1987	6,340	November 19
1988	2,050	October 15
1989	553	September 18
1990	3,210	October 15
1991	2,340	October 24
1992	3,220	October 23
1993	1,510	October 4
1994	2,330	October 21
1995	2,690	November 1
1996	3,460	December 1
1997	2,480	November 4
1998	4,350	November 22
1999	3,680	December 3
2000	1,800	November 17
2001	1,740	November 12

Before the observed peak discharges were analysed, a brief validation exercise was carried out on the available data. Since Cay Muong is the only discharge measurement station in the Kone basin, there is no possibility of data validation through comparison with other discharge series. Besides a visual check of time series graphs, a validation of flood discharges has been carried out by comparison of the water level – discharge relations in the different years.

Most of the “observed” peak discharges are derived from rating curves, rather than actually measured. (No hysteresis loop is found in the water level discharge relations during floods, although such phenomena is anticipated as a result of the flashy character of the floods.)



From the comparison it is learned that there is an increasing scatter of observed discharges at higher water levels. Since this scatter is relatively small at the lower water levels, it is not likely that the deviations at the higher levels are due to morphological changes in the river channel.

An evaluation with a calculated level discharge relation at Cay Muong, applying the Manning formulae, makes it likely that the 1987 peak discharge has been overestimated. The extrapolation of the1987 rating curve, leading to the maximum “observed” discharge of 6,340 m^3/s, seems moreover not to be underpinned with measurements. A tentative correction of the 1987 peak discharge would lead to probable peak discharges that are 6-8% lower than the probable peak discharges that are calculated when the “observed “ 1987 peak discharge is not corrected. Such correction has, however, not been made in the present study for the sake of safety.

For the annual main flood peak discharge, the following distribution functions have been examined:

GEV
Log-Normal (3 parameters))
Log Pearson (3 parameters)
Pearson 3 (3 parameters)
Gumble Type 1 (2 parameters)
Raleigh
Goodrich

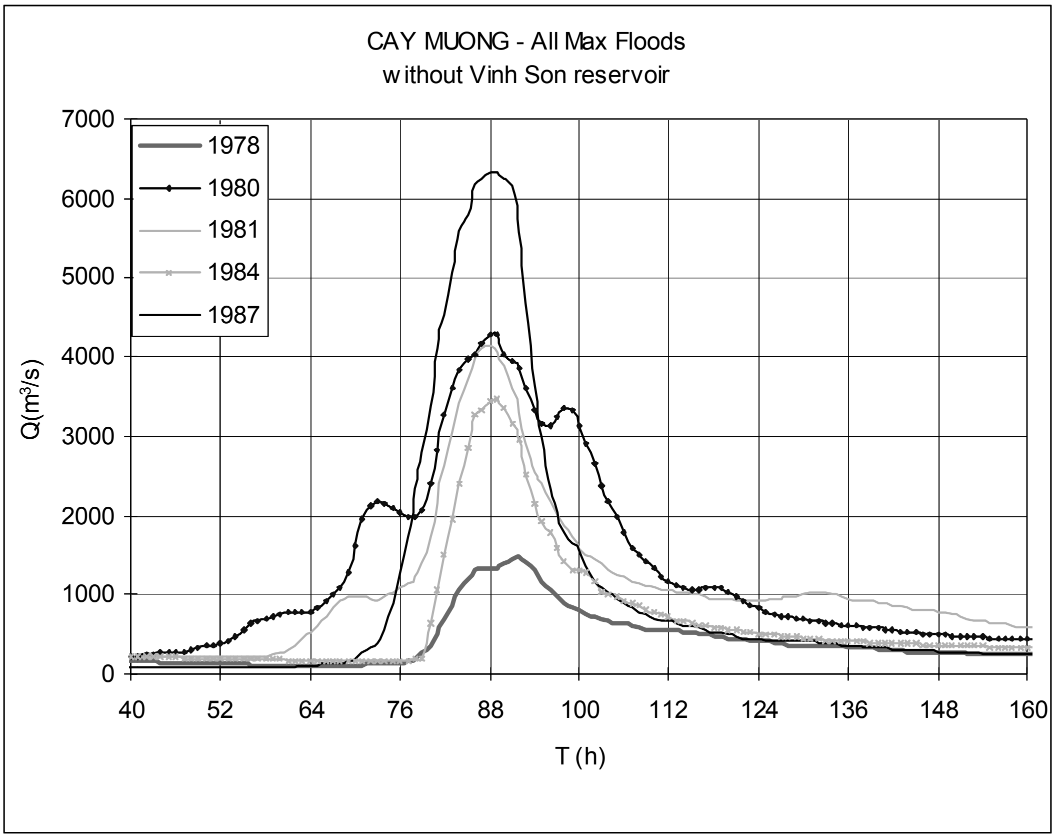
The results are summarised below:

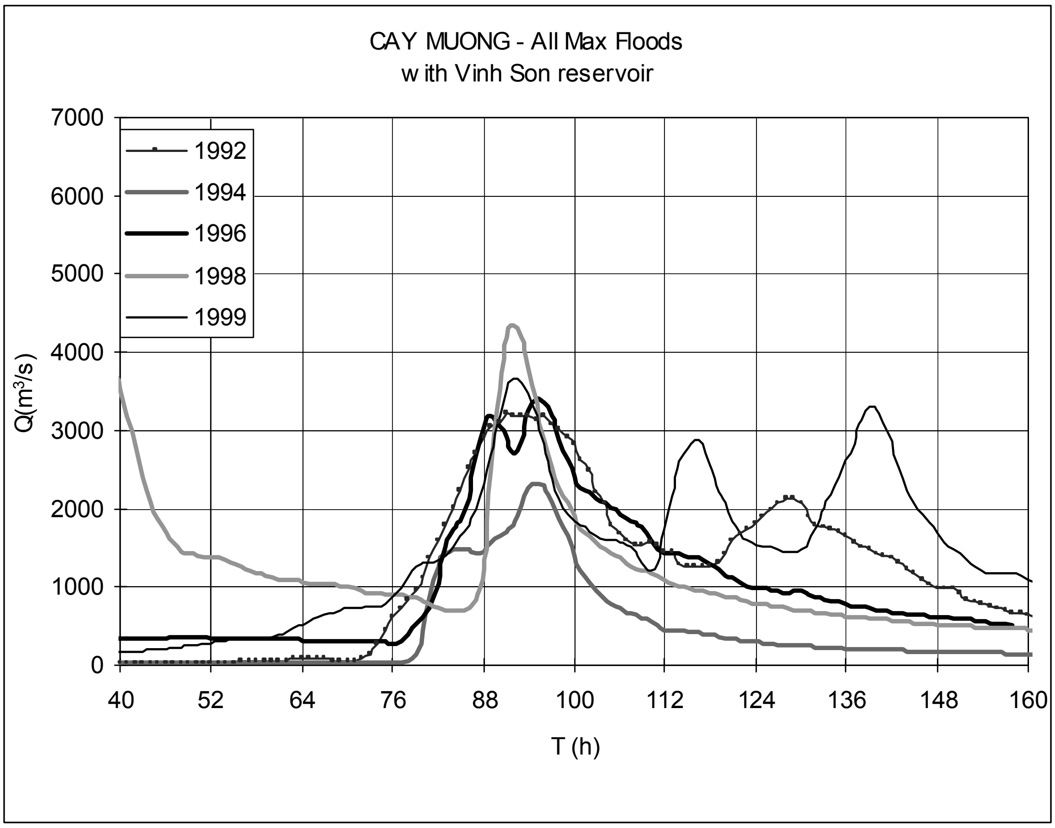
Annual Peak Discharges Main Flood at Cay Muong **(m^3/s)**

Distribution Function	Probability (% per year)						
	50%	20%	10%	5%	2%	1%	0.5%
GEV	2526	3704	4409	5035	5777	6286	
Log Normal 3	2541	3698	4384	5020	5739	6269	6851
Log Pearson 3	2497	3905	4653	5237	5829	6176	6613
Pearson 3	2536	3706	4396	5007	5738	6253	6746
Gumble	2452	3603	4364	5095	6041	6750	7456
Raleigh	2511	3772	4491	5108	5822	6309	6759
Goodrich	2561	3753	4402	4953	5560	5971	6364

In addition to the analysis of the probability of peak discharges, also the shape and volume of the 10 *main floods* that have occurred in the period 1976 – 2001 have been examined. Under the assumption that the construction of Vinh Son reservoir has an impact on the shape of the flood hydrograph that passes at Cay Muong, a distinction has been made between the flood events prior to and after the construction of Vinh Son. It is anticipated that the assumed impact of Vinh Son will be minor, since the higher flood peaks of the major floods can pass the (ungated) Vinh Son spillway without any retention.

The 10 major floods are shown in the figures overleaf. The floods are presented in such a way that the peak of all floods coincide. This facilitates the comparison between these floods.





From these figures it is learned that the duration of the main floods varies between one and four days. Taking respectively two and three days as typical duration of the floods, the following characterisation of the historical floods have been derived:

Historical Flood Characteristics, considering 2-day flood duration

Year	1978	1980	1981	1984	1987	1992	1994	1996	1998	1999
Qp (m3/s)	1,475	4280	4140	3480	6340	3,220	2,330	3,30	4,350	3,680
Return Period (Qp-LN3) (yrs)	1.2	8.9	7.7	4.1	101.9	3.3	1.8	4.0	10	5
Corresponding 2-days area rain (mm)	166	292	312	190	313	380	267	314	331	354
Return Period rainfall (Pda-LN3) (yrs)	1.1	2.8	3.7	1.2	3.8	14.6	2.1	3.8	5.1	8.1
Volume of main peak (Mm3)	136	447	334	245	426	378	175	335	330	377
Return Period Volume (Vol-LN3) (yrs)	1.3	32.4	5.6	2.3	22.8	10.7	1.5	5.9	5.6	10.5
Overall Runoff Factor	0.5	0.9	0.6	0.8	0.8	0.6	0.4	0.6	0.6	0.6
Time to peak (hrs)	12	20	19	9	14	8	15	13	7	31
Average Overall Flood Runoff Factor	0.65									
Average Time to Peak (hrs)	14.8									

Historical Flood Characteristics, considering 3-day flood duration

Year	1978	1980	1981	1984	1987	1992	1994	1996	1998	1999
Qp (m3/s)	1,475	4,280	4,140	3,480	6,340	3,220	2,330	3,430	4,350	3,680
Return Period (Qp-LN3) (yrs)	1.2	8.9	7.7	4.1	101.9	3.3	1.8	4.0	10	5
Corresponding 3-days area rain (mm)	357	359	329	191	358	511	280	380	456	520
Return Period rainfall (Pda-LN3) (yrs)	7	7	6	1.1	7	14	1.6	3.4	7	15
Volume of main peak (Mm3)	164	520	416	279	459	494	192	396	480	549
Return Period Volume (Vol-LN3) (yrs)	1.3	18.1	6	2.1	9.2	13.5	1.4	5	12	26
Overall Runoff Factor	0.3	0.9	0.8	0.9	0.8	0.6	0.4	0.6	0.6	0.6
Time to peak (hrs)	13	20	20	9	16	12	15	15	7	30
Average Overall Flood Runoff Factor	0.65									
Average Time to Peak (hrs)	15.7									

It is noted that the "Overall Runoff Factor" tends to be lower after the construction of Vinh Son reservoir than it was before. This points to the possibility that the fraction of the flood volume that is stored in the Vinh Son reservoir is substantial. It is recommended not to reckon with the retarding effect of this reservoir, in line with the suggestion made above that the retarding effect of this reservoir could be neglected. Neglecting the retarding effect would lead to an average overall runoff factor of about

0.7.

(2) Late Floods

Following the main floods that usually occur in the period October - November, preparations are made for planting the so-called winter-spring crop. Once land preparation and planting has started, agricultural damage can be caused by flooding. Floods that occur after the main flood season, and after the preparation for the winter-spring crop has started, are indicated as the so called Late Floods. Protection against these floods is one of the options for flood damage mitigation measures in the flood prone area.

The following practice is assumed for the lower floodprone Delta area:

- The last decade of November is waited for to decide whether preparation will start in the first decade of December. When flooding takes place during the last November decade ($Q_{Cay\ Muong}$>350 m^3/s), then the decision is postponed until the first decade of December.
- In case the decision in the last November decade is positive, then preparation will start in the first decade of December, provided that at the start of that decade the main flood has sufficiently receded ($Q_{Cay\ Muong}$<350 m^3/s). If not, preparation is postponed until the second decade.
- \- Actual start of preparation in the second decade of December will only be done when at the beginning of that decade the flood has sufficiently receded. Otherwise, preparation is postponed until the next decade, and so on.The late flood is defined as the peak discharge that occurs during or after the decade in which the preparation is started.

Following above described approach, the following late flood peak discharges have been observed or estimated:

Historical Late Flood Peak Discharges **(m^3/s)**

Year	Planting Decade	Peak Discharge	Date
1976	December-1	85	3-December
1977	December-1	64	3-December
1978	December-1	240	7-December
1979	December-1	129	3-December
1980	December-1	134	1-December
1981	December-2	274/348*	11-December
1982	December-1	31	9-December
1983	December-1	115	19-December
1984	December-2	206/248*	25-December
1985	December-2	156/174*	21-December
1986	December-1	2850	3-December
1987	December-2	81	10-December
1988	December-1	87	5-December
1989	December-1	99	1-December
1990	December-1	151	5-December
1991	December-2	193	14-December
1992	December-1	109	25-December
1993	December-2	835	16-December
1994	December-1	135	22-December
1995	December-1	428	26-December
1996	December-1	1,550	20-December
1997	December-1	209	3-December
1998	December-2	1,830	11-December
1999	December-1	3,680	3-December
2000	December-2	450	28-December
2001	December-1	254	11-December

* instantaneous peak flows derived from the peak average day discharge, using the relation $\hat{Q} = 1.47\ Q_{day} - 55$, that was found for the late flood peak discharges.

On the basis of the above derived late flood peak discharges frequency analyses have been carried out for different distribution functions. It is noted that for most functions a rather poor fit was achieved. The following results have been calculated:

Annual Late Flood Peak Discharges (m^3/s)

Distribution Funtion	Probability (% per year)					
	50%	20%	10%	5%	2%	1%
Log Normal 3	320	1,068	1,652	2,290	3,175	3,918
Log Pearson 3	221	695	1,250	2,045	3,657	5,499
Pearson 3	229	1,034	1,704	2,389	3,346	4,075
Gumble	407	1,217	1,752	2,266	2,931	3,430
Raleigh	452	1,314	1,805	2,227	2,716	3,048
Goodrich	235	798	1,523	2,064	3,131	4,036

In order to assess the allowable Dinh Binh reservoir level in the last two decades of December, an estimate has been made of the probable floods that may occur during the periods 11 December – 31 December and 21 December – 31 December.

For this purpose the maximum daily discharges at Cay Muong have been analysed and the probabilities estimated (it appeared that the Pearson-3 distribution function gave a reasonable fit, and better than other distribution functions). The following probable maximum discharges at Cay Muong were found, estimating the instantaneous peak discharges at 1.5 times the daily peak discharges, in accordance with above mentioned relation between maximum daily and instantaneous peak discharges.

Probable maximum discharge at Cay Muong during late December **(m^3/s)**

Period	50%	20%	10%	5%	2%	1%
December 11–December 31	240	740	1,130	1,515	2,060	2,460
December 21–December 31	170	350	480	600	750	870

(3) Early Floods

The same distribution functions have been examined for the annual early flood peak discharges. These floods happen to occur during August-September and could potentially endanger the Seasonal crops. The occurrence of these floods in terms of flood discharges and volumes has been analysed, in order to assess the potential damage that can be caused by these floods under the present and future land use and water management conditions.

The following historical instantaneous peak discharges have been identified for the months August-September.

Historical Early Flood Peak Discharges (August-September) **(m^3/s)**

Year	Peak Discharge	Date
1976	319	September 25
1977	978	September 25
1978	246	September 17
1979	308	September 29
1980	353	September 19
1981	70	September 21
1982	55	September 8
1983	163	September 30
1984	37	September 5
1985	89	September 28
1986	57	August 19
1987	240	September 11
1988	84	September 24
1989	553	September 18
1990	79	August 15
1991	105	September 28
1992	119	August 29
1993	49	September 28
1994	529	September 17
1995	400	September 12
1996	225	September 28
1997	212	September 22
1998	173	September 23
1999	132	September 29
2000	515	August 22
2001	63	August 19

Based on these observations the following probabilities have been calculated:

Annual Peak Discharges Early Flood (August – September) at Cay Muong **(m^3/s)**

Distribution Function	Probability (% per year)					
	50%	20%	10%	5%	2%	1%
GEV	171	338	483	654	935	1200
Log Normal 3	187	375	511	647	839	991
Log Pearson 3	172	339	482	649	908	1,145
Pearson 3	176	373	519	664	858	1,006
Gumble	201	393	521	643	801	920
Raleigh	211	416	533	634	750	828
Goodrich	164	360	517	679	897	1,060

(4) Minor Floods

During the months May and June minor floods happen to occur that potentially could endanger the Summer-Autumn crop. The occurrence of these floods in terms of flood discharges and volumes has been analysed, in order to assess the potential damage that can be caused by these floods under the present and future land use and water management conditions.

For the analysis of the minor floods it is considered appropriate to take into account the maximum discharges and corresponding rainfall that have been observed during the full Summer-Autumn crop period that spans the month April – July. Although the minor floods use to happen in May – June, also exceptional events that could occur in April or July are to be considered.

The following instantaneous peak discharges have been identified:

Historical Instantaneous Peak Discharges during Summer Autumn **(m^3/s)**

Year	Peak Discharge	Date
1976	36	May 24
1977	16	May 25
1978	45	May 13-14
1979	189	May 23
1980	118	June 24
1981	174	June 17
1982	64	June 17
1983	52	June 26
1984	80	May 26
1985	147	May 1
1986	420	May 19
1987	66	June 10
1988	41	July 18
1989	142	July 17
1990	812	June 15
1991	60	July 11
1992	54	June 14
1993	23	June 24
1994	133	June 29
1995	59	June 1
1996	387	May 18
1997	112	May 30
1998	136	June 30
1999	236	June 15
2000	232	June 1
2001	130	May 14

On the basis of these identified peak discharges frequency analyses have been carried out for different distribution functions. The following results have been calculated:

Annual Peak Discharges Minor Flood (during Summer-Autumn Crop) at Cay Muong (m^3/s)

Distribution Funtion	Probability (% per year)					
	50%	20%	10%	5%	2%	1%
Log Normal 3	109	242	350	470	637	780
Log Pearson 3	104	211	312	427	652	862
Pearson 3	90	231	357	490	676	820
Gumble	127	275	373	467	588	680
Raleigh	135	293	383	460	549	610
Goodrich	130	270	357	434	531	597

2.2.4 Area Rainfall

(1) Main Flood Season

In Section 2.2.2 it has been mentioned that the basic principal used in the present study is as follows: “a p% flood is generated by a p% area rainfall”. This basic principle refers to the flood volume, rather than to the peak discharge. The p% peak discharge is in principle derived from the frequency distribution analysis as presented in the previous section.

For the generation of the hydrographs with different probabilities and for the different sub-catchments, the area rainfall on these catchments has been estimated with the help of the daily rainfall data as explained in the Section 2.1.2.

The results of the frequency analysis of the yearly maximum rainfall are shown below for the respective sub-catchment areas for the 3-day, 2-day and 1-day rainfall. From the table it is learned that the area rainfall increases in the upstream direction. The increase is sharper for the 3-rainfall (some 25% between Delta area and Dinh Binh area) than for the 1-day rainfall (10 – 20%).

Maximum 3-Day Catchment Rainfall (Gumbel Distribution)

Sub-catchment	Area	P3da,50%	P3da,20%	P3da,10%	P3da,5%	P3da,2%	P3da,1%
	(km2)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
Dinh Binh	1,040	349	474	557	636	739	816
The 0.5% maximum 3-day Dinh Binh catchment rainfall has been calculated at 893 mm							
Cay Muong	1,677	316	424	496	565	654	721
Intermediate area	637	268	348	401	452	518	567
Binh Thanh	2,250	299	397	461	524	604	665
Nui Mot	180	280	358	410	460	524	572
La Vi	240	312	428	505	579	674	745
Ha Tanh	590	283	368	423	477	546	598
Delta	380	282	378	441	502	581	640

Maximum 2-Day Catchment Rainfall (Gumbel Distribution)

Sub-catchment	Area	P2da,50%	P2da,20%	P2da,10%	P2da,5%	P2da,2%	P2da,1%
	(km2)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
Dinh Binh	1,040	289	382	444	503	580	637
The 0.5% maximum 2-day Dinh Binh catchment rainfall has been calculated at: 694 mm							
Cay Muong	1,677	262	345	399	451	519	570
Intermediate area	637	229	298	343	387	443	486
Binh Thanh	2,250	249	324	374	422	483	530
Nui Mot	180	238	300	340	380	430	468
La Vi	240	274	372	437	499	580	640
Ha Tanh	590	247	313	357	399	453	493
Delta	380	244	327	382	435	503	555

Maximum 1-Day Catchment Rainfall (Gumbel Distribution)

Sub-catchment	Area	P1da,50%	P1da,20%	P1da,10%	P1da,5%	P1da,2%	P1da,1%
	(km2)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
Dinh Binh	1,040	193	255	296	336	387	425
The 0.5% maximum 1-day Dinh Binh catchment rainfall has been calculated at: 463 mm							
Cay Muong	1,677	176	231	267	302	348	382
Intermediate area	637	160	210	243	275	315	346
Binh Thanh	2,250	168	217	250	282	323	353
Nui Mot	180	170	224	260	295	339	373
La Vi	240	180	253	301	348	407	452
Ha Tanh	590	185	243	282	319	367	403
Delta	380	159	218	258	296	345	382

(2) Late Flood Season Area Rainfall

For the estimate of the volumes of the late floods, the probable area rainfall during the month of December has been calculated (using the Log-Normal distribution) for different durations. The results are as follows:

Maximum Kone Basin Area Rainfall during December (mm)

	50%	20%	10%	5%	2%	1%
1-day rainfall	46	109	156	203	269	322
2-day rainfall	71	167	239	313	417	502
3-day rainfall	82	196	283	379	503	608

For the evaluation of future reservoir operation alternatives, the probability of the 2-day rainfall in the two last and the last decade of December has been calculated as follows:

Probable Kone Basin Area Rainfall u/s Dinh Binh during the later December decades (mm)

Period	50%	20%	10%	5%	2%	1%
December 11 – December 31	48	102	142	184	243	291
December 21 – December 31	25	52	69	86	107	123

(3) Early Flood Season Area Rainfall

The area rainfall in the early flood season has been estimated similarly for the entire basin as follows.

