5. HYDROLOGICAL CONDITIONS IN THE MEKONG DELTA

5.1 Key International Monitoring Stations in the Mekong Delta

5.1.1 International Monitoring Stations from Phnom Penh to the Mekong Delta

The Mekong River enters Vietnam from Cambodia via two major rivers that flow around the Vam Nao Island; namely, the Mekong (Tien) River to the north-east and the Bassac (Hau) River to the south-west. At present, water level, discharge and water quality are monitored at Tan Chau for the Mekong and at Chau Doc for the Bassac. These stations are located at about 10 km downstream from the Cambodia-Vietnam border and at about 200 km inland from the South China Sea.

The Strategic Master Scheme for Hydro-Meteorological Network in the Mekong River Basin undertaken by MRC in 2000 proposed 25 key hydrological network stations in total that are classified as high level stations for real-time monitoring of the Mekong mainstream flow in the near future under the framework of the 1995 Mekong Agreement. In Vietnam, a total of 5 key stations have been selected; namely, the Tan Chau, My Thuan, Chau Doc, Can Tho and Vam Nao stations. Both the Tan Chau and Chau Doc stations are key international monitoring stations in the management of water resources in the Mekong Delta.

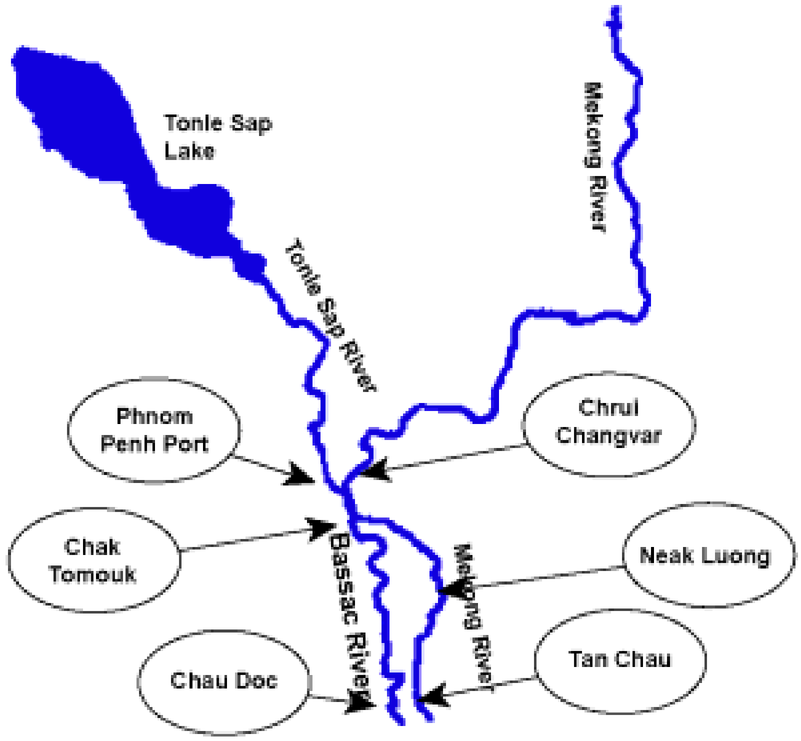


Fig. 5.1 Location Map of Key Hydrological Stations from Phnom Penh to the Mekong Delta in Vietnam

In Cambodia, Chak Tomuk and Neak Luong stations are also categorized as key hydrological network stations for monitoring the flow volume to Vietnam from the upstream Mekong countries. Both the Phnom Penh Port and Chrui Changvar stations are classified as primary stations under the hydro-meteorological network. In view of monitoring of the Mekong discharge flowing into the Mekong Delta, six stations are selected as key stations. The hydrological relationship of these stations is shown in Fig. 4.1 and the relationship thereof is illustrated in Fig. 5.2. It is noted however that no historic long-term discharge records are available at all of these stations, and four stations in

Cambodia have not been provided with the discharge rating curves for the past over 30 years. This is because of the hydraulic complexity of Mekong flows at Phnom Penh where the Mekong River joins the Tonle Sap River and bifurcates into the Mekong mainstream and the Bassac River.

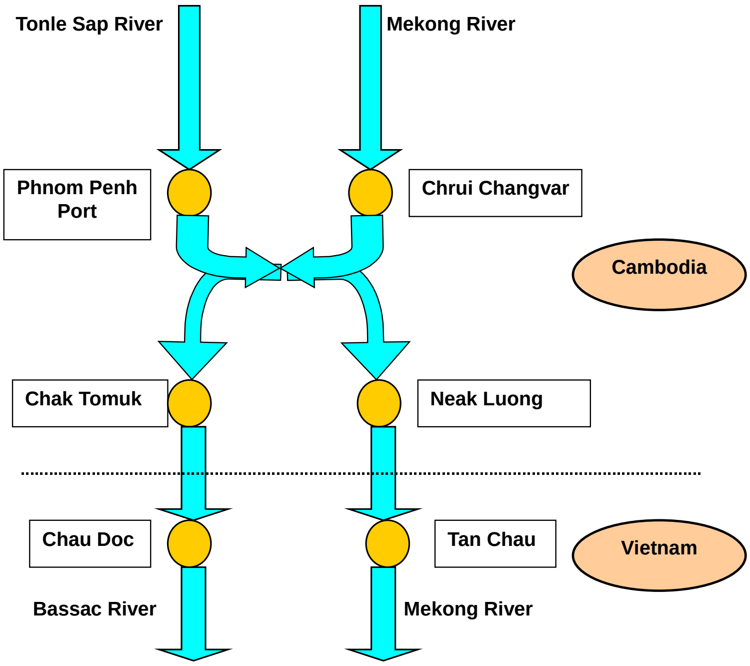


Fig. 5.2 Key Hydrological Stations for Monitoring of Discharge Flowing into the Mekong Delta

5.1.2 Key Monitoring Stations of Tan Chau and Chau Doc

Both the Tan Chau and Chau Doc stations are used as the key international monitoring station in the management and monitoring of water resources in the Mekong Delta, due to the following technical factors:

(1) Discharges and water quality monitored at Tan Chau and Chau Doc reflect the volume and quality of Mekong water passed onto Vietnam by the upstream Mekong riparian countries.

(2) Discharges and water quality monitored at Tan Chau and Chau Doc would be the basis to examine the water use performance of upstream Mekong countries on the future agreement on water quantity and quality.

(3) From the standpoint of Vietnam, the accurate and reliable flow volume delivered into Vietnam from Cambodia is of great concern especially in the dry season. The sum of discharges at Chak Tomuk and Neak Luong would almost be the discharge entering the Mekong Delta in Vietnam. The monitored inflow discharge in Cambodia would thus be worthy of comparison with the discharges at Tan Chau and Chau Doc.

(4) Lowered dry season flows allow saltwater from the sea to intrude further into the upstream Mekong branches, where it interferes with fresh water supply to the existing irrigation systems in the delta. The dry season period of concern is March to May, and the month of highest concern is April when the Mekong flow becomes the lowest. In this respect, Tan Chau and Chau Doc stations are also key national monitoring stations in Vietnam.

(5) Magnitude of the dry season discharge into the Mekong Delta in relation to salinity intrusion length is the most important hydrological constraint to the existing irrigation farming activities as well as future agricultural development in the delta. The possibilities of extraction of irrigation water would be determined by the monitored discharge that will provide the hydrological information on the flow into the delta.

5.1.3 Average Water Levels at Tan Chau and Chau Doc

Variation of water levels at the Tan Chau and Chau Doc stations is high due to:

(1) Strong effect of flood flow from the upstream Mekong countries during the wet season in July-December; and

(2) Strong effect of tide from the South China Sea during the dry season in January-June.

At the moment, monthly mean water level data at Tan Chau and Chau Doc are available only from two reports, as follows:

Table 5.1 Mean Monthly Water Levels at Tan Chau and Chau Doc

(Unit: cm)

Station	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tan Chau	135	96	74	60	64	113	190	295	375	383	306	204
Chau Doc	110	77	59	46	46	80	136	211	304	331	269	170

Note: Observation period is unknown.
Source: Flood Control Planning for the Inundation Area of the Mekong Delta in Vietnam, SIWRP, 1998

Table 5.2 Mean Monthly Water Levels in Dry Season at Tan Chau and Chau Doc in 1984-1990

(Unit: cm)

Station	Month				
	Jan	Feb	Mar	Apr	May
Tan Chau	133	97	74	57	61
Chau Doc	107	77	58	43	44

Source: Water Level Analysis, Program of Salinity Intrusion Studies in The Mekong Delta Phase III, SIWRPM, 1992

As seen above, in the dry season the monthly mean water level at Tan Chau is higher than at Chau Doc in the range of 15 cm to 25 cm. Due to the difference of water levels at these stations, the Vam Nao River as the connecting channel between the Mekong and Bassac, located about 47 km downstream of Tan Chau and 59 km downstream of Chau Doc, conveys the Mekong River flow to the Bassac. The highest daily mean water level is usually recorded in September-October. The long-term records show that yearly fluctuation is rather high. At Tan Chau, it varies from elevation +3.0 m to +5.0 m, and at Chau Doc, it is from +2.5 m to +4.5 m. In April-May, the lowest daily mean water level is observed. It varies from elevation +0.5 m to +0.7 m at Tan Chau, and from +0.4 m to +0.6 m at Chau Doc.

Shown below is a comparison of hourly water levels at Tan Chau and Chau Doc in the shifting period from the dry season to the wet season in 1992.

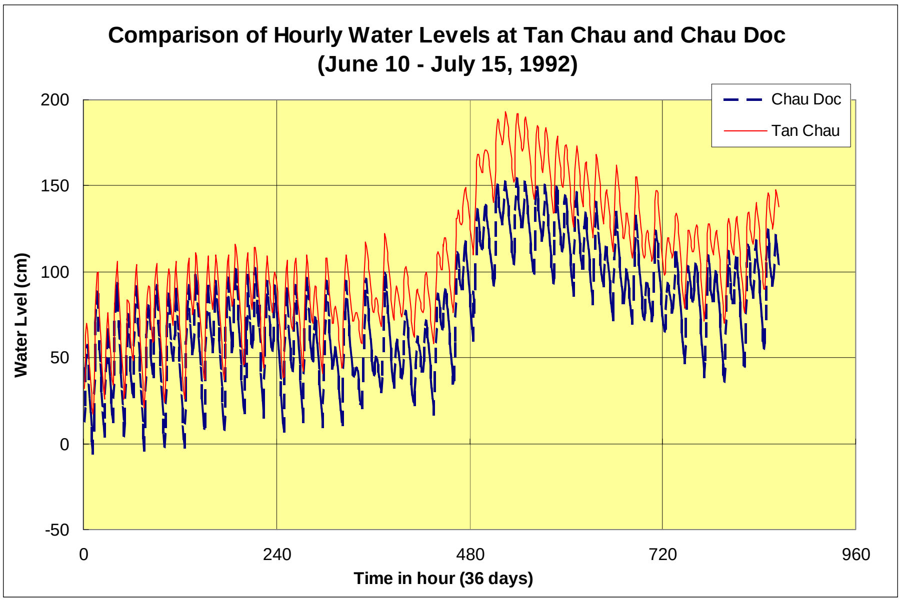


Fig. 5.3 Comparison of Hourly Water Levels at Tan Chau and Chau Doc

The table below shows the representative tidal range throughout the year in the Mekong and Bassac rivers at Tan Chau and Chau Doc. Results are presented for six tides.

Photo: Chau Doc Hydrological Station on Bassac River

Table 5.3 Representative Tidal Ranges at Tan Chau and Chau Doc

Location	Tide	Tidal Range (m)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mekong River at Tan Chau	HHT	0.81	0.97	1.07	1.10	1.10	1.02	0.80	0.44	0.07	NR	0.33	0.69
	MHT	0.40	0.61	0.68	0.72	0.69	0.48	0.25	0.14	NR	NR	0.11	0.20
	LHT	0.40	0.10	0.40	0.20	0.50	0.20	0.20	0.20	0.02	NR	0.01	0.02
	HLT	0.86	0.98	1.08	1.16	1.12	1.08	0.86	0.37	0.08	NR	0.37	0.59
	MLT	0.40	0.61	0.68	1.45	0.69	0.46	0.23	0.12	NR	NR	0.13	0.23
	LLT	0.50	0.20	0.60	0.10	0.11	0.30	0.20	0.02	0.02	NR	0.03	0.02
Bassac River at Chau Doc	HHT	1.13	1.10	1.27	1.29	1.29	1.19	1.11	0.64	0.23	0.12	0.39	0.86
	MHT	0.50	0.66	0.78	0.85	0.83	0.64	0.30	0.18	0.90	0.60	0.13	0.25
	LHT	0.40	0.50	0.20	0.10	0.20	0.10	0.10	0.20	0.20	0.10	0.10	0.10
	HLT	1.10	1.14	1.28	1.35	1.30	1.25	1.18	0.51	0.21	0.14	0.40	0.78
	MLT	0.51	0.66	0.78	0.85	0.83	0.62	0.28	0.16	0.80	0.70	0.19	0.27
	LLT	0.20	0.40	0.30	0.10	0.13	0.70	0.20	0.10	0.10	0.10	0.30	0.10

Note: NR means no record. HHT refers to higher high tide. MHT: mean high tide, LHT: lower high tide, HLT: higher low tide, MLT: mean low tide, LLT: lower low tide. Observation period is unknown.

Source: Water Management Case Study for the Mekong Delta in Vietnam, 1999

The following observations are made:

(1) The tidal range at Tan Chau is generally less than at Chau Doc. This is because the Mekong River at Tan Chau conveys much more of the total flow than the Bassac River at Chau Doc.

(2) The tidal range at both stations is greatest over the dry season period March-May when flows are the lowest. At Tan Chau, the maximum tidal range from March to May is 1.08-1.45 m, at Chau Doc it is 1.28-1.35 m.

Mean daily water level records at Tan Chau and at Chau Doc since 1980 are available in the HYMOS database system at MRC. Fig. 5.4 and 5.5 show the comparison of daily mean water levels in 1980-1999 at Tan Chau and at Chau Doc.

Photo: Tan Chau Hydrological Station on Mekong River

5.1.4 Discharges at Tan Chau and Chau Doc

Accurate and reliable monitoring of flows entering Vietnam is made difficult by the effect of tides in the South China Sea and the complex waterway network around Vam Nao Island. During the dry season, flow reversal occurs at both Tan Chau and Chau Doc.

According to the Hydro-meteorological Data Centre in Hanoi, the discharge measurement at Tan Chau and Chau Doc started in 1979. However, the discharges at both stations have been intensively monitored since 1997. Over the period 1979-1996, discharge monitoring was undertaken for only several months in the dry season and in the wet season.

Mean monthly flows at Tan Chau and Chau Doc are available in several reports as presented below, although the data source and observation periods are unknown.

Table 5.4 Mean Monthly Flows at Tan Chau and Chau Doc

(Unit: m3/s)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Tan Chau	6,220	3,720	2,600	2,010	2,640	7,180	11,270	16,390	21,140	20,340	15,260	10,180	**9,830**
Chau Doc	1,360	700	420	330	460	1,450	2,390	3,970	5,200	5,480	4,700	2,710	**2,440**
Total	**7,580**	**4,420**	**3,020**	**2,340**	**3,100**	**8,630**	**13,660**	**20,360**	**25,430**	**25,820**	**19,960**	**12,800**	**12,270**

Source: MRC and KOICA, Flood Control Planning for Development of the Mekong Delta, 2000

Shown below is a comparison of hourly discharges at Tan Chau and Chau Doc in the transition period from the dry season to the wet season in 1992.

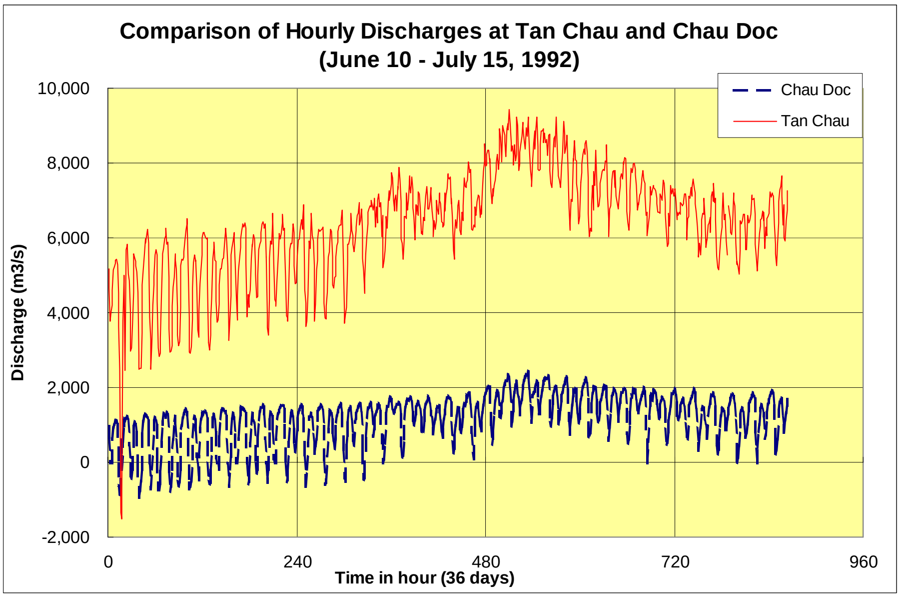


Fig. 5.7 Comparison of Hourly Discharges at Tan Chau and Chau Doc

Probable April discharges at Tan Chau and Chau Doc are available in the UNDP report. The table below presents various exceedance (excess) probabilities of low flow in April at both stations. These results are based on the estimated low flows in April over the period 1978-1999 (22 years). The report says the accuracy and consistency of pre-1997 estimates is not known. By fitting a Log-Pearson III distribution to the recorded data, the exceedance probabilities were derived.

Table 5.5 Statistics of April Discharge at Tan Chau and Chau Doc in 1978-1999

Non-Exceedance Probability (%)	Monthly Discharge (m^3/s)	
	Tan Chau (Mekong River)	Chau Doc (Bassac River)
50	1,620	300
20	1,360	260
10	1,270	250
5	1,230	240
2	1,200	240
1	1,180	240
Maximum Recorded	**2,630**	**540**
Average	**1,730**	**330**
Minimum Recorded	**1,290**	**230**

Source: UNDP, Water Management Case Study for the Mekong Delta in Vietnam, December 1999

5.1.5 Discharges at Phnom Penh

Together with the importance of discharges at Tan Chau and Chau Doc, the discharge downstream Phnom Penh is of great importance in view of international flow management of the Mekong River Basin.

In the report of the Netherlands Team prepared in 1973-1974, monthly discharge downstream of Phnom Penh was preliminarily estimated for the period 1935-1942. This estimation was based on the preliminary water balance of the Great Lake as well as the discharge at Kratie and Kampong Cham. Although it was mentioned in the report that the accuracy of computation method was unknown, the discharge downstream of Phnom Penh was the first approximation. The estimated monthly mean discharge is as follows:

Table 5.6 Monthly Mean Discharge Downstream of Phnom Penh in 1935-1942

(Unit: m^3/s)

Month	Year							
	1935	**1936**	**1937**	**1938**	**1939**	**1940**	**1941**	**1942**
Jan	7,400	7,900	5,300	-	9,250	7,700	-	-
Feb	5,100	5,200	3,050	-	6,400	5,300	-	-
Mar	3,200	3,100	1,850	-	3,700	3,700	2,600	-
Apr	2,000	2,400	1,930	-	3,000	2,400	2,400	2,670
May	3,300	3,000	4,100	-	4,700	3,500	3,850	4,300
Jun	10,500	8,000	11,000	-	13,000	9,500	12,500	10,000

Note: Recommendations Concerning Agricultural Development with Improved Water Control in the Mekong Delta, Working Paper IV, Hydrology, The Netherlands Delta Development Team, April 1974

In the HYMOS database system at MRC, daily discharge record is available only at Chrui Changvar on the Mekong mainstream. The available data period is 1961 to 1973. The monthly mean discharges at Chrui Changvar are presented below.

Table 5.7 Monthly Mean Discharges at Chrui Changvar in 1961-1973

(Unit: m^3/s)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1961	3,488	2,497	2,065	1,933	3,462	14,691	27,900	33,719	44,187	36,394	14,300	7,213	15,987
1962	4,255	3,185	2,538	2,153	3,403	13,487	24,622	35,849	34,580	23,848	11,914	5,491	13,777
1963	3,375	2,416	1,939	1,783	1,789	8,628	20,610	37,932	34,133	21,897	13,634	7,103	12,937
1964	3,658	2,599	2,006	1,864	3,419	8,620	18,084	25,532	35,567	32,119	14,076	7,192	12,895
1965	4,132	2,934	2,311	1,958	2,369	14,872	27,271	30,190	31,143	16,635	11,820	5,668	12,609
1966	3,126	1,998	1,756	1,696	4,295	9,539	23,210	37,790	42,450	22,087	11,169	6,556	13,806
1967	3,724	2,223	1,805	2,596	3,523	7,514	13,744	27,235	35,760	24,823	9,065	5,315	11,444
1968	2,825	1,977	1,757	1,658	3,037	5,563	12,273	27,765	37,387	16,694	8,311	4,283	10,294
1969	2,296	1,841	1,712	1,630	1,691	8,367	25,390	38,016	37,303	21,445	9,553	5,042	12,857
1970	2,659	1,902	1,717	1,675	2,594	9,983	26,729	36,165	40,960	23,261	10,574	6,662	13,740
1971	3,939	2,204	1,830	1,732	2,041	10,255	30,352	35,290	37,863	23,658	10,901	6,134	13,850
1972	3,405	2,078	1,748	2,227	2,099	8,874	22,400	39,758	40,750	19,971	11,229	7,107	13,471
1973	3,974	2,748	2,345	2,201	3,629	7,313	18,563	28,271	40,533	31,348	11,749	6,925	13,300
Mean	**3,451**	**2,354**	**1,964**	**1,931**	**2,873**	**9,824**	**22,396**	**33,347**	**37,894**	**24,168**	**11,408**	**6,207**	**13,151**

Source: HYMOS database at MRC, Phnom Penh

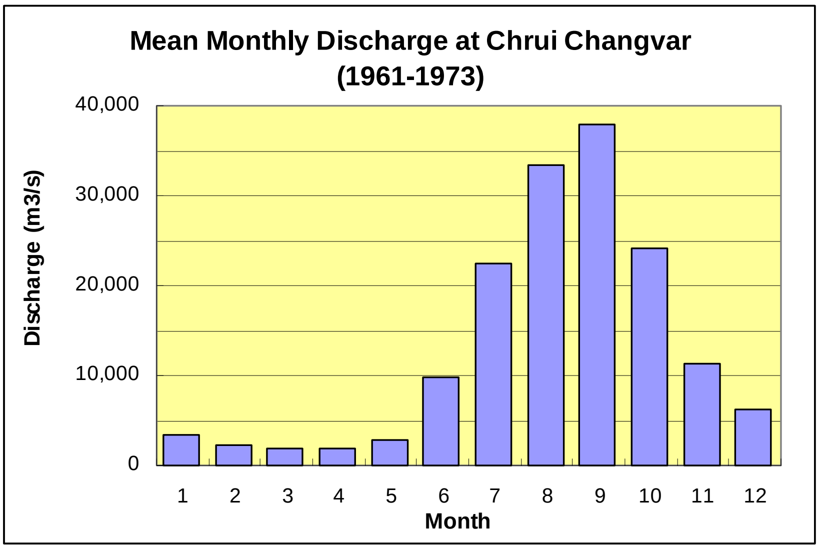


Fig. 5.8 Mean Monthly Discharge at Chrui Changvar

Furthermore, the Netherlands Team estimated the monthly discharges of various probabilities in the low flow period, as presented below.