Maximum Kone Basin Area Rainfall during August- September (mm)

	50%	20%	10%	5%	2%	1%
1-day rainfall	40	70	90 140	100	130	160
2-day rainfall	70	110	160	180	220	270
3-day rainfall	80	120		200	250	300

(4) Minor Flood Season Area Rainfall.

For the estimate of the volumes of the minor floods, the probable area rainfall during the Summer – Autumn crop period has been calculated (using the Log-Normal distribution) for different durations. The results are as follows:

Maximum Kone Basin Area Rainfall during Summer-Autumn Crop season (mm)

	50%	20%	10%	5%	2%	1%
1-day rainfall	50	60	70	80	90	100
2-day rainfall	60	80	90	100	120	130
3-day rainfall	70	90	100	120	130	140

(5) Delta Area Rainfall

The previously calculated probable rainfall intensities refer to the occurrence of floods in the river system. Besides that, flooding is also anticipated as the consequence of impeded drainage, especially in the low lying and flat delta area. The probable rainfall intensities in the delta region have been estimated for the main flood season under the sub-section (1) above. However, when (river) flooding is accepted during the main flood season and flood protection aims at the rest of the year, then also the drainage system in the delta area should be able to cope with the rainfall on this area during the rest of the year.

The delta area rainfall outside of the main October-November flood season has been estimated as follows:

Maximum Delta Area Rainfall outside the Main Flood season (mm)

	50%	20%	10%	5%	2%	1%
1-day rainfall	77	109	134	157	190	216
2-day rainfall	109	155	185	216	254	284
3-day rainfall	129	184	222	259	306	342

2.2.5 Hydrographs for Flood Control Studies

Following the approach as described in Section 2.2.2 and based on the analysis of the historical floods and area rainfall in the sections 2.2.3 and 2.2.4, hydrographs with different estimated probabilities have been generated for the different sub-catchments of the Kone basin. These hydrographs are principally meant for the evaluation of flood mitigation alternatives. For the design of the flood protection works, it is essential to realize that the series that are available for the estimate of probable peak discharges are rather short, and that, consequently, a safety margin is to be taken into account.

In the process of the generation of flood hydrographs, the following assumptions have been made:

1. for the estimate of peak discharges at Cay Muong, with different return periods, the average value of the best fitting distribution has been adopted for both the instantaneous maximum peak discharges. The respective estimates are as follows:

Probable Peak Discharges at Cay Muong (m^3/s)

	Return Period (in years)						
	2	5	10	20	50	100	200
Main flood	2,530	3,700	4,400	5,20	5,50	6,270	6,740
Late flood	250	900	1,530	2,200	3,330	4,380	
Early flood	180	360	500	660	880	1,070	
Minor flood	120	250	360	460	610	720	

2. for the estimate of the probable peak discharges of non-gauged sub catchment areas, an "n" value (see equation (4) in section 2.2.2) of 0.45 has been adopted, being the average value between the regional factor for the Southern Central Region of Vietnam (0.35) and the approximate Creager value (0.55) describing the envelop of maximum peak discharges. Consequently, the probable peak discharges of the respective sub-catchments are as follows:

Probable Yearly Maximum Peak Discharges of ungauged sub-catchments (m^3/s)

		Return Period (in years)						
	Area (km^2)	2	5	10	20	50	100	200
Dinh Binh	1,040	1,950	2,850	3,380	3,860	4,420	4,820	5,180
Binh Thanh	2,250	2,970	4,350	5,170	5,900	6,760	7,370	
Intermediate	637	1,490	2,170	2,580	2,950	3,380	3,680	
Nui Mot	180	740	1,080	1,290	1,470	1,690	1,840	
La Vi	240	870	1,270	1,510	1,720	1,970	2,150	
Ha Thanh	590	1,420	2,080	2,480	2,830	3,240	3,530	

Probable Late Flood Peak Discharges of ungauged sub-catchments (m^3/s)

		Return Period (in years)					
	Area (km^2)	2	5	10	20	50	100
Dinh Binh	1,040	190	690	1,180	1,690	2,560	3,370
Binh Thanh	2,250	290	1,060	1,800	2,590	3,910	5,150
Intermediate	640	150	530	900	1,290	1,960	2,570
Nui Mot	180	70	260	450	650	980	1,280
La Vi	240	90	310	530	760	1,140	1,500
Ha Thanh	590	140	510	860	1,240	1,880	2,470

Probable Early (August September) Peak Discharges of ungauged sub-catchments (m^3/s)

		Return Period (in years)					
	Area (km^2)	2	5	10	20	50	100
Dinh Binh	1,040	140	280	380	510	680	820
Binh Thanh	2,250	210	420	590	780	1,030	1,260
Intermediate	637	110	210	290	390	520	630
Nui Mot	180	50	110	150	190	260	310
La Vi	240	60	120	170	230	300	370
Ha Thanh	590	100	200	280	370	500	600

Comparison of the peak discharges and corresponding rainfall of the Minor (Summer-Autumn) floods with those of the Early floods indicate that the Summer-Autumn floods are both in peak and volume of the order of 70% of the Early floods. It is considered justified to use the 70% reduced design early floods for the evaluation of potential damages due to these floods under present and future water management and land use conditions.

3. for the estimate of the flood volumes the three day rainfall volumes have been taken as starting point for the Main Floods. For the rainfall runoff factor a value of 0.7 has been adopted, in line with the recommendation made in section 2.2.3. For the Early Flood a lower rainfall-runoff factor is considered more appropriate: a value of 0.5 has been adopted, while the one-day probable rainfall has been assumed to produce the runoff volume of the corresponding probable flood. For the Late Floods a rainfall runoff factor of 0.6 has been adopted, assuming that the catchment is still partly saturated after the main floods. For the Late Flood volumes the 2-day probable rainfall has been adopted as starting point, after comparing the calculated probable peak discharges with the historical late floods and corresponding rainfall data.
4. the time to peak of the Cay Muong synthetic hydrograph is assumed to be of the order of 15 – 20 hours. The times to peak of hydrographs generated in other sub-catchments are assumed to be in the ratio of the length of the respective catchments. The actual time to peak has been adjusted in the process of “calibration” of the synthetic hydrographs.

This estimate of time-to-peak (in hours) is in line with the result of the Kirpich formula that says:

$$t_c = 0.00013 \frac{L^{0.77}}{S^{0..385}}$$

With L is the length of the basin in feet along the watercourse from the gauging station to the upstream limit of the basin, and S the average river slope upstream of the station.

Applying this formula for the different locations along the Kone river gives the following results
t_c-Dinh Binh: 10 hours
t_c-Cay Muong: 15.3 hours
t_c-Binh Thanh: 18.5 hours

5. The base flow during the passage of the flood hydrograph is assumed to be the 10% wet season discharge (= discharge that on the average is exceeded in 1 out of ten years) during the respective early, main and late flood seasons.

Based on the above starting points and applying the methodology presented in the Section 2.2.2, the probable flood hydrographs have been generated for several types of flood and several probabilities Detailed results are presented in Appendix 3. Several probable main, early and late floods are presented in the Figures C.5 to C.12.

Validation of the synthetic hydrographs has been carried out by comparison the generated hydrograph of a catchment area with of the sum of generated hydrographs of the composing sub-catchments. An example of the result is shown in Figure C.13.

2.2.6 Flood Hydrographs for Design Purposes

(1) Evaluation of previous results

In this section the results of the present flood analysis are compared with the results of previous studies. The purpose of this comparison is to facilitate the selection of the appropriate approach for the development of flood protection measures in the Kone basin.

Earlier studies have, among others, been carried out by IWRP (1997) for the Water Use Planning in the basin, and by HEC-1 (2000) in the framework of the feasibility study of the Dinh Binh Reservoir.

The results of these studies can be summarized as follows (only flood events with an estimated return period shorter than 100 years is considered here, because the impact of events with lower frequency on the economics of flood control is considered marginal)

Peak Discharges at Cay Muong Estimated from Frequency analysis

	Return Period		
	10 years	100 years	200years
IWRP (series 1976 – 1996, distribution function Pearson-3)	4,917 m^3/s	7,778 m^3/s	
HEC-1 (series 1976 – 1998, distribution function Pearson-3)	4,860 m^3/s	7,860 m^3/s	8,720 m^3/s
JICA (series 1976 – 2001, several distribution functions)	4,400 m^3/s	6,270 m^3/s	6,740 m^3/s

Observation: The IWRP and HEC-1 results are quite similar, certainly when the different length of the observation period is taken into account. The present analysis, however, produces much lower values. It is anticipated that the values calculated by both IWRP and HEC-1 include a "confidence margin". Such margin is relevant in a risk (safety) analysis. In the present planning study, however, is such margin not appropriate, as it creates a biased picture of the economic feasibility of the flood protection measures. It is recommended to use in this phase the results of the present analysis, certainly because most of the examined distribution functions give a picture that is consistent with these results.

Estimated Peak Discharges at Dinh Binh			
	Return Period		
	10 years	100 years	200 years
IWRP (Flow Cutting Module)	3,604 m^3/s	5,702 m^3/s	
HEC-1 (Integrated Water Concentration Model)		7,300 m^3/s	8,080 m^3/s
JICA (Flow Cutting – Creager))	3,380 m^3/s	4,820 m^3/s	5,180 m^3/s

Observation: The transpose function used by IWRP to convert Cay Muong discharges into Dinh Binh discharges gives a more pronounced difference between these two stations, than a Creager approach does. The more conservative Creager approach is included in the present JICA analysis.

The approach followed by HEC-1 seems to aim at safety, rather than at the accuracy of the estimated peak flows.

Estimated Flood Volume at Dinh Binh

	Return Period	
	10 years	100 years
IWRP (3-day)	278 Mm^3	386 Mm^3
HEC-1		614 Mm^3
JICA (3-day)	405 Mm^3	590 Mm^3/s

Observation: It seems that the IWRP results are an underestimate, taking into account the area rainfall volumes on the sub-basin upstream of Dinh Binh. The 100-years three-day area rainfall has been calculated at 816 mm. The volume estimated by IWRP corresponds with only 45% of the rainfall volume. Historical data, however point at runoff coefficients of 0.65 on the average.

(2) Design Peak Discharges

It has been mentioned above that the estimates of the probable peak discharges by IWRP and HEC-1 include a safety margin. Such safety margin is considered essential when the estimated probable peak discharges are to be used for the design of the hydraulic works. In a probabilistic design approach, the risk should be estimated that the actual probable peak discharges are higher then the calculated values. Such risk depends, among other factors, on the length of the series that is used in the probability analysis and tends to increase when the series are shorter.

In case the designs are made on the basis of a deterministic approach, then it is important to make an estimate of the "possible underestimate" of the calculated probable peak discharges. For this estimate, use can be made of the confidence margins that are calculated together with the estimate of probable peak discharges for different probability distribution functions. In that case, it is to be decided which level of confidence is aimed at.

In the approach that is followed by IWRP for the estimate of the possible "underestimate", the following formula is applied:

$$\Delta \hat{Q}_p = aE_p \left(\frac{\hat{Q}_p}{\sqrt{n}} \right)$$

in which *"a"* is a factor ranging between 0.7 and 1.5, depending on the length of the series,

$$E_p = f(C_v, p)$$

in which *"C_v"* refers to the *Coefficient of Variation* of the series and *"p"* to the probability.

For the 1976 – 2001 series of the yearly instantaneous peak discharges in Cay Muong, this formula leads to safety factors of 1.13 and 1.21 for the 10% and 1% probable peak discharges respectively.

This result corresponds with the upper limit of the 80% confidence interval when the Pearson-3 probability function is assumed.

Under application of these safety factors, for all types of floods, the design peak discharges have been assessed as follows (for the 5% probable peak a safety factor of 1.16 has been applied):

Design Discharges at Cay Muong (m^3/s)

Type of Flood	Return Period			
	10 years	20 years	100 years	200 years
Main Flood	4,970	5,820	7,590	8,320
Late Flood	1,730	2,550	5,300	
Early Flood	570	770	1,300	
Minor Flood	410	540	870	

(3) Design Hydrographs

Hydraulic structures for water resources management and flood control are envisaged at Dinh Binh (dam site), Van Phong (weir and irrigation water intake) and in the flood prone river delta. For the design of these structures the respective probable peak discharges and hydrographs need to be estimated. The design hydrographs have been prepared for the 10%, 5% 1% and 0.5% estimated design peak discharges, in accordance with the methodology as presented under section 2.2.5. (the 0.5% hydrograph has been prepared for the Dinh Binh dam only). The design hydrographs are summarized below.

For the design of the Dinh Binh dam, also design hydrographs with lower probabilities are to be considered. These exceptional floods are described in the following paragraph.

For the design of the flood control works the following flood characteristics have been assessed.

Design characteristics Main Floods

Probability		10%		5%		1%	
Parameter		Q (m^3/s)	Vol (Mm^3)	Q (m^3/s)	Vol (Mm^3)	Q (m^3/s)	Vol (Mm^3)
Station	Area (km^2)						
Dinh Binh	1,040	3,821	405	4,475	463	5,836	594
Cay Muong	1,677	4,970	583	5,820	665	7,590	847
Binh Thanh	2,250	5,842	726	6,841	825	8,922	1,047
Nui Mot	180	1,456	52	1,705	58	2,224	72
La Vi	240	1,706	85	1,998	98	2,605	125
Ha Thanh	590	2,798	175	3,276	197	4,273	248

Design characteristics 0.5% Main Flood at Dinh Binh

Probability		0.5%	
Parameter		Q (m^3/s)	Vol (Mm^3)
Station	Area (km^2)		
Dinh Binh	1040	6397	650

Design characteristics Late Floods

Probability		10%		5%		1%	
Parameter		Q (m^3/s)	Vol (Mm^3)	Q (m^3/s)	Vol (Mm^3)	Q (m^3/s)	Vol (Mm^3)
Station	Area (km^2)						
Dinh Binh	1,040	1,330	149	1,961	196	4,075	313
Cay Muong	1,677	1,730	240	2,550	315	5,300	505
Binh Thanh	2,250	2,034	323	2,997	423	6,230	677
Nui Mot	180	507	26	747	34	1,553	54
La Vi	240	594	34	875	45	1,819	72
Ha Tanh	590	974	85	1,436	111	2,984	178

(4) Probable Maximum Flood

In addition to the Design Hydrographs for the hydraulic works, an estimate has been made of the Maximum Probable Flood at the Dinh Binh dam site. In the absence of detailed meteorological and streamflow information in the Dinh Binh catchment area, a simplified approach has been followed to estimate the Probable Maximum Precipitation on this catchment. In this approach the PMP is calculated with the help of the formula (Hershfield):

$$PMP = \overline{P} + KS_P$$

in which $\overline{P}$ refers to the mean annual maximum rainfall and S_P corresponds with the standard deviation of the series of annual maximum rainfall. The factor K depends on rainfall duration and the mean of annual series and can be estimated for the 1-day rainfall with the help of the following relation:

$$K = 19 \cdot 10^{-0.000965\overline{P}}$$

The area rainfall of the Dinh Binh area has been calculated with the help of the 1977 – 2001 series of daily rainfall data of the stations Ba To, Gia Vuc and Vinh Kim following the Thiessen method. The following characteristics of the area rainfall series have been assessed:

Basic Statistics of Annual Maximum Dinh Binh Area Rainfall series (mm)

	Series Maximum	Mean Annual Maximum ($\overline{P}$)	Standard Deviation Annual Maximum (S_P)
1-day rainfall	406	204	70.5
2-days rainfall	626	307	105
3-days rainfall	732	372	141

Applying the above formula for the PMP and assuming a Gumble distribution of the annual maximum values, the following probable extreme rainfall has been estimated. For the 2- and 3-day PMP it has been assumed that they are proportionately similar as the 10.000 years rainfall is:

Probable Extreme Dinh Binh Area Rainfall (mm)

	r.p.=10.000 years (Gumble)	PMP
1-day rainfall	679	1,055
2-days rainfall	1,016	1,575
3-days rainfall	1,324	2,050

For the estimate of the corresponding Probable Maximum Flood, it has been assumed that the frequency distribution of the extreme peak discharges is similar to the frequency distribution of the extreme rainfall events. As a consequence, it has been assumed that the probability of the PMF is similar to the probability of the PMP.

After transposing the calculated probable peak discharges (according to Gumble) from

Cay Muong to Dinh Binh, the following probable peak discharges have been assessed:

Estimated Probable Extreme Peak Discharges at Dinh Binh (according to Gumble) (m^3./s)

r.p = 100 years	r.p. = 1000 years	r.p. = 10000 years	PMF
5,249	7,068	8,882	13,900

Applying the upper limit of the 80% confidence interval of the Pearson 3 distribution function, as explained above, would lead to the following results:

Estimated Probable Extreme Peak Discharges at Dinh Binh (80% confidence Pearson 3) (m^3./s)

r.p = 100 years	r.p. = 1000 years	r.p. = 10000 years	PMF
5,836	7,718	9,578	15,000[1)]

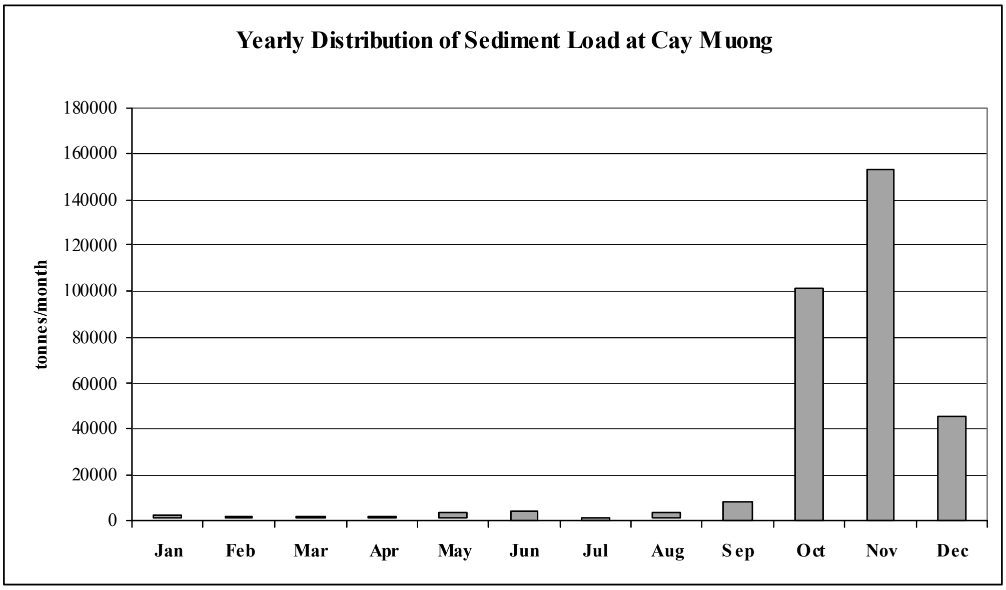
[1)] these values are on the average some 9% higher than the Gumble values, such factor has, therefor, also applied for the PMF.

Taking the 2 and 3-day PMP causing the PMF, the hydrograph of the PMF would show as shown in Figure C.14.

3. SEDIMENT ANALYSIS

The concentration of suspended sediments is measured in Cay Muong. For this study, daily data of suspended sediment concentration have been available for the period 1980 – 2000. In the absence of the grain size distribution of the sediments, it is difficult to assess whether the measured sediment load refers to wash load only, or whether also bed material load is included. Here it is assumed that the measured sediment load consists practically entirely of wash load.

Sediment concentrations at Cay Muong vary from practically zero in the low flow period to values of over 500 - 1000 gr/m^3 (ppm) during the floods in October – November. As a consequence most of the sediment load occurs during the flood season. The distribution of the average suspended load of some 320,000 tonnes per year is shown in the figure below.



Almost 80% of the transport of suspended sediments take place during October – November. Moreover, during wet years, the total load may be as high as 600,000 tonnes, while during dry years. the load is of the order of 150,000 tonnes only. This indicates that by far most of the sediment load is produced during the extreme floods.

The yearly volume of sediments at Cay Muong corresponds with a sediment production of 192 tonnes per km^2 per year on the average. If this production is assumed to be representative for the entire basin, then it can be estimated that the sediment load that is passing yearly the Dinh Binh dam site will be of the order of 200,000 tonnes, or some 150,000 m^3 at a density of 1400 kg/m^3.

It is anticipated that the trap efficiency of a future Dinh Binh reservoir will be relatively low. Most of the floodwaters that enter the reservoir in October – November will be discharged almost immediately, without allowing the wash load to settle. The volume of suspended load that enters the reservoir in December and the subsequent months (about 20% of the yearly volume on the average) could most likely settle in the reservoir.

It is assumed that in addition to the suspended sediments there will be some bed load with a volume corresponding with some 10% of the suspended load. Assuming that all these sediments will be trapped in the reservoir, then it is roughly estimated that on a yearly basis sedimentation could take place in the reservoir in the order of maximum 100,000 m^3 on the average.