Table 5.8 Statistics of Monthly Discharge Downstream of Phnom Penh

(Unit: m^3/s)

Month	Non-Exceedance Probability (%)		
	90 %	50%	10%
Jan	9,400	7,500	5,700
Feb	6,000	4,600	3,200
Mar	3,700	3,100	2,400
Apr	2,800	2,400	1,900
May	4,900	3,700	2,500
Jun	14,000	10,800	7,700

Source: Recommendations Concerning Agricultural Development with Improved Water Control in the Mekong Delta, Working Paper IV, Hydrology, The Netherlands Delta Development Team, April 1974

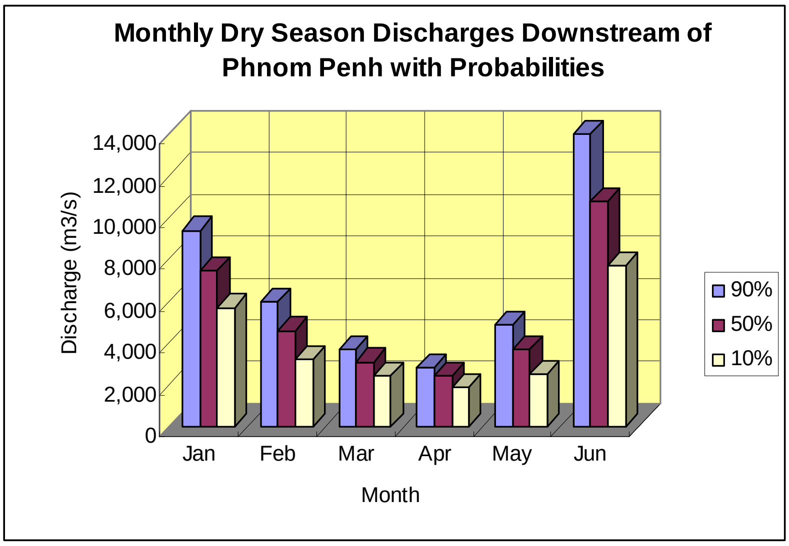


Fig. 5.9 Probable Dry Season Monthly Discharges at Phnom Penh

In the ongoing WUP-JICA study, the observed records from the HYMOS database system at MRC were used for the preliminary estimation of drought flow at representative stations along the Mekong River in April. The records are more or less affected by the existing water uses in the upper reaches. The estimated probable discharge at Phnom Penh (Chrui Changvar station on the Mekong) is as shown below. It is noted that although the flow downstream of Phnom Penh is the sum of both flows of the Mekong and Tonle Sap, it is unknown due to lack of reliable historic data at Prek Kdam on the Tonle Sap River.

Table 5.9 Monthly Flows in April at Representative Stations on the Mekong Mainstream

Station	Chiang Saen	Luang Prabang	Vientiane	Mukdahan	Pakse	Phnom Penh (Chrui Changvar)
Data Period	1961-1998	1961-2000	1961-2000	1961-1998	1961-2000	1961-1973
Maximum	1,210	1,400	1,470	2,030	2,430	2,600
Average	920	1,110	1,190	1,570	1,820	1,930
Minimum	620	630	770	1,220	1,280	1,630
10-year	740	890	880	1,340	1,480	1,650
5-yaer	800	980	970	1,420	1,600	1,720

Source: Progress Report, The Study on Hydro-Meteorological Monitoring for Water Quantity Rules in the Mekong River Basin, WUP-JICA, February 2002

5.2 Flow Distribution in the Mekong Delta

Flow distribution in the Mekong branches has been studied since the 1970s by using a mathematical model in the process for understanding the hydrodynamic features of the Mekong Delta water system during the dry season. The flow distribution in the dry season has been of great concern in view of irrigation management and developments in the Mekong Delta area. Study results of flow distribution are available in several reports, as briefly discussed below.

5.2.1 Studies Carried out by the Netherlands Team in 1973-1974

The discharge distribution was computed by use of the mathematical model of the main river corresponding to the discharge of 2,285 m^3/s at Phnom Penh. The model has its upstream and downstream boundaries at Phnom Penh (called Chak Tomuk area) and the South China Sea respectively. The flow distribution has been used for many years as a reference. The estimated flow distributions under several discharges downstream of Phnom Penh are presented below.

Table 5.10 Estimated Discharges in the Mekong Delta Branches by the Netherlands Team in 1973-1974

(unit: m^3/s)

River/Branch	Discharge at Phnom Penh (Qp)				
	1,660	2,385	3,950	5,835	7,300
Mekong (Qm1)	-	2,285 (96%)	-	-	-
Bassac (Qb1)	-	100 (4%)	-	-	-
Xang Canal	-	140 (6%)	-	-	-
Tan Chau	-	2,145 (90%)	-	-	-
Chau Doc	-	240 (10%)	-	-	-
Van Nao River	-	935 (39%)	-	-	-
Mekong (Qm2)	830 (50%)	1,210 (51%)	2,005 (51%)	2,995 (51%)	3,765 (52%)
Bassac (Qb2)	830 (50%)	1,175 (49%)	1,935 (49%)	2,840 (49%)	3,535 (48%)

Note: Location of rivers and branches above are schematically shown below.
Source: Recommendations Concerning Agricultural Development with Improved Water Control in the Mekong Delta, Working Paper IV, Hydrology, The Netherlands Delta Development Team, April 1974

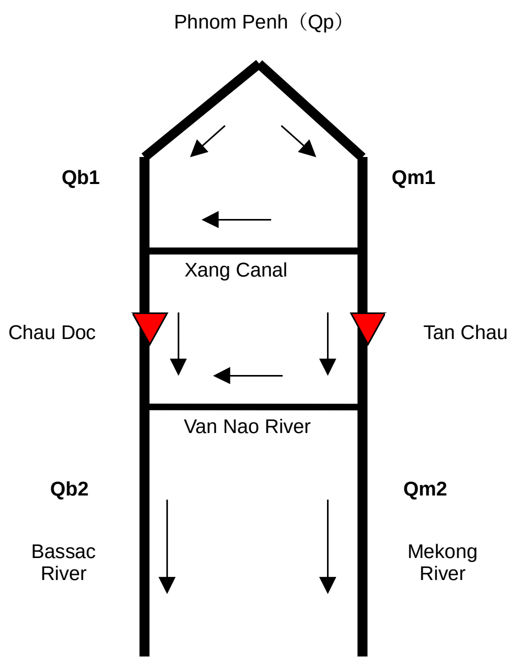


Fig. 5.10 Location of Rivers and Canal for Discharge Distribution in the Mekong Delta

Photo: Bassac River at the Junction to Xang Canal

Further details of flow distribution of the Mekong branches are summarised below and the location map of branches is also shown below.

Table 5.11 Details of Estimated Discharges in the Mekong Delta Branches by the Netherlands Team in 1973-1974

(unit: m3/s)

River	Discharge at Phnom Penh (Qp)				
	1,660	**2,385**	**3,950**	**5,835**	**7,300**
Bassac (Qb)	830 (50%)	1,175 (49%)	1,935 (49%)	2,840 (49%)	3,535 (48%)
Mekong (Qm1)	830 (50%)	1,210 (51%)	2,005 (51%)	2,995 (51%)	3,765 (52%)
Mekong (Qm2)	360 (22%)	555 (23%)	960 (24%)	1,470 (25%)	1,865 (26%)
Co Chien (Qc)	470 (28%)	655 (28%)	1,045 (27%)	1,525 (26%)	1,900 (26%)
Mekong (Qm3)	95 (6%)	195 (8%)	415 (11%)	685 (12%)	900 (12%)
Ham Luong (Qh)	265 (16%)	360 (15%)	545 (14%)	785 (13%)	965 (13%)

Note: Location is illustrated in Fig. 5.11 in the next page.
Source: Recommendations Concerning Agricultural Development with Improved Water Control in the Mekong Delta, Working Paper IV, Hydrology, The Netherlands Delta Development Team, April 1974

From the estimates above, the following observations on the flow distribution are made:

(1) In the dry season, most of the Mekong flows to Vietnam arrive via the Mekong River. The volume of flow delivered into Vietnam through the Mekong River is around 95% of the total inflow into Vietnam (Qp).

(2) Van Nao Island is located between the Mekong and Bassac rivers being formed by the Xang Canal to the north and the Van Nao River to the south. Because of the contribution of diverted discharge through the Xang Canal, the distribution ratios of Tan Chao and Chau Doc discharges become around 90% and 10% of the total inflow into Vietnam.

(3) However, downstream of the island, both the Mekong and Bassac Rivers carry about half the flow because much more Mekong water joins the Bassac River via the Van Nao River.

(4) The Mekong water is further distributed into the Mekong branches. The Mekong discharge at Phnom Penh (Qp) is finally accumulated from among the major branches with ratios of 50% in the Bassac, 28% in the Co Chien, 16% in the Ham Luong and 6% in the Cua Dai.

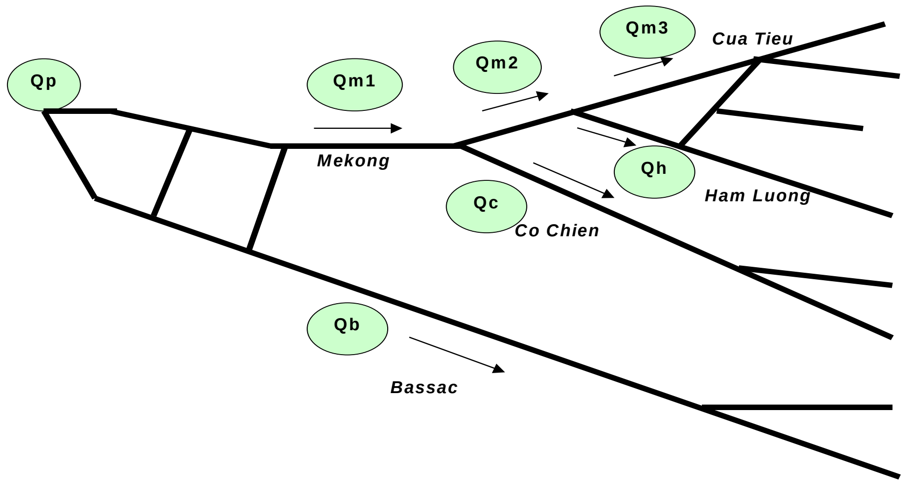


Fig. 5.11 Schematic Diagram of Mekong Branches for Discharge Distribution

The flow distribution in the dry season is schematically summarized below.

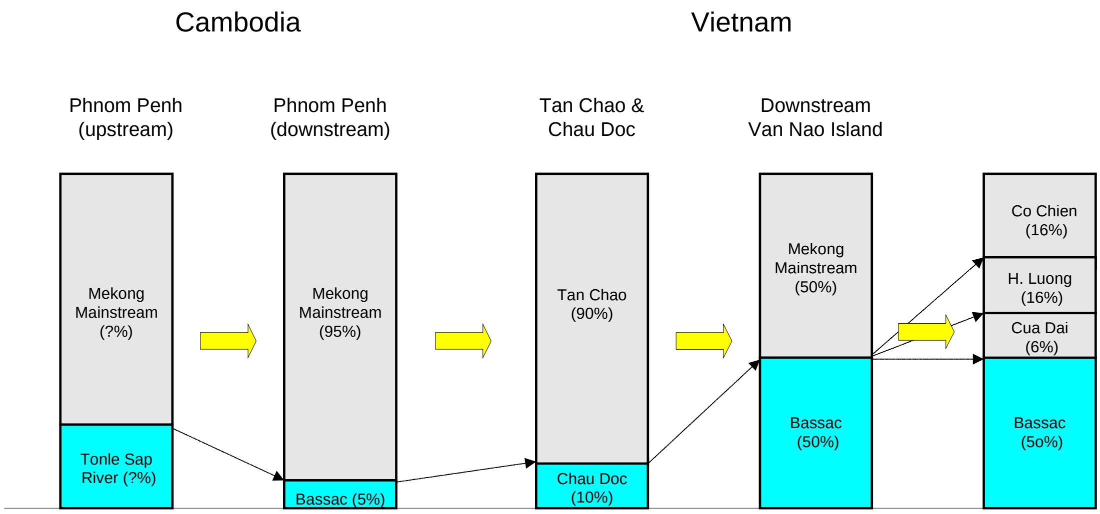


Fig. 5.12 Summary of Estimated Flow Distribution along the Mekong River from Phnom Penh to Mekong Delta

As seen above, flow contribution of the Tonle Sap River into the Mekong discharge at Phnom Penh (Qp) is unknown. This flow contribution is newly analysed under the current study and to be discussed in Section 5.5.

5.2.2 Studies carried out by SIWRP in 1981-1992

Under the Programme of Salinity Intrusion Studies undertaken by SWWRP, distribution of low flow under average conditions was established to form a basis for detailed studies and guidelines for balanced development. The established low flow distribution is presented below. This distribution is applicable to the inflow into Vietnam (sum of the discharges at Tan Chau and Chau Doc) with the range between 1,500 and 5,000 m^3/s.

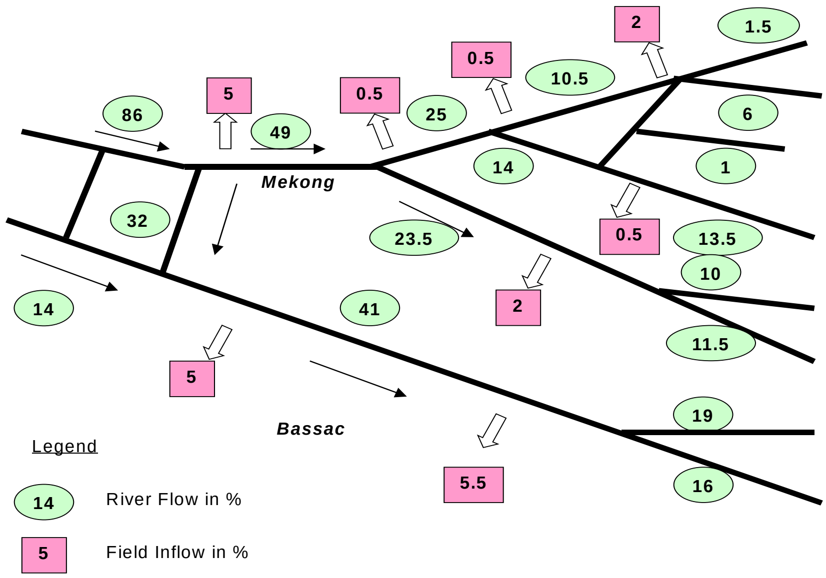


Fig. 5.13 Estimated Low Flow Distribution in the Mekong Delta by SIWRP

Field inflows from both the Mekong and Bassac shown above are the diverted flows into the many canals existing in the Mekong Delta. In the dry season from February to April, around 79% of the total inflow into the Mekong Delta runs out through branches to the South China Sea. The remaining 21% of the total loss flows into the canals for irrigation and other water uses. As for the estimated flow ratios, there is a large difference between these two studies, as summarized below.

Table 5.12 Comparison of Flow Distributions in the Mekong Delta by Two Studies

Study	Tan Chaoon Mekong	Chau Docon Bassac	My Tho on Mekong	Can Tho on Bassac
Netherlands Team in 1973-1974	90%	10%	51%	49%
SIWRP in 1981-1992	86%	14%	49%	41%

Source: WUP-JICA Study Team

Together with the above, low flow distributions estimated for both 1986 and 1990 dry seasons are available in the related report, as shown below.

Table 5.13 Monthly Flow Distribution in the Mekong Delta in 1986 Dry Season

Station /Branch	February		March		April		Average	
	m3/s	%	m3/s	%	m3/s	%	m3/s	%
Tan Chau	4,465	84.6	2,665	95.1	1,621	55.8	2,917	85.0
Chau Doc	815	15.4	466	14.9	268	15.0	516	15.0
Total	**5,280**	**100**	**3,131**	**100**	**1,889**	**100**	**3,433**	**100**
My Thuan	2,410	45.6	1,424	45.5	958	50.7	1,497	46.5
Can Tho	2,515	47.6	1,508	48.2	702	37.1	1,575	45.9
Tran De	1,050	11.9	616	19.7	236	12.5	634	18.5
Dinh An	1,437	27.2	890	28.4	398	21.0	908	26.5
Co Chien	1,075	20.4	585	18.7	370	19.6	677	19.7
Ham Luong	542	10.3	279	8.9	207	11.0	343	10.0
Ba Lai	7	0.1	5	0.2	4	0.2	5	0.2
Cua Dai	569	10.6	443	14.1	306	16.2	448	13.0
Cua Tieu	167	3.1	103	2.7	52	2.1	107	3.1

Source: Some Fundamental Hydrodynamic Characteristics of the Mekong Delta Water System during the Dry Season, Program of Salinity Intrusion Studies in The Mekong Delta Phase III, SIWRPM, 1992

Table 5.14 Monthly Flow Distribution in the Mekong Delta in 1990 Dry Season

Station /Branch	February		March		April		May		Average	
	m3/s	%	m3/s	%	m3/s	%	m3/s	%	m3/s	%
Tan Chau	3,357	84.7	2,223	85.4	1,641	85.7	2,680	85.2	2,480	85.2
Chau Doc	598	15.3	383	14.6	274	14.3	464	14.8	430	14.8
Total	**3,960**	**100**	**2,617**	**100**	**1,915**	**100**	**3,144**	**100**	**22,910**	**100**
My Thuan	1,786	45.1	1,479	56.2	865	45.2	1,600	50.9	1,426	49.0
Can Tho	1,777	44.9	845	32.3	765	39.1	1,311	41.7	1,180	40.5
Tran De	753	19.0	268	10.2	268	14.2	510	16.2	450	15.5
Dinh An	1,066	26.9	455	17.4	429	22.4	733	23.3	670	23.0
Co Chien	760	19.2	651	24.9	355	18.5	708	22.5	618	21.2
Ham Luong	370	9.3	374	14.3	206	10.8	422	13.4	343	11.8
Ba Lai	6	0.2	5	0.2	4	0.2	5	0.2	5	0.2
Cua Dai	497	12.5	349	13.3	233	12.2	365	11.6	361	12.4
Cua Tieu	131	3.3	72	1.7	32	1.7	82	2.6	80	2.7
Canals in left	100	2.5	100	3.9	90	4.7	90	2.8	95	3.2
Canals in right	240	6.0	220	8.4	160	8.4	160	5.9	195	6.7

Source: Some Fundamental Hydrodynamic Characteristics of the Mekong Delta Water System during the Dry Season, Program of Salinity Intrusion Studies in The Mekong Delta Phase III, SIWRPM, 1992

5.3 Intermediate Stage Discharge Measurement Campaign in the Mekong Delta in 1992

An intermediate stage discharge measurement campaign in the Mekong Delta was executed by the Institute of Meteorology and Hydrology in Vietnam in the period from June 10 to July 15, 1992. The campaign aimed at providing valuable hydrological information about the flow regime in the transition stage between the low flow and high flow of the Mekong Delta. Obtaining information on the flow distribution between the Mekong and Bassac rivers (flow contribution of the Van Nao River) was also another purpose for mathematical modelling.

In the campaign, hourly water level measurement was made at Tan Chau (recording plate steven), Chau Doc (recording plate steven), Van Nao (plate), My Thuan (plate) and Can Tho (plate). The location map of these five stations is presented below.

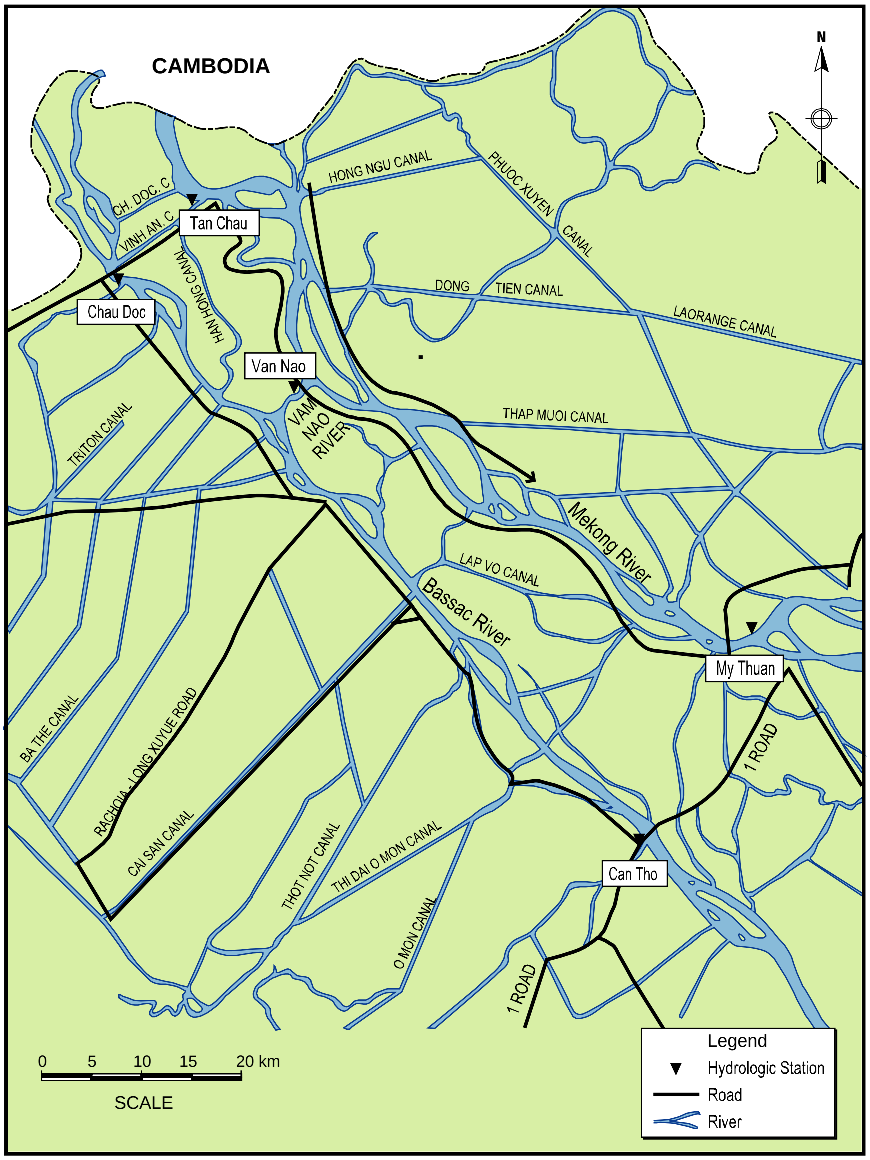
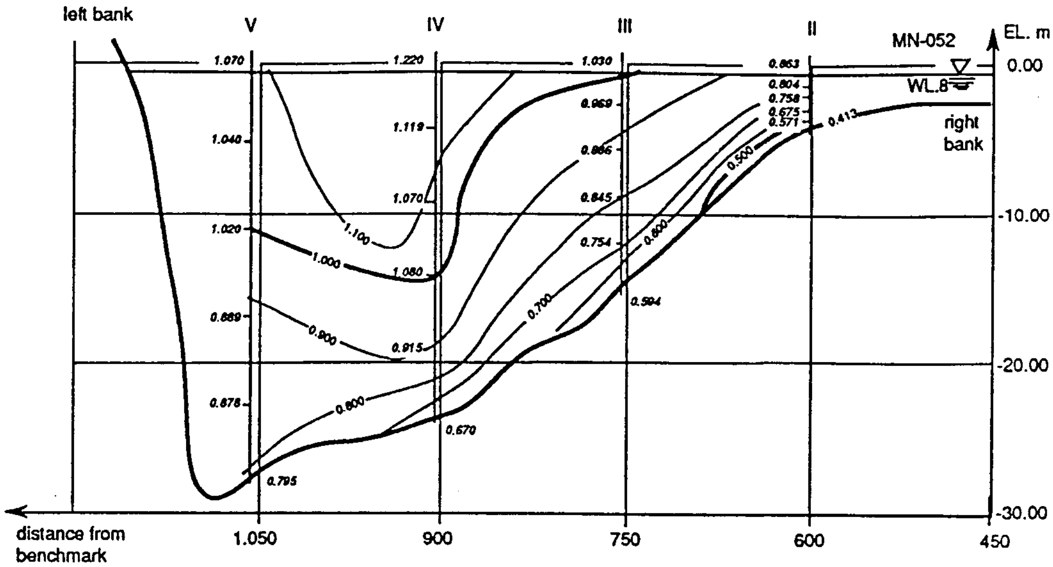


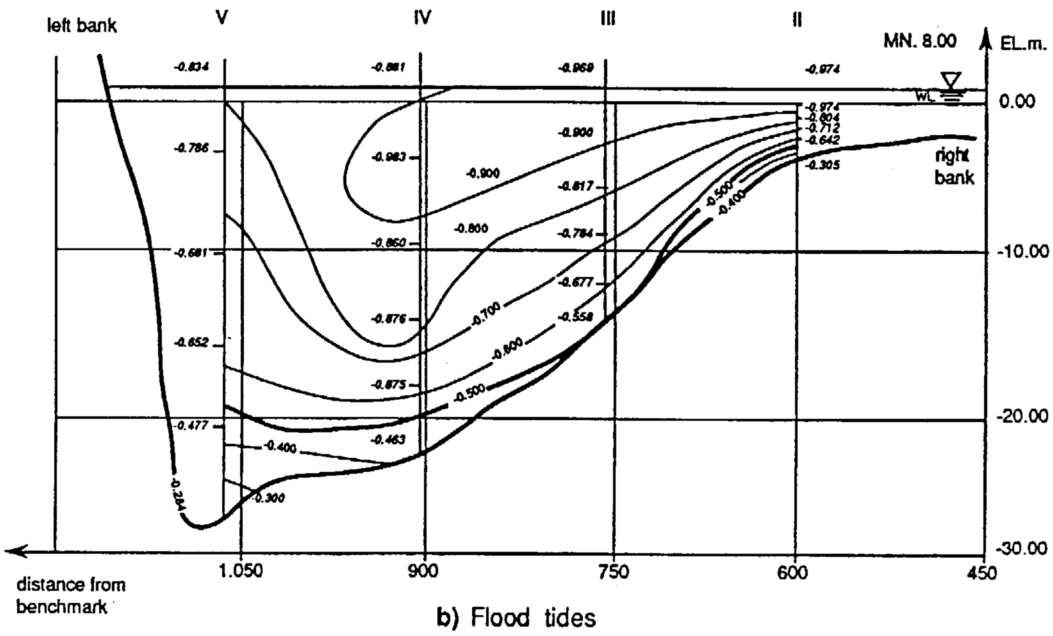
Fig. 5.14 Location Map of Hydrological Stations under the Measurement Campaign in 1992

Discharge measurements in the tidal river reaches are always difficult in view of the different velocity distribution between the flood and ebb tides. Figure 5.15 in the next page presents an example of measured cross sectional flow velocity distribution at Can Tho on the Bassac River.