Table C.1 10-Days Runoff Series at Respective Sub-catchment Areas (1)

	Natural Decade Runoff at Dinh Binh (generated) in Mm3																								
	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Jan1		56.7	26.7	23.4	46.6	60.9	10.4	30.7	53.6	52.9	78.1	39.2	24.3	16.9	41.9	44.0	29.8	60.5	22.0	48.9	99.9	30.3	127.2	90.2	62.8
Jan2		45.4	20.5	19.2	38.0	50.7	8.6	25.1	42.7	42.9	60.7	32.0	19.4	13.9	34.2	38.0	24.5	48.7	17.9	39.2	80.5	25.2	104.9	74.0	49.0
Jan3		34.1	18.2	17.4	34.2	44.9	8.0	22.5	37.8	38.1	54.0	28.6	17.4	12.7	30.8	35.2	22.0	43.1	16.1	34.4	71.3	23.5	96.4	84.7	41.9
Feb1		26.0	13.7	12.9	25.4	33.7	6.2	16.8	27.9	28.3	39.5	21.3	13.2	9.5	23.1	24.7	16.6	32.1	13.1	26.2	52.5	17.1	60.7	61.0	31.1
Feb2		21.0	11.5	10.8	21.2	27.8	5.4	14.1	23.1	23.5	32.5	17.9	11.1	8.0	19.8	20.5	14.0	26.0	10.2	21.2	43.2	14.4	49.6	48.0	26.0
Feb3		14.4	7.9	8.4	14.6	19.1	3.8	10.8	15.6	16.0	22.3	13.7	7.7	5.6	16.1	15.5	9.7	17.6	7.1	16.1	29.3	10.0	36.4	36.2	17.5
Mar1		15.5	8.6	8.1	15.8	20.6	4.3	10.3	16.7	17.2	24.6	13.1	8.4	6.1	15.7	14.7	10.6	18.8	7.7	15.3	31.3	10.9	44.7	33.8	19.1
Mar2		13.2	7.4	7.0	13.6	17.8	3.8	8.9	14.2	14.6	20.3	11.2	7.6	5.3	14.6	12.5	9.2	15.8	6.7	13.1	26.4	9.5	34.7	28.5	16.6
Mar3		12.3	7.0	6.6	12.9	16.8	3.7	8.5	13.5	13.7	18.9	10.7	7.6	5.1	14.8	11.7	8.8	16.7	6.4	12.3	24.6	9.3	31.5	26.5	16.4
Apr1		9.7	5.6	5.3	10.3	13.4	3.0	6.7	10.4	10.8	14.6	8.5	5.7	4.1	14.7	9.9	7.0	13.2	5.1	9.8	19.2	7.4	24.0	20.5	12.3
Apr2		9.4	5.0	4.7	9.0	12.1	2.8	6.0	9.0	9.5	13.1	7.5	5.1	3.6	11.5	8.9	6.3	11.7	4.7	8.5	16.8	6.5	21.5	18.8	10.7
Apr3		9.1	4.5	4.3	8.2	10.5	2.6	5.3	8.3	8.4	11.2	6.7	4.6	3.3	10.5	8.1	5.7	10.1	4.1	7.6	14.7	6.1	21.6	16.1	9.6
May1		10.4	9.4	6.8	6.5	15.4	2.7	13.3	19.4	7.5	6.1	7.3	11.4	3.4	12.9	6.6	6.3	7.8	6.9	12.5	13.3	10.2	32.2	13.9	10.7
May2		13.3	9.7	14.1	18.4	11.2	5.5	12.5	10.4	25.6	5.4	6.7	8.0	8.9	9.5	6.8	5.9	13.8	9.0	42.2	14.7	8.8	26.4	24.3	26.4
May3		11.6	16.2	30.0	35.7	9.2	3.9	19.0	10.1	18.4	8.5	5.9	14.9	36.2	10.8	7.8	9.8	21.3	13.7	20.4	32.8	12.8	47.1	23.4	12.7
Jun1		6.8	25.5	16.9	19.7	12.6	2.9	22.1	7.8	7.8	13.5	6.8	15.1	14.8	16.0	9.1	5.9	13.5	17.1	16.8	18.6	6.6	26.0	34.3	18.4
Jun2		10.1	30.5	19.2	27.2	29.2	6.3	34.3	11.0	8.1	10.8	8.1	10.5	44.1	8.4	19.2	5.8	10.9	13.1	28.8	18.2	6.8	42.0	22.5	12.7
Jun3		7.6	65.7	26.2	21.0	13.8	10.0	7.0	7.0	8.2	6.0	5.2	10.2	24.6	6.8	10.5	7.8	23.0	15.8	17.9	10.2	13.2	28.5	29.6	10.6
Jul1		13.2	14.2	9.6	25.0	8.0	5.4	8.0	4.2	4.9	6.4	3.9	5.9	7.4	5.2	4.2	4.1	8.6	10.9	16.1	12.0	18.3	13.4	23.4	6.0
Jul2		13.0	11.6	7.9	28.4	8.1	4.8	6.7	3.9	4.5	6.0	3.6	5.6	6.2	5.0	3.9	3.4	7.1	12.0	13.6	12.8	14.5	13.1	19.6	5.5
Jul3		13.7	10.7	8.9	25.9	7.1	4.2	7.1	3.9	4.8	6.1	3.6	7.3	5.7	4.7	5.8	3.9	6.8	9.3	11.0	11.9	13.0	12.9	18.9	5.4
Aug1		9.2	8.3	6.5	18.8	5.8	6.3	5.1	3.3	4.9	4.8	3.0	6.4	4.5	3.9	5.0	3.1	5.4	7.3	8.5	9.0	11.3	10.0	15.4	7.0
Aug2		7.9	6.7	5.4	16.6	5.3	7.1	4.4	3.1	4.3	4.6	2.8	10.7	4.9	3.6	5.7	2.8	4.8	5.9	7.3	8.1	8.8	9.2	13.9	11.0
Aug3		8.3	6.2	5.3	14.7	5.8	5.1	4.3	3.2	4.4	5.0	2.9	11.4	3.7	3.8	8.0	2.9	5.0	9.3	6.9	8.2	9.3	9.9	21.4	13.2
Sep1	13.1	7.3	5.2	7.5	11.5	8.1	5.9	4.2	3.3	3.8	9.2	2.5	15.4	7.7	3.4	5.7	3.4	30.1	12.3	6.0	6.8	7.5	11.2	15.9	8.3
Sep2	42.1	14.6	4.7	10.4	10.3	7.0	7.6	3.2	10.6	3.1	54.7	2.9	50.0	31.2	3.2	10.0	4.5	33.8	36.1	9.6	6.9	13.1	15.0	15.2	8.4
Sep3	227.5	18.4	7.5	34.3	15.7	11.3	11.0	4.8	47.5	4.2	35.4	16.7	38.8	18.2	6.7	15.6	6.9	21.5	17.6	17.8	88.4	33.8	18.4	14.5	11.6
Oct1	63.6	17.2	10.1	133.2	17.4	12.5	31.3	7.8	60.5	148.0	20.9	81.2	30.6	112.3	20.7	43.6	131.2	19.6	154.0	15.8	53.9	48.3	46.2	22.5	10.6
Oct2	95.8	14.2	112.7	82.6	187.1	21.5	93.2	152.4	138.3	49.6	16.9	243.0	30.3	463.4	15.5	66.3	59.7	36.8	97.3	69.2	35.9	42.1	122.9	69.6	29.0
Oct3	46.7	59.1	86.1	249.0	399.5	34.4	234.6	88.0	62.7	250.5	15.7	84.2	25.4	206.4	246.9	471.8	154.3	112.3	218.8	356.7	49.1	188.3	252.6	76.8	226.3
Nov1	249.9	149.0	34.8	339.8	325.4	58.3	160.3	199.6	172.1	120.2	196.5	122.3	22.5	113.7	70.7	144.4	48.0	41.2	243.5	280.8	256.7	96.3	473.5	34.1	99.8
Nov2	184.6	78.6	131.5	342.5	284.2	30.0	257.2	78.5	199.2	121.8	294.5	94.7	66.7	350.3	66.4	116.6	34.3	51.8	160.4	416.9	58.0	412.6	125.6	385.9	108.5
Nov3	71.8	38.8	66.1	123.4	128.0	20.4	83.4	207.6	229.8	86.8	201.5	58.9	50.9	149.8	246.8	68.5	167.8	79.9	95.9	329.6	46.2	421.3	151.8	150.7	45.9
Dec1	59.7	47.8	59.9	87.0	194.3	18.1	58.6	224.1	209.4	504.8	78.8	44.6	39.2	87.5	88.3	53.5	233.4	54.3	81.2	374.2	85.2	320.0	542.0	127.1	36.7
Dec2	46.2	39.1	39.9	79.2	139.2	15.7	49.2	78.2	83.8	110.4	61.5	40.7	27.9	66.0	138.1	41.9	231.1	43.1	84.7	225.4	53.7	295.3	246.8	101.2	84.3
Dec3	41.2	49.7	31.9	68.8	85.9	13.7	43.2	87.2	92.9	130.2	54.8	33.3	24.0	58.8	62.4	47.4	87.7	37.0	129.6	196.4	41.3	141.6	128.2	147.5	70.1

Table C.1 10-Days Runoff Series at Respective Sub-catchment Areas (2)

	Observed Decade Runoff at Cay Muong (observed) in Mm3																									
	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Jan1	28.7	35.2	43.2	38.6	31.2	45.6	66.0	8.6	49.5	59.8	48.4	61.3	37.8	54.3	20.1	40.0	36.5	34.7	69.6	40.8	82.8	89.6	21.6	109.8	76.9	86.5
Jan2	26.4	30.0	28.1	30.2	26.7	35.8	55.8	10.3	38.2	44.5	41.2	42.5	37.9	37.4	18.2	32.1	36.1	28.6	44.3	29.9	55.3	63.0	19.7	96.4	54.4	59.0
Jan3	36.1	26.9	20.8	25.2	24.4	34.6	51.6	12.7	37.9	41.5	39.0	38.8	31.8	35.5	18.9	28.5	38.0	26.2	36.6	25.5	43.3	48.9	21.5	114.7	103.3	44.4
Feb1	27.8	22.3	17.5	18.9	20.2	28.6	42.4	6.9	33.6	35.9	31.6	29.6	20.6	26.3	13.9	23.8	23.3	19.0	28.1	38.1	50.8	37.1	16.9	59.4	68.0	32.6
Feb2	24.0	22.3	13.6	15.9	21.0	22.1	36.4	5.7	28.5	26.1	28.9	22.5	18.4	19.9	11.1	19.7	18.2	15.5	22.4	21.9	33.6	33.3	10.8	50.0	48.3	33.5
Feb3	18.8	18.0	10.7	10.6	17.3	14.1	25.8	4.2	20.4	16.7	22.0	13.2	21.8	13.7	8.0	24.9	15.4	9.6	14.7	13.6	25.6	24.5	8.2	40.7	35.8	21.5
Mar1	17.5	24.2	13.4	11.6	18.4	14.5	28.7	4.6	20.0	17.8	24.6	26.5	17.0	15.9	8.6	18.8	14.6	11.8	17.1	18.0	24.9	25.7	8.6	53.5	31.9	25.1
Mar2	15.1	17.0	14.7	11.5	13.1	11.7	24.9	4.3	16.3	15.2	20.1	15.8	15.7	19.4	7.9	20.6	12.5	11.1	13.9	14.9	21.9	22.8	7.2	36.5	29.6	25.5
Mar3	15.2	16.2	11.7	10.1	11.9	10.4	26.4	4.1	14.8	16.3	18.1	14.7	12.0	26.0	8.7	17.8	12.5	11.9	24.3	14.6	21.1	23.1	9.7	33.8	24.2	32.5
Apr1	12.2	10.9	9.1	9.8	9.6	8.3	26.5	3.3	13.3	13.5	13.6	11.1	8.9	14.6	8.7	24.7	12.5	7.5	14.4	12.8	18.7	19.3	10.8	29.6	21.6	20.7
Apr2	13.3	9.5	12.2	7.9	12.2	11.8	25.4	2.4	13.2	13.1	11.9	11.7	11.1	13.9	6.3	15.4	9.6	8.3	13.0	10.5	18.6	24.6	10.5	24.0	35.6	17.8
Apr3	10.1	7.5	11.7	8.8	12.2	12.2	25.6	1.6	20.7	13.2	10.3	8.6	10.2	11.0	6.0	14.6	8.5	8.7	10.5	10.4	16.2	18.1	12.5	37.3	21.9	17.5
May1	15.1	6.4	15.0	11.0	9.8	8.8	22.3	3.6	18.9	26.5	10.4	8.1	10.4	19.3	4.9	15.3	8.7	9.0	10.0	9.8	17.0	18.4	14.1	41.0	19.2	14.5
May2	15.3	5.1	18.2	10.3	21.0	18.2	16.3	7.9	17.6	14.6	35.3	7.1	9.5	12.8	13.1	11.2	8.9	8.4	17.9	12.8	61.3	20.9	11.5	33.0	34.9	36.0
May3	16.7	8.9	14.8	15.0	44.0	32.4	13.4	5.4	28.8	14.2	28.0	11.4	8.3	24.1	56.1	12.6	10.3	14.3	25.1	17.7	29.0	44.0	14.9	62.0	33.3	17.1
Jun1	9.3	4.5	9.0	26.6	23.8	18.6	18.5	3.9	35.0	10.9	11.4	17.4	9.4	25.2	21.0	19.1	12.1	8.5	14.8	21.9	22.2	25.0	7.8	37.4	49.8	22.4
Jun2	12.6	5.6	13.6	28.0	29.3	37.2	39.3	7.9	64.5	15.7	11.8	13.0	11.8	17.7	84.1	10.2	25.6	8.3	12.0	14.2	39.8	24.6	8.1	63.8	30.0	15.5
Jun3	17.3	3.7	10.2	60.4	43.4	31.4	18.1	11.8	13.1	10.0	12.0	7.3	7.0	18.2	51.6	8.3	13.6	11.4	27.0	17.4	23.8	13.8	15.8	41.0	35.8	13.1
Jul1	8.2	4.0	21.2	20.7	28.2	14.4	14.2	6.7	15.7	8.4	8.5	5.8	11.9	31.6	24.4	13.8	7.9	7.7	15.5	21.1	20.4	10.4	17.3	50.4	36.9	9.6
Jul2	19.7	7.9	15.9	12.5	16.3	34.4	14.5	8.1	11.5	10.8	8.9	6.0	20.8	27.6	19.8	16.7	7.6	8.7	10.4	21.4	24.4	21.5	8.6	33.9	23.9	10.0
Jul3	22.3	4.3	17.9	10.6	21.0	18.5	13.1	8.1	12.6	7.9	10.7	6.5	14.3	39.7	21.6	10.7	14.4	9.3	12.2	17.9	19.2	16.0	7.6	28.4	31.6	10.6
Aug1	9.6	5.7	8.6	9.7	23.1	18.4	8.6	39.6	8.0	6.5	17.9	5.8	7.1	21.0	16.3	12.5	9.4	5.9	10.7	14.2	13.4	10.9	15.1	20.8	26.4	18.3
Aug2	10.5	5.5	7.8	7.4	31.4	12.7	7.7	51.5	7.1	4.3	19.1	6.8	5.6	30.6	31.3	8.0	15.9	4.1	11.3	14.3	12.5	8.6	8.9	21.3	25.3	20.7
Aug3	26.3	12.9	13.6	6.8	59.2	8.4	13.8	18.3	7.8	4.6	21.0	12.4	6.8	36.9	12.9	9.0	23.9	6.6	19.6	31.2	11.9	8.7	18.4	25.2	89.0	22.1
Sep1	23.3	14.6	20.5	9.0	59.7	6.9	26.2	23.1	11.8	5.0	16.2	10.0	5.5	39.0	21.3	8.2	10.8	10.1	46.9	28.4	13.8	7.1	16.1	22.2	28.1	11.3
Sep2	28.2	39.2	61.1	6.9	85.1	7.6	15.5	18.5	6.5	12.2	10.9	35.2	8.9	141.2	19.7	11.4	15.5	15.0	82.6	66.4	29.2	7.7	21.7	24.6	29.3	13.4
Sep3	52.4	200.0	47.8	30.5	93.6	20.6	20.9	27.8	9.3	30.5	10.6	25.5	41.0	73.4	12.9	33.5	24.7	19.9	35.0	36.9	48.3	54.8	44.2	28.2	32.7	20.6
Oct1	50.2	45.0	34.5	18.9	252.1	25.7	20.1	91.8	14.3	68.7	121.2	15.2	116.7	53.1	118.6	56.7	34.8	200.8	33.9	180.8	28.5	29.2	61.8	33.7	70.4	15.4
Oct2	171.1	72.3	23.2	186.0	138.4	297.2	20.4	147.2	215.0	163.2	36.3	9.8	411.6	58.2	605.1	28.1	70.5	41.1	79.7	127.3	61.2	22.1	60.4	175.7	191.3	29.4
Oct3	73.9	34.3	90.5	130.4	420.8	712.9	27.5	336.7	97.6	39.7	237.3	9.3	160.3	38.0	225.6	346.3	895.1	151.5	219.6	336.2	291.9	37.4	378.3	357.9	130.2	275.6
Nov1	79.1	413.9	267.1	35.6	540.4	657.2	37.7	358.6	464.5	115.4	125.6	124.8	249.4	33.4	111.9	84.1	210.5	50.5	55.5	396.8	452.2	285.1	120.5	729.4	69.4	60.7
Nov2	284.2	365.9	107.3	274.3	693.8	488.6	21.6	287.1	158.7	155.6	59.6	548.6	124.7	68.7	502.9	58.1	150.2	27.5	36.3	238.7	624.6	53.6	611.4	178.2	488.1	166.2
Nov3	104.6	73.1	54.2	129.1	182.0	164.5	19.5	126.0	279.8	366.0	63.2	308.4	84.7	61.6	152.0	93.0	81.7	307.0	61.6	121.4	520.0	35.6	803.9	152.9	257.5	45.7
Dec1	59.7	46.0	77.1	86.7	94.0	309.9	16.4	69.9	275.3	264.0	577.6	96.8	61.7	47.3	90.1	58.3	56.9	283.0	63.8	93.5	574.4	56.5	345.3	905.5	172.5	28.4
Dec2	41.6	30.5	60.5	56.4	74.6	197.9	15.4	71.1	113.1	92.0	118.6	59.7	57.7	33.6	62.9	112.4	41.1	311.0	58.9	91.1	249.3	39.8	490.3	368.4	139.3	84.0
Dec3	39.2	24.5	65.8	41.2	68.5	113.4	12.1	64.4	136.8	93.0	93.7	49.2	48.5	28.2	52.1	56.4	50.7	142.3	72.5	196.4	233.0	32.5	129.2	167.4	175.7	77.5

Table C.1 10-Days Runoff Series at Respective Sub-catchment Areas (3)