Flow velocities were measured at hourly intervals throughout the day and night by current meter at the representative velocity vertical set at each station. The mean velocity at the representative vertical was used to estimate the mean cross section velocity via the predetermined velocity regression relationship between these two velocities. The regression relationship was derived with enough accuracy by intensive stream gauging at five stations. Five verticals were applied at each station. In order to better take tidal flow reversal into account, separate regression relationships were prepared for ebb and flood flows at My Thuan and Can Tho stations where effects by tides are significant.



a) Ebb tides



b) Flood tides

Fig. 5.15 Cross Sectional Distribution of Flow Velocity of the Bassac River at Can Tho

The measurement campaign results at these five stations are graphically shown in Fig. 5.16. The relationship of five stations is illustrated as follows:

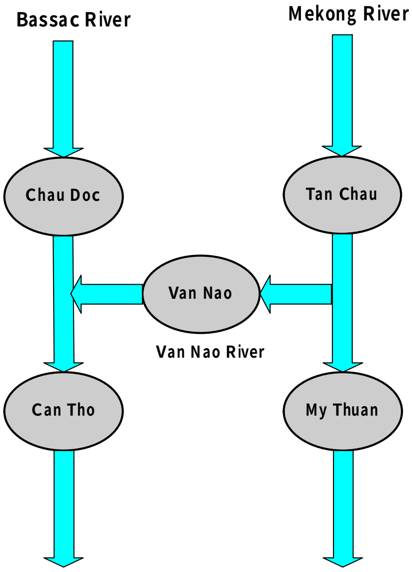


Fig. 5.17 Relationship of Hydrological Stations under the Intermediate Measurement Campaign in 1992

Following observations are made:

(1) All the five stations are apparently affected by the tidal fluctuations. Tidal effects are very significant both at My Thuan and Can Tho.

(2) Flow reversal occurred at all stations in the campaign period. However in June when the dry season usually almost ceases, no reverse flow occurred at Tan Chau on the Mekong River, although almost every day reverse flow occurred at Chau Doc on the Bassac River.

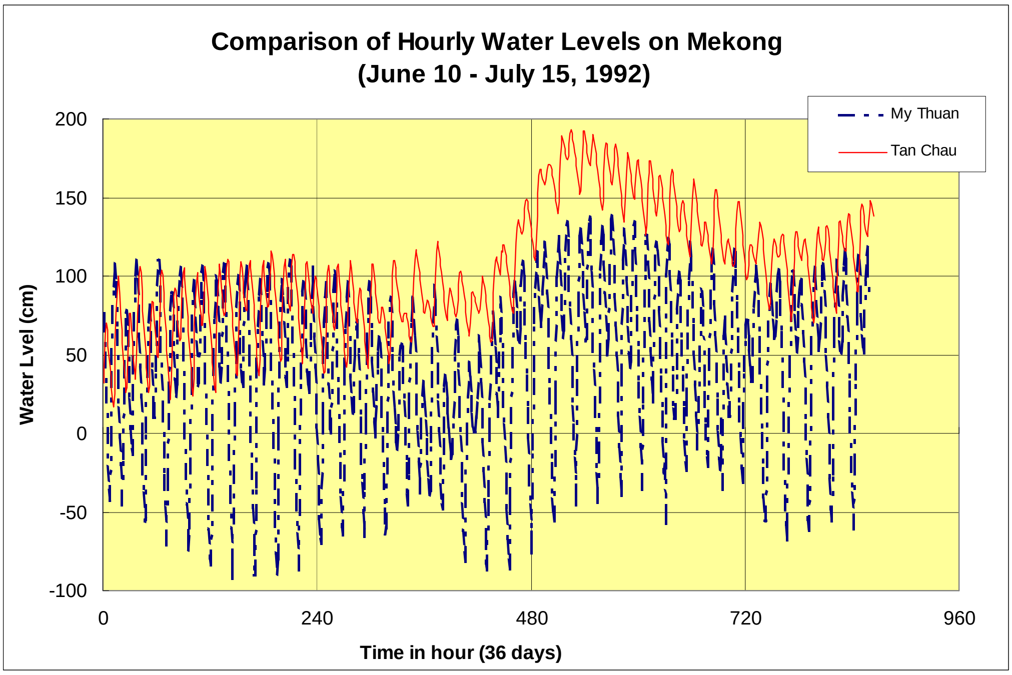
(3) In the Van Nao River, at the end of dry season, the reverse flow from the Bassac to the Mekong occurred for several days.

(4) At My Thuan on the Mekong, the hourly flow variation with a maximum range between -8,000 m3/s and 16,000 m3/s was observed, while the net discharge (daily mean) was less than 2,000 m3/s. Almost the same flow variation was observed at Can Tho on the Bassac.

The estimated daily discharges at five stations are presented in Table 5.15. Comparison of hourly water levels in both the Mekong and Bassac rivers are presented in Fig. 5.18.

Photo: Can Tho Hydrological Station on Bassac River

Photo: Ferry Terminal at Can Tho Hydrological Station



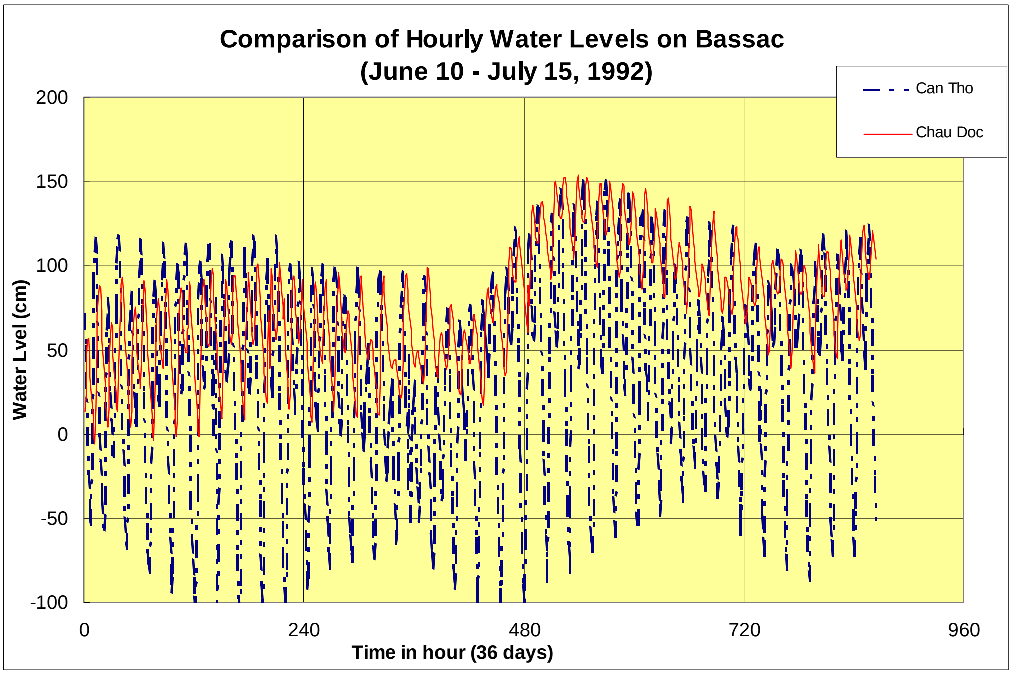
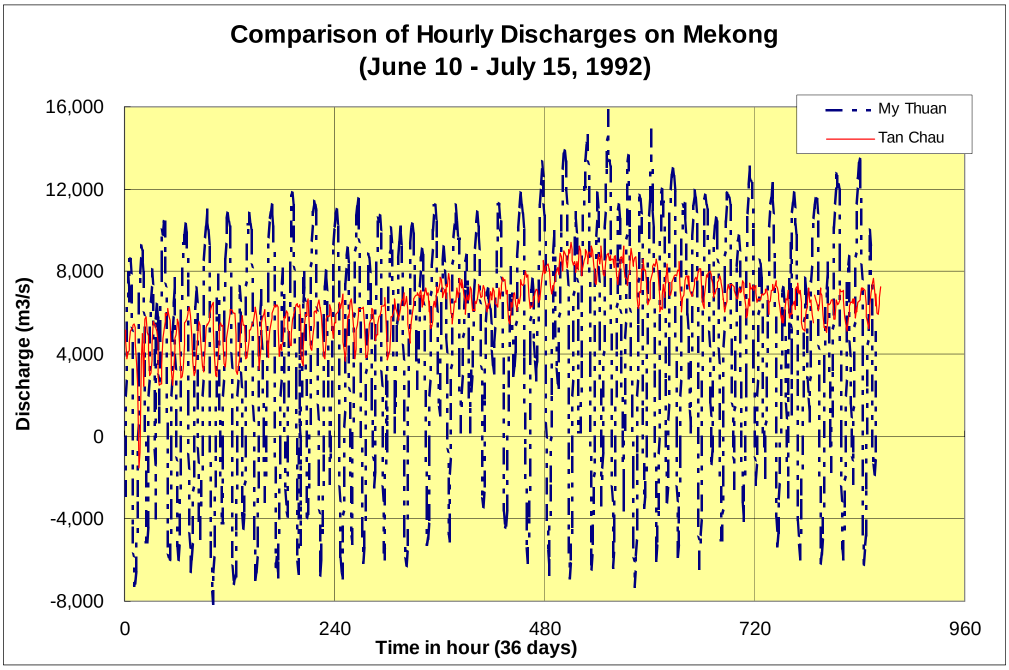


Fig. 5.18 Comparison of Hourly Water Levels on the Mekong and Bassac Rivers under the Measurement Campaign in 1992

Besides, comparison of hourly discharges in both the Mekong and Bassac rivers are also presented below.



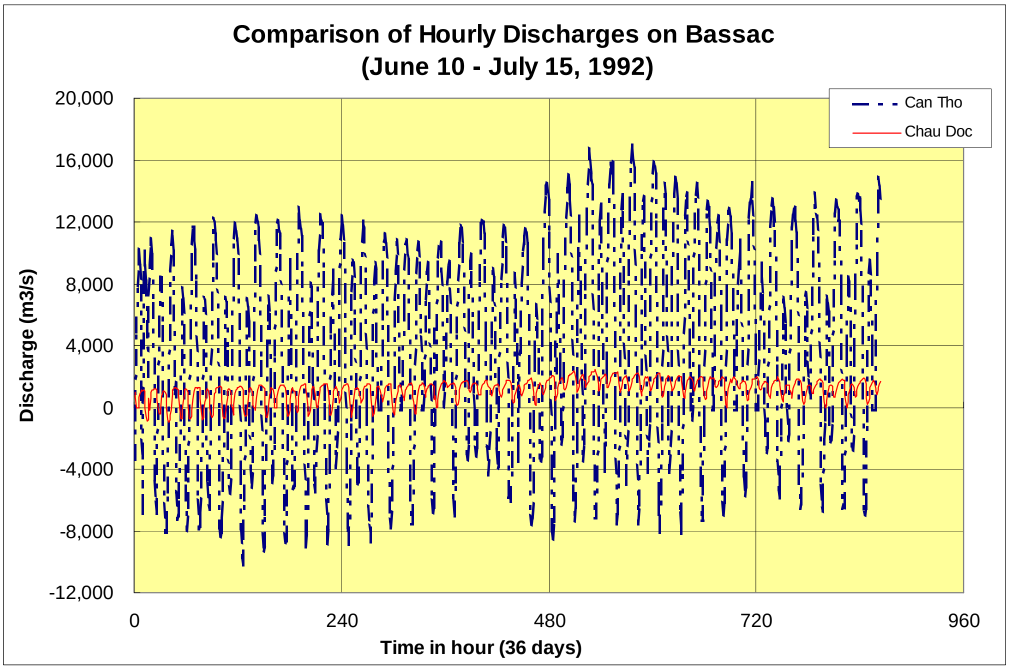


Fig. 5.19 Comparison of Hourly Discharges on the Mekong and Bassac Rivers under the Measurement Campaign in 1992

Photo: Velocity Observation by Anchored Boat at My Thuan on the Mekong River

Photo: Inside of Anchored Boat at My Thuan

5.4 Extreme Drought Year in 1998/99

The year 1998/99 was of an extreme drought that is readily understood by a wider range of local people engaging mainly in agriculture and fishery activities in the Mekong Delta as well as the Tonle Sap Lake. Figure below summarizes consequences of causes and impacts of the drought in 1998/99.

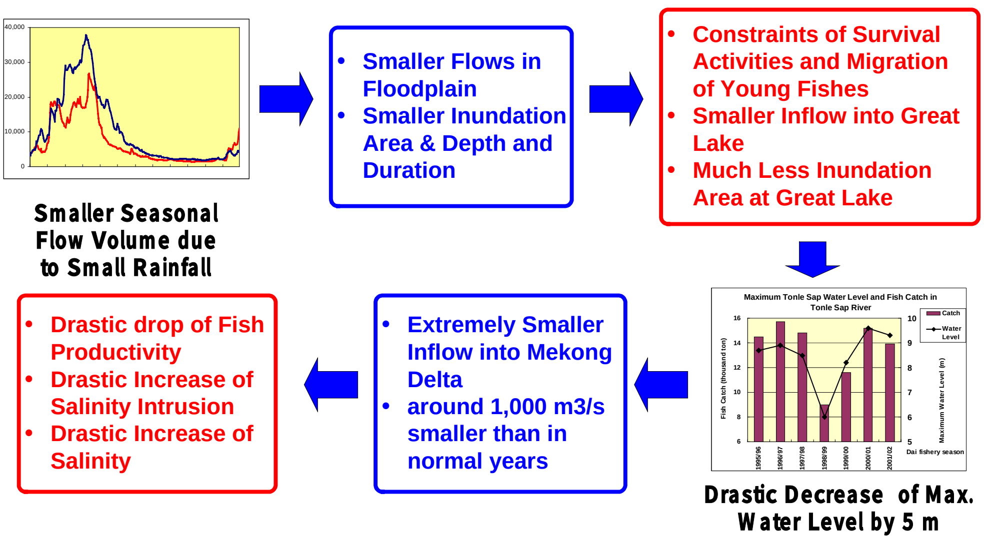


Fig. 5.20 Summary of Consequences of Causes and Impacts of the Drought in 1998/99

Although the occurrence probability of the 1998/99 drought has not yet been officially evaluated, the magnitude and impacts of the drought is understandable from a variety of available information, as discussed below.

5.4.1 Water Levels at Kratie on the Mekong River

The Kratie hydrologic station is located on the Mekong mainstream. From Kratie, an extensive floodplain area in the lower part of the Mekong is formed up to the Mekong Delta as given below.

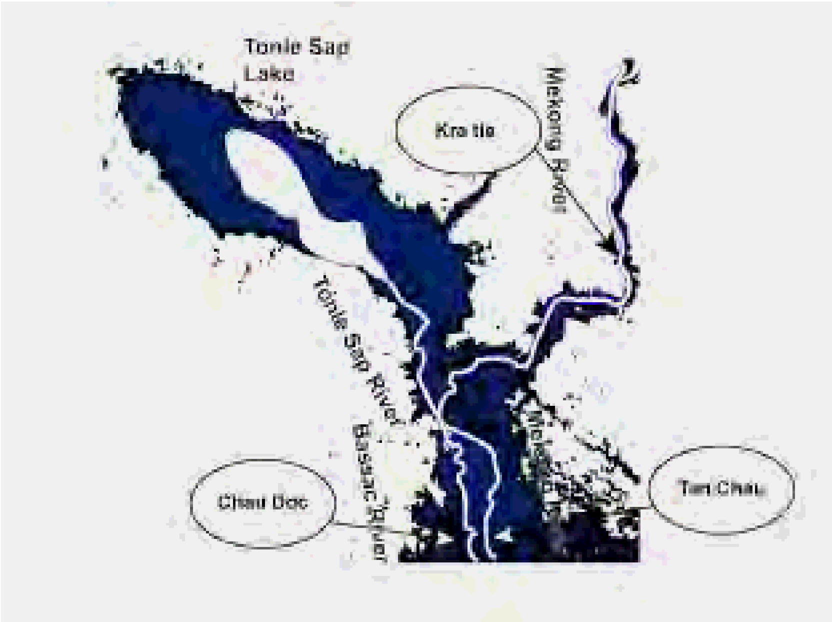


Fig. 5.21 Location of Kratie Station on the Floodplain in Cambodia

Figure below presents the variation of daily mean water levels at Kratie in recent years (1990-2001).

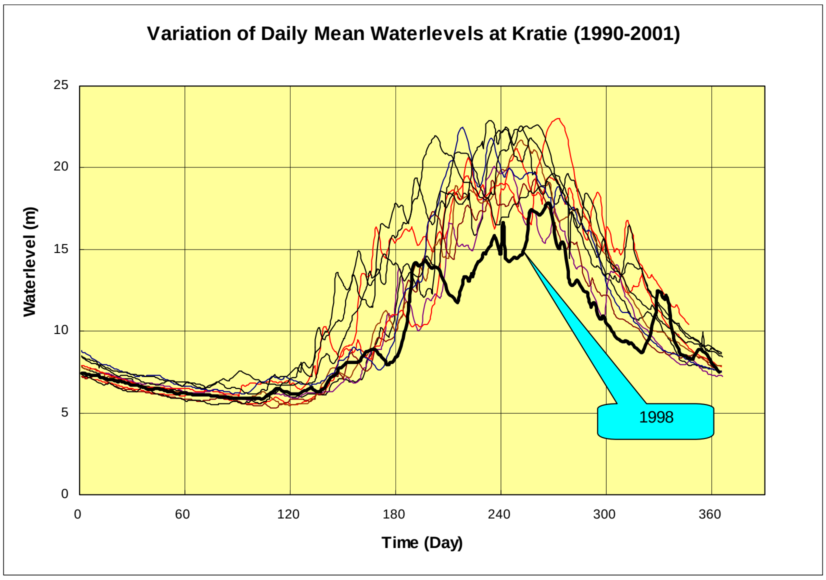
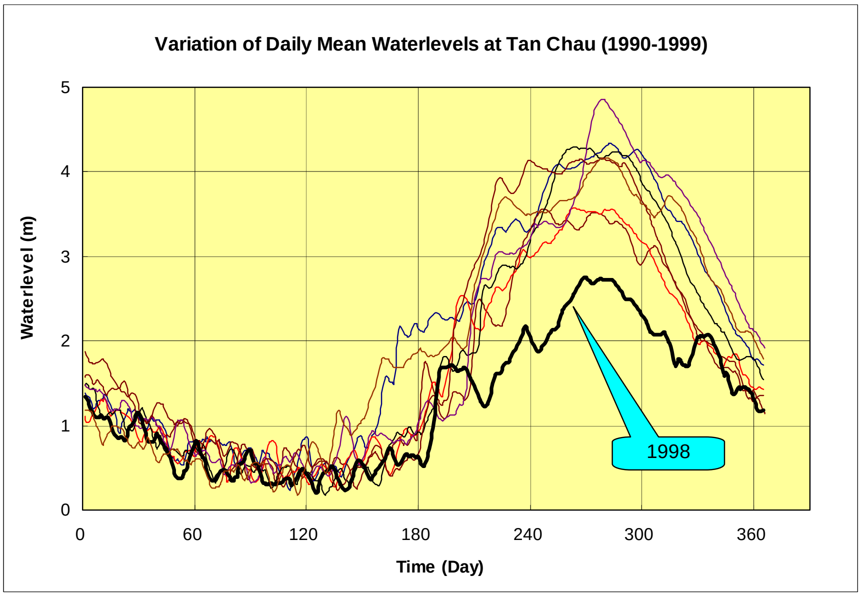


Fig. 5. 22 Variation of Daily Mean Water Levels at Kratie on the Mekong River (1990-2001)

As seen above, the maximum Kratie water level in 1998 is considerably below the water levels in other years. The total water volume in 1998 that has flown into the Great Lake through the Tonle Sap River as a reverse flow and the extensive flood plains extending downstream of Kratie were expected far smaller than in normal years.

5.4.2 Water Levels at Tan Chau and Chau Doc in the Mekong Delta

Comparison of water level variations at both Tan Chau and Chau Doc in the Mekong Delta in 1990-1999 is presented below.



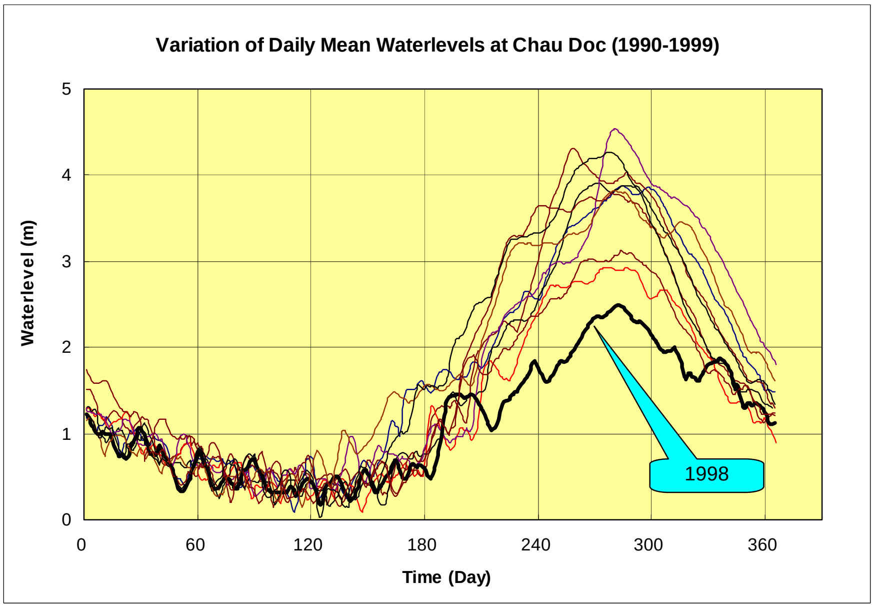


Fig. 5.23 Variation of Daily Mean Water Levels at Tan Chau and Chau Doc (1990-1999)

Both stations in 1998 show the lowest variations in recent 10 years. The maximum water level at both stations in 1998 is around 1.5 m lower than in normal years.