Natural Decade Runoff at Binh Thanh (generated) in Mm3

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Jan1		87.0	36.6	43.6	78.7	113.8	15.9	57.4	94.7	91.9	123.7	72.6	44.6	27.9	69.1	73.5	55.2	101.0	41.5	80.1	166.2	48.3	203.9	158.9	101.9
Jan2		73.9	29.5	35.6	64.3	93.4	13.3	46.9	76.0	74.6	96.9	59.1	36.3	23.0	56.3	61.7	45.2	81.9	33.6	64.4	134.1	40.8	174.2	129.5	80.0
Jan3		60.4	26.3	32.1	57.9	83.3	12.4	42.0	67.5	66.4	85.8	52.7	32.8	21.0	50.8	57.3	40.7	72.0	30.2	57.4	118.6	37.7	154.0	132.3	68.4
Feb1		46.9	19.8	23.9	43.2	62.3	9.6	31.4	49.9	49.2	63.0	39.2	24.7	15.8	38.2	40.2	30.6	53.3	24.3	43.5	87.3	27.6	104.7	99.4	50.7
Feb2		37.8	16.7	20.1	36.2	51.8	8.4	26.3	41.4	40.9	52.0	32.7	21.0	13.4	32.5	33.4	25.7	43.6	19.0	35.0	71.9	23.3	84.9	79.8	42.2
Feb3		26.0	11.6	15.4	24.9	35.6	5.9	20.1	28.2	27.9	35.5	25.7	14.6	9.3	26.9	25.4	17.8	29.5	13.1	26.6	48.7	16.2	62.6	60.2	28.9
Mar1		28.2	12.6	14.9	27.0	38.5	6.7	19.2	30.2	30.0	38.7	23.8	15.9	10.3	25.8	24.1	19.4	31.5	14.2	25.2	52.0	17.7	73.0	56.5	31.5
Mar2		24.2	10.9	12.7	23.3	33.1	5.9	16.6	25.7	25.6	32.0	20.4	14.9	9.0	24.9	20.6	16.8	26.5	12.3	21.5	43.9	15.4	57.5	47.7	27.4
Mar3		22.8	10.4	12.1	22.1	31.5	5.9	15.7	24.4	24.1	29.8	19.3	16.9	8.6	24.0	19.4	16.0	26.5	11.7	20.3	41.0	15.0	52.6	44.4	27.0
Apr1		18.0	8.4	9.7	17.5	25.1	4.8	12.5	19.0	19.0	23.2	15.2	11.6	6.9	20.7	15.9	12.8	20.2	9.3	16.0	31.9	12.0	40.4	34.6	20.1
Apr2		16.4	7.5	8.6	15.6	22.2	4.4	11.1	16.6	16.6	20.4	13.4	10.3	6.2	16.5	13.8	11.4	17.4	8.3	14.1	28.5	10.6	35.2	32.5	17.6
Apr3		15.6	6.7	7.7	14.0	19.6	4.0	9.9	14.9	14.8	17.7	12.0	9.2	5.6	14.7	12.1	10.2	15.1	7.4	12.5	24.5	9.7	33.8	27.0	15.8
May1		18.3	12.9	12.4	10.8	28.6	4.0	25.6	34.3	13.3	9.6	13.1	28.2	5.9	18.1	10.4	11.3	12.0	12.2	20.2	22.4	16.7	47.2	23.4	17.6
May2		21.4	11.7	26.6	18.0	20.8	9.8	23.2	19.0	43.4	8.5	12.0	18.2	15.3	13.1	10.7	10.5	22.2	16.4	70.1	26.5	13.7	38.3	45.9	44.4
May3		17.0	16.1	61.4	30.8	17.1	6.8	41.0	18.7	32.6	13.6	10.4	34.4	62.7	14.4	12.2	17.6	28.2	22.2	30.6	52.7	16.0	74.6	42.8	20.7
Jun1		10.7	28.4	32.6	13.2	23.7	5.0	56.4	14.0	13.5	20.4	11.2	31.9	21.2	23.5	14.7	10.9	15.7	26.3	23.9	28.8	8.8	48.9	63.6	24.9
Jun2		16.0	26.5	40.5	29.1	44.7	8.9	103.3	20.1	14.3	15.1	14.5	21.8	114.2	12.1	29.2	10.5	13.1	14.9	43.7	29.2	9.3	82.0	36.2	17.9
Jun3		12.1	60.1	59.8	31.1	20.5	13.7	20.3	12.9	14.4	8.5	8.3	20.4	79.5	9.9	15.2	14.2	30.9	18.1	24.2	16.0	15.4	49.5	41.3	15.2
Jul1		24.2	13.3	22.3	37.1	11.9	8.6	19.3	7.6	8.7	9.3	6.5	15.6	22.6	8.1	6.3	6.5	12.1	9.7	19.6	19.0	16.3	23.8	35.2	9.0
Jul2		20.5	11.1	18.2	50.3	11.3	7.2	15.5	7.3	8.0	9.1	7.0	13.4	19.3	7.5	5.8	5.7	10.1	8.3	16.1	18.3	13.4	22.7	29.8	8.4
Jul3		19.3	10.8	17.8	50.6	10.9	6.4	16.2	7.2	8.8	9.1	6.4	16.3	17.5	7.2	9.1	5.8	9.8	7.1	14.6	17.6	11.5	22.1	31.7	8.4
Aug1		13.4	8.5	13.2	36.5	9.2	12.9	11.4	6.1	8.2	7.3	5.2	13.0	13.9	6.2	7.8	4.6	7.9	5.6	11.6	13.4	13.8	17.2	24.5	9.2
Aug2		11.6	6.8	10.9	29.6	8.5	14.6	9.7	5.8	8.2	6.9	4.9	24.1	16.0	5.7	6.7	4.3	7.2	5.2	9.9	12.2	9.9	16.7	21.7	11.0
Aug3		11.6	6.4	10.9	25.8	10.0	11.1	9.2	5.9	7.6	7.5	5.0	25.0	11.3	5.9	8.0	4.5	7.5	13.9	9.6	12.3	10.8	17.3	37.9	11.0
Sep1	26.8	10.2	5.4	13.7	20.4	11.0	10.9	8.9	5.5	6.9	8.9	4.3	27.9	16.2	5.1	5.4	4.1	25.1	16.0	8.4	10.2	9.1	17.9	26.8	7.0
Sep2	69.7	19.0	4.9	18.4	18.5	8.7	13.1	6.8	11.4	5.6	41.0	4.6	84.6	33.5	5.3	8.8	4.5	42.9	45.9	13.5	9.7	17.9	24.5	26.4	7.2
Sep3	497.5	23.5	11.2	50.0	35.1	13.3	16.6	13.5	45.9	7.6	37.7	24.6	59.3	26.0	18.6	18.4	7.4	32.6	29.5	25.5	102.3	44.0	28.3	25.2	11.1
Oct1	140.2	21.1	17.1	238.5	36.5	12.4	81.9	20.7	129.4	188.0	26.3	122.0	59.9	158.2	62.9	41.5	196.2	38.3	249.4	25.0	70.8	77.4	67.4	41.8	11.2
Oct2	216.1	19.7	208.8	144.6	326.7	23.8	198.6	297.1	275.8	66.5	20.3	490.8	63.4	795.9	43.0	99.0	94.2	80.3	143.0	121.7	50.4	66.5	207.4	194.9	28.6
Oct3	102.3	79.2	179.4	458.5	748.3	37.3	430.2	159.6	117.9	336.8	19.5	190.8	51.2	332.8	466.1	861.2	261.9	252.3	389.0	529.5	71.8	400.1	473.7	154.3	380.4
Nov1	452.7	235.6	68.2	618.1	635.5	71.5	291.4	454.9	258.4	194.5	310.2	259.3	40.7	196.0	160.7	246.9	78.8	75.4	371.1	468.5	426.0	185.0	842.8	72.1	171.7
Nov2	387.2	103.9	235.8	558.1	552.0	43.1	435.0	154.2	317.9	154.2	546.3	185.9	94.5	596.2	133.3	200.0	57.5	71.7	257.7	712.4	102.7	731.9	239.1	583.6	197.2
Nov3	145.0	60.3	124.3	215.1	251.0	35.1	149.3	341.5	495.9	125.6	397.8	106.7	74.3	218.5	352.5	130.6	283.7	110.3	153.8	535.0	81.1	797.1	286.8	263.0	80.3
Dec1	116.8	64.9	108.5	150.7	382.8	28.2	104.8	348.0	344.1	790.2	147.2	80.5	60.3	136.6	139.6	97.8	377.4	106.4	125.9	658.6	110.7	494.7	887.2	231.7	64.3
Dec2	93.5	52.5	69.6	130.6	239.4	24.1	90.1	142.5	143.1	178.2	114.9	70.9	47.2	108.2	204.3	75.8	367.0	82.2	111.2	330.5	81.9	546.6	453.2	165.9	118.0
Dec3	82.7	62.8	59.7	114.2	159.6	20.9	80.7	147.1	151.0	193.7	100.2	61.1	39.7	99.1	101.4	79.8	145.8	72.6	179.4	321.9	65.8	244.8	226.2	217.0	105.9

Table C.1 10-Days Runoff Series at Respective Sub-catchment Areas (4)

Natural Decade Runoff Nui Mot (generated) in Mm3																									
	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Jan1		7.1	3.3	3.7	4.4	9.2	1.8	5.5	7.5	7.8	8.0	6.0	5.0	3.3	6.3	4.7	3.6	8.4	3.4	5.9	11.6	3.2	11.6	10.5	6.9
Jan2		5.4	2.7	3.0	3.5	7.5	1.6	3.9	6.0	6.3	6.4	4.9	3.8	2.7	4.8	3.8	2.9	6.9	2.8	4.7	9.4	2.7	9.9	8.4	5.4
Jan3		4.5	2.4	2.7	3.2	6.7	1.4	3.5	5.5	5.6	5.7	4.4	3.5	2.4	4.3	3.4	2.6	5.9	2.5	4.5	8.3	2.5	8.5	8.3	4.7
Feb1		3.7	1.8	2.0	2.4	5.0	1.0	2.6	4.0	4.1	4.1	3.2	2.6	1.8	3.2	2.5	2.0	4.4	1.9	3.9	6.1	1.9	6.4	6.0	3.5
Feb2		3.0	1.5	1.7	2.0	4.1	0.9	2.2	3.3	3.4	3.4	2.7	2.2	1.5	2.7	2.1	1.7	3.6	1.6	3.0	5.1	1.6	5.2	4.8	2.9
Feb3		2.0	1.1	1.3	1.4	2.8	0.6	1.7	2.2	2.5	2.4	2.1	1.5	1.1	2.1	1.6	1.1	2.4	1.1	2.2	3.4	1.1	3.7	3.7	2.0
Mar1		2.2	1.2	1.2	1.5	3.0	0.7	1.6	2.4	2.5	2.7	1.9	1.7	1.1	2.1	1.6	1.2	2.6	1.2	2.1	3.7	1.2	3.9	3.4	2.2
Mar2		1.9	1.0	1.1	1.3	2.6	0.6	1.3	2.0	2.2	2.2	1.7	2.1	1.0	2.1	1.3	1.1	2.2	1.0	1.8	3.1	1.0	3.2	3.0	1.9
Mar3		1.8	1.0	1.0	1.2	2.5	0.6	1.3	1.9	2.0	2.0	1.6	3.0	0.9	1.9	1.3	1.0	2.1	1.0	1.7	2.9	1.0	3.0	2.7	2.3
Apr1		1.4	0.8	0.8	1.0	1.9	0.5	1.0	1.5	1.6	1.6	1.2	2.1	0.7	1.7	1.0	0.8	1.6	0.8	1.3	2.3	0.8	2.3	2.2	2.0
Apr2		1.2	0.7	0.7	0.9	1.7	0.4	0.9	1.3	1.4	1.4	1.1	1.8	0.7	1.3	0.9	0.7	1.4	0.7	1.3	2.1	0.7	2.0	2.1	1.6
Apr3		1.1	0.6	0.6	0.8	1.5	0.4	0.8	1.2	1.2	1.2	1.0	1.5	0.6	1.3	0.8	0.6	1.2	0.6	1.1	1.7	0.6	1.8	1.7	1.4
May1		1.2	1.2	1.0	0.6	2.2	0.3	2.1	5.0	1.1	0.7	1.1	3.1	0.6	1.5	0.7	0.7	1.0	1.0	1.6	1.6	1.1	2.2	1.5	1.5
May2		1.3	0.8	2.5	0.8	1.6	0.6	1.8	2.8	3.4	0.6	1.0	2.1	1.9	1.0	0.8	0.6	2.1	1.4	4.8	1.8	0.9	1.9	2.6	3.6
May3		0.9	0.7	7.7	0.9	1.4	0.5	2.8	3.2	2.1	0.9	0.8	3.3	3.8	1.1	0.8	1.4	1.7	1.4	1.5	2.3	1.1	3.7	2.4	1.6
Jun1		0.6	1.2	2.6	0.3	1.8	0.3	4.9	2.0	0.9	1.3	0.9	2.9	1.0	2.8	1.1	0.9	1.1	1.5	1.3	1.1	0.6	2.3	3.1	1.6
Jun2		0.9	1.3	3.9	0.3	2.5	0.3	9.2	2.8	1.0	1.0	1.1	2.1	8.0	1.4	2.0	0.9	1.0	0.8	1.9	1.2	0.6	3.3	1.9	1.3
Jun3		0.6	2.3	8.4	0.4	1.4	0.5	1.7	1.7	1.0	0.6	0.6	1.5	6.3	1.1	1.0	1.0	2.6	0.8	1.1	0.7	0.8	2.0	1.9	1.1
Jul1		2.0	0.5	2.8	0.6	0.8	0.4	1.5	1.0	0.6	0.6	0.5	1.1	1.8	0.8	0.4	0.4	1.3	0.3	0.9	0.9	0.6	1.0	1.6	0.7
Jul2		1.5	0.5	2.3	0.9	0.7	0.3	1.3	0.9	0.6	0.6	0.8	0.9	1.5	0.8	0.4	0.4	1.1	0.3	0.8	0.8	0.4	0.9	1.2	0.6
Jul3		1.3	0.5	2.1	0.7	0.8	0.3	1.2	0.8	0.7	0.6	0.8	0.9	1.8	0.7	0.6	0.4	1.0	0.3	0.7	0.8	0.4	0.9	1.5	0.6
Aug1		1.0	0.3	1.5	0.6	0.6	0.4	0.9	0.7	0.6	0.5	0.6	0.7	1.5	0.6	0.5	0.3	0.8	0.3	0.6	0.7	0.4	0.7	1.1	0.5
Aug2		0.9	0.3	1.3	0.5	0.6	0.5	0.8	0.6	0.6	0.4	0.5	1.1	1.5	0.5	0.5	0.3	0.7	0.3	0.5	0.7	0.3	0.7	0.9	0.5
Aug3		0.9	0.3	1.2	0.5	0.6	0.4	0.7	0.6	0.5	0.5	0.5	0.9	1.2	0.6	0.5	0.3	0.7	0.4	0.6	0.7	0.3	0.8	1.6	0.5
Sep1	1.7	0.7	0.3	1.0	0.4	0.6	0.3	0.6	0.5	0.4	0.4	0.4	0.7	1.1	0.5	0.3	0.3	0.8	0.4	0.5	0.6	0.3	0.6	1.1	0.4
Sep2	2.1	1.3	0.3	1.2	0.4	0.5	0.3	0.5	0.6	0.4	0.8	0.8	0.9	1.2	0.8	0.3	0.3	1.9	2.0	1.0	0.7	0.4	0.6	1.0	0.4
Sep3	23.9	2.4	0.4	1.8	1.8	0.6	1.3	1.0	2.1	0.8	0.6	1.7	1.1	1.0	3.6	0.4	0.8	3.3	4.9	3.6	5.8	1.0	0.7	0.9	0.4
Oct1	10.3	2.9	0.9	10.9	2.0	0.6	9.5	1.1	7.6	9.8	1.0	14.3	2.9	5.4	10.6	0.4	25.3	6.2	19.3	5.2	3.0	1.7	1.6	2.8	0.5
Oct2	18.8	2.6	17.4	6.4	24.5	3.4	13.3	18.2	17.8	4.1	1.0	56.9	9.3	54.4	7.0	2.2	8.6	5.9	9.6	27.8	2.6	2.9	5.7	24.2	1.1
Oct3	7.7	12.2	15.2	18.9	57.4	6.9	23.7	11.3	6.3	13.4	1.1	17.4	8.3	23.5	32.0	47.9	18.8	17.2	28.3	34.2	6.0	35.5	39.6	15.4	19.4
Nov1	31.1	28.4	5.5	31.2	47.7	8.6	22.7	44.3	16.6	11.9	37.6	37.0	8.1	13.2	17.9	12.5	7.0	7.7	17.0	28.7	30.4	19.2	51.3	7.2	10.9
Nov2	26.3	9.6	18.0	31.7	48.0	4.1	28.9	12.6	23.2	6.7	41.0	15.8	16.3	37.7	12.9	14.0	4.8	4.7	14.3	51.4	7.6	48.4	17.6	37.2	17.1
Nov3	9.7	6.2	9.6	12.3	21.5	4.3	10.1	27.8	44.5	9.6	31.2	11.9	10.7	11.2	10.8	9.9	24.6	3.9	10.6	37.9	6.0	50.4	26.3	21.3	5.8
Dec1	7.9	6.5	13.5	8.1	34.4	3.2	7.4	23.4	31.8	53.4	12.3	8.9	7.5	11.2	8.4	6.8	35.4	6.3	8.1	44.7	6.2	24.2	42.9	22.0	4.4
Dec2	6.2	5.2	6.3	6.5	17.5	2.7	7.5	10.8	13.0	11.9	9.8	7.3	6.2	8.2	9.5	5.0	27.6	5.9	6.1	17.9	5.4	43.5	34.5	11.8	8.8
Dec3	5.5	5.0	5.1	5.7	13.0	2.4	7.3	11.8	12.4	12.1	8.3	6.4	4.8	13.0	6.4	5.1	12.2	6.7	13.3	26.2	4.4	16.2	14.8	11.3	6.3

Table C.1 10-Days Runoff Series at Respective Sub-catchment Areas (5)

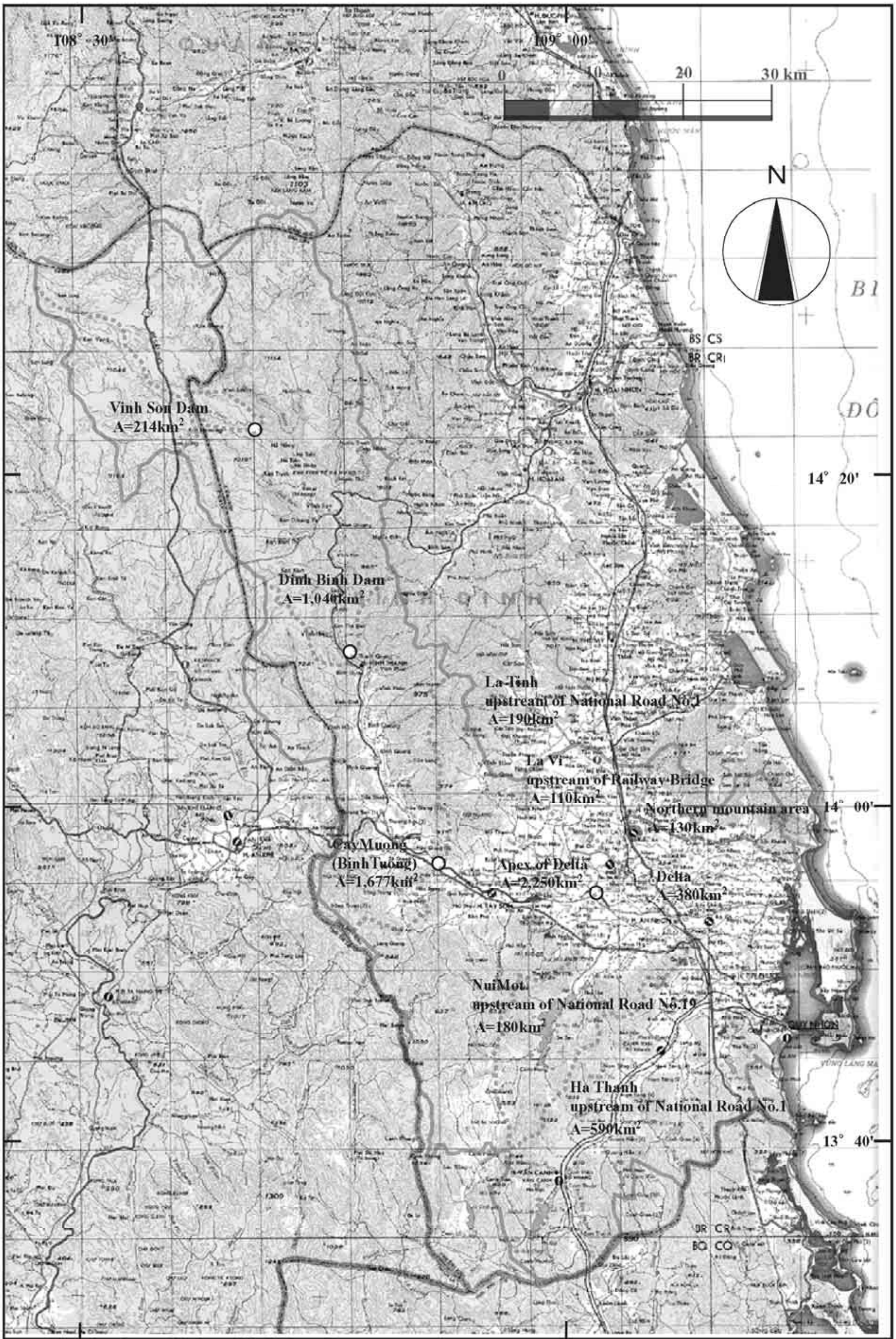
	Natural Decade Runoff La Vi (generated) in Mm3																								
	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Jan1		10.9	5.1	4.6	5.8	13.1	3.0	8.2	8.5	9.6	8.7	8.6	6.9	0.9	8.2	4.9	5.1	9.3	4.7	6.6	9.9	5.1	15.7	12.6	6.6
Jan2		7.7	4.2	3.8	4.8	10.7	2.5	6.2	6.9	7.8	7.0	6.9	5.2	0.8	6.7	4.1	4.2	7.6	3.8	5.3	8.2	4.5	15.7	10.2	5.8
Jan3		6.8	3.8	3.4	4.3	9.5	2.3	5.5	6.2	6.9	6.2	6.2	4.7	0.8	6.0	3.7	3.8	6.7	3.5	4.7	7.4	3.9	12.2	10.3	4.9
Feb1		5.2	2.9	2.6	3.2	7.1	1.7	4.1	4.6	5.2	4.6	4.5	3.5	0.6	4.5	2.7	2.8	5.0	2.6	6.0	5.6	2.9	8.9	7.8	3.7
Feb2		4.2	2.5	2.2	2.7	5.9	1.5	3.4	3.8	4.3	3.8	3.8	3.0	0.6	3.8	2.3	2.4	4.1	2.2	4.6	4.7	2.5	7.5	6.3	3.1
Feb3		2.9	1.7	1.7	1.9	4.0	1.0	2.6	2.7	3.1	2.6	3.2	2.0	0.4	3.0	1.8	1.7	2.8	1.5	3.4	3.3	1.7	5.1	4.8	2.1
Mar1		3.1	1.9	1.6	2.1	4.3	1.1	2.5	2.9	3.2	2.8	2.9	2.3	0.5	3.0	1.7	1.8	3.0	1.6	3.2	3.6	1.9	5.3	4.5	2.3
Mar2		2.7	1.7	1.4	1.8	3.7	1.0	2.2	2.4	2.7	2.4	2.4	6.1	0.4	3.2	1.5	1.6	2.6	1.4	2.6	3.2	1.6	4.4	3.8	2.1
Mar3		2.5	1.6	1.3	1.7	3.5	0.9	2.0	2.3	2.6	2.2	2.3	7.8	0.4	3.2	1.4	1.5	2.5	1.3	2.4	3.0	1.5	4.1	3.6	2.9
Apr1		2.0	1.3	1.1	1.4	2.7	0.8	1.6	1.8	2.0	1.7	1.8	4.4	0.3	3.2	1.1	1.2	1.9	1.0	1.9	2.4	1.2	3.2	2.8	2.6
Apr2		1.7	1.2	1.0	1.3	2.4	0.7	1.4	1.6	1.8	1.5	1.5	3.7	1.0	2.4	1.0	1.1	1.7	0.9	2.0	2.2	1.1	2.7	2.4	2.1
Apr3		1.5	1.1	0.8	1.1	2.2	0.6	1.3	1.5	1.6	1.3	1.4	3.1	1.3	2.1	0.9	1.0	1.5	0.8	2.0	2.0	1.0	2.6	2.1	1.8
May1		2.6	1.9	1.4	0.8	3.1	0.6	3.6	3.2	1.4	0.7	1.5	6.2	1.2	2.5	0.8	1.1	1.2	1.4	2.9	1.8	1.7	3.1	1.9	2.0
May2		3.1	1.4	2.6	1.1	2.3	0.9	3.2	1.8	5.1	0.7	1.4	4.0	2.5	1.7	0.8	1.0	1.9	3.4	3.8	2.0	1.3	2.7	5.7	4.4
May3		2.6	1.2	2.5	1.1	1.8	0.8	5.7	2.0	3.4	1.1	1.1	5.7	18.0	1.9	1.8	2.5	1.6	3.1	1.2	2.6	1.9	5.4	5.8	2.1
Jun1		1.7	1.8	1.4	0.4	2.5	0.4	38.6	1.4	1.5	1.9	1.2	4.8	5.3	3.6	3.5	2.2	1.0	3.2	1.1	1.3	1.0	3.5	10.0	2.3
Jun2		2.0	1.8	2.1	0.5	3.5	0.5	52.6	2.3	1.5	1.3	1.5	3.3	109.2	1.8	5.7	2.0	1.0	1.7	1.5	1.5	1.0	5.1	4.8	1.7
Jun3		1.6	2.3	3.4	0.4	1.9	1.0	5.8	1.5	1.6	0.8	0.9	2.4	23.4	1.5	2.7	2.3	2.0	1.8	0.9	0.9	1.3	3.2	4.6	1.5
Jul1		2.8	0.6	1.4	0.8	1.1	0.8	5.0	0.9	1.0	0.8	0.7	1.3	6.8	1.5	1.1	1.1	0.8	0.6	0.8	1.1	0.7	1.5	3.8	0.8
Jul2		2.5	0.6	1.1	1.0	1.1	0.8	4.1	0.8	0.9	1.1	0.9	1.1	5.5	1.3	1.0	1.0	0.7	0.6	0.7	1.1	0.6	1.3	3.0	0.8
Jul3		2.8	0.6	1.1	0.8	1.0	0.7	3.7	0.8	0.9	1.1	2.0	1.2	4.8	1.2	0.9	0.9	0.7	0.6	0.7	1.5	0.6	1.3	3.3	0.8
Aug1		2.0	0.6	0.9	0.7	1.0	1.0	2.7	0.8	0.7	0.8	1.5	1.4	3.5	1.0	0.7	0.8	0.6	0.4	2.3	1.1	0.6	1.1	2.4	0.9
Aug2		1.7	0.5	0.8	0.6	0.8	1.7	2.3	0.6	0.7	0.8	1.3	10.0	2.9	0.8	0.6	0.6	0.6	0.4	2.4	1.0	0.7	1.0	2.1	1.3
Aug3		2.5	0.5	0.9	0.6	0.9	1.6	2.1	0.7	0.7	0.8	1.2	5.2	2.8	0.9	0.7	0.6	0.6	0.5	6.6	1.0	0.6	1.0	5.0	1.8
Sep1	2.2	2.2	0.5	1.0	0.5	1.6	1.2	1.7	0.7	0.6	0.6	0.9	3.7	2.4	1.2	0.5	0.7	1.0	0.5	4.9	0.8	0.5	0.8	3.4	1.4
Sep2	2.2	2.7	0.4	2.4	0.5	1.7	1.2	1.4	1.1	0.5	1.1	1.0	3.0	2.9	1.3	0.6	1.6	2.8	1.6	24.7	0.9	1.1	0.8	3.2	1.3
Sep3	41.4	7.6	0.6	1.8	2.2	1.5	1.6	1.4	5.1	0.7	0.8	2.8	2.5	2.3	2.1	0.8	3.1	3.5	1.4	38.3	9.6	2.9	0.8	2.6	1.2
Oct1	13.6	8.1	2.2	22.9	2.1	1.8	17.6	1.4	12.3	13.2	0.9	20.9	2.6	17.6	4.0	1.3	40.1	8.3	18.6	43.1	5.0	5.4	1.4	6.4	2.7
Oct2	30.8	6.3	26.7	20.0	27.2	4.1	26.4	30.3	31.2	5.5	1.0	63.1	2.9	86.4	4.8	8.2	12.7	5.2	9.5	113.3	3.9	5.3	7.5	28.4	5.0
Oct3	12.2	54.6	21.2	41.9	74.6	4.3	41.6	17.7	11.8	31.9	1.1	26.7	3.3	23.3	36.6	72.5	27.6	13.1	34.5	58.1	12.1	41.4	54.4	25.1	65.4
Nov1	47.0	38.9	8.2	40.6	83.1	8.4	37.3	55.2	22.5	15.5	32.3	33.7	2.4	14.4	11.4	19.6	11.7	9.4	24.5	41.9	48.3	22.1	75.5	10.2	16.5
Nov2	34.1	15.9	12.9	33.0	65.5	4.6	52.4	18.6	33.2	10.6	61.9	17.6	2.0	42.5	10.6	17.0	8.5	5.6	17.0	24.1	12.0	57.9	23.2	24.9	28.3
Nov3	14.5	11.6	12.6	16.2	47.2	8.6	16.8	22.0	52.1	10.5	38.2	13.0	1.7	15.9	8.6	14.3	27.3	5.3	13.8	43.3	9.4	72.6	34.5	18.8	12.1
Dec1	12.1	9.9	14.6	11.1	39.9	5.8	12.6	22.8	35.2	49.2	15.6	10.2	1.4	14.5	7.7	10.4	27.0	5.8	10.2	19.0	9.6	30.4	48.1	14.4	9.4
Dec2	9.5	7.7	7.3	9.3	24.4	4.8	11.7	12.3	16.0	13.6	14.1	8.7	1.2	12.8	9.4	7.9	29.5	5.8	7.5	15.2	8.3	51.2	35.5	9.5	9.8
Dec3	8.4	6.9	6.4	8.0	18.2	4.1	10.6	12.5	14.1	12.8	11.9	7.9	1.1	13.5	6.8	7.0	13.7	8.0	10.9	13.5	6.9	21.0	17.6	7.9	8.8