5.4.3 Salinity Increase in the Mekong Delta

According to the SIWRP, the salinity intrusion in the delta in 1999 was more significant than in normal years. Decreased dry season flows allowed salty seawater to intrude further upstream in the Mekong branches. The following figures give a comparison of maximum salinity variations in February of the recent five years in the Mekong and Bassac rivers.

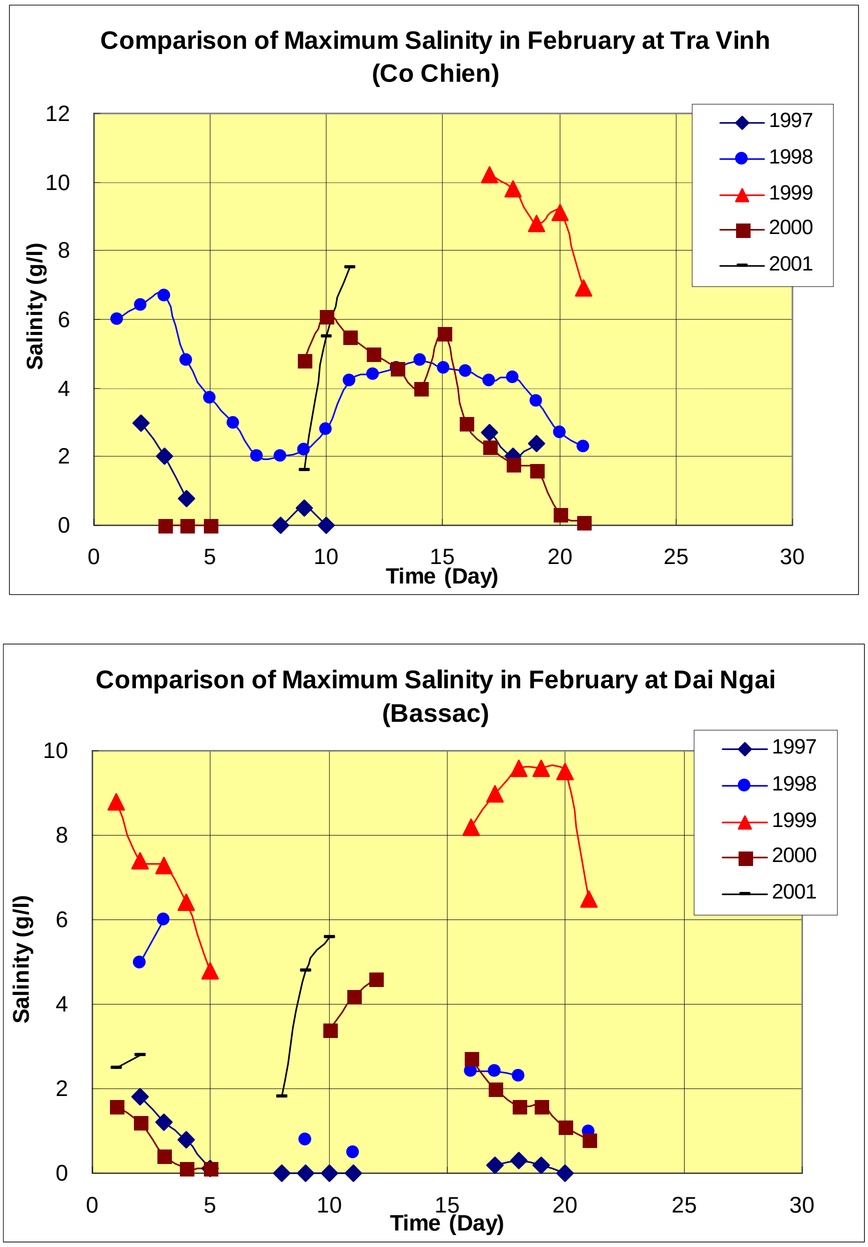


Fig. 5.24 Comparison of Maximum Salinity in February in the Mekong and Bassac Rivers

In 1999, salinity drastically increased in both rivers. At Tra Vinh on the Mekong, the maximum salinity was recorded at more than 10 g/l, where the salinity was usually less than 6 g/l. At Dai Ngai on the Bassac, the salinity increase was more significant as it increased to around 10 g/l from less than 4 g/l in most years.

According the Overview of Saltwater Intrusion in the Mekong Delta by Quang M. Nguyen, P. E. in 1999, the following findings were presented concerning the prolonged seawater intrusion occurred in 1999:

(1) Chloride concentration in the Mekong River at My Tho, where freshwater had been found all year round, was measured at 5.3 g/l at the beginning of April 1999 and the trend was toward an increase by the end of the month. This concentration exceeds the standard for drinking water, surface irrigation water, and livestock water consumption. Saline water, which was reported to intrude 50 km inland in 1995, extended as far as 70 km in 1999, the worst in recorded history (See Table 4.8 and Fig. 4.7 respectively. Average salinity at My Tho in dry season is under 2.0 g/l).

(2) Actual magnitude and extent of salinity intrusion in the Mekong River may be larger if appropriate data and information can be obtained. Catching a stingray, a deep-saltwater fish, in the Mekong River at Sa Dec appears to verify the seriousness of the saltwater intrusion problem because Sa Dec is located approximately 120 km from the coast.

5.4.4 Fish Catch Decrease in the Tonle Sap River

As mentioned in Section 2.10, inland fishery is of great economic and social importance in Cambodia. In the drought year of 1998/99, *dai* fish production was much less than in most years as presented in Fig. 2.27. Fish productivity is closely related to the extent of floodplain inundation.

A dai is a kind of bagnet or stationary trawl positioned in the Tonle Sap River to capture migratory fish. The dai fishery operates usually from the end of October until around the middle of March. As the floods recede, fish move out of the submerged lands (floodplains) around the Great Lake into the lake itself. They then migrate via the Tonle Sap River to the Mekong mainstream. More than half of the season's catch is taken place in January. There is a close relationship between the maximum flood level of the season and the fish catch. The greater the area of flood plain is inundated and the longer the duration of flooding, the greater the volume of fish becomes.

Every year, the size of the Tonle Sap floodplain (see location map in Fig. 5.20) varies tremendously from the dry to the wet season. In the dry season, the Great Lake is only around 3,000 km^2, while in the wet season the lake grows to between 10,000-15,000 km^2. Thus in case of a drought year in 1998/99, fish production is far less than in normal years, since much less land is inundated. Fish productivity is closely related to the extent of floodplain inundation.

Under the current WUP-JICA Study, the water balance of the Great Lake has been assessed with the hydraulic model (to be detailed in Section 5.5) for the recent years 1998-2002. The years represent the range from the dry year to extreme wet year. The water balance is made on a monthly basis using the model results of the 1998-2002 simulations. The 1998-2002 simulations have water level and discharge results stored at daily increments, hence the discharge results have been converted to volumes and lumped to give monthly results. In the assessment, the five flow elements are separately simulated: (i) Runoff from the Great Lake basin (sub-catchment around the Lake), (ii) Direct rainfall on the Lake, (iii) Evaporation of the Lake, (iv) Inflow from the Tonle Sap River as the natural reverse flow of the Mekong River, and (v) Overland flow from the Mekong River on the floodplain. The monthly flow balance is shown below.

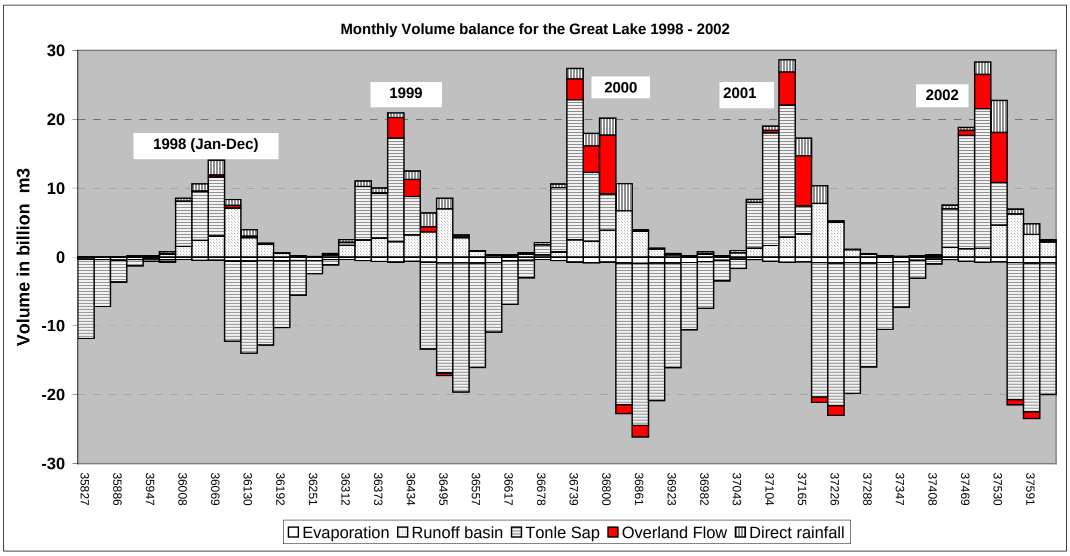


Fig. 5.25 Monthly Flow Balance in the Great Lake in 1998-2002

The years of 2000-2002 are the wet years. The overland flow contribution from the Mekong is highly dependent on the magnitude of the floods on the mainstream, i.e. the conditions upstream of Cambodia (the Kratie Station). Thus in a dry year like 1998, there is almost negligibly small overland flow, and in wet years, this contribution is significant. The estimated maximum water level and volume of the Great Lake are around 6 m and 28 billion m^3 in 1998 and 9.5 m and 65 billion m^3 in 2000. The lake inundation areas are significantly different, from around 13,000 km^2 in 1998 to 5,500 km^2 in 2000.

Considering the important findings of the MRC Fishery Program that the floodplains in Cambodia are very productive for young fishes for growing and migration and thus fish productivity has a close relation with the extent of floodplain inundation, the drastic drop of fish catch in Cambodia is very likely to occur. In this sense, the drought in 1998 might be of an exceptional historically severe drought stipulated in Article 6.

5.4.5 Paddy Production in the Mekong Delta

As mentioned in subsection 5.4.3, in 1999 the salinity intrusion in the Mekong Delta was more significant than in normal years. The likely impact of serious salinity intrusion might be paddy production that is of predominant economic activity in the delta. Irrigation sector is the largest water user in the delta. Historic paddy yield by province in the delta is available in the statistical book in Vietnam as presented below.

Table 5.16 Annual Yield of Paddy by Province in the Mekong Delta

(Unit: 100 kg/ha)

Province	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Long An	26.9	30.4	29.6	30.3	33.3	28.7	31.1	25.3	29.4	31.0	31.2	31.8	33.1	35.0	34.5	34.7
Dong Thap	30.5	32.4	32.3	39.0	43.4	45.5	40.4	44.9	41.2	44.9	44.8	44.0	47.0	45.7	46.9	46.0
An Giang	32.0	32.8	34.1	37.3	44.1	45.5	43.9	48.7	49.4	47.6	48.3	47.3	47.7	47.6	45.4	46.9
Tien Giang	39.3	38.0	35.0	37.5	39.7	40.5	38.6	41.7	44.4	44.0	44.2	43.8	45.7	46.9	45.6	46.1
Vinh Long	34.4	37.0	35.4	39.3	40.1	41.9	44.6	41.1	42.5	47.5	41.8	42.2	44.1	42.4	43.1	44.5
Ben Tre	33.8	34.7	31.8	32.5	32.7	33.0	33.7	32.1	33.6	34.6	34.4	36.1	32.3	33.6	32.3	35.2
Kien Giang	26.7	27.4	26.1	29.2	30.8	31.8	31.3	31.8	32.3	33.6	38.5	37.8	38.5	37.6	39.4	42.2
Can Tho	28.0	28.0	24.6	30.8	37.0	37.1	37.4	40.2	34.8	42.4	42.6	44.4	44.0	43.7	42.4	45.6
Tra Vinh	26.4	28.5	27.2	30.2	30.9	32.2	34.3	31.6	25.1	37.3	38.2	42.6	35.5	35.4	36.1	40.1
Soc Trang	35.1	30.7	28.1	28.8	31.3	31.9	33.3	34.1	28.4	36.9	39.5	35.9	35.7	40.2	42.3	43.7
Bac Lieu	31.7	30.6	26.1	34.3	38.7	38.4	43.4	41.8	45.6	43.2	38.0	39.7	34.0	39.7	38.4	40.3
Ca Mau	22.3	22.2	18.7	24.4	27.4	27.8	31.1	30.6	32.2	31.5	28.4	29.7	24.9	30.7	33.3	36.4
Average	30.6	31.1	29.1	32.8	35.8	36.2	36.9	37.0	36.6	39.5	39.2	39.6	38.5	39.9	40.0	41.8

Note: Data of 2000 is "Preliminary estimate" taken from "Socio-Economic Statistical Data of 61 Provinces and Cities in Vietnam General Statistical Office" (Statistical Publishing House)

Source: Vietnam 1975-2000, Statistical Data of Vietnam, Agriculture, Forestry and Fishery 1975-2000, General Statistical Office, Department of Agriculture, Forestry and Fishery (Statistical Publishing House)

As shown above, no significant drop of paddy yield is observed in 1999 in all the twelve provinces in the Mekong Delta. The unit paddy yield in each province has been steadily increasing. However although this increase does not always means that no drought damages had occurred in the delta area, it might be most likely that the existing irrigation projects in the Mekong Delta have effectively managed the Mekong water to cope with the prolonged salinity intrusion.

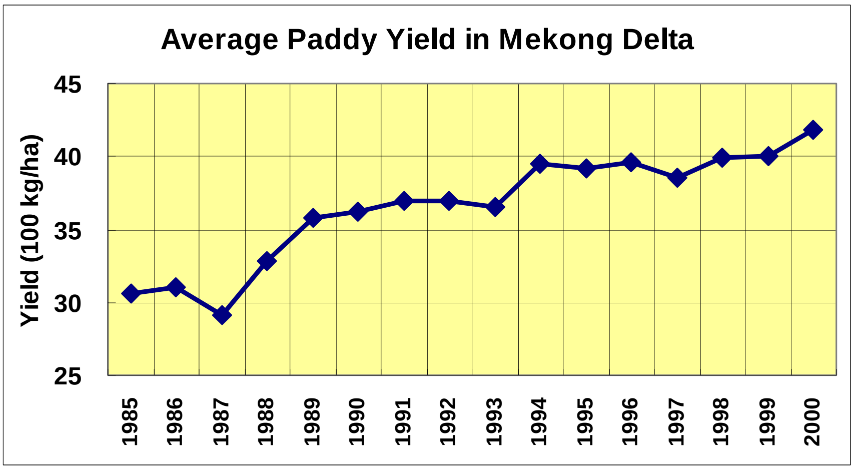


Fig. 5.26 Annual Average Paddy Yield in the Mekong Delta

5.5 Preliminary Flow Contribution Analysis in the Mekong Delta under the Current Study

Under the current study, mathematical modelling for the hydraulics of the rivers, lake and flood plain system in Cambodia was undertaken. A one-dimensional river and floodplain model (MIKE11) has been established for the Cambodian part of the Mekong Delta including the Mekong mainstream, Bassac River, Tonle Sap River and Great Lake. The model covers the Mekong River from Kratie in Cambodia to both Tan Chau in Vietnam and Chau Doc on the Bassac River in Vietnam. Model calibration and verification made and the analysis results are detailed in the separate report of the current study. By use of the simulated flow conditions (7 year period in 1995-2001) at various locations on the Mekong River system, flow contribution analysis is made to clarify the flow contribution in the dry season inflow into the Mekong Delta in Vietnam. Fig. 5.27 below shows the location map of the flow conditions computed by the hydraulic model simulation. The computed daily discharges from the model simulation are graphically presented in Fig. 5.28. It should be noted that the model calibration is made with the focus of best fitting to the observed flood water levels (discharge measurement in the low flow stages is poor). Flow distribution herein is thus of preliminary nature.

5.5.1 Flow Contribution of Discharge Upstream of Phnom Penh

The Tonle Sap River joins the Mekong River at Phnom Penh in Cambodia. In the dry season the stored water in the Great Lake is gradually naturally released into the Mekong mainstream through the Tonle Sap River. Flow contribution of the dry season discharges just upstream of the confluence was evaluated in terms of the simulated discharges at Chrui Changvar on the Mekong and Phnom Penh Port on the Tonle Sap. The discharge upstream of Phnom Penh is estimated by means of the sum of discharges at both two locations. Fig. 5.29 in the next page shows the comparison of the computed daily discharges as well as the estimated discharge upstream Phnom Penh. Table 5.17 presents the results of flow contribution analysis and summarized in Table 5.18 in the next page.

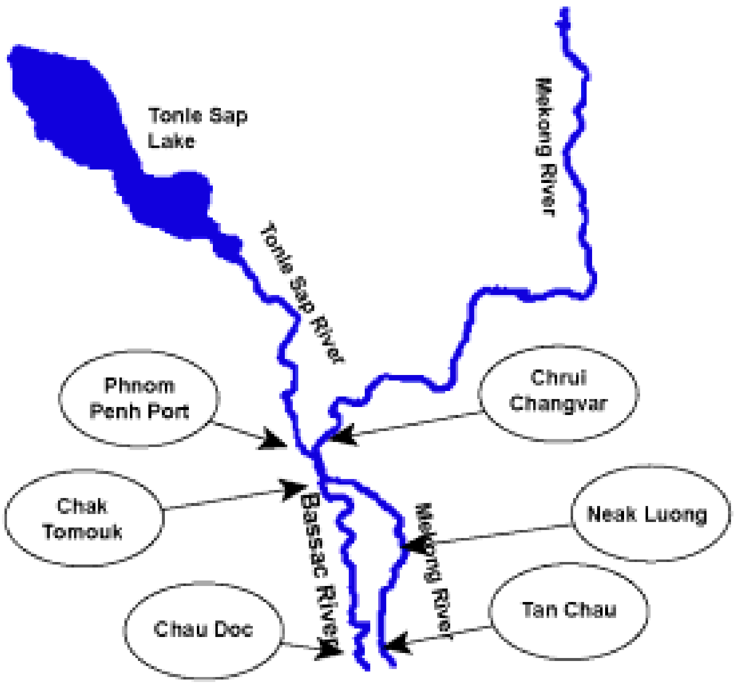


Fig. 5.27 Location of Points of Discharge Computation for Flow Contribution Analysis

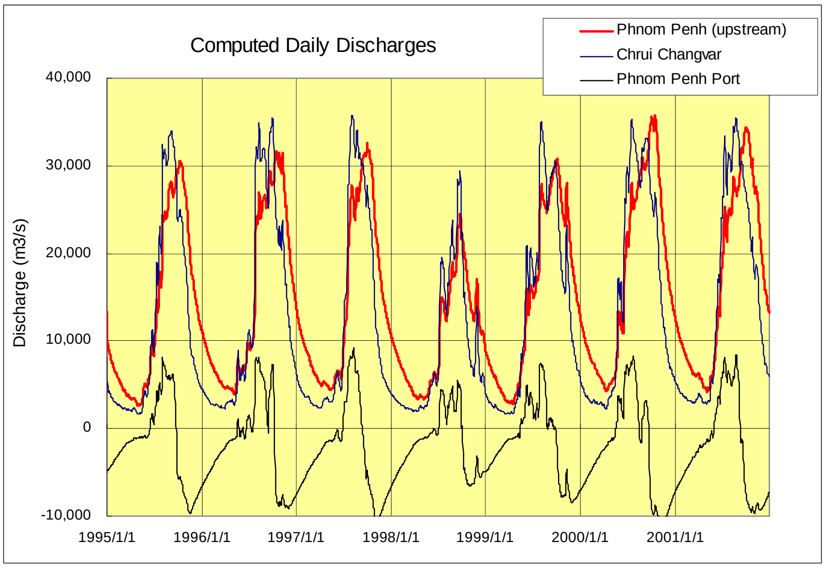


Fig. 5.29 Comparison of Computed Discharges just Upstream of the Confluence at Phnom Penh

Table 5.18 Summary of Flow Contribution Upstream of Phnom Penh

(Unit: %)

Month	Chrui Changvar (Mekong)	Phnom Penh Port (Tonle Sap)
Jan	41.5	58.5
Feb	42.2	57.8
Mar	48.8	51.2
April	62.8	37.2
May	86.4	13.6

Source: WUP-JICA Study Team

In April when the Mekong flow becomes the lowest, flow contribution of discharge at Phnom Penh is around 60% from the Mekong River and 40% from the Tonle Sap River. The Great Lake functions apparently as a natural seasonal regulation reservoir.

5.5.2 Flow Distribution of Discharge Downstream of Phnom Penh

At the confluence of the Tonle Sap River, the Mekong River bifurcates two rivers; the Mekong mainstream and the Bassac River. Flow distribution in the dry season is estimated in terms of the computed flows at Kon Norea on the Mekong and Chak Tomuk on the Bassac. The simulated results are shown in Fig. 5.30 below. Table 5.19 presents the analysis results and summarised in Table 5.20.

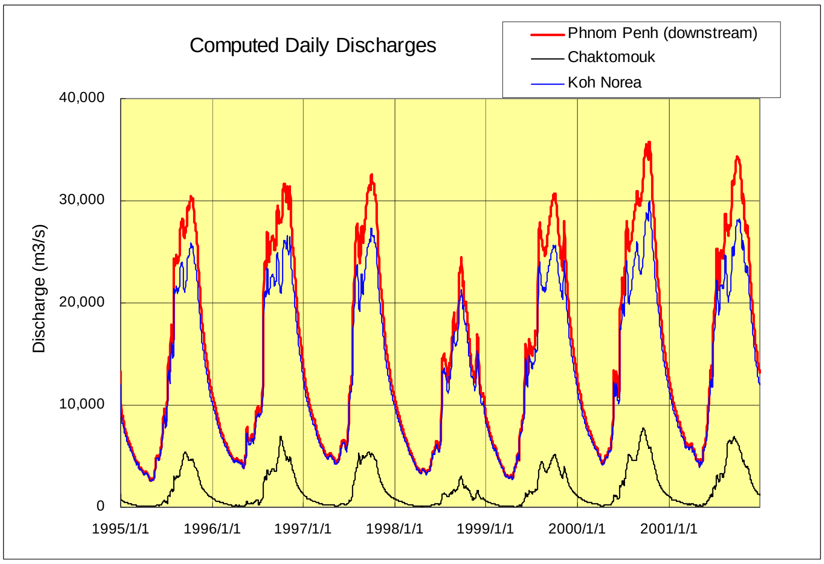


Fig. 5.30 Comparison of Computed Discharges just Downstream of the Confluence at Phnom Penh

As seen above, most of the dry-season Mekong flows at Phnom Penh are delivered to the Mekong River. The ratio distributed to the Bassac River is around 4-7% of the total discharge at Phnom Penh.