Table C.1 10-Days Runoff Series at Respective Sub-catchment Areas (6)

	Natural Decade Runoff Ha Thanh (generated) in Mm3																								
	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Jan1		21.0	12.7	13.3	14.3	30.9	6.5	18.7	25.3	27.1	27.7	20.8	17.1	14.3	23.6	17.2	11.9	30.8	12.1	20.9	43.7	11.2	39.1	36.7	24.5
Jan2		17.4	9.5	10.8	11.4	25.4	5.8	12.9	20.7	21.9	22.0	17.1	13.4	11.8	17.6	14.6	9.8	25.3	9.9	16.7	35.2	9.3	32.3	29.5	19.4
Jan3		13.9	8.5	9.7	10.3	22.4	5.2	11.6	18.7	19.5	19.6	15.0	12.6	10.7	15.8	13.4	8.8	21.8	8.9	16.7	31.1	8.6	27.8	29.5	16.9
Feb1		12.6	6.4	7.2	8.0	16.6	3.8	8.5	13.8	14.4	14.3	11.1	9.2	7.8	11.7	9.5	6.6	16.0	6.7	14.1	22.8	6.5	21.0	21.1	12.6
Feb2		10.3	5.4	6.0	6.5	13.8	3.3	7.1	11.2	11.9	11.8	9.3	7.8	6.5	9.7	7.9	5.6	13.2	5.6	10.5	18.8	5.4	17.1	17.0	10.5
Feb3		7.0	3.7	4.6	4.5	9.5	2.3	5.4	7.6	9.0	8.2	7.1	5.4	4.5	7.4	6.1	3.8	8.9	3.8	7.9	12.7	3.8	12.7	12.8	7.2
Mar1		7.4	4.0	4.4	4.9	10.2	2.5	5.1	8.1	9.0	10.0	6.7	6.1	4.9	7.4	5.8	4.2	9.5	4.3	7.4	13.5	4.1	12.8	12.0	7.7
Mar2		6.3	3.7	3.8	4.3	8.7	2.2	4.4	6.9	7.7	7.8	5.7	7.0	4.2	7.2	5.0	3.6	8.0	3.6	6.7	11.4	3.6	10.7	10.8	6.8
Mar3		5.9	3.4	3.6	4.1	8.2	2.2	4.1	6.5	7.2	7.3	5.4	9.1	4.0	6.5	4.8	3.4	7.5	3.4	6.0	10.6	3.5	10.0	9.7	8.1
Apr1		4.6	2.7	2.8	3.2	6.5	1.8	3.2	5.1	5.6	5.6	4.3	6.3	3.1	5.7	3.9	2.7	5.8	2.7	4.8	8.3	2.8	7.9	7.6	7.2
Apr2		4.0	2.4	2.5	2.9	5.7	1.6	2.8	4.5	4.9	4.9	3.8	5.4	2.8	4.6	3.4	2.4	5.0	2.4	4.9	7.7	2.5	6.7	7.4	5.9
Apr3		3.6	2.2	2.3	2.6	5.1	1.4	2.5	4.1	4.3	4.3	3.3	4.7	2.6	4.7	3.0	2.2	4.4	2.2	4.0	6.4	2.2	6.1	6.0	5.3
May1		3.8	3.9	3.6	2.0	7.3	1.3	6.3	22.8	3.9	2.3	3.6	9.6	2.6	6.0	2.7	2.4	3.5	3.6	6.2	5.8	3.8	7.3	5.2	5.7
May2		4.3	2.6	9.8	2.5	5.3	2.2	5.9	14.9	11.7	2.0	3.3	6.6	7.7	3.9	2.8	2.2	8.1	4.9	19.4	6.1	3.6	6.5	8.5	12.4
May3		3.0	2.4	32.7	3.0	4.7	1.9	7.7	16.7	7.4	3.2	2.9	10.6	9.2	4.3	3.0	4.2	6.8	4.6	6.4	7.7	5.0	11.4	7.3	5.7
Jun1		2.0	4.3	9.7	0.9	6.2	1.0	9.7	10.5	3.3	4.6	3.0	10.5	3.0	11.4	3.9	2.5	4.4	5.0	5.4	3.8	2.6	6.8	9.5	5.9
Jun2		2.7	4.8	15.5	1.3	8.6	1.2	12.9	13.7	3.6	3.3	4.0	8.0	14.2	6.0	7.5	2.6	3.8	2.9	8.3	4.2	2.6	9.4	6.3	4.8
Jun3		2.1	8.9	36.6	1.6	4.6	1.5	2.6	8.2	3.6	1.9	2.2	5.6	9.8	4.5	3.7	2.9	10.0	3.0	4.6	2.5	3.3	6.2	6.2	4.1
Jul1		7.5	2.2	11.5	2.3	2.7	1.1	2.5	4.6	2.2	2.1	1.9	3.8	2.9	3.3	1.7	1.3	5.0	1.2	3.7	3.1	3.0	3.0	5.1	2.4
Jul2		5.3	1.9	9.3	3.6	2.5	1.0	2.1	4.1	2.1	2.0	2.7	3.2	2.6	3.1	1.5	1.2	4.2	1.1	3.3	2.9	2.0	2.7	4.0	2.4
Jul3		4.9	1.8	8.4	2.9	2.6	1.0	2.0	3.7	2.4	2.0	2.3	3.1	4.5	2.8	2.4	1.2	3.9	1.1	3.0	3.0	1.9	2.7	4.7	2.3
Aug1		3.7	1.4	6.2	2.3	2.2	1.1	1.6	3.0	2.7	1.7	1.8	2.4	4.0	2.4	1.9	1.0	3.0	1.0	2.4	2.5	1.7	2.3	3.5	2.0
Aug2		3.2	1.3	5.1	1.9	2.0	1.2	1.4	2.6	2.4	1.6	1.7	2.3	4.7	2.0	2.1	1.0	2.7	0.9	2.1	2.3	1.4	2.2	3.1	1.8
Aug3		3.0	1.3	4.7	1.9	2.1	1.0	1.4	2.6	2.0	1.6	1.7	2.2	4.2	2.1	2.3	1.0	2.9	1.2	2.1	2.4	1.4	2.7	4.5	1.8
Sep1	5.6	2.5	1.0	4.0	1.5	2.2	0.9	1.2	2.2	1.6	1.4	1.4	1.9	3.9	1.7	1.6	0.8	2.7	1.7	1.9	2.0	1.3	2.2	3.1	1.6
Sep2	7.1	4.5	1.0	4.3	1.5	1.8	0.7	1.1	2.4	1.7	2.9	2.7	2.7	3.9	3.6	1.4	1.0	5.7	7.9	2.1	2.9	1.4	1.9	2.7	1.6
Sep3	59.9	7.2	1.4	7.7	6.0	2.1	5.7	2.5	8.4	3.6	2.2	5.9	4.3	3.0	14.3	1.4	3.3	12.4	28.8	6.0	25.1	3.1	2.4	2.6	1.6
Oct1	36.2	10.3	2.6	35.7	7.3	1.9	28.1	2.7	24.7	41.3	3.7	53.2	17.0	14.4	47.3	1.7	105.1	23.1	64.4	7.5	11.5	6.4	6.3	11.2	1.7
Oct2	57.2	9.2	57.9	16.3	81.9	14.8	36.8	56.4	53.1	15.2	4.5	209.0	44.2	173.1	26.9	9.7	39.1	20.4	34.8	42.8	11.6	13.4	21.2	84.4	4.2
Oct3	26.3	24.0	54.2	46.2	185.1	31.7	64.5	35.4	19.1	40.9	5.3	56.3	35.7	89.9	111.8	157.5	62.5	59.4	90.4	99.9	27.0	130.4	130.9	50.5	45.4
Nov1	96.4	94.1	19.0	86.5	147.2	33.8	69.9	143.5	49.6	42.2	152.2	129.8	39.8	45.8	76.0	40.0	25.9	28.8	54.7	97.8	102.4	71.1	154.3	24.0	34.6
Nov2	78.0	35.3	72.7	104.7	166.4	16.0	85.5	39.8	79.8	23.1	132.5	55.7	75.7	119.1	49.5	50.1	18.0	17.1	47.6	199.5	25.8	170.5	54.5	138.9	53.6
Nov3	28.4	20.4	31.9	39.8	62.7	14.1	31.1	101.3	146.5	38.0	106.7	42.5	48.5	38.6	40.2	31.8	90.9	13.2	36.9	133.8	20.4	161.7	88.3	73.1	17.5
Dec1	23.1	23.1	52.5	25.8	108.5	11.8	22.3	80.0	117.8	188.1	42.9	31.6	32.1	40.6	31.1	22.2	138.8	22.5	28.6	170.2	21.3	83.3	143.6	81.8	13.5
Dec2	18.5	18.9	24.3	20.7	60.1	10.0	23.7	35.9	46.7	41.0	33.0	25.8	28.2	28.5	33.5	16.6	98.8	22.8	21.6	68.6	18.9	147.0	130.2	45.8	29.8
Dec3	16.3	18.5	18.4	18.3	43.9	8.7	23.9	40.4	44.1	41.3	28.6	22.6	22.0	52.1	23.1	17.0	46.0	23.9	50.7	109.7	15.3	54.6	52.0	42.0	19.8

Table C.1 10-Days Runoff Series at Respective Sub-catchment Areas (7)

	Natural Decade Runoff at Estuary (generated) in Mm3																								
	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Jan1		126.0	57.6	65.2	103.1	167.0	27.2	89.8	135.9	136.3	168.2	108.0	73.6	46.4	107.3	100.4	75.8	149.6	61.8	113.5	231.4	67.9	270.3	220.6	139.8
Jan2		104.3	45.8	53.3	83.9	137.0	23.2	69.8	109.6	110.6	132.3	88.1	58.7	38.2	85.4	84.2	62.0	121.6	50.1	91.0	186.8	57.2	232.0	179.4	110.6
Jan3		85.6	41.0	47.9	75.6	121.9	21.2	62.6	97.9	98.4	117.3	78.3	53.5	34.9	77.0	77.8	56.0	106.4	45.0	83.3	165.4	52.7	202.5	182.3	94.9
Feb1		68.4	30.9	35.8	56.8	90.9	16.2	46.6	72.4	73.0	86.1	58.1	40.0	26.0	57.6	54.9	42.0	78.7	35.4	67.5	121.8	38.8	141.0	134.3	70.4
Feb2		55.3	26.2	30.0	47.5	75.7	14.0	38.9	59.7	60.6	71.0	48.4	33.9	22.1	48.7	45.8	35.4	64.5	28.3	53.0	100.6	32.8	114.7	107.9	58.7
Feb3		37.9	18.1	23.0	32.7	51.9	9.9	29.8	40.7	42.5	48.6	38.1	23.5	15.3	39.4	34.9	24.4	43.6	19.5	40.2	68.1	22.8	84.1	81.4	40.2
Mar1		41.0	19.7	22.1	35.5	56.0	11.0	28.4	43.6	44.8	54.2	35.3	30.5	16.7	38.3	33.2	26.6	46.6	21.2	37.9	72.8	24.9	94.9	76.4	43.8
Mar2		35.0	17.4	19.0	30.6	48.1	9.7	24.4	37.1	38.2	44.4	30.2	34.5	14.6	37.3	28.4	23.0	39.3	18.2	32.8	61.6	21.7	75.8	65.4	38.3
Mar3		33.0	16.4	18.1	29.1	45.7	9.6	23.1	35.1	35.9	41.3	28.5	41.7	13.9	35.7	26.9	22.0	38.6	17.3	30.4	57.5	21.1	69.7	60.4	40.3
Apr1		25.9	13.1	14.3	23.1	36.2	7.8	18.3	27.4	28.2	32.1	22.5	24.4	11.1	31.2	22.0	17.5	29.5	13.7	24.0	44.8	16.8	53.9	47.1	31.9
Apr2		23.3	11.7	12.7	20.7	32.0	7.1	16.2	24.0	24.7	28.1	19.8	21.1	10.7	24.9	19.1	15.7	25.5	12.3	22.3	40.4	14.9	46.6	44.5	27.2
Apr3		21.8	10.6	11.4	18.6	28.4	6.5	14.5	21.6	21.9	24.5	17.6	18.4	10.1	22.9	16.8	14.0	22.2	10.9	19.6	34.6	13.6	44.3	36.9	24.4
May1		25.8	20.0	18.3	14.2	41.2	6.2	37.5	65.3	19.7	13.3	19.3	47.2	10.4	28.1	14.6	15.5	17.6	18.1	31.0	31.6	23.3	59.8	44.4	26.9
May2		30.2	16.5	41.5	22.4	30.0	13.6	34.1	38.6	63.6	11.8	17.7	30.9	27.4	19.8	15.1	14.3	34.4	26.0	98.1	36.4	19.5	49.4	83.4	64.7
May3		23.6	20.4	104.4	35.7	25.0	10.0	57.2	40.6	45.6	18.8	15.2	54.0	93.7	21.8	17.9	25.7	38.3	31.4	39.8	65.3	23.9	95.1	76.0	30.1
Jun1		15.0	35.8	46.2	14.7	34.3	6.7	113.0	28.0	19.2	28.2	16.3	50.2	41.8	41.4	23.2	16.5	22.3	35.9	31.7	35.0	13.0	61.4	86.2	34.7
Jun2		21.7	34.4	62.0	31.2	59.2	10.9	180.8	38.9	20.5	20.7	21.1	35.2	274.4	21.3	44.4	16.0	18.9	20.3	55.4	36.1	13.5	99.7	49.3	25.8
Jun3		16.5	73.6	108.2	33.6	28.4	16.6	31.1	24.3	20.6	11.8	12.0	29.8	135.7	17.0	22.6	20.3	45.5	23.7	30.9	20.2	20.7	60.9	54.0	21.9
Jul1		36.6	16.6	38.0	40.8	16.6	10.9	28.2	14.2	12.6	12.8	9.7	21.7	34.1	13.7	9.5	9.2	19.2	11.9	25.0	24.1	20.7	29.4	45.6	12.9
Jul2		29.8	14.0	30.9	55.8	15.6	9.4	22.9	13.1	11.6	12.7	11.4	18.6	28.9	12.7	8.7	8.3	16.1	10.3	20.9	23.1	16.4	27.5	38.0	12.2
Jul3		28.3	13.7	29.4	55.0	15.3	8.4	23.1	12.7	12.8	12.7	11.4	21.5	28.7	11.9	13.0	8.3	15.4	9.1	19.0	22.9	14.4	27.1	41.2	12.1
Aug1		20.1	10.9	21.7	40.0	12.9	15.4	16.6	10.6	12.3	10.2	9.1	17.5	22.9	10.1	11.0	6.8	12.3	7.2	17.3	17.7	16.5	21.4	31.4	12.6
Aug2		17.4	9.0	18.0	32.6	12.0	18.0	14.2	9.6	11.9	9.6	8.4	37.5	25.1	9.1	9.9	6.2	11.1	6.8	15.4	16.2	12.4	20.6	27.9	14.6
Aug3		18.0	8.5	17.7	28.7	13.6	14.0	13.5	9.8	10.9	10.4	8.4	33.3	19.6	9.4	11.5	6.4	11.7	16.0	19.3	16.4	13.2	21.8	49.0	15.1
Sep1	80.1	18.0	7.2	22.5	22.8	15.4	15.3	12.4	25.8	9.6	11.3	9.1	34.1	23.6	19.0	7.9	16.6	32.1	28.3	64.5	33.6	13.3	21.5	34.4	10.4
Sep2	124.9	30.0	6.5	29.1	21.0	12.7	17.3	9.8	32.3	8.3	45.8	11.2	91.1	41.5	21.5	11.1	18.0	55.8	67.1	90.0	34.2	22.7	27.8	33.3	10.5
Sep3	666.5	43.1	13.6	64.2	45.1	17.6	27.3	18.3	78.5	12.7	41.3	37.1	67.2	32.3	49.1	20.9	25.4	54.3	74.3	122.2	162.7	53.0	32.2	31.3	14.3
Oct1	225.9	85.4	66.7	378.5	150.8	36.2	205.4	69.5	210.3	307.1	40.1	302.2	89.3	299.9	182.5	132.7	446.7	104.8	402.2	183.5	122.0	149.7	144.6	115.7	77.1
Oct2	348.6	81.0	354.7	257.7	563.1	65.5	343.3	445.7	414.3	146.1	35.0	911.4	126.8	1213.9	139.2	206.8	234.7	140.7	247.6	408.5	100.1	147.1	309.7	385.4	99.9
Oct3	176.8	217.4	318.3	643.0	1178.4	101.6	635.0	272.0	195.2	483.3	36.0	392.1	106.1	584.1	709.9	1235.6	458.8	373.7	597.9	834.9	151.7	672.2	773.4	304.2	577.7
Nov1	671.8	419.2	123.8	818.2	1021.2	134.1	464.2	775.4	432.0	271.5	657.4	482.2	96.8	301.1	287.9	331.0	154.8	121.8	492.4	704.3	632.3	421.6	1195.9	144.5	249.4
Nov2	570.1	186.9	362.3	769.1	939.7	79.6	644.8	302.6	539.0	202.0	906.7	297.4	194.3	827.3	228.2	293.1	120.3	99.5	361.8	1054.8	173.3	1132.9	406.4	815.6	312.1
Nov3	242.1	120.6	201.4	325.0	490.1	73.9	250.3	570.0	823.9	191.2	699.0	196.6	141.1	315.9	434.0	198.6	457.9	133.2	240.2	817.4	142.1	1206.1	507.9	407.1	131.4
Dec1	159.8	104.4	192.5	195.8	581.4	49.0	151.3	476.4	545.4	1122.6	218.0	131.3	101.4	215.5	188.5	137.2	614.9	157.2	175.8	901.3	150.6	667.6	1178.2	358.0	93.9
Dec2	127.8	84.3	110.9	167.1	357.4	41.6	137.3	203.7	235.3	286.2	171.8	112.7	82.7	170.5	258.4	105.3	559.2	132.9	149.4	441.1	117.2	823.3	709.8	241.1	168.7
Dec3	113.0	93.1	93.4	146.2	252.3	36.0	127.1	214.2	239.7	305.6	149.0	98.1	67.6	191.8	139.6	108.8	257.6	129.0	257.6	481.0	95.3	375.1	372.8	287.2	143.3