Table 5.20 Summary of Flow Distribution Downstream of Phnom Penh

(Unit: %)

Month	Koh Norea (Mekong)	Chak Tomuk (Bassac)
Jan	92.7	7.3
Feb	94.2	5.8
Mar	95.8	4.2
April	96.8	3.2
May	95.7	4.3

Source: WUP-JICA Study Team

5.5.3 Flow Distribution of Mekong Inflow into Vietnam

The Mekong River enters Vietnam from Cambodia via two major rivers; the Mekong and Bassac. Flow distribution of two rivers is evaluated by use of the computed discharges at Tan Chau on the Mekong and Chau Doc on the Bassac. Fig. 5.31 below shows the comparison of daily discharges at both locations. Table 5.21 presents the results of flow contribution analysis and summarized below.

Table 5.22 Summary of Flow Distribution of Inflow into the Mekong Delta in Vietnam

(Unit: %)

Month	Tan Chau (Mekong)	Chau Doc (Bassac)
Jan	92.4	7.6
Feb	94.0	6.0
Mar	95.6	4.4
April	96.5	3.5
May	95.4	4.6

Source: WUP-JICA Study Team

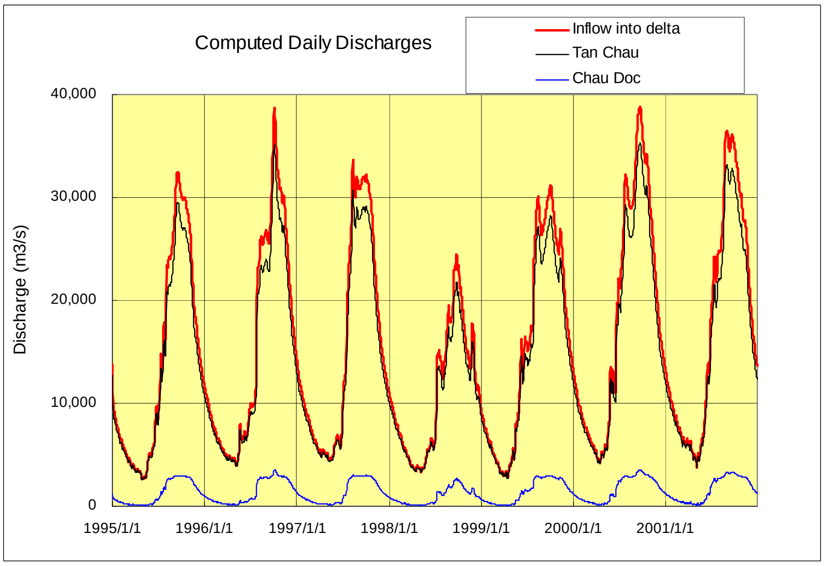


Fig. 5.31 Comparison of Computed Discharges Flowing into the Mekong Delta in Vietnam

Almost the same flow distribution is seen as the distribution at the bifurcation point at Phnom Penh where the Mekong splits into two rivers, the Mekong and Bassac. The volume of flow delivered into the Mekong Delta in Vietnam through the Mekong mainstream in the dry season is around 93-97% of the total inflow into Vietnam.

5.5.4 Flow Contribution of Colmatage Outflow into Mekong River

Along the river banks of Bassac and Mekong, there are field reservoirs called colmatage where in the wet season the flood waters are stored for recession cropping because the low lying alluvial soils associated with cropping are usually more fertile. In the dry season, the stored water is hydraulically discharged into both rivers. The colmatage system largely relies on water levels of Bassac and Mekong Rivers. The flow contribution rate of water release from the existing colmatages to the total Mekong flow into Vietnam is roughly estimated in terms of the difference between the estimated mean discharge at Phnom Penh and the total Mekong discharge into Vietnam. The results are given in Table 5.23 and summarized below.

Table 5.24 Summary of Flow Contribution of Colmatage Outflow into the Mekong River

Month	Mean Mekong Inflow into Vietnam (m3/s)	Mean Colmatage Outflow (m3/s)	Contribution Rate (%)
Jan	9,921	336	3.4
Feb	7,144	196	2.8
Mar	5,249	143	2.8
April	4,360	106	2.5
May	5,605	72	1.3

Source: WUP-JICA Study Team

As seen above, the flow contribution of colmatages to the dry-season Mekong flow is around 2-3%.

6. PRELIMINARY FLOW REGIME ANALYSIS OF MEKONG DISCHARGES

6.1 Selected Hydrological Stations for Flow Regime Analysis on the Mekong Mainstream

Locations of key hydrological stations on the Mekong mainstream are shown on the figure below.

Fig. 6.1 Selected Hydrologic Stations for Flow Regime Analysis on the Mekong Mainstream

Table below shows the availability of monthly mean discharges at these stations.

Table 6.1 Availability of Monthly Mean Discharge Data at Selected Hydrological Stations on the Mekong Mainstream

No.	Station	Country	Availability of Monthly Data																																							
			61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01
1	Chiang Saen	Thailand	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O			
2	Luang Prabang	Lao PDR	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	
3	Chiang Khan	Thailand								O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O			
4	Vientiane	Lao PDR	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	
5	Nong Khai	Thailand										O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O			
6	Nakhon Phanom	Thailand	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O			
7	Mukdahan	Thailand	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O			
8	Khong Chiam	Thailand						O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O		O	O	O	O	O	O	O	O	O	O			
9	Pakse	Lao PDR	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	
10	Stung Treng	Cambodia	O	O	O	O	O	O	O	O	O	O																					O	O	O	O	O		O	O			
11	Kratie	Cambodia	O	O	O	O	O	O	O	O	O	O																															
12	Kompong Cham	Cambodia				O	O	O	O	O	O	O	O	O	O	O																											
13	Chroui Changvar	Cambodia	O	O	O	O	O	O	O	O	O	O	O	O																													
14	Tan Chau	Vietnam																																					O	O	O	O	O
15	Chau Doc	Vietnam																																					O	O	O	O	O

Source: WUP-JICA Study Team

Discharge records at stations downstream in the Mekong floodplain from Kompong Cham to Chroui Changgvar are of limited availability in recent years due to hydraulic complexity and tidal effects. Totally 11 stations have been selected for flow regime analysis as listed below.

Table 6.2 Selected Hydrological Stations for Flow Regime Analysis

No.	Station Name	Classification	Drainage Area (km²)
1	Chiang Saen	Key	189,000
2	Luang Prabang	Key	268,000
3	Chiang Khan	Key	292,000
4	Vientiane	Primary	299,000
5	Nong Khai	Key	302,000
6	Nakhon Phanom	Key	373,000
7	Mukdahan	Key	391,000
8	Khon Chiam	Key	419,000
9	Pakse	Key	545,000
10	Tan Chau	Key	-
11	Chau Doc	Key	-

Note: Drainage area at theCambpdia- Vietnam border into the Mekong Delta (Tan Chau plus Chau Doc) is around 756,000 km^2.

Source: WUP-JICA Study Team

The available data periods at Stung Treng, Kratie, Kompong Cham and Chrui Changvar are not sufficient for statistical (frequency) analysis. At Tan Chau and Chau Doc, records for only 5 years in 1997-2001 are available. However, mean daily water levels at both stations are available from 1980 in the HYMOS database at MRC. As detailed in the succeeding Section 6.2, discharge gap filling is made for both stations by means of the generated daily mean discharges.

6.2 Gap Filling of Discharge Data at Tan Chau and Chau Doc

6.2.1 Observed Discharges at Tan Chau and Chau Doc

The observed hourly water level and discharge records at Tan Chau and Chau Doc stations for the period of 1997-2001 have been newly obtained around the end of 2002 with the kind arrangement of the Vietnam National Mekong Committee. These data are very valuable for evaluating the drought conditions in the Mekong Delta in recent years and, further, for the preliminary trial searching of the maintenance flows in the Mekong Delta. The observed hourly discharges at both two stations are computed to the daily mean discharge tables as presented in Tables 6.3 and 6.4, and summarized below.

Table 6.5 Monthly Mean Discharges at Tan Chau and Chau Doc (1997-2001)

Tan Chau (1997-2001)

(Unit: m3/s)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1997	8,135	5,334	3,228	2,626	2,711	4,173	12,664	21,841	22,353	21,624	15,925	8,438	**10,754**
1998	5,863	3,437	1,800	1,461	1,984	3,830	8,056	11,989	15,125	14,669	10,254	7,435	**7,158**
1999	4,164	2,614	1,497	1,748	4,684	9,635	12,478	20,784	21,132	20,769	18,700	14,063	**11,022**
2000	6,617	4,480	3,208	2,800	5,325	14,064	22,430	20,988	22,365	19,399	12,947	10,111	**12,061**
2001	7,279	4,792	3,386	2,767	3,138	9,344	15,439	20,258	22,625	19,930	17,154	11,886	**11,500**
Mean	**6,411**	**4,132**	**2,624**	**2,280**	**3,569**	**8,209**	**14,213**	**19,172**	**20,720**	**19,278**	**14,996**	**10,386**	**10,499**

Chau Doc (1997-2001)

(Unit: m3/s)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1997	1,454	1,032	765	609	489	1,356	2,624	3,657	4,676	4,344	3,437	2,258	**2,225**
1998	1,190	683	425	359	442	811	1,994	2,837	3,647	4,115	3,021	2,206	**1,811**
1999	1,036	576	356	443	1,185	2,770	3,379	5,252	5,548	5,784	4,888	3,252	**2,872**
2000	1,859	1,043	698	607	1,259	2,588	5,113	6,444	7,258	5,948	4,174	2,771	**3,313**
2001	1,824	980	650	528	590	1,983	4,007	5,583	7,001	6,262	4,988	3,069	**3,122**
Mean	**1,472**	**863**	**579**	**509**	**793**	**1,902**	**3,424**	**4,754**	**5,626**	**5,291**	**4,102**	**2,711**	**2,669**

Tan Chau + Chau Doc (1997-2001)

(Unit: m3/s)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1997	9,588	6,366	3,993	3,235	3,200	5,530	15,288	25,498	27,029	25,968	19,362	10,696	**12,979**
1998	7,052	4,120	2,225	1,820	2,426	4,641	10,050	14,826	18,771	18,783	13,275	9,640	**8,969**
1999	5,200	3,191	1,853	2,191	5,869	12,405	15,857	26,036	26,680	26,554	23,588	17,315	**13,895**
2000	8,476	5,523	3,906	3,407	6,583	16,652	27,543	27,432	29,624	25,347	17,120	12,882	**15,375**
2001	9,102	5,773	4,037	3,295	3,728	11,326	19,446	25,840	29,626	26,192	22,142	14,955	**14,622**
Mean	**7,884**	**4,995**	**3,203**	**2,789**	**4,361**	**10,111**	**17,637**	**23,926**	**26,346**	**24,569**	**19,097**	**13,097**	**13,168**

Source: Vietnam National Mekong Committee

As seen above, the total mean annual inflow into the Mekong Delta (sum of discharges of both Tan Chau and Chau Doc) is around 13,200 m^3/s. The mean monthly inflow varies from around 2,800 m^3/s in April to 26,300 m^3/s in September. Figs. 6.2 to 6.5 present the hourly discharge and water level hydrographs at both stations in 1998.

Flow distributions in the dry season are estimated based on the mean monthly discharges as given in Table 6.6. Flow distribution between Tan Chau and Chau Doc is almost constant in the dry season. The Bassac River delivers the flow volume of around 18% of the total inflow into Vietnam.

Table 6.6 Flow Distribution of Inflow into the Mekong Delta in Vietnam

(Unit: %)

Month	Tan Chau (Mekong)	Chau Doc (Bassac)
Jan	81.3	18.7
Feb	82.7	17.3
Mar	81.9	18.1
April	81.7	18.3
May	81.8	18.2

Source: WUP-JICA Study Team

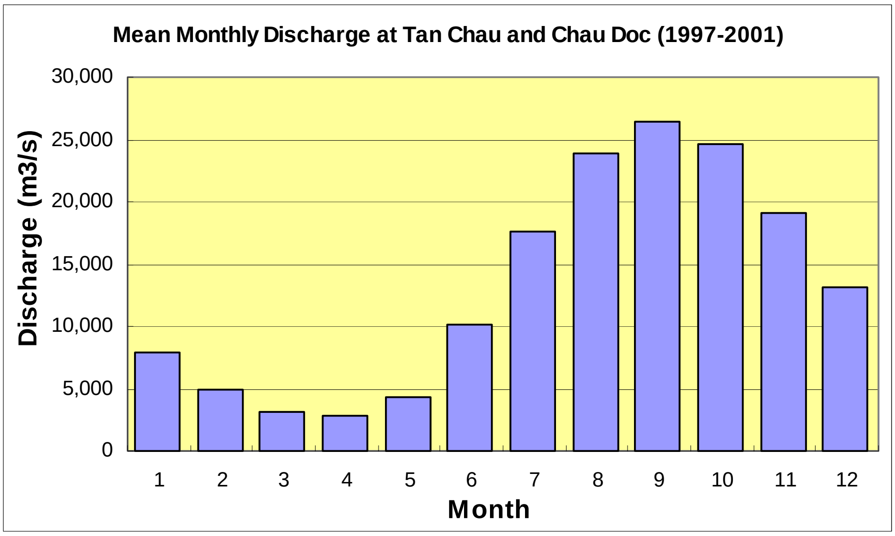
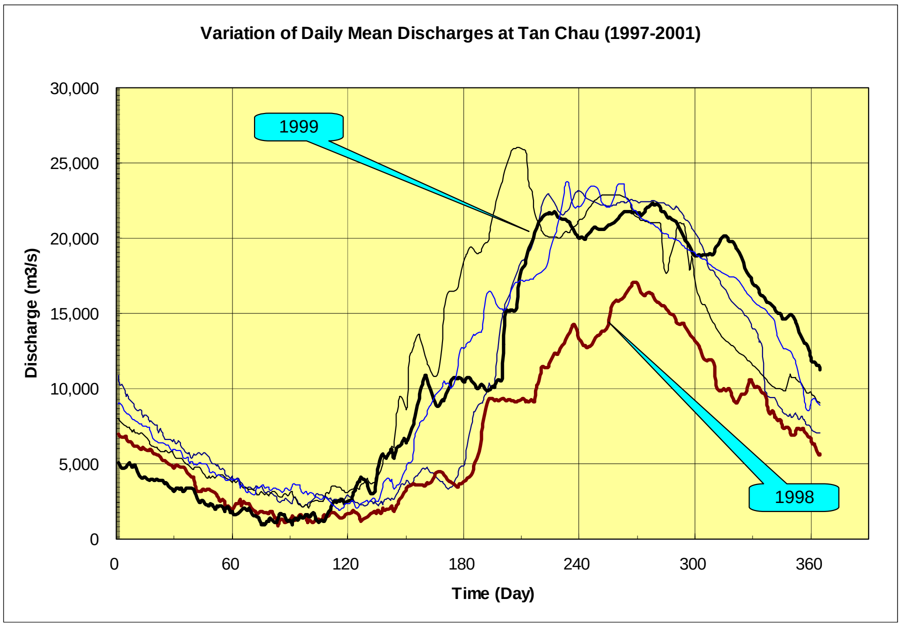


Fig. 6.6 Mean Monthly Discharge Distribution Flowing into the Mekong Delta

6.2.2 Droughts both in 1998 and 1999 in the Mekong Delta

As discussed in Section 5.4, the maximum water levels in 1998 at Kratie, Tan Chau and Chau Doc are lowest compared to those in normal years. As a result, severe drought occurred in the next dry season in 1999 due to the drastic decrease of maximum water levels in the Great Lake (more than 2.5 m lower than the maximum water levels in normal years).

Further, it appeared from the comparison of daily mean water levels in the dry season at Tan Chau and Chau Doc as given in Fig. 6.7 below that the dry season in 1998 was also of drought. This drought is due to the fact that the delay of beginning of water level rising (that is, the delay of coming of the south-west monsoon, synonymous with beginning of the wet season, that delivers most of rainfall to the Mekong River Basin).



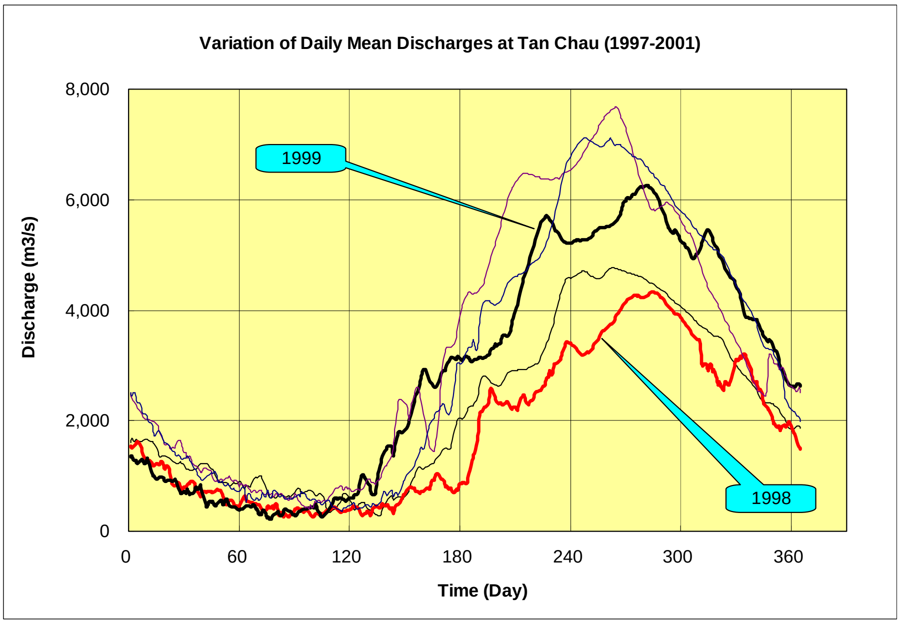
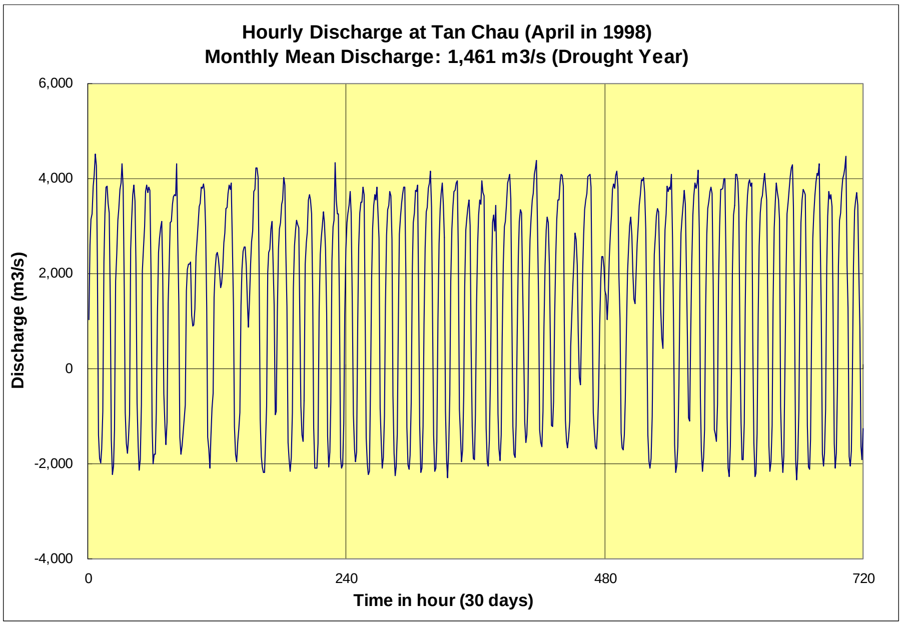


Fig. 6.7 Comparison of Daily Mean Discharges at Tan Chau and Chau Doc (1997-2001)

As seen above, discharges at both stations in 1998 started to rise only towards the end of June, although normally around the beginning of May. The monthly mean discharges at Tan Chau were then around 2,000 m^3/s in May and 3,800 m^3/s in June, which are extremely low compared to the mean monthly discharges of 3,600 m^3/s in May and 8,200 m^3/s in June.

The monthly mean discharge in April 1998 at Tan Chau was also the lowest, as small as 1,460 m^3/s compared with the mean monthly discharge of 2,280 m^3/s. Significant drops of discharges are observed from January to April in 1998, although the foregoing wet season in 1997 seemed to be normal (the annual mean discharge in 1997 was 10,750 m^3/s almost as same as the mean annual discharge of 10,500 m^3/s). This hydrological behavior were thus subject to examination and clarification in the later stage of the current study considering that the projection of drought condition would be of great importance in establishing the future basin-wide water utilization monitoring framework.

Both figures below present the comparison of hourly discharges and water levels in April at Tan Chau in both drought (1998) and normal (2000) years.



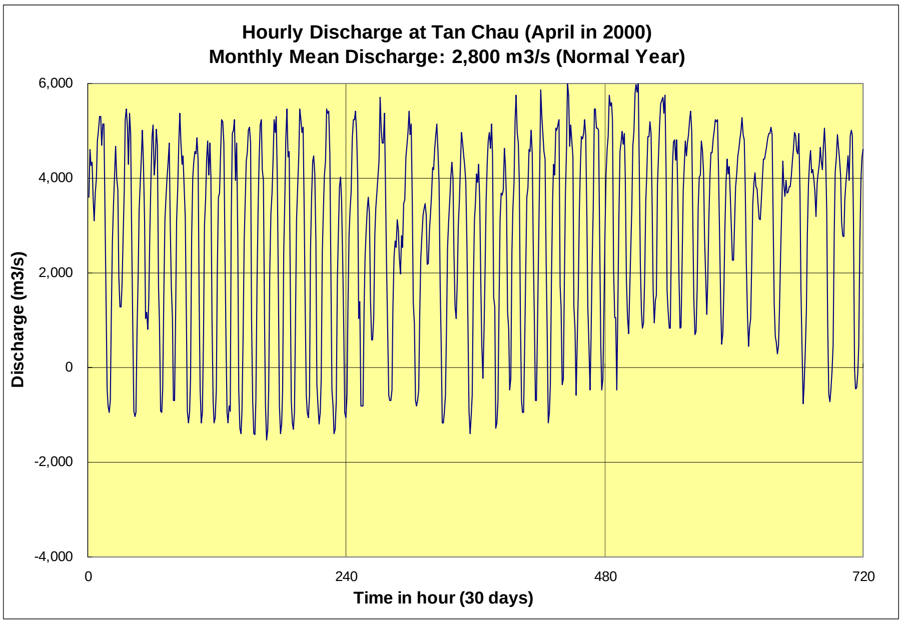
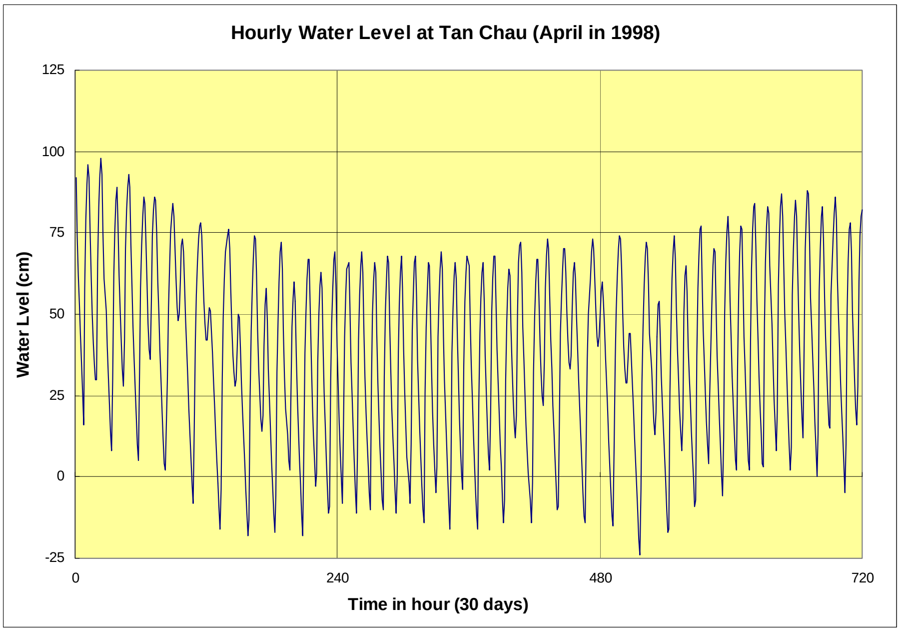


Fig. 6.8 Comparison of Hourly Discharges at Tan Chau in April in Drought and Normal Years



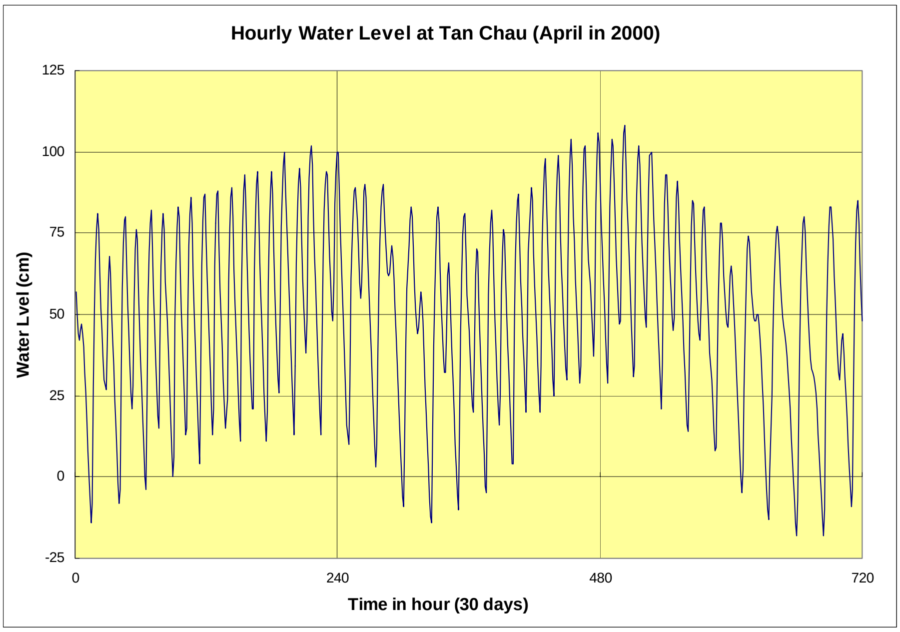


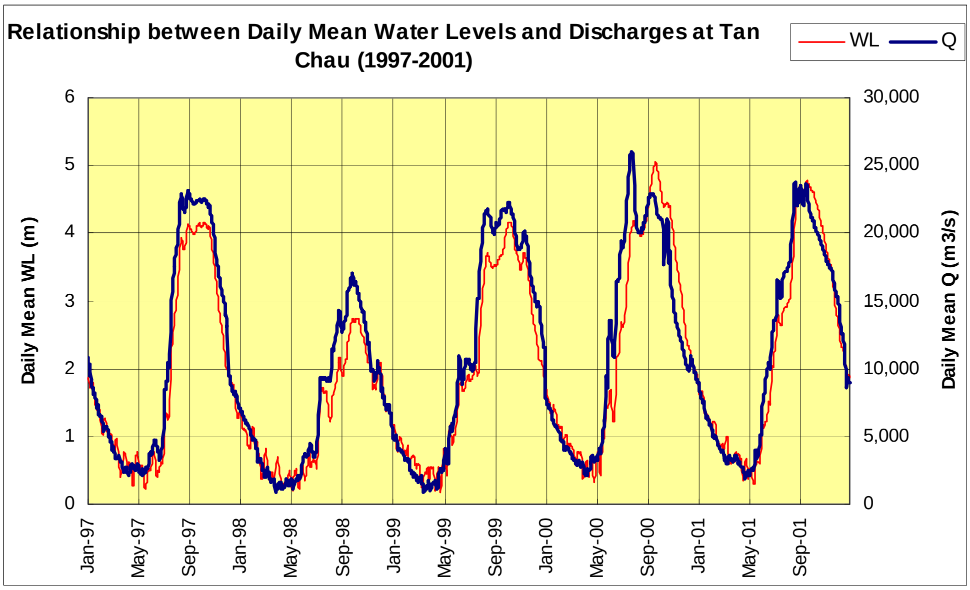
Fig. 6.9 Comparison of Hourly Water Levels at Tan Chau in April in Drought and Normal Years

As compared above, hourly fluctuations of water level and discharges at Tan Chau are almost the same in both the drought and normal years, although mean water level and discharge dropped significantly in the drought year of 1998. It can be said that variation ranges due to tidal effects are almost constant in both the drought and normal years.

6.2.3 Gap Filling of Daily Mean Discharges at Tan Chau and Chau Doc

Observed hourly discharge data at Tan Chau and Chau Doc are available only in 5 years, 1997-2001. This available data period is not sufficient for statistical analysis on evaluation of droughts in 1998 and 1999. As mentioned in Section 5.1, mean daily water levels at both stations from 1980 are available in the HYMOS database at MRC.

Simple linear regression method was applied to generate the daily mean discharges at Tan Chau and Chau Doc based on the correlation between the daily mean water level and the daily mean discharge. The correlation analysis was made dividing into the dry and wet seasons. Consequently the water levels above 2.0 m and below 2.0 m showed higher correlation coefficients. Results of analyses are as follows:



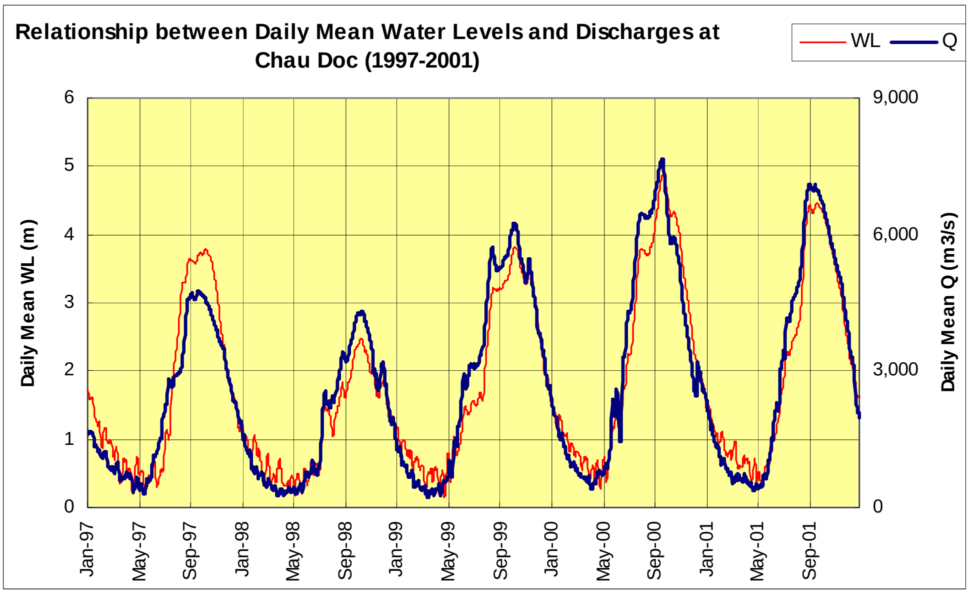
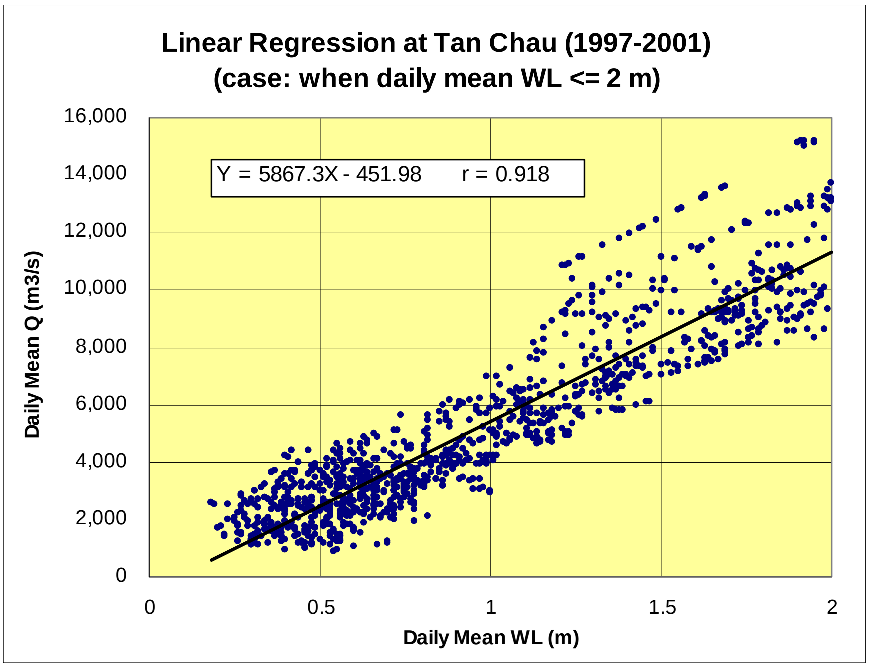


Fig. 6.10 Relationship between Daily Mean Water Levels and Discharges at Tan Chau and Chau Doc



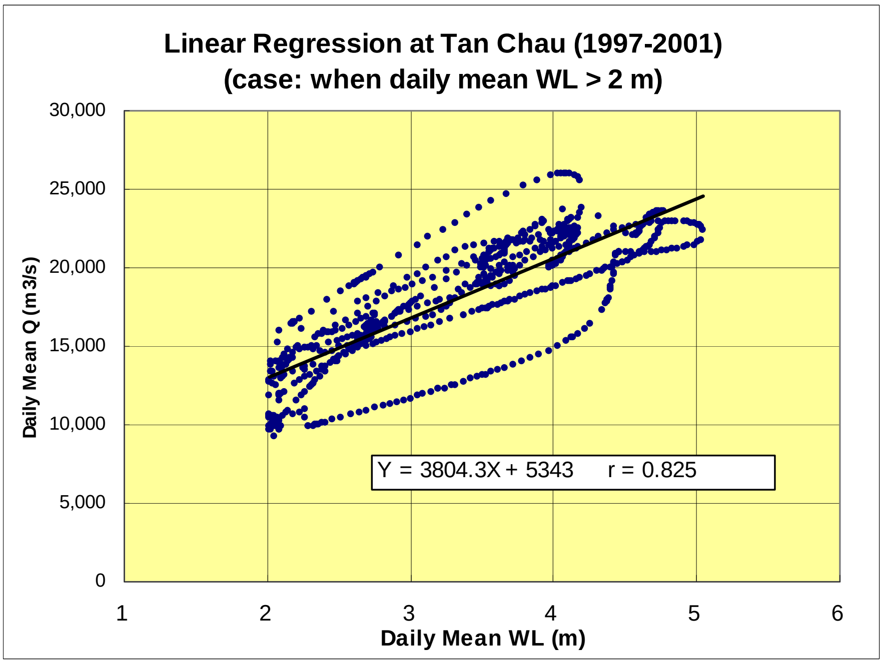
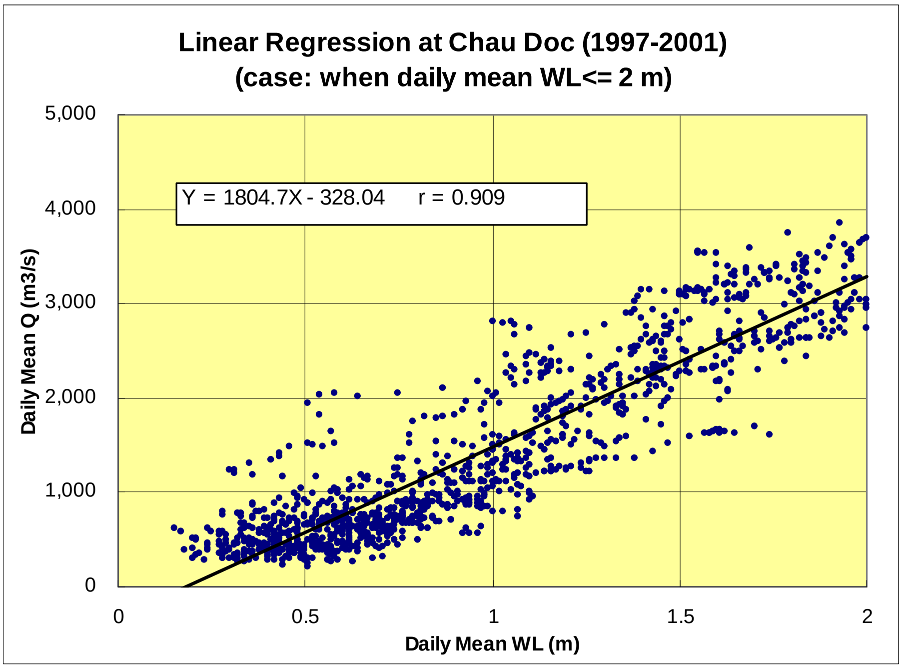


Fig. 6.11 Linear Regression Analysis at Tan Chau



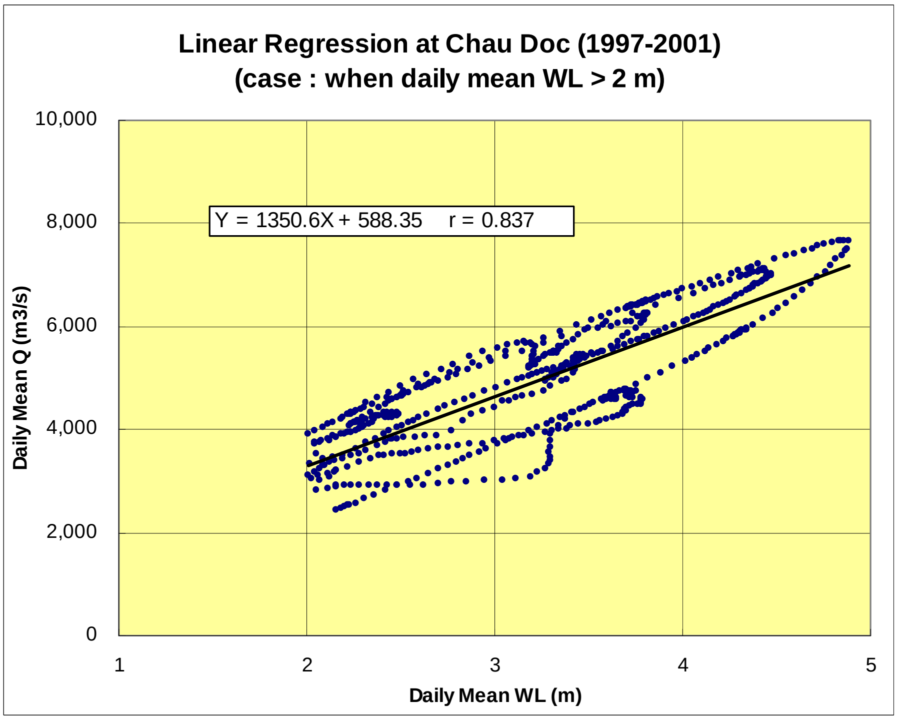


Fig. 6.12 Linear Regression Analysis at Chau Doc

As seen above, all correlation coefficients were found sufficient enough (>0.8). Thus the simple linear regression method was applied. It should be noted however that this generation of daily mean discharge is of preliminary tentative estimate, because the observed hourly water level and discharge data at Tan Chau and Chau Doc before 1996 (preferably from 1980) might be available at the concerned agency in Vietnam i.e., the required data might be obtained through cooperation of the Vietnam National Mekong Committee in Hanoi.

The daily mean discharges were thus generated at both stations by means of linear regression method. Tables below present the estimated monthly mean discharges at both stations.

Table 6.7 Estimated Monthly Mean Discharges at Tan Chau

(Unit: m3/s)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1980	5,886	4,575	3,108	2,761	2,956	5,751	11,452	16,172	21,044	22,128	19,255	13,703
1981	7,915	6,291	4,357	2,511	3,397	11,423	17,466	21,143	20,742	19,205	16,829	12,207
1982	7,586	4,983	3,715	3,942	3,675	4,949	9,676	15,838	20,486	21,437	17,467	13,387
1983	7,354	4,533	3,704	3,052	2,922	3,733	7,234	14,459	17,821	20,166	19,241	14,732
1984	9,210	6,687	4,645	3,236	4,096	6,811	14,205	19,360	23,238	21,264	17,903	12,292
1985	7,686	5,819	4,737	3,187	4,328	7,825	14,706	17,714	20,785	20,614	16,721	12,913
1986	8,017	5,615	4,010	2,933	3,821	7,578	11,707	17,787	20,612	19,805	16,622	11,442
1987	7,217	4,726	3,274	2,784	2,103	3,580	10,389	12,420	19,063	18,553	15,064	10,731
1988	6,512	4,911	3,426	3,105	2,924	6,109	7,362	14,746	15,812	16,822	15,174	8,805
1989	5,878	3,669	2,826	1,971	2,392	5,863	8,580	16,525	17,908	18,788	15,868	9,456
1990	6,584	4,470	3,933	2,818	2,994	9,610	14,143	17,736	20,558	21,417	18,337	12,938
1991	8,300	5,895	4,270	3,577	3,188	4,092	9,916	16,250	22,817	22,325	18,105	12,211
1992	7,868	5,330	3,581	2,602	2,432	4,108	8,494	15,657	18,413	17,745	14,985	8,557
1993	6,109	4,132	3,388	2,514	2,381	3,997	10,811	15,618	18,150	18,235	14,297	9,488
1994	6,692	4,368	4,394	3,189	2,521	6,636	13,689	19,076	22,388	22,384	16,242	10,729
1995	6,426	4,224	2,860	2,072	1,751	3,666	8,905	16,205	20,679	20,968	17,017	11,394
1996	6,965	4,966	2,818	2,667	3,250	4,703	8,242	16,892	19,335	22,391	19,541	14,731
1997	8,134	5,334	3,228	2,625	2,711	4,173	12,664	21,840	22,352	21,624	15,924	8,438
1998	5,862	3,436	1,799	1,460	1,984	3,830	8,056	11,988	15,124	14,668	10,254	7,434
1999	4,163	2,614	1,497	1,748	4,684	9,635	12,477	20,784	21,132	20,769	18,700	14,062
2000	6,617	4,491	3,208	2,800	5,325	14,064	22,430	20,988	22,365	19,399	12,946	10,110
2001	7,278	4,792	3,386	2,766	3,138	9,343	15,439	20,257	22,624	19,929	17,153	11,885
Mean	**7,012**	**4,812**	**3,462**	**2,742**	**3,135**	**6,431**	**11,729**	**17,248**	**20,157**	**20,029**	**16,529**	**11,438**

Note: Monthly mean discharges in 1980-1996 are based on the estimated daily mean discharges.
Source: WUP-JICA Study Team

Table 6.8 Estimated Monthly Mean Discharges at Chau Doc

(Unit: m3/s)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1980	1,173	871	458	366	359	970	2,094	3,267	4,896	5,851	4,917	3,192
1981	1,841	1,274	779	418	609	2,159	3,601	4,889	5,539	5,100	4,402	3,101
1982	1,766	1,118	658	704	485	727	2,093	3,009	4,705	5,446	4,287	2,615
1983	1,611	832	603	353	290	427	1,264	2,795	3,820	4,817	4,888	3,316
1984	1,947	1,255	585	344	611	1,164	2,532	4,081	6,210	5,546	4,430	2,794
1985	1,583	1,149	967	502	746	1,403	2,948	3,755	5,143	5,463	4,161	2,968
1986	1,783	1,140	775	490	601	1,413	2,260	3,799	5,079	5,132	4,080	2,564
1987	1,593	964	552	475	268	576	1,916	2,453	4,388	4,622	3,540	2,389
1988	1,414	1,031	689	545	426	1,134	1,481	3,028	3,458	3,849	3,567	2,029
1989	1,377	913	662	301	311	1,101	1,665	3,414	4,088	4,648	3,934	2,262
1990	1,534	955	807	469	481	1,750	2,721	3,815	5,111	5,722	4,815	3,098
1991	1,872	1,208	760	568	461	710	2,252	3,901	5,993	5,836	4,491	2,810
1992	1,717	1,056	639	356	289	675	1,682	3,207	4,307	4,372	3,567	1,938
1993	1,303	808	636	342	329	725	2,198	3,393	4,348	4,640	3,456	2,277
1994	1,428	787	794	461	277	1,412	3,224	4,801	5,856	5,854	3,890	2,441
1995	1,526	1,002	588	360	265	718	1,961	3,627	5,279	5,695	4,427	2,812
1996	1,666	1,197	620	561	673	1,018	1,804	3,940	4,922	6,290	5,369	3,823
1997	1,453	1,032	764	608	489	1,356	2,624	3,657	4,676	4,343	3,437	2,257
1998	1,189	683	425	359	441	811	1,994	2,837	3,647	4,114	3,020	2,205
1999	1,036	576	355	442	1,184	2,769	3,379	5,251	5,547	5,784	4,887	3,251
2000	1,859	1,049	698	606	1,258	2,588	5,113	6,444	7,258	5,947	4,173	2,771
2001	1,823	980	650	528	589	1,982	4,007	5,582	7,001	6,262	4,988	3,069
Mean	**1,568**	**995**	**657**	**462**	**520**	**1,254**	**2,492**	**3,861**	**5,058**	**5,242**	**4,215**	**2,726**

Note: Monthly mean discharges in 1980-1996 are based on the estimated daily mean discharges.
Source: WUP-JICA Study Team

Table 6.9 Estimated Monthly Mean Inflow Discharges into the Mekong Delta (Tan Chau plus Chau Doc)

(Unit: m3/s)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1980	7,060	5,446	3,566	3,127	3,316	6,721	13,547	19,440	25,941	27,979	24,172	16,895
1981	9,757	7,565	5,136	2,928	4,006	13,583	21,067	26,032	26,282	24,306	21,231	15,308
1982	9,352	6,102	4,374	4,646	4,161	5,677	11,770	18,847	25,192	26,883	21,754	16,003
1983	8,965	5,366	4,308	3,406	3,213	4,161	8,498	17,255	21,641	24,984	24,129	18,049
1984	11,157	7,943	5,231	3,580	4,707	7,976	16,737	23,441	29,449	26,810	22,334	15,086
1985	9,270	6,969	5,705	3,689	5,074	9,228	17,655	21,469	25,929	26,077	20,883	15,882
1986	9,801	6,756	4,786	3,424	4,423	8,991	13,968	21,587	25,691	24,938	20,702	14,007
1987	8,810	5,690	3,826	3,260	2,371	4,156	12,305	14,874	23,451	23,176	18,604	13,120
1988	7,927	5,942	4,115	3,651	3,351	7,244	8,844	17,774	19,270	20,671	18,742	10,834
1989	7,256	4,583	3,489	2,272	2,703	6,964	10,245	19,939	21,996	23,436	19,802	11,718
1990	8,119	5,425	4,741	3,287	3,475	11,360	16,865	21,551	25,670	27,140	23,152	16,037
1991	10,171	7,104	5,030	4,146	3,649	4,803	12,169	20,151	28,810	28,161	22,597	15,021
1992	9,585	6,386	4,220	2,959	2,722	4,784	10,176	18,865	22,720	22,117	18,553	10,496
1993	7,413	4,941	4,024	2,856	2,710	4,722	13,009	19,011	22,499	22,876	17,753	11,765
1994	8,120	5,155	5,189	3,651	2,798	8,049	16,913	23,877	28,244	28,238	20,132	13,171
1995	7,952	5,227	3,449	2,433	2,016	4,384	10,866	19,833	25,959	26,664	21,444	14,206
1996	8,631	6,163	3,438	3,229	3,923	5,722	10,047	20,832	24,258	28,682	24,910	18,555
1997	9,588	6,366	3,992	3,234	3,200	5,529	15,288	25,497	27,028	25,968	19,362	10,695
1998	7,052	4,120	2,224	1,820	2,426	4,641	10,050	14,825	18,771	18,783	13,274	9,640
1999	5,199	3,190	1,852	2,191	5,868	12,405	15,857	26,035	26,680	26,553	23,588	17,314
2000	8,476	5,540	3,906	3,406	6,583	16,652	27,543	27,431	29,623	25,347	17,120	12,882
2001	9,102	5,772	4,036	3,294	3,728	11,326	19,446	25,840	29,625	26,192	22,142	14,954
Mean	**8,580**	**5,807**	**4,120**	**3,204**	**3,656**	**7,685**	**14,221**	**21,109**	**25,215**	**25,272**	**20,745**	**14,165**