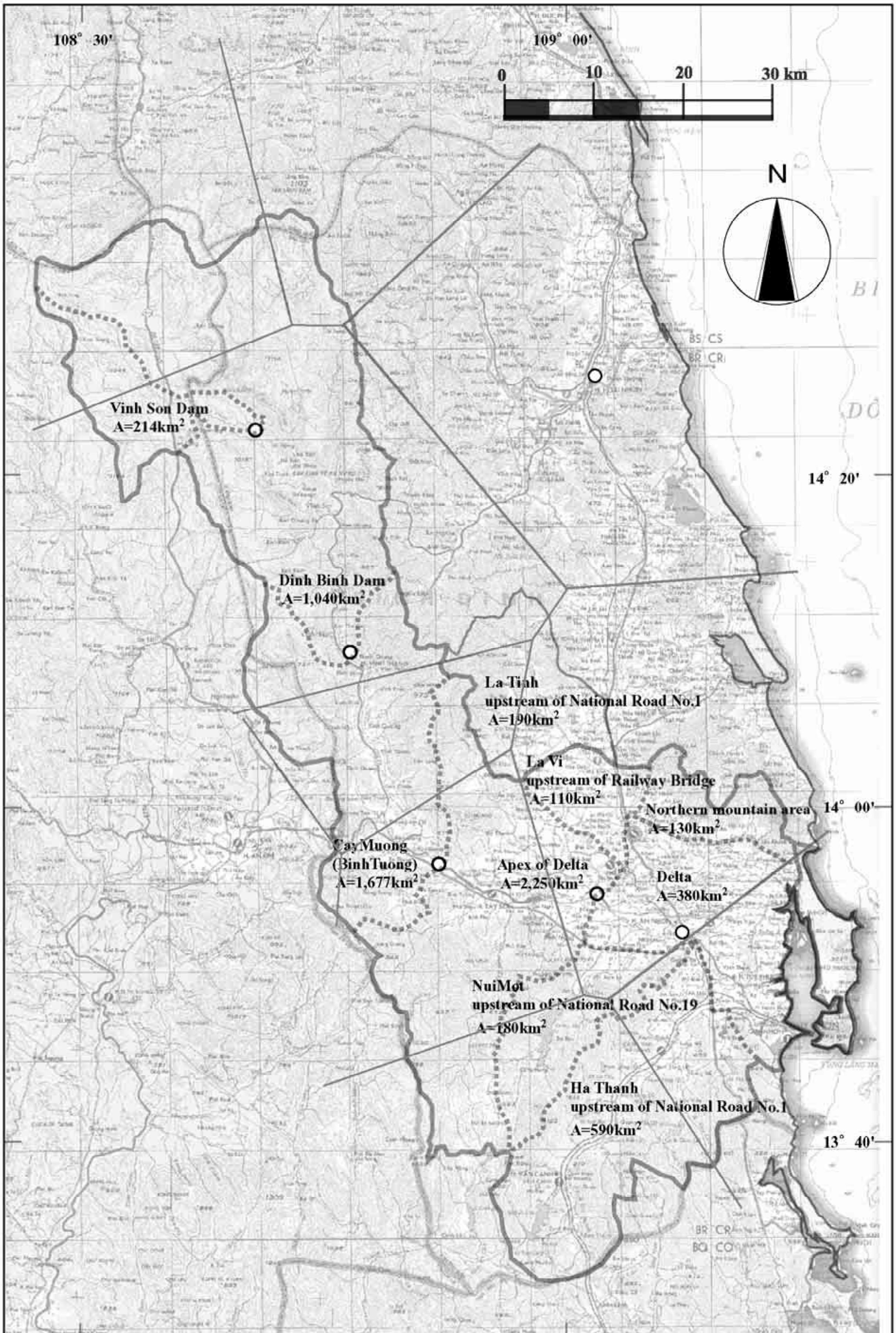


The Study on Nationwide Water Resources Development and Management in the Socialist Republic of Vietnam

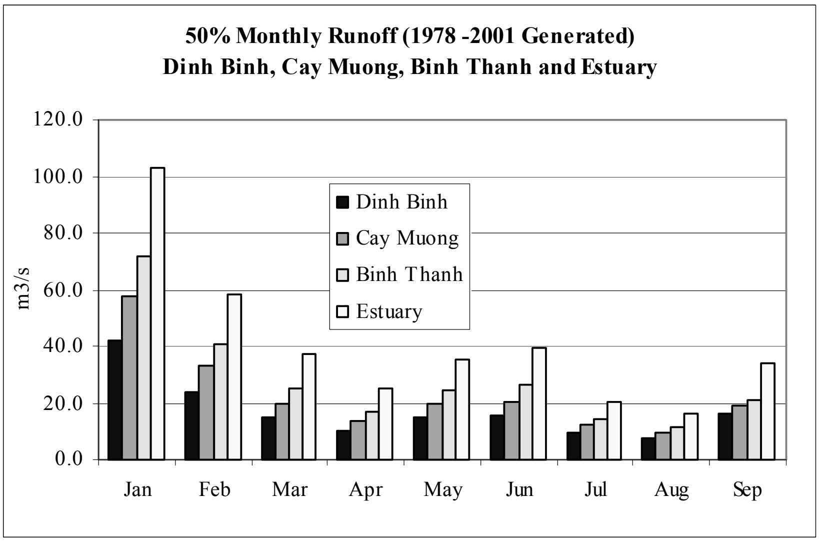
JAPAN INTERNATIONAL COOPERATION AGENCY

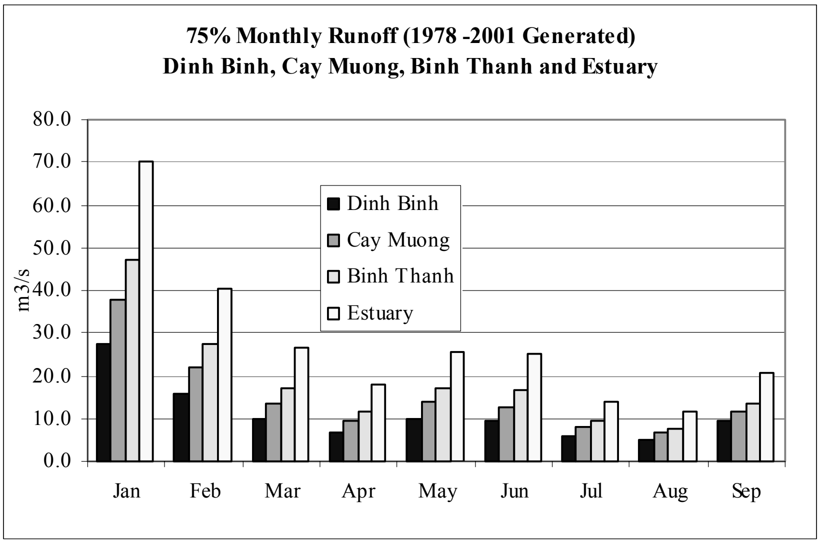
Figure C.1

Kone River Basin



The Study on Nationwide Water Resources Development and Management in the Socialist Republic of Vietnam	Figure C.2
JAPAN INTERNATIONAL COOPERATION AGENCY	**Kone River Basin and Hydrological Stations**





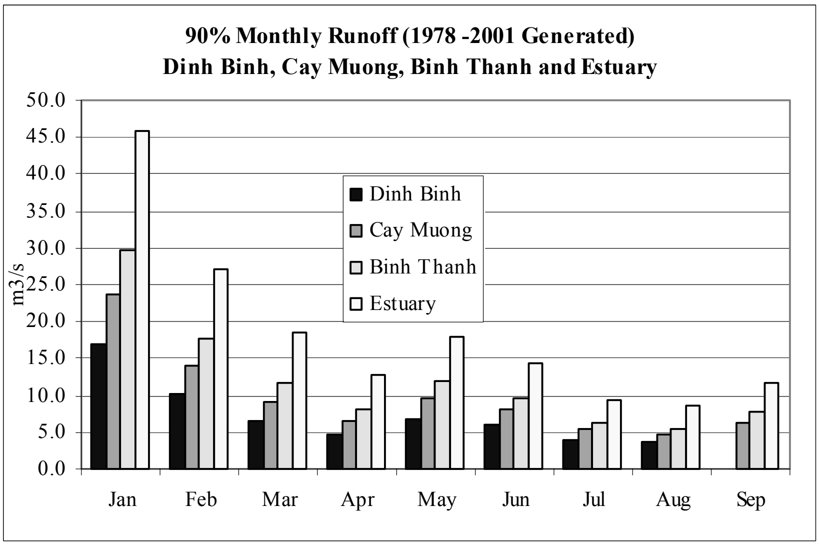


Figure C.3 Monthly Runoff (1978-2001 Generated) at Dinh Binh, Cay Muong, Binh Thanh, and Estuary

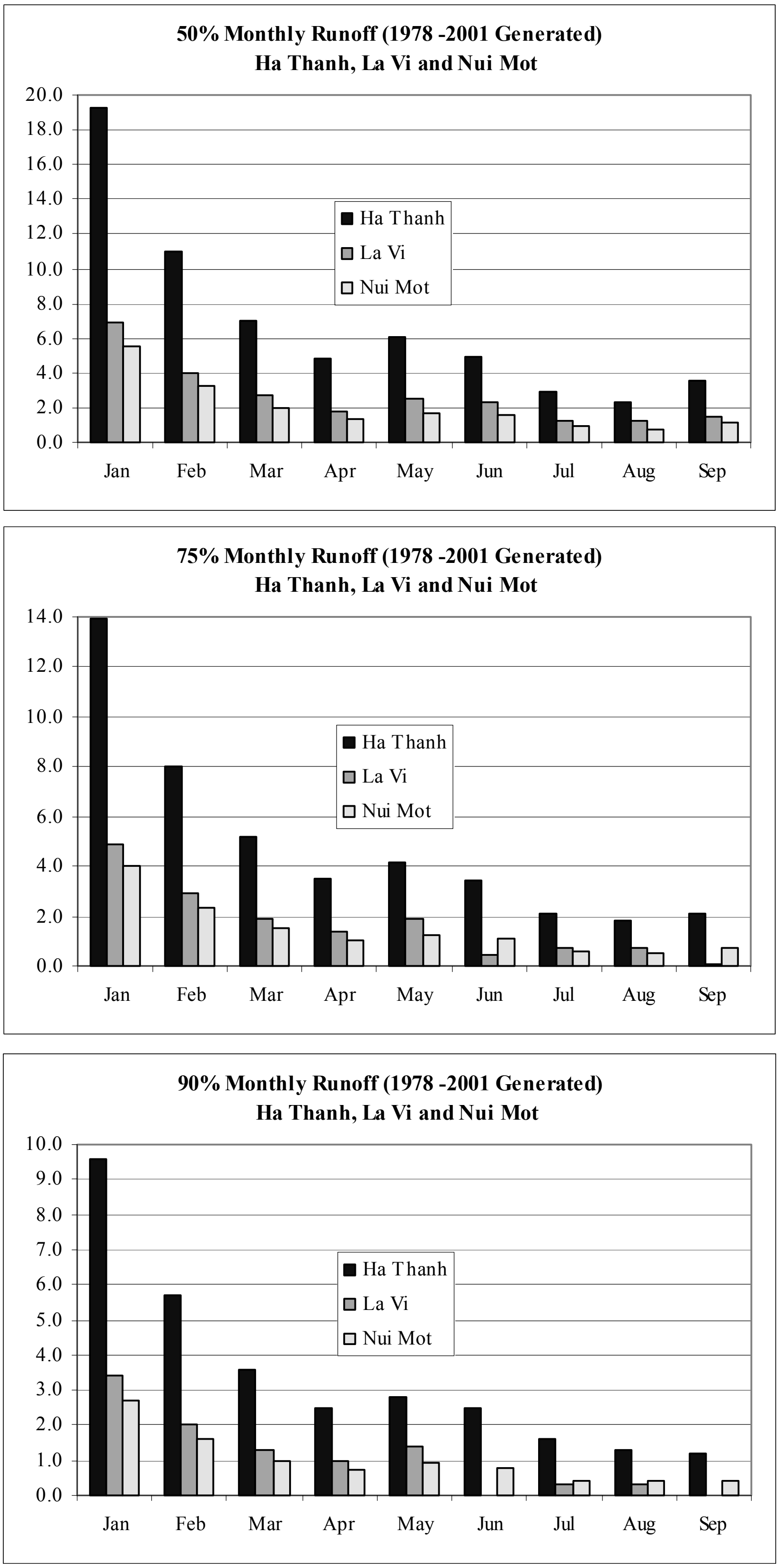
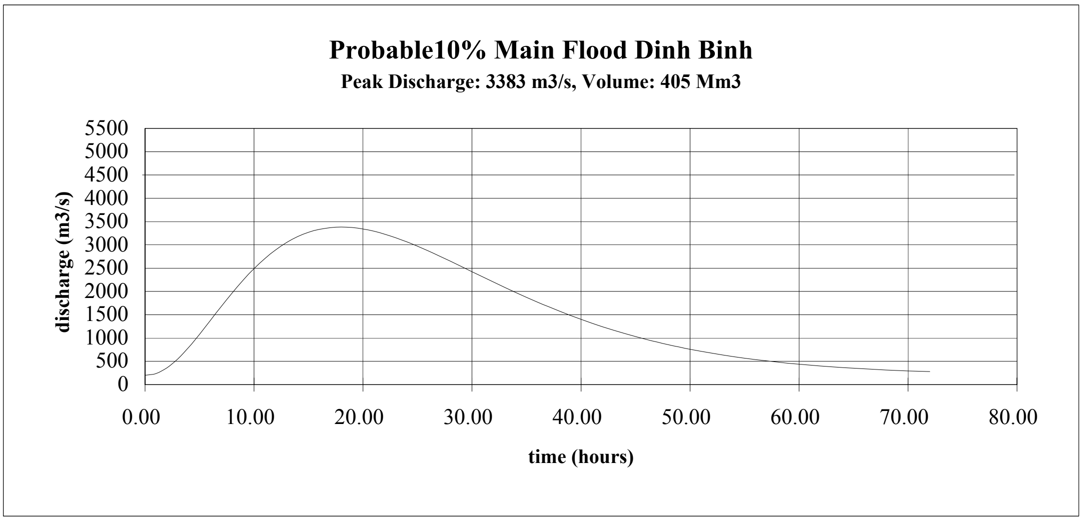
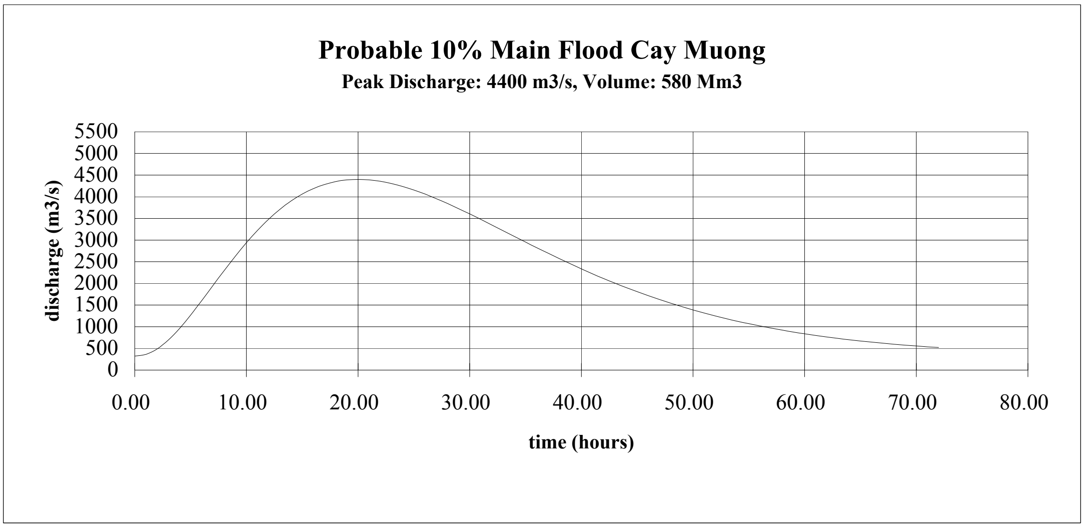


Figure C.4 Monthly Runoff (1978-2001 Generated) at Ha Thanh, La Vi, and Nui Mot





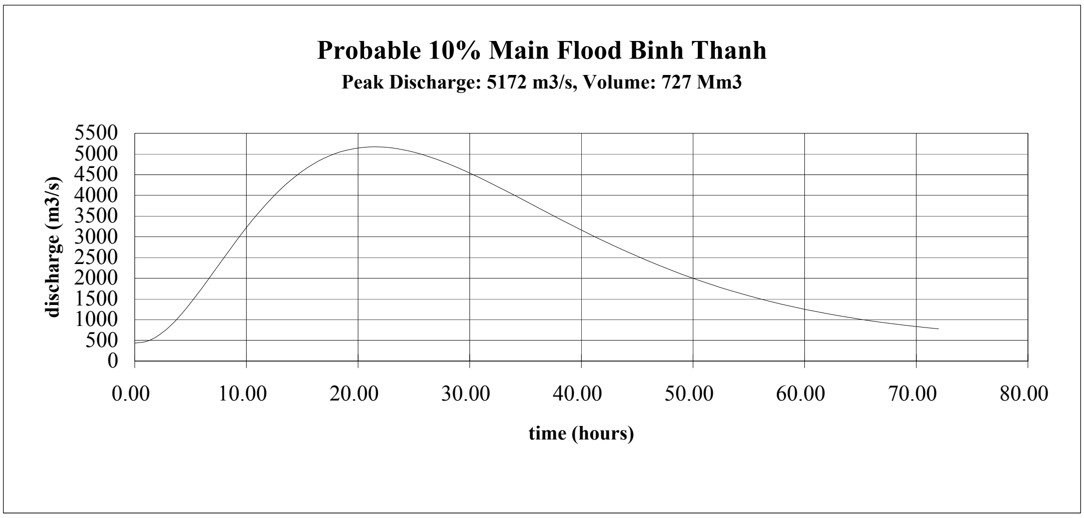
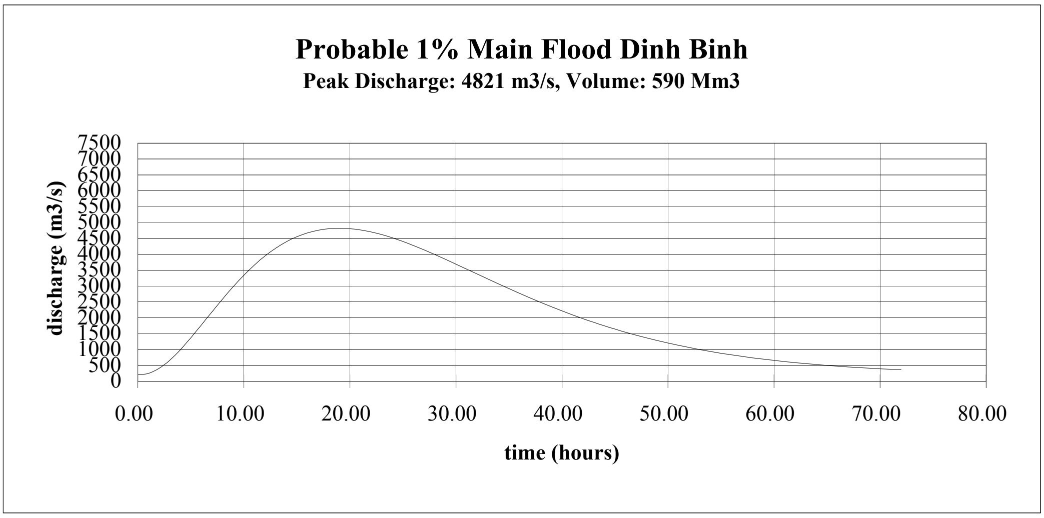
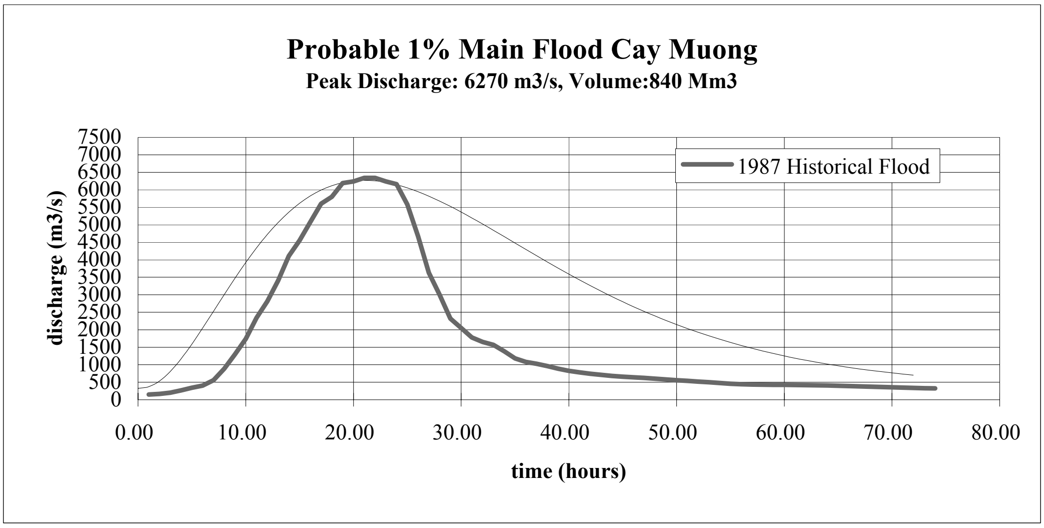


Figure C.5 Probable 10% Hydrograph Main Flood at Dinh Binh, Cay Muong and Binh Thanh





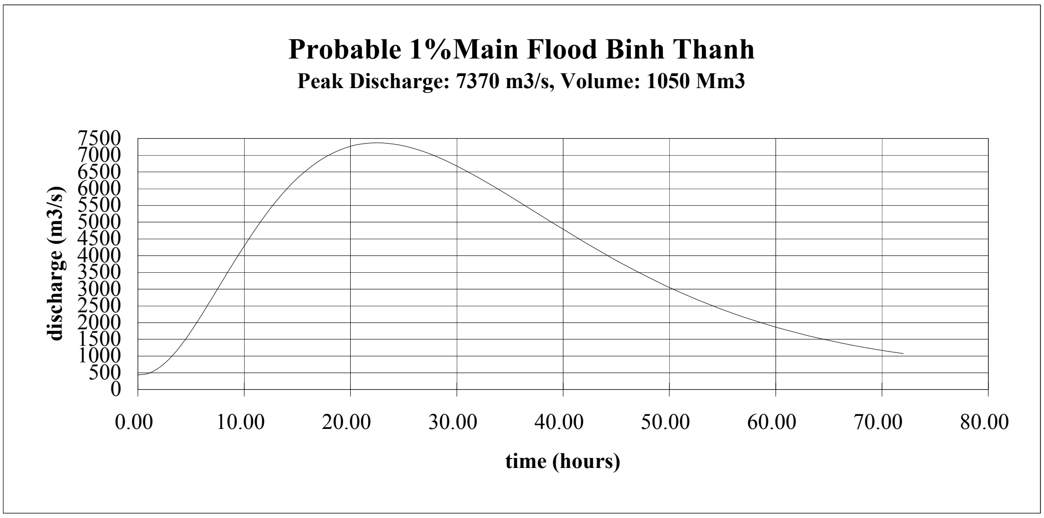
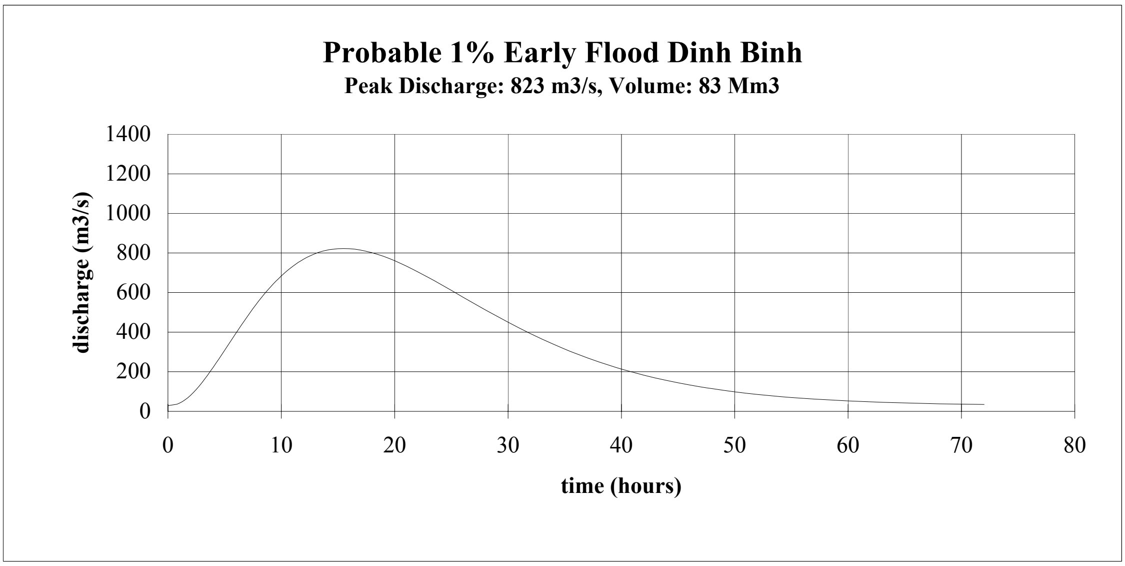
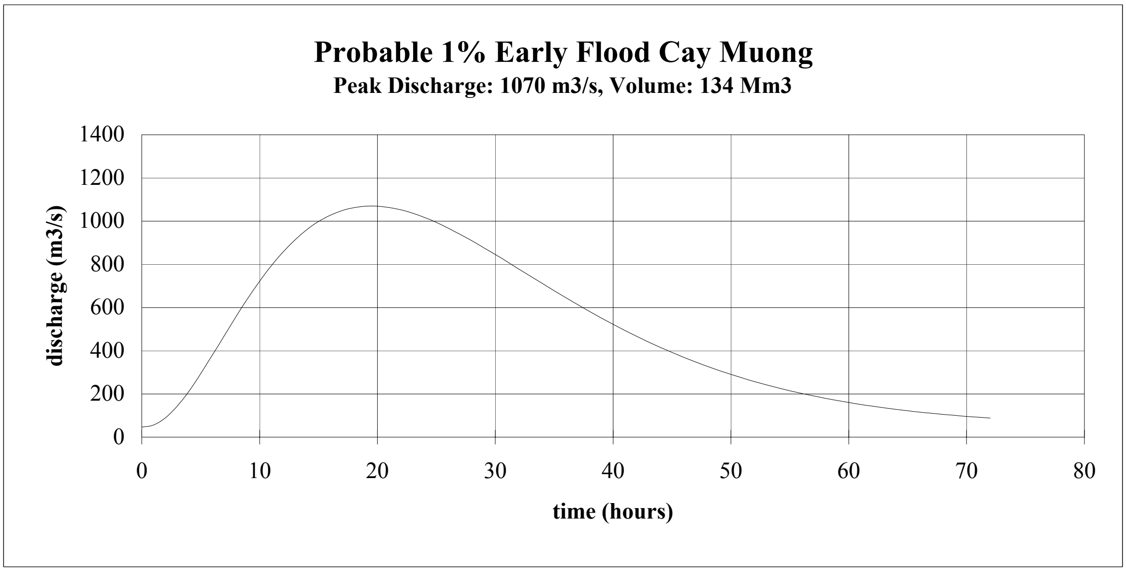


Figure C.6 Probable 1% Hydrograph Main Flood at Dinh Binh, Cay Muong and Binh Thanh





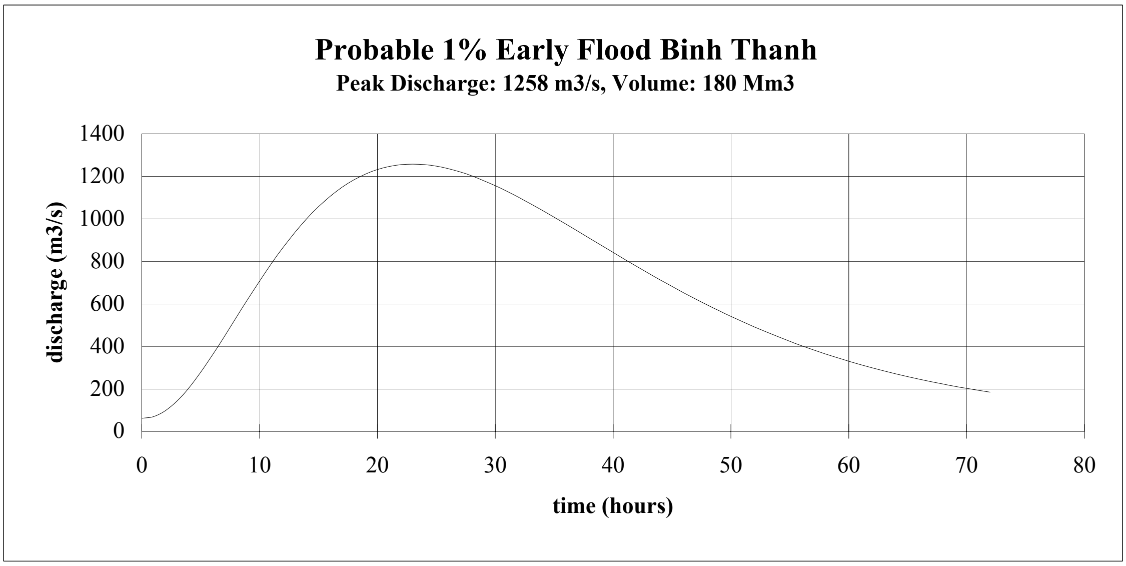
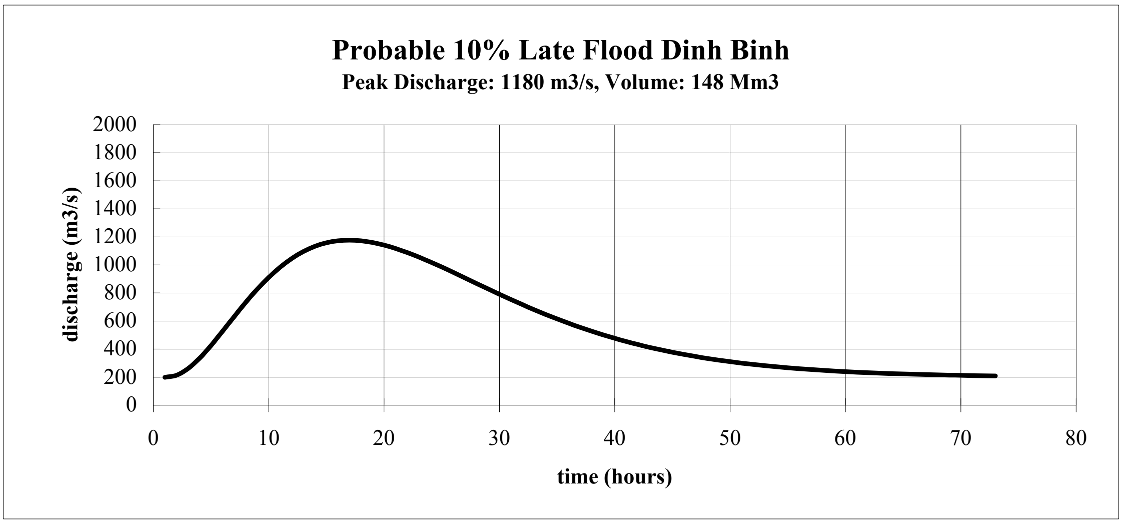
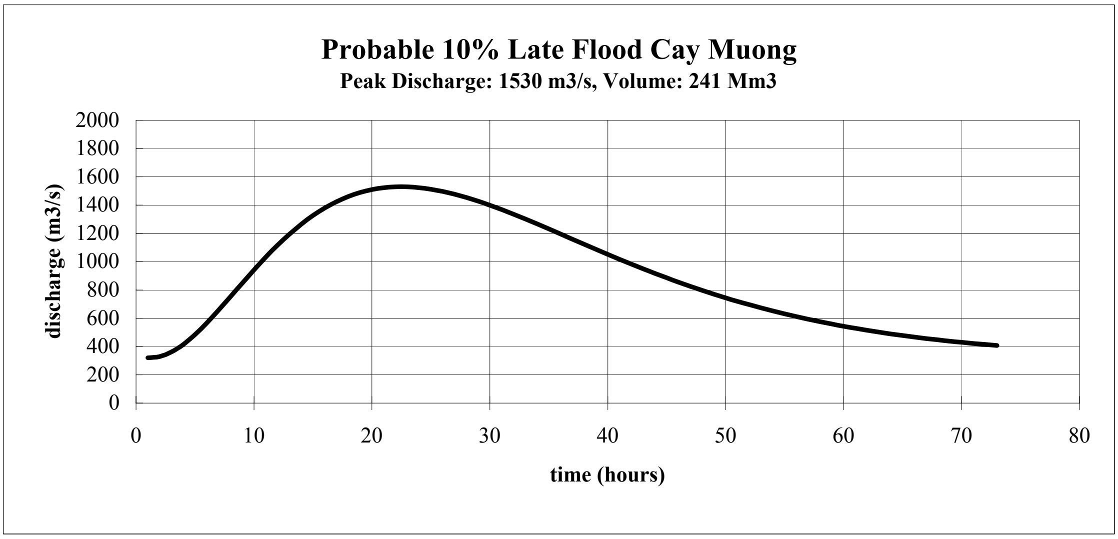


Figure C.7 Probable 1% Hydrograph Early Flood at Dinh Binh, Cay Muong and Binh Thanh





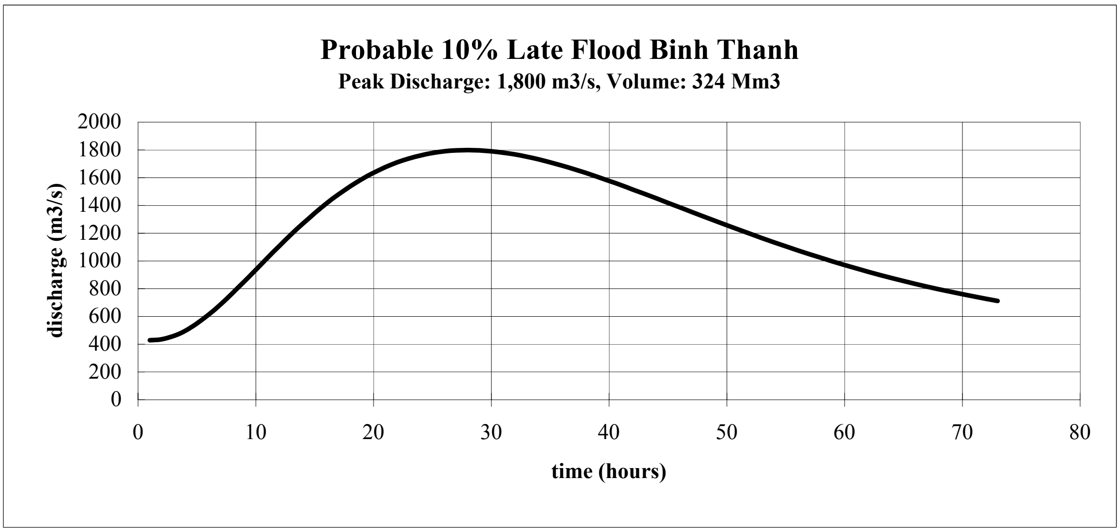


Figure C.8 Probable 10% Hydrograph Late Flood at Dinh Binh, Cay Muong and Binh Thanh