Note: Monthly mean discharges in 1980-1996 are based on the estimated daily mean discharges.
Source: WUP-JICA Study Team

6.2.4 Monthly Mean Discharges of Non-exceedance Probabilities at Tan Chau and Chau Doc

Frequency analysis was made to estimate the monthly mean discharges with several non-exceedance probabilities at Tan Chau and Chau Doc. The analysis results are as follows:

Table 6.10 Monthly Mean Discharges of Non-exceedance Probabilities at Tan Chau

(Unit: m3/s)

Month	Min	10%	20%	30%	40%	50%	60%	70%	80%	90%	Max
Jan	4,163	5,862	5,886	6,426	6,617	6,965	7,278	7,686	7,915	8,134	9,210
Feb	2,614	3,436	4,132	4,368	4,533	4,726	4,911	5,330	5,615	5,895	6,687
Mar	1,497	1,799	2,826	3,108	3,274	3,388	3,581	3,933	4,270	4,394	4,737
Apr	1,460	1,748	2,072	2,514	2,667	2,766	2,800	3,052	3,187	3,236	3,942
May	1,751	1,984	2,381	2,432	2,922	2,956	3,138	3,397	3,821	4,328	5,325
Jun	3,580	3,666	3,830	4,092	4,703	5,751	6,109	7,578	9,343	9,635	14,064
Jul	7,234	7,362	8,242	8,580	9,916	10,811	11,707	13,689	14,205	15,439	22,430
Aug	11,988	12,420	14,746	15,657	16,205	16,525	17,714	19,076	20,257	20,988	21,840
Sep	15,124	15,812	17,908	18,413	20,486	20,612	20,742	21,132	22,365	22,624	23,238
Oct	14,668	16,822	18,235	18,788	19,805	20,166	20,769	21,417	21,624	22,325	22,391
Nov	10,254	12,946	14,985	15,174	16,242	16,721	17,017	17,903	18,337	19,241	19,541
Dec	7,434	8,438	8,805	9,488	10,731	11,442	12,207	12,913	13,387	14,062	14,732

Source: WUP-JICA Study Team

Table 6.11 Monthly Mean Discharges of Non-exceedance Probabilities at Chau Doc

(Unit: m3/s)

Month	Min	10%	20%	30%	40%	50%	60%	70%	80%	90%	Max
Jan	1,036	1,173	1,303	1,414	1,526	1,583	1,611	1,766	1,823	1,859	1,947
Feb	576	683	808	871	964	1,002	1,032	1,118	1,149	1,208	1,274
Mar	355	425	552	588	636	650	662	760	775	794	967
Apr	301	342	353	359	418	461	475	528	561	606	704
May	265	268	289	311	426	461	485	601	611	746	1,258
Jun	427	576	710	725	970	1,101	1,164	1,412	1,750	2,159	2,769
Jul	1,264	1,481	1,682	1,916	2,093	2,198	2,260	2,721	3,224	3,601	5,113
Aug	2,453	2,795	3,009	3,207	3,414	3,657	3,799	3,940	4,801	5,251	6,444
Sep	3,458	3,647	4,088	4,348	4,705	4,922	5,111	5,539	5,856	6,210	7,258
Oct	3,849	4,114	4,372	4,640	5,100	5,446	5,546	5,784	5,851	5,947	6,290
Nov	3,020	3,437	3,540	3,567	4,080	4,173	4,402	4,491	4,887	4,917	5,369
Dec	1,938	2,029	2,257	2,277	2,564	2,771	2,810	3,069	3,101	3,251	3,823

Source: WUP-JICA Study Team

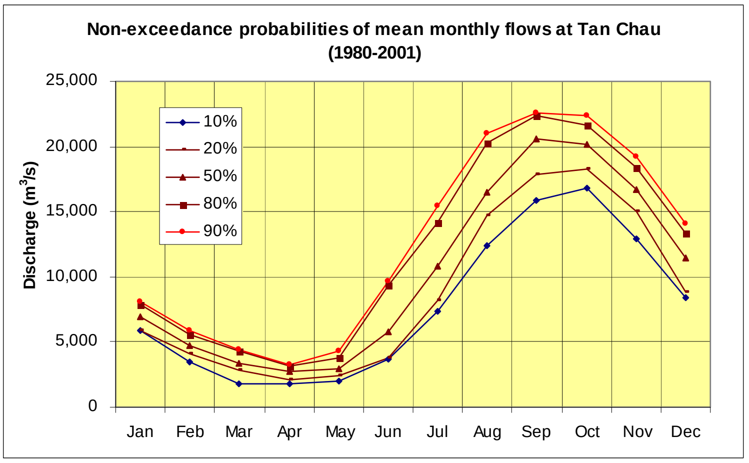
Table 6.12 Monthly Mean Discharges of Mekong Delta Inflow of Non-exceedance Probabilities (Tan Chau plus Chau Doc)

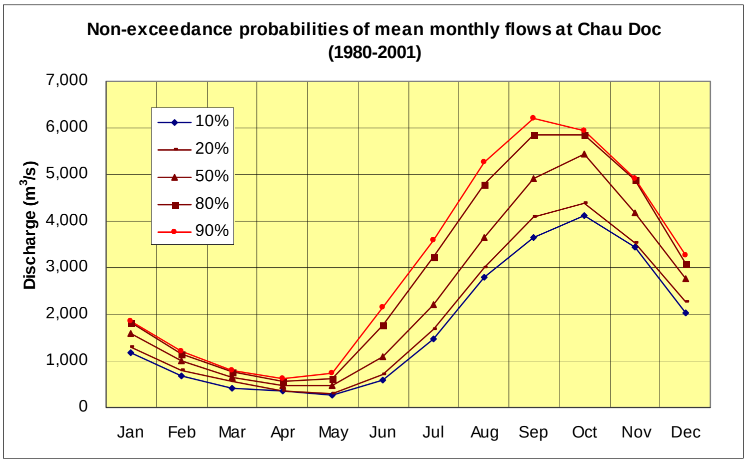
(Unit: m3/s)

Month	Min	10%	20%	30%	40%	50%	60%	70%	80%	90%	Max
Jan	5,199	7,052	7,256	7,927	8,120	8,631	8,965	9,352	9,588	9,801	11,157
Feb	3,190	4,120	4,941	5,227	5,446	5,690	5,942	6,366	6,756	7,104	7,943
Mar	1,852	2,224	3,449	3,566	3,992	4,036	4,220	4,741	5,030	5,189	5,705
Apr	1,820	2,191	2,433	2,928	3,229	3,260	3,294	3,424	3,651	3,689	4,646
May	2,016	2,371	2,703	2,722	3,213	3,351	3,649	4,006	4,423	5,074	6,583
Jun	4,156	4,161	4,641	4,784	5,677	6,721	7,244	8,991	11,326	12,405	16,652
Jul	8,498	8,844	10,050	10,245	12,169	13,009	13,968	16,737	16,913	19,446	27,543
Aug	14,825	14,874	17,774	18,865	19,833	20,151	21,469	23,441	25,497	26,032	27,431
Sep	18,771	19,270	21,996	22,720	25,192	25,691	25,941	26,680	28,244	29,449	29,625
Oct	18,783	20,671	22,876	23,436	24,984	25,968	26,192	26,810	27,140	28,161	28,682
Nov	13,274	17,120	18,553	18,742	20,132	20,883	21,444	22,334	23,152	24,129	24,910
Dec	9,640	10,496	10,834	11,765	13,171	14,206	15,021	15,882	16,037	17,314	18,555

Source: WUP-JICA Study Team

Monthly mean discharges of several non-exceedance probabilities are presented graphically below.





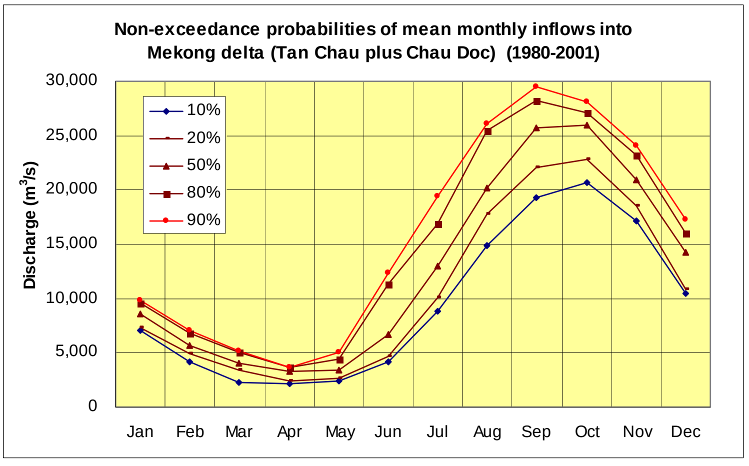


Fig. 6.13 Monthly Mean Discharges of Non-exceedance Probabilities at Tan Chau and Chau Doc

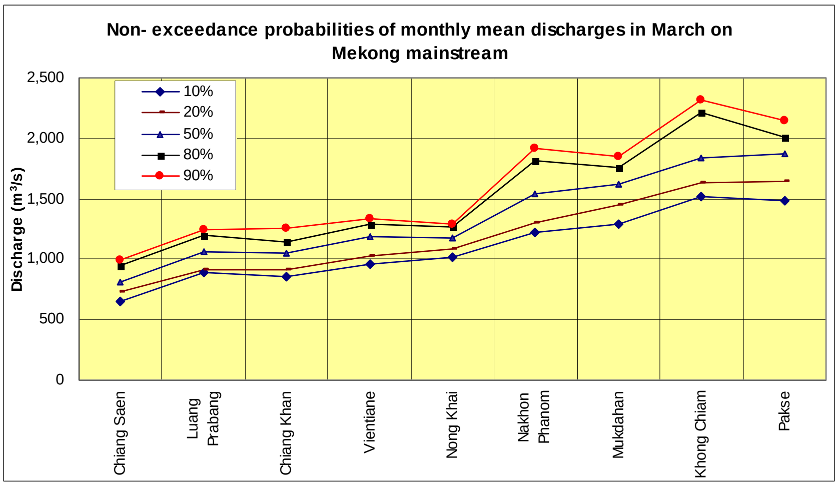
6.3 Flow Regime Analysis on the Mekong Mainstream

6.3.1 Monthly Mean Discharge Records at Hydrologic Stations

Monthly mean discharge records on the Mekong mainstream from Chiang Saen to Pakse are shown in Tables 6.13 to 6.21. These data were retrieved from the HYMOS database system at MRC.

6.3.2 Probable Monthly Mean Drought Discharges at Hydrologic Stations

Probable monthly mean drought discharges were estimated for the nine stations above based on the monthly mean discharge records. Available data at downstream stations from Stung Treng to Chrui Changvar are too short to make statistical analysis. Table 6.22 presents the monthly mean discharges of various non-exceedance probabilities at each station. Fig. 6.14 present the plots of monthly mean discharges of selected non-exceedance probabilities at each station. With the use of these probable discharges, longitudinal distribution of monthly mean discharges of various non-exceedance probabilities were compiled, as given in Table 6.23. Fig. 6.15 presents the longitudinal plots of several probable monthly mean drought discharge distributions by month along the Mekong mainstream. Among them distributions in March and April were picked up as shown below.



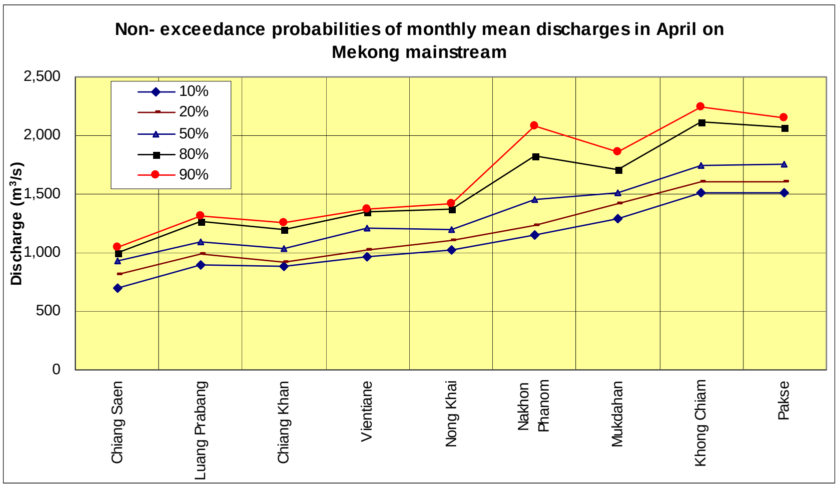


Fig. 6.16 Distribution of Probable Monthly Mean Drought Discharges on the Mekong Mainstream in March and April

6.3.3 Summary of Probable Drought Discharges on the Mekong Mainstream

The 10-year, 5-year and 2-year monthly mean drought discharges at 11 stations along the Mekong mainstream from Chiang Saen to Tan Chao are summarized below based on the estimated probable discharges by rounding up as follows:

Table 6.24 Monthly Mean Discharges of 10-year Drought Probability

Station	Dec	Jan	Feb	Mar	Apr	May
Chiang Saen	1,200	940	780	660	700	910
Luang Prabang	1,950	1,390	1,060	890	900	1,160
Chiang Khan	2,120	1,490	1,070	870	890	1,230
Vientiane	1,930	1,420	1,120	960	970	1,250
Nong Khai	2,000	1,500	1,210	1,020	1,030	1,290
Nakhon Phanom	2,550	1,920	1,480	1,230	1,160	1,360
Mukdahan	2,650	2,010	1,610	1,300	1,290	1,620
Khon Chiam	3,040	2,220	1,830	1,520	1,520	1,940
Pakse	3,150	2,220	1,740	1,490	1,520	2,020
Tan Chao (Mekong)	8,440	5,870	3,440	1,800	1,750	1,990
Chao Doc (Bassac)	2,030	1,180	690	430	350	270
Tan Chao + Chau Doc	10,500	7,060	4,120	2,230	2,200	2,380

Source: WUP-JICA Study Team, Interim Report, February 2003

Table 6.25 Monthly Mean Discharges of 5-year Drought Probability

Station	Dec	Jan	Feb	Mar	Apr	May
Chiang Saen	1,310	1,000	800	730	820	1,090
Luang Prabang	2,010	1,450	1,130	920	990	1,300
Chiang Khan	2,160	1,540	1,140	910	920	1,310
Vientiane	2,110	1,490	1,210	1,030	1,030	1,340
Nong Khai	2,120	1,580	1,290	1,090	1,100	1,490
Nakhon Phanom	2,810	2,030	1,580	1,310	1,230	1,800
Mukdahan	2,830	2,090	1,680	1,450	1,430	1,900
Khon Chiam	3,390	2,410	1,890	1,640	1,610	2,200
Pakse	3,460	2,380	1,890	1,650	1,600	2,200
Tan Chao (Mekong)	8,810	5,890	4,140	2,830	2,080	2,390
Chao Doc (Bassac)	2,260	1,310	810	560	360	290
Tan Chao + Chau Doc	10,840	7,260	4,950	3,450	2,440	2,710

Source: WUP-JICA Study Team, Interim Report, February 2003

Table 6.26 Monthly Mean Discharges of 2-year Drought Probability

Station	Dec	Jan	Feb	Mar	Apr	May
Chiang Saen	1,600	1,130	920	810	940	1,240
Luang Prabang	2,340	1,630	1,280	1,060	1,100	1,490
Chiang Khan	2,330	1,710	1,290	1,060	1,040	1,422
Vientiane	2,500	1,770	1,360	1,190	1,210	1,670
Nong Khai	2,400	1,750	1,380	1,180	1,200	1,630
Nakhon Phanom	3,130	2,360	1,790	1,540	1,460	2,180
Mukdahan	3,290	2,330	1,860	1,620	1,520	2,220
Khon Chiam	3,950	2,810	2,160	1,840	1,750	2,680
Pakse	4,080	2,850	2,220	1,870	1,760	2,650
Tan Chao (Mekong)	11,450	6,970	4,730	3,390	2,770	3.000
Chao Doc (Bassac)	2,780	1,590	1,010	650	470	470
Tan Chao + Chau Doc	14,210	8,640	5,690	4,040	3,260	3,360

Source: WUP-JICA Study Team, Interim Report, February 2003

Fig. 6.17 presents a comparison of 10-year and 5-year probable drought discharges to the mean monthly discharge at each station.

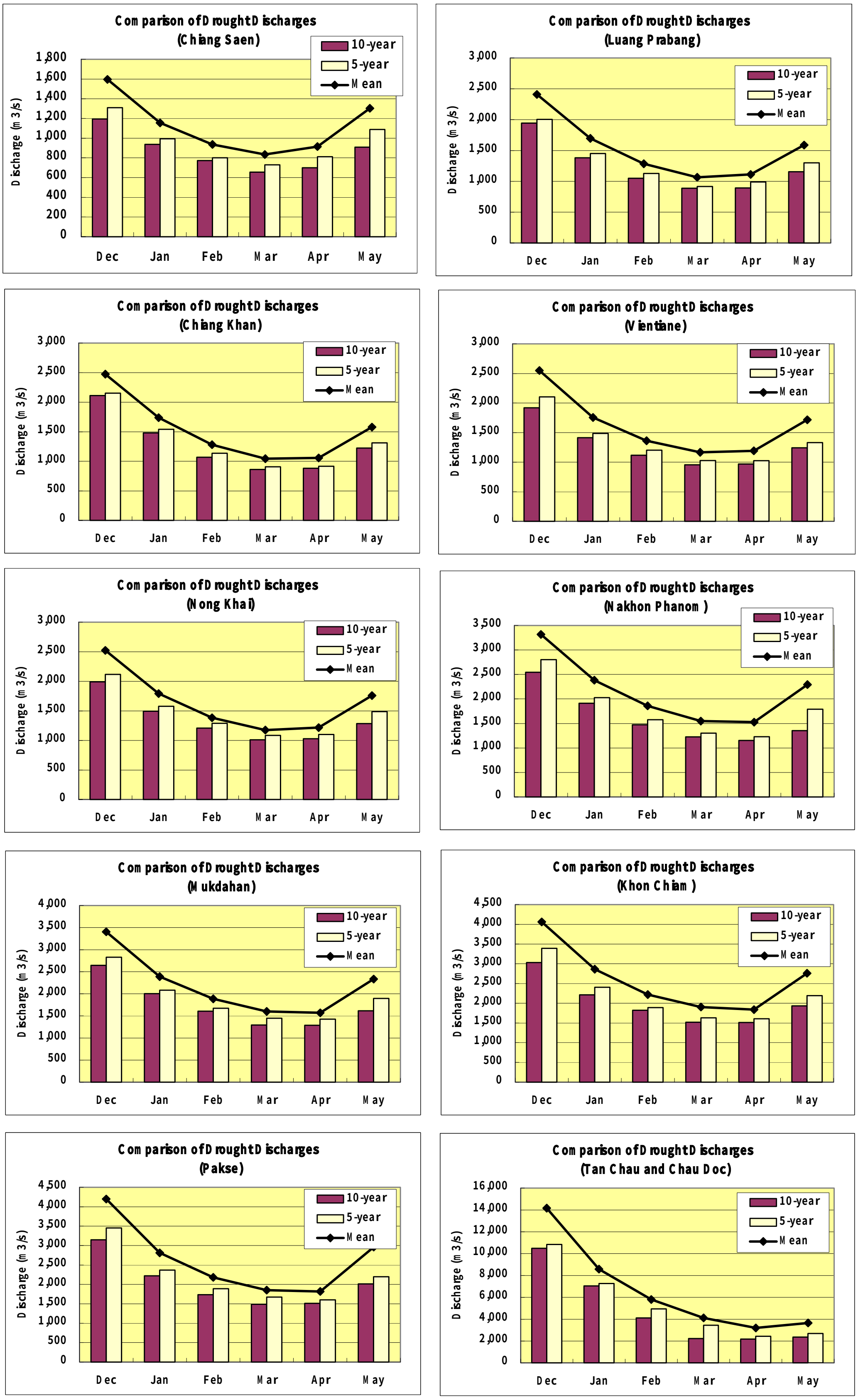


Fig. 6.17 Comparison of 5-Year and 10-Year Probable Drought Discharges with the Mean Monthly Discharge at Each Station

6.4 Drought Analysis of Annual Flows on the Mekong Mainstream

6.4.1 Comparison of Probabilities of Occurrence of 1998 Drought on the Mekong Mainstream

Actual hydrological events are changeable and of large fluctuation in behaviour. The occurrence of events is probabilistic and stochastic. Thus hydrological events (flow regime) may vary from season to season, from year to year and from place to place. This is easily undestandable in terms of difference of occurrence probabilities of a hydrological event. To illustrate, the probability of occurrence of the 1998 drought was estimated at nine stations from Chiang Saen to Pakse on the Mekong mainstream by means of the total flow volume in the wet season from June to November. Figure below presents the comparison of estimated probabilities of occurrence along the Mekong mainstream.

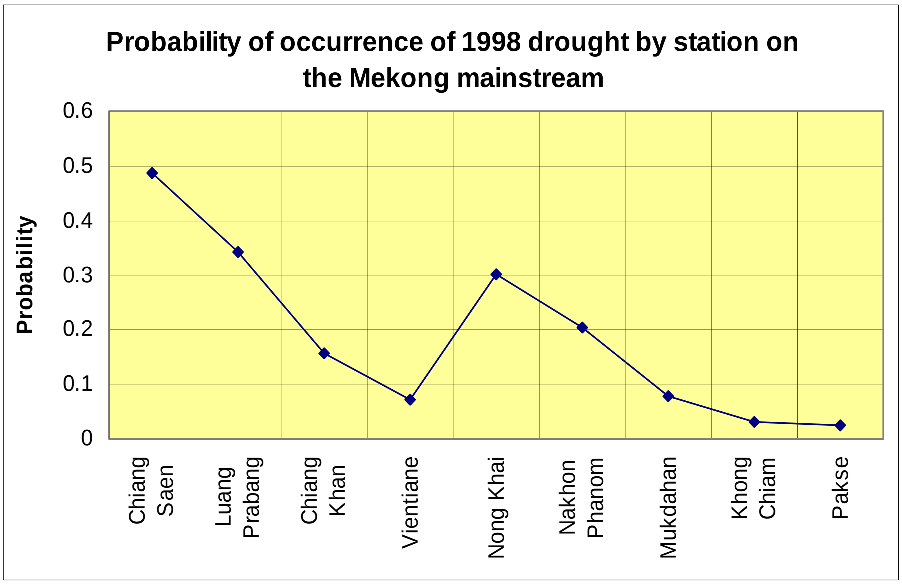


Fig. 6.18 Comparison of Probabilities of Occurrence of 1998 Drought

As seen above, probabilities of occurrence of 1998 drought are different from station to station on the Mekong mainstream. Probability of 1998 drought varies from 0.5 (to occur once in 2 years) at Chiang Saen to 0.025 (once in 40 years) at Pakse. Considering that probabilities are below 0.1 from Mukdahan to Pakse, it implies that in 1998 severe drought occurred in a wider range of the contributing left bank tributaries in Lao PDR and Vietnam; Se Bang Hien, Se Sang, Se Kong and Sre Pok Rivers. Fig. 6.19 shows the flow contributions of major sub-basins to the annual runoff of the Mekong River, the results of the water balance study in the Lower Mekong Basin in the 1980s. As seen, these tributaries contribute around 22% of the annual runoff of the Lower Mekong Basin, although area contribution is only 13%. It could be argued that these tributaries are the dominant influence on the incidence and severity of drought in the Mekong Delta. The total inflow volume in the wet season in the 1998 drought at the Nam Ngum reservoir was compared with those in 1972-2001 and the probability in the 1998 drought was estimated at 0.2 (once in 5 years). This occurrence probability of the 1998 drought coincides with the probability at Nakhon Phanom. The Nam Ngum River joins to the Mekong River in the upstream reaches of Nakhon Phanom.