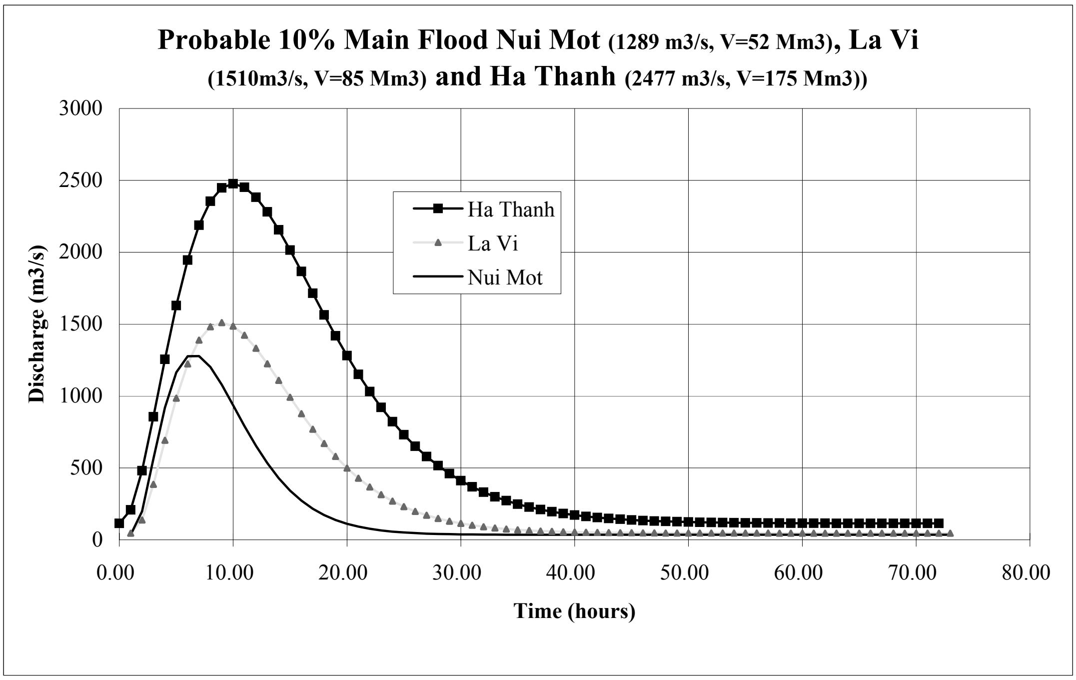


Figure C.9 Probable 10% Hydrograph Main Flood at Nui Mot, La Vi and Ha Thanh

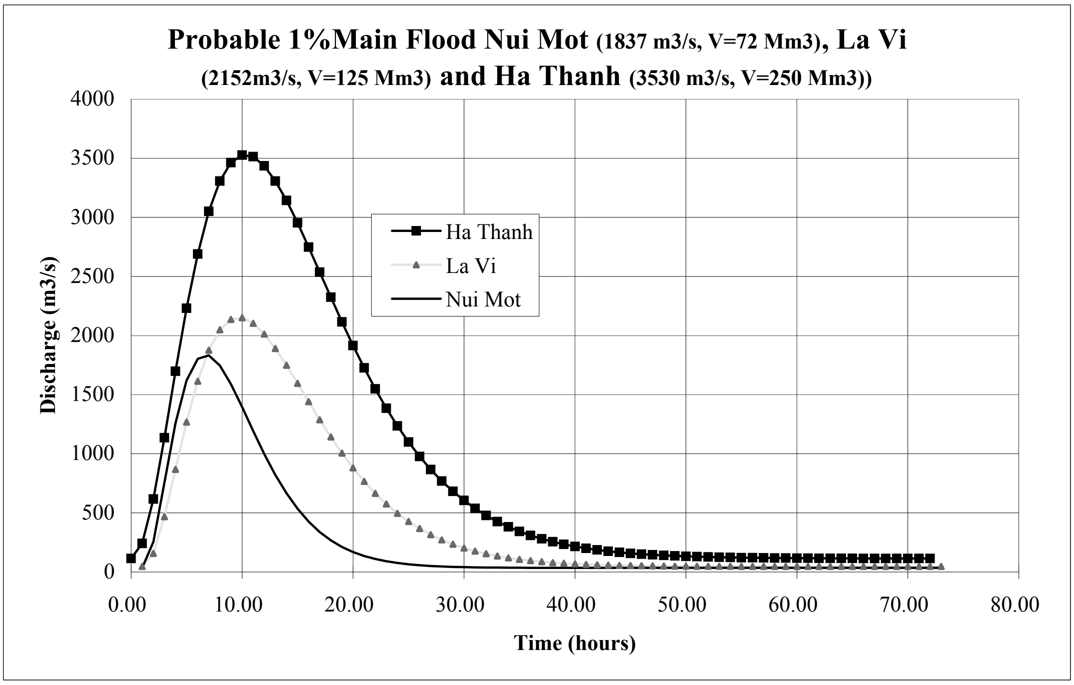


Figure C.10 Probable 1% Hydrograph Main Flood at Nui Mot, La Vi, and Ha Thanh

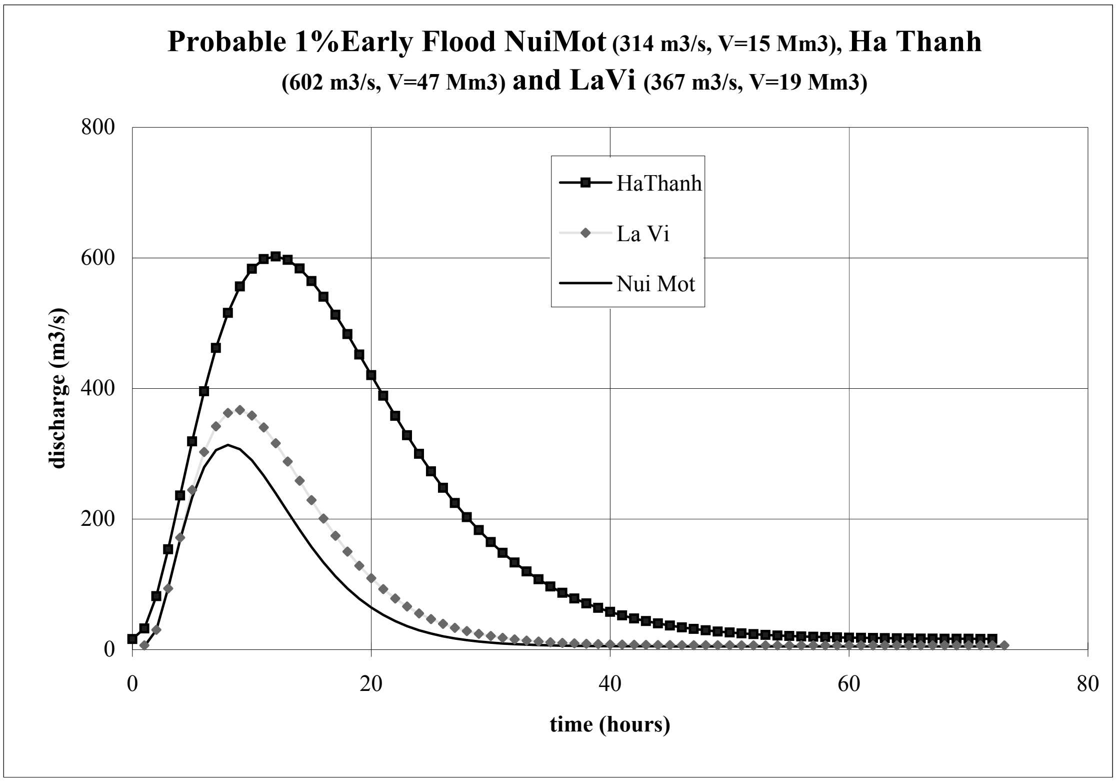


Figure C.11 Probable 1% Hydrograph Early Flood at Nui Mot, Ha Thanh and La Vi

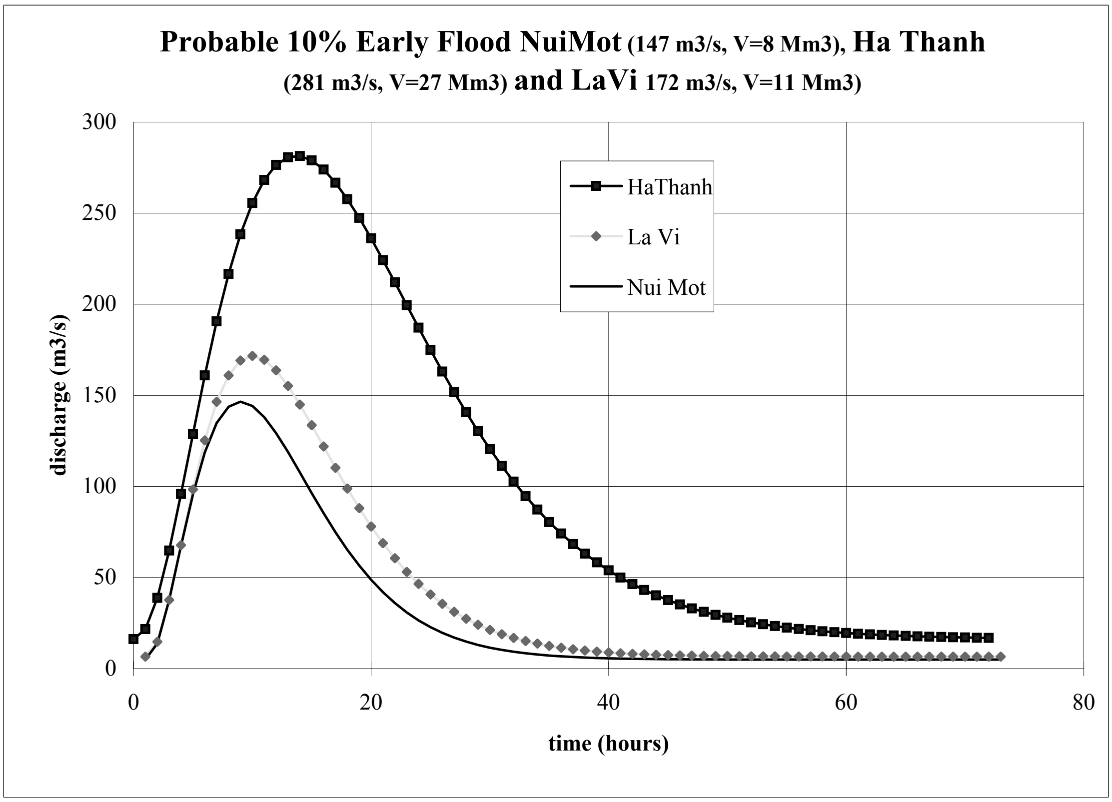


Figure C.12 Probable 10% Hydrograph Early Flood at Nui Mot, Ha Thanh and La Vi

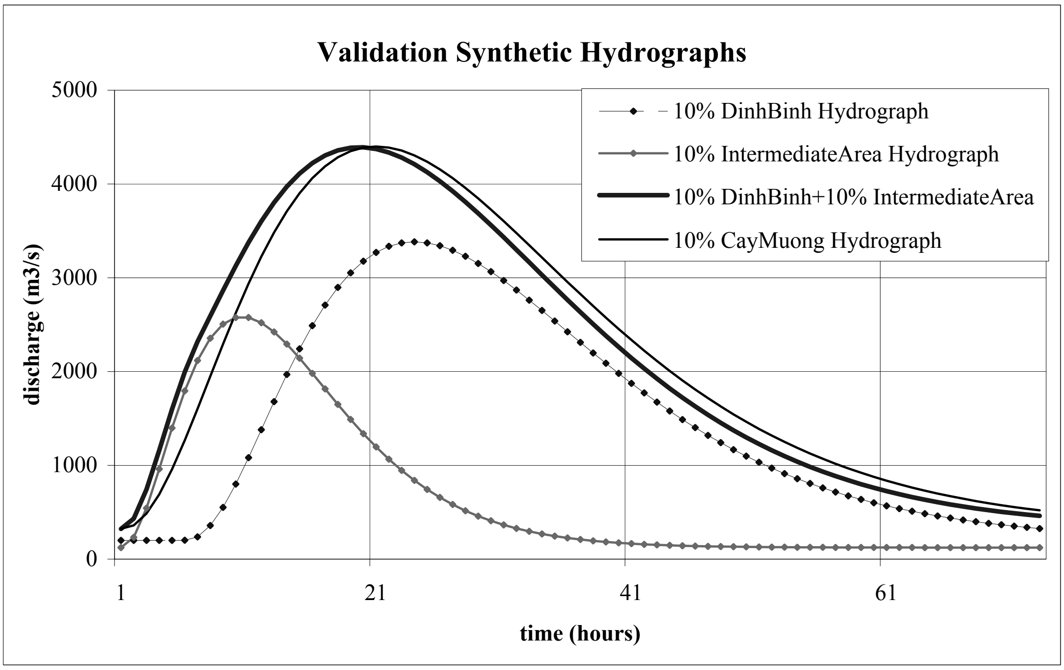


Figure C.13 Validation Synthetic Hydrographs

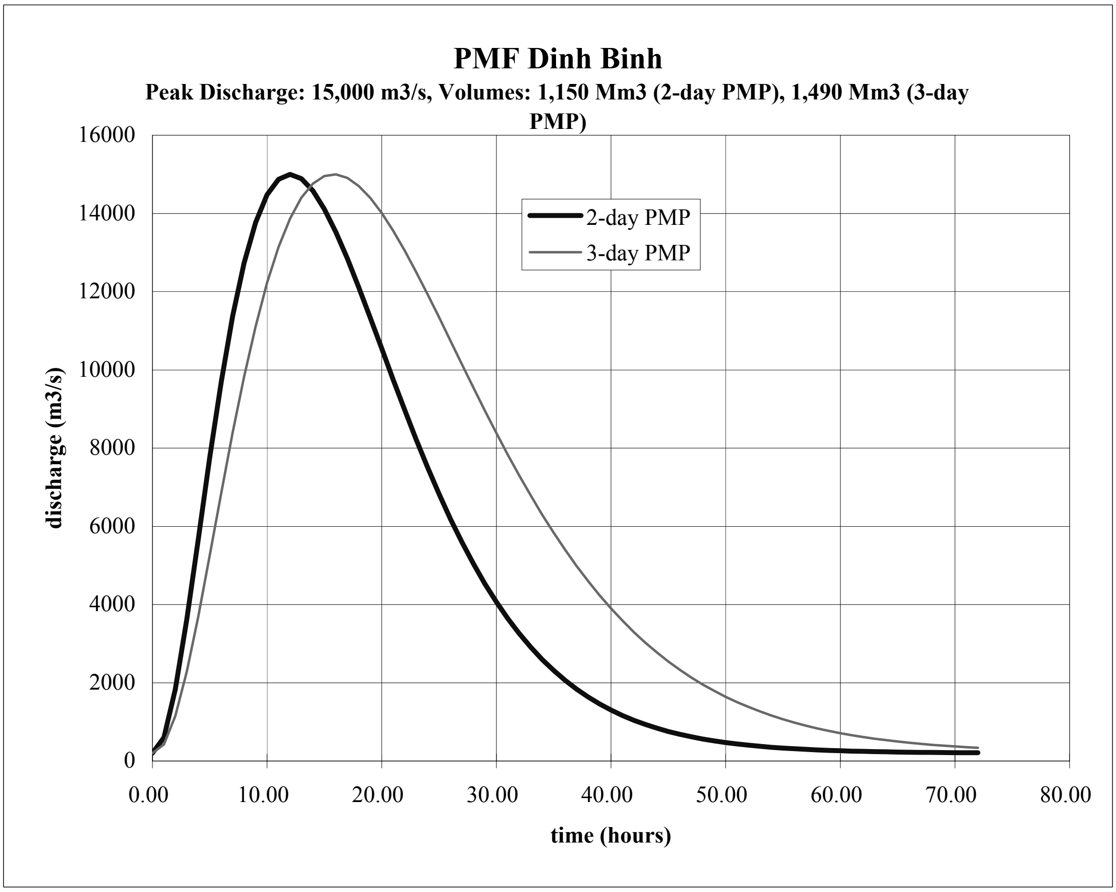


Figure C.14 Hydrograph of Probable Maximum Flood at Dinh Binh

ANNEX RAINFALL RUNOFF MODELING

1 MODELLING AND MODEL CALIBRATION

For the estimate of probable peak discharges at different locations in the Kone basin, an attempt has been made to calibrate a model that reproduces accurately the basin flood runoff as a result of the area rainfall on the respective sub-catchments. For this purpose use has been made of the SACRAMENTO model.

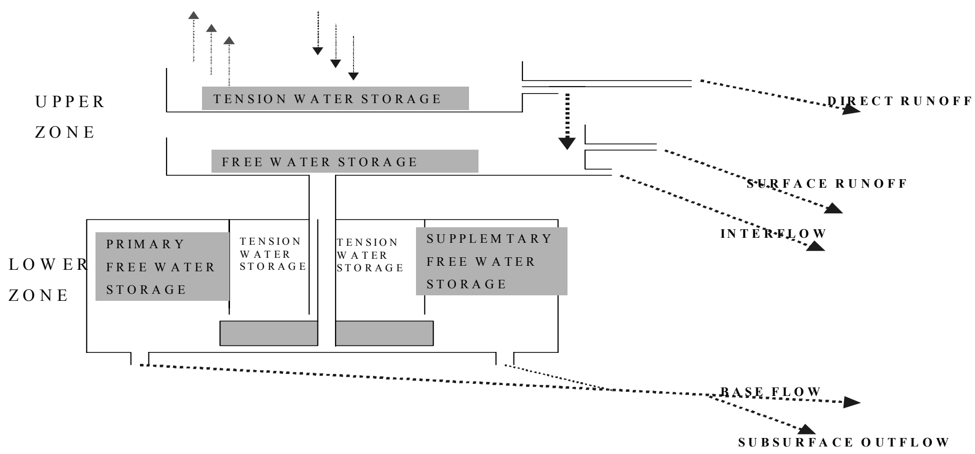
The concept of the Sacramento model was developed by Burnash et al as far back as in1973. The simulation of the runoff process by the Sacramento model distinguishes the *land-phase* and the *channel-phase*. The land-phase is represented by an explicit moisture accounting lumped parameter model. The propagation and attenuation of the outflow floodwaves from the land-phase segments into the channel is simulated with the Standard Muskingum method.

The land-phase component of the model distinguishes the pervious and the impervious part of the catchment (see the figure below). From the impervious areas, precipitation immediately discharges to the channel. The drainage system of the pervious part is divided onto:

- an upper zone, representing the catchment surface system;
- a lower zone, representing the catchment groundwater reservoir system.

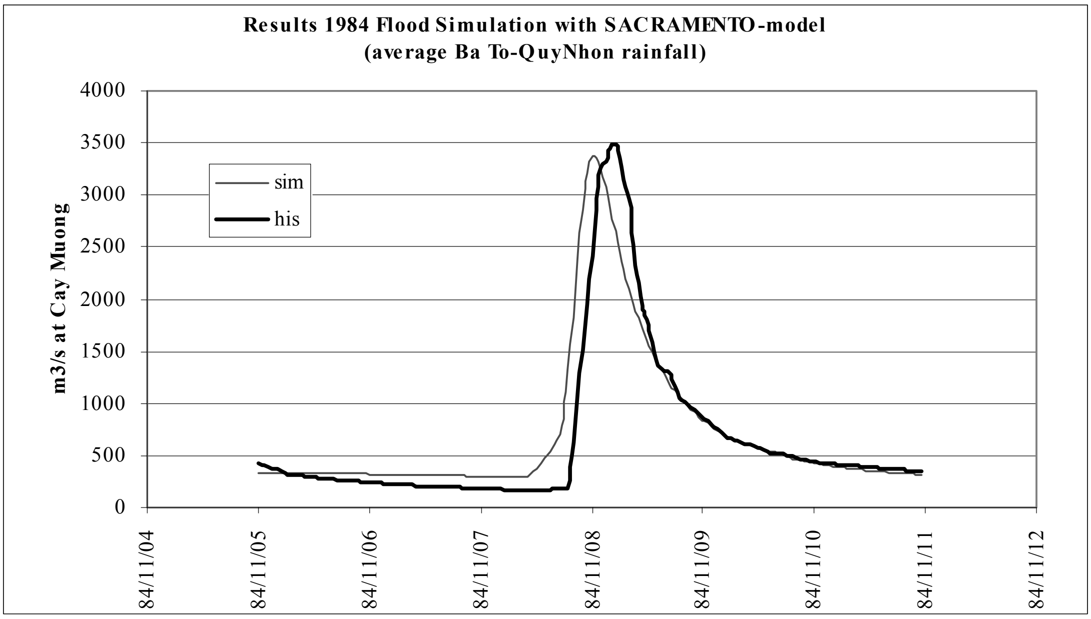
Both zones have a tension and a free water storage element. Tension water is considered as the water closely bound to soil particles. Generally first the tension water requirements are fulfilled before water is entering the free water storage. Two lower zone free water storages (groundwater) are distinguished representing a slow

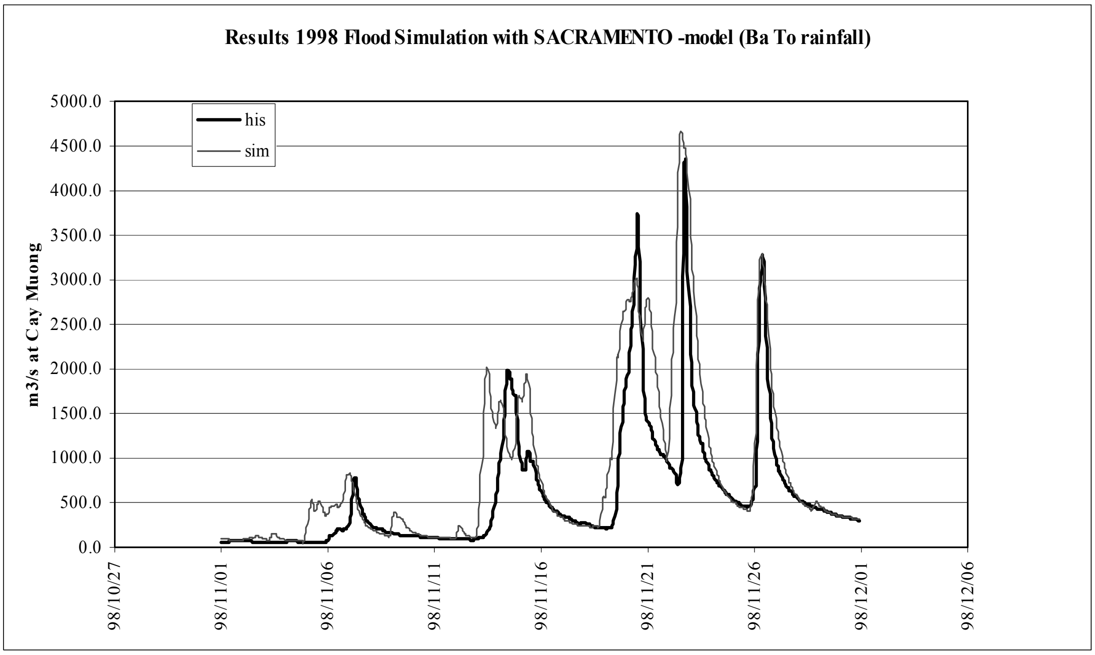
The SACRAMENTO Model



and a fast groundwater flow component respectively.

With the help of hourly discharge data at Cay Muong and simultaneous hourly rainfall data from Quy Nhon, Ba To and Hoai Nhon for a number of historic floods it has been possible to calibrate and verify the SACRAMENTO. As a consequence of the geographical position of the rainfall stations with respect to the catchment area upstream of Cay Muong, it appeared that for some floods the Ba Tho rainfall was representative for the basin rainfall, while for floods a combined Quy Nhon – Ba To gave better results. In most cases, however, the use of the Ba To rainfall gave the best results. Some of these results are presented hereunder





Parameter		Initial conditions
Upper zone tension water (capacity)	10mm	0
Upper zone free water (capacity)	100mm	0
Lower zone tension water (capacity)	175mm	75
Lower zone free water (fast draining) (capacity)	200mm	0
Lower zone free water (slow draining) (capacity)	600mm	100-400
Upper zone lateral drainage rate	0.5/day	
Lower zone drainage rate (fast)	0.8/day	
Lower zone drainage rate (slow)	0.06/day	
Other parameters		
ZPERC (percolation parameter)	40	
REXP (percolation parameter)	1.5	
PFREE (percolation parameter)	0.2	
RSERV (lower zone free water not available for transpiration)	0.2	
PCTIM (permanent impervious fraction)	0.1	
ADIMP (additional impervious fraction)	0.2	

For routing of the sub-basin land-phase runoff to the respective locations the following Muskingum parameters have been used:

Sub-basin	Location	Muskingum parameter	
		K (hours)	X
Kone basin u/s Cay Muong	Cay Muong	6	0.2
Kone basin u/s Dinh Binh	Dinh Binh	4	0.2

2 PROBABLE FLOOD SIMULATION

An attempt has been made to use the above described model for the generation of probable floods. The decisive factor in such exercise is the assessment of the probable rainfall distributions in time (hours) and location. Such assessment is not possible with the available rainfall data.

Alternatively, a historic flood has been selected that could be used as a base case for the development of the probable floods. For this purpose the highest observed flood at Cay Muong has been selected, i.e. the 19-20 November 1987 flood. Although the reliability of the reported discharges is not beyond any doubt (reference is made to section 2.2.3), it was found that appropriate to use this flood for further analysis.

The rainfall that caused the flood was measured in Ba To at 549.2 mm in two days. This amount has been evaluated at the probability of 0.013 and 0.029 for the two-day rainfall on the Cay Muong and Dinh Binh sub-catchment areas respectively. The probability of the Cay Muong 1987 peak discharge of 6340 m^3/s was estimated at a probability of 0.009, which is well in line with the probability of the two-day rainfall on the corresponding sub-catchment.

The two-day rainfall on the Binh Dinh sub-catchment with probabilities of 0.1 and 0.01 have been estimated at 444 mm and 637 mm respectively, this corresponds with 81% and 116% of the 19-20 November 1987 rainfall. Consequently, the actual 19-20 November 1987 hourly rainfall at Ba To has been multiplied with these factors and the calibrated SACRAMENTO model was run with these assumed 10 year and 100 year rainfall for the Dinh Binh sub-catchment in order to arrive at an estimate of the corresponding discharges.

The results of this flood runoff simulation are shown overleaf.

The shape of the simulated flood does not correspond fully with the shape of the observed Cay Muong flood. This is most probably due to the fact that the hourly area rainfall distribution that generated the flood is not completely the same as the observed distribution at Ba To.

The simulated peak discharges and flood volumes are as follows:

Simulated Flood	Peak discharge	Volume	Runoff-coeff.
1987	4281	352	0.73
10%	3222	271	0.71
1%	5673	427	0.75

Comparison of these values with the estimated probable and design peak discharges at Dinh Binh shows the following:

	Estimated Probable Flood		Calculated Design Flood	
Flood	Peak discharge	Volume	Peak discharge	Volume
10%	3383	405	3821	405
1%	4821	594	5836	594

It appears that the simulated 10% peak discharge corresponds rather well with the estimated probable 10% peak discharge, while the simulated 1% peak discharge is more in accordance with the calculated 1% design discharge.

The volumes of the design floods are larges than the simulated volumes. This is due to the fact that for the design hydrograph the 3-day rainfall has been taken, while the simulated hydrograph is the result of a 2-day rainfall.