Fig. 6.19 Annual Water Balance of Lower Mekong Basin

Monthly mean discharges at nine stations on the Mekong mainstream in the 1998 drought were compared with the estimated monthly mean discharges with non-exceedance probabilities of 10%, 50% and 90%. From the hydrological point of view, the monthly mean discharge of 90% non-exceedance probability means that the mean monthly river flow below the 90% discharge is expected to occur once in 10 years. The results of comparison are given in Fig. 6.20. Illustrations quoted below are at the stations of Chiang Saen, Vientiane and Pakse.

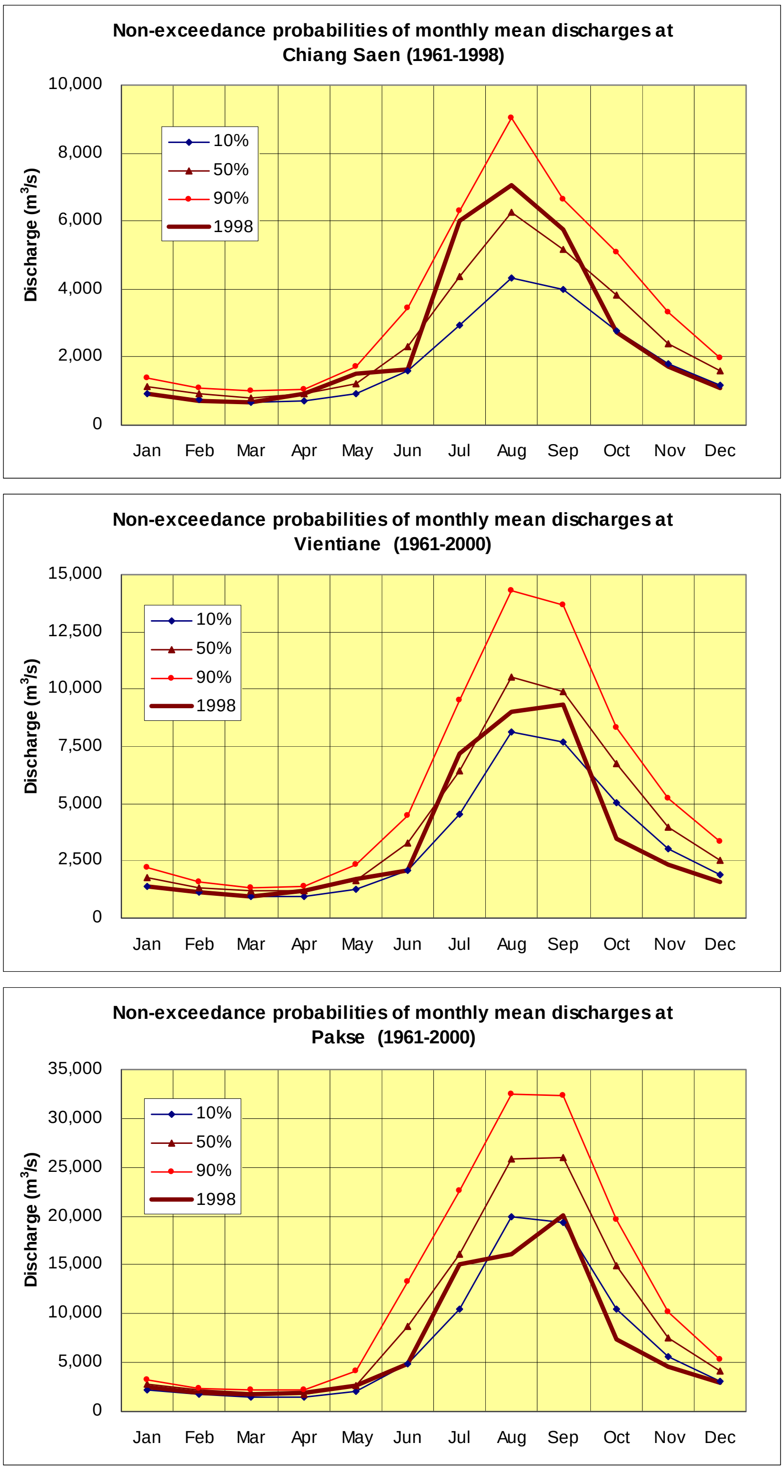


Fig. 6.21 Comparison of Monthly Mean Discharges in 1998 to Drought Discharges at Chiang Saen, Vientiane and Pakse

As mentioned, monthly mean discharges in the 1998 drought have quite different probabilities of non-exceedance from station to station on the Mekong mainstream. At Chiang Saen, river flows in the wet season (from July to September) are over the 50% monthly mean discharges. Focusing on the wet season flows it may be concluded that river flows in 1998 are of normal years (to occur once in every 2 years). However, at Vientiane, river flows in the wet season became 50% monthly mean discharges. Further, at Pakse, river flows became far less than in the wet season. Discharges in the flood recession period in October to December show serious drops under the respective 10% discharges at all the stations.

Monthly mean discharges in the 1998 drought are plotted on the monthly distribution profiles of monthly mean discharges on the Mekong mainstream with non-exceedance probabilities of 10%, 50% and 90%, as shown in Fig. 6.22. Plots below present the monthly profiles in April, September and November.

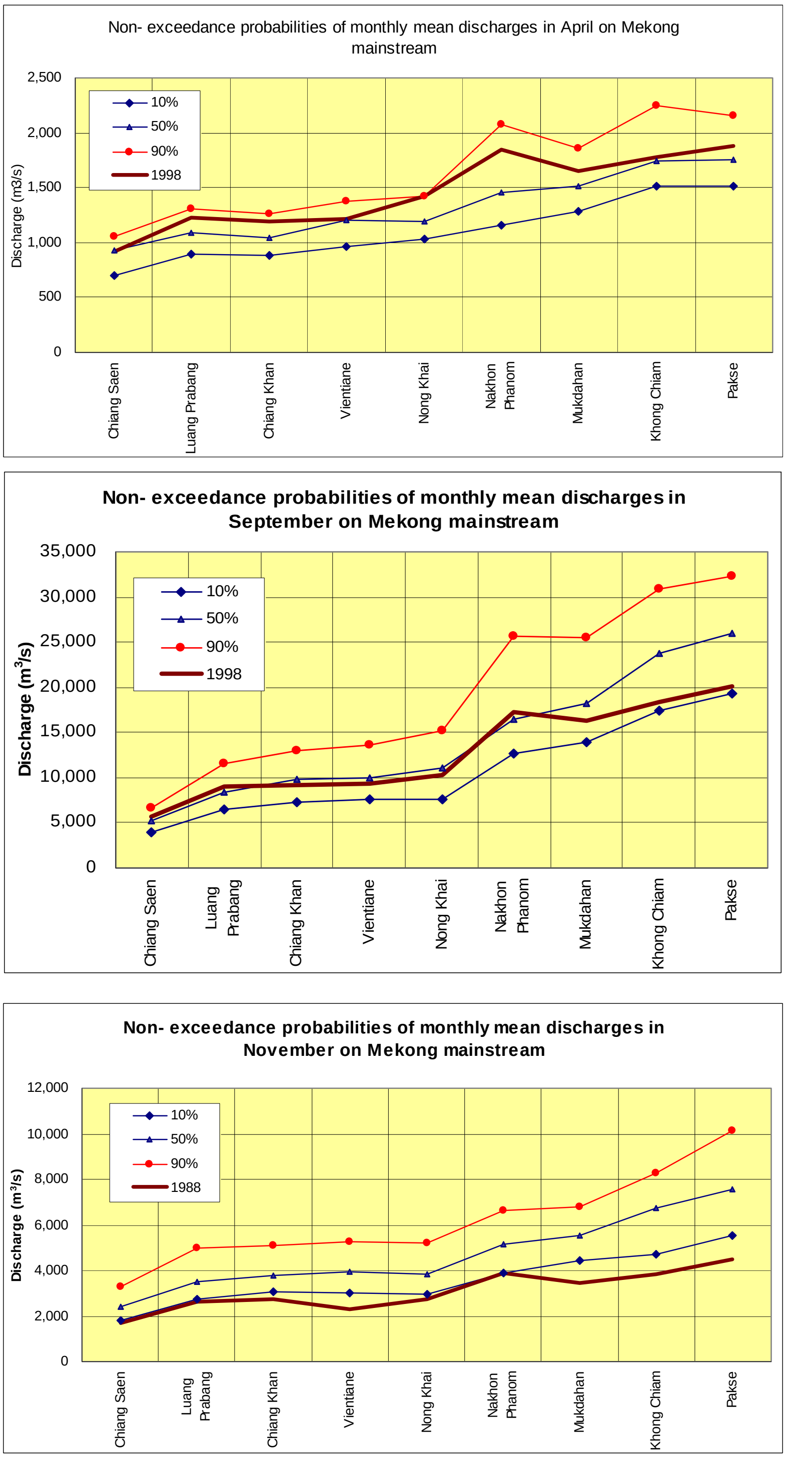


Fig. 6.23 Comparison of Monthly Mean Discharges in 1998 to Drought Discharges in April, September and November

The annual mean discharge at Pakse in 2000 was 12,666 m^3/s, the largest in the recent 20 years. It was 6,807 m^3/s in 1998 of the dry year. The year 2000 is of a hydrological wet year. Other than Pakse, discharge records in 2000 are available only at Luang Prabang and Vientiane. Monthly mean discharges in both 1998 and 2000 were compared to the estimated drought discharges with non-exceedance probabilities of 10%, 50% and 90%. Below are the comparison results.

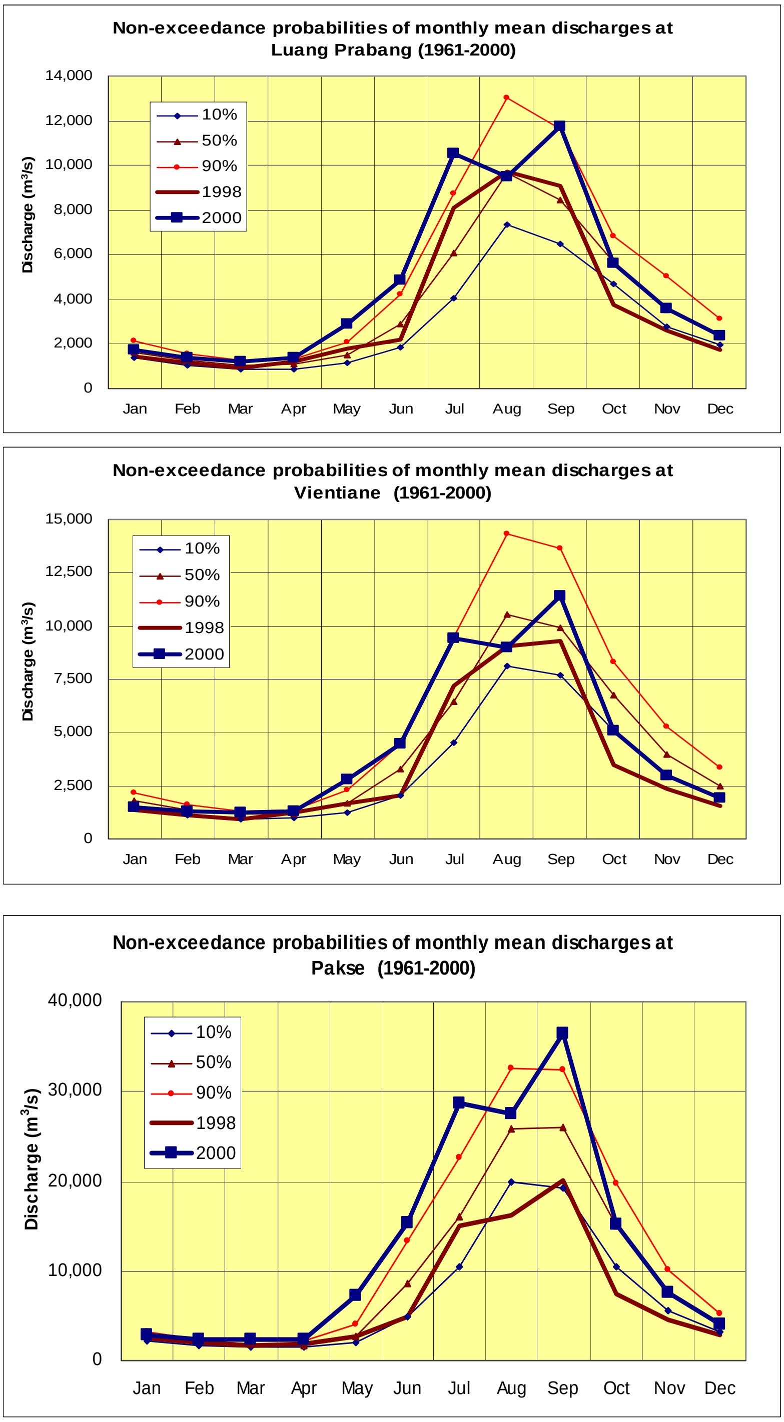
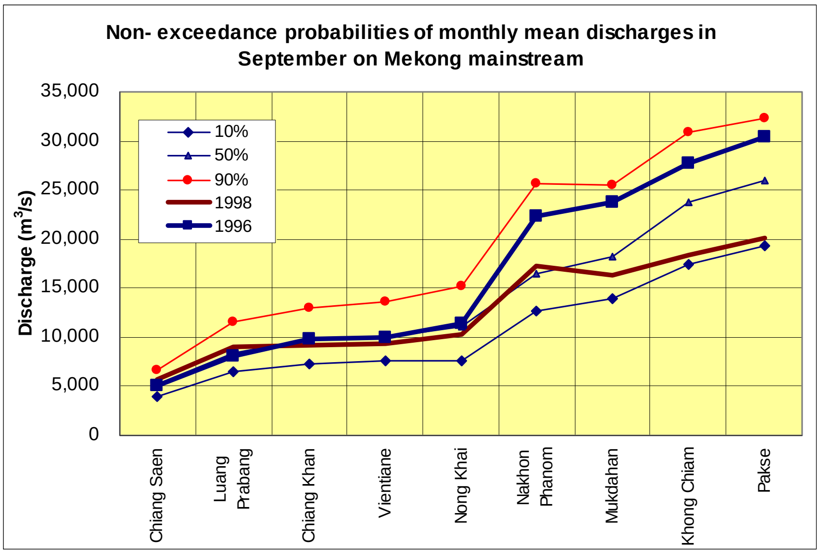


Fig. 6.24 Comparison of Monthly Mean Discharges in 1998 Drought Year and 2000 Water-Rich Year to Drought Discharges at Luang Prabang, Vientiane and Pakse

Besides the year 2000, the year 1996 was also relatively water rich. The annual mean discharge at Pakse in 1996 was 10,422 m^3/s. Monthly mean discharges are available at all of the nine stations on the Mekong mainstream. Monthly mean discharges in 1996 and 1998 were plotted to compare the monthly discharge profiles of non-exceedance probabilities. Plots below are in September and November.



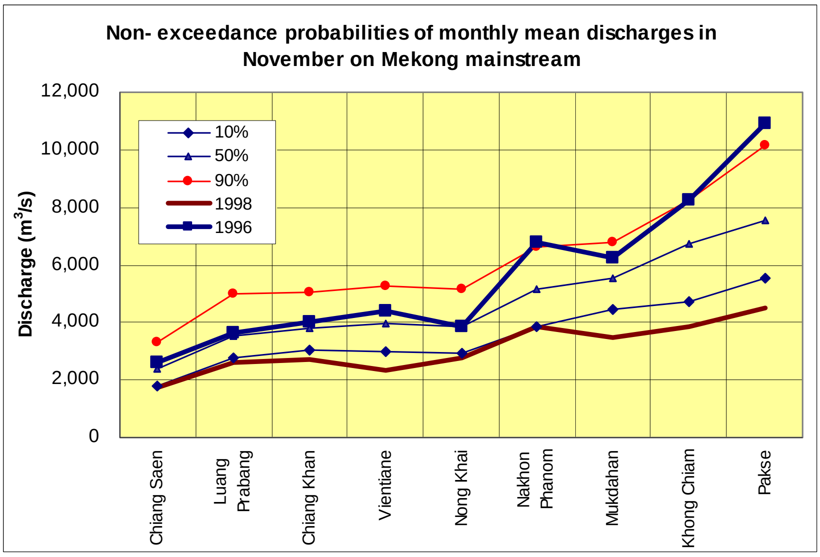


Fig. 6.25 Comparison of Monthly Mean Discharges in 1998 Drought Year and 1996 Water-Rich Year to Longitudinal Plots of Drought Discharges in September and November

6.4.2 Drought Analysis of Annual Flows

Annual flow regimes from 1961 to 2000 at nine hydrologic stations from Chiang Saen to Pakse on the Mekong mainstream were evaluated in view of variations of occurrence probability of drought. Evaluation of probability was based on the total flow volume in the wet season from June to November. Fig. 6.26 presents the comparison of longitudinal plots of occurrence probabilities of annual flow regime at hydrologic stations along the Mekong mainstream. As seen, even within an annual flow regime, occurrence probabilities are different from station to station on the Mekong mainstream. This is mainly due to great varieties of contribution of lateral inflow from tributaries caused by unequal and stochastic distribution of annual rainfall over the basin.

From these longitudinal plots of probability distribution, six distribution patterns of annual flow regime were drawn for further analysis. Out of annual flow regimes, several typical years were selected for each pattern as follows:

Table 6.27 Selection of Typical Annual Flow Regimes

Type	Typical Year	Description
Type-A	1970, 1981, 1995	Water rich year when drought probability is far over 0.5 (to occur once in 2 years) at all stations
Type-B	1974, 1982, 1990	Normal year when drought probability is almost 0.5 at all stations
Type-C	1987, 1992	Historical basin-wide severe drought when drought probability is far below 0.1 (to occuronce in 10 years) at all stations
Type-D	1977, 1998	Historical but partial drought when drought probability varies from station to station. Severe drought occurred only in the downstream reaches.
Type-E	1972, 1986	Historical but partial drought when drought probability varies from station to station. Severe drought occurred only in the upstream reaches.
Type-F	1989, 1993	Historical but partial drought when drought probability varies from station to station. Severe drought occurred except the middle reaches.

Source: WUP-JICA Study Team

Plots of probability distribution of the selected annual flow regimes are shown below.

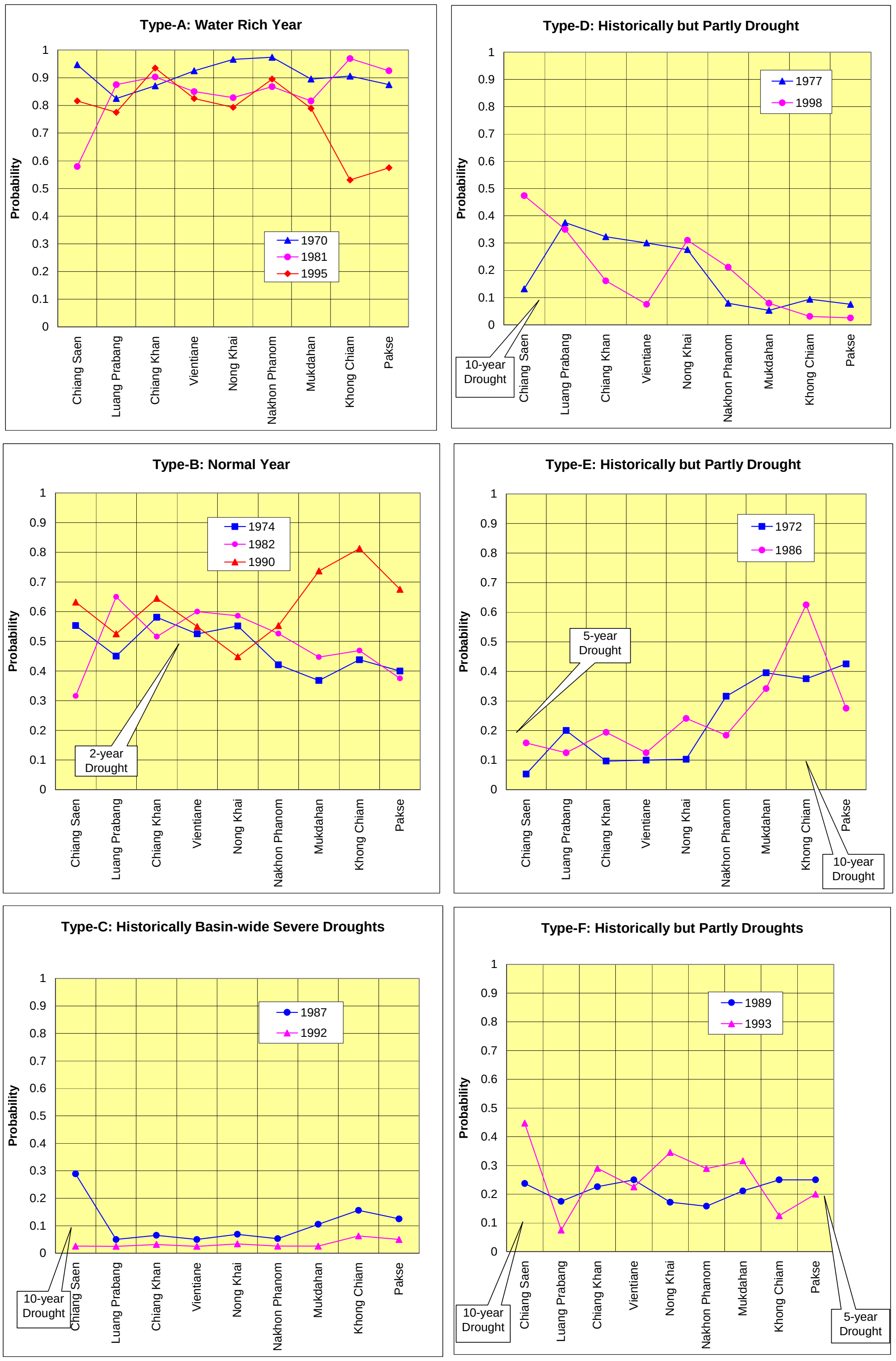


Fig. 6.27 Longitudinal Plots of Occurrence Probabilities of Selected Annual Flows

6.5 Provisional Estimation of Surplus Water on Mekong Mainstream

As discussed earlier in Section 2.9, the total surplus quantity of water in the entire Mekong River basin shall be based on the downstream end location. Due to the fact that IBFM project has just started with a study timeframe of around 1.5 years for setting up the initial mutually acceptable minimum flows (the agreed low flow regime) stipulated in Article 6A, quantification of the surplus water was thus provisionally made at the national border between Cambodia and Vietnam almost where there are two stations; the Tan Chau on the Mekong and the Chau Doc on the Bassac. The basic assumption of quantification was that the initial acceptable minimum flows are tentatively selected as two sets of the drought monthly mean discharges that are estimated in Subsection 6.3.3. Even though the initially agreed acceptable flows are set up, the surplus quantity of water will still be variable and stochastic. Hence, the flow regime may vary from season to season, from year to year and from station to station. In this study, the mean surplus quantity of water is estimated at both stations applying two cases of acceptable minimum monthly flows and the mean monthly discharges as follows:

Mean Surplus Quantity of Water at the National Border	=	Mean Monthly Discharge at the National Border	-	Acceptable Minimum Monthly Natural Flow (2 case of Probable Drought Discharge)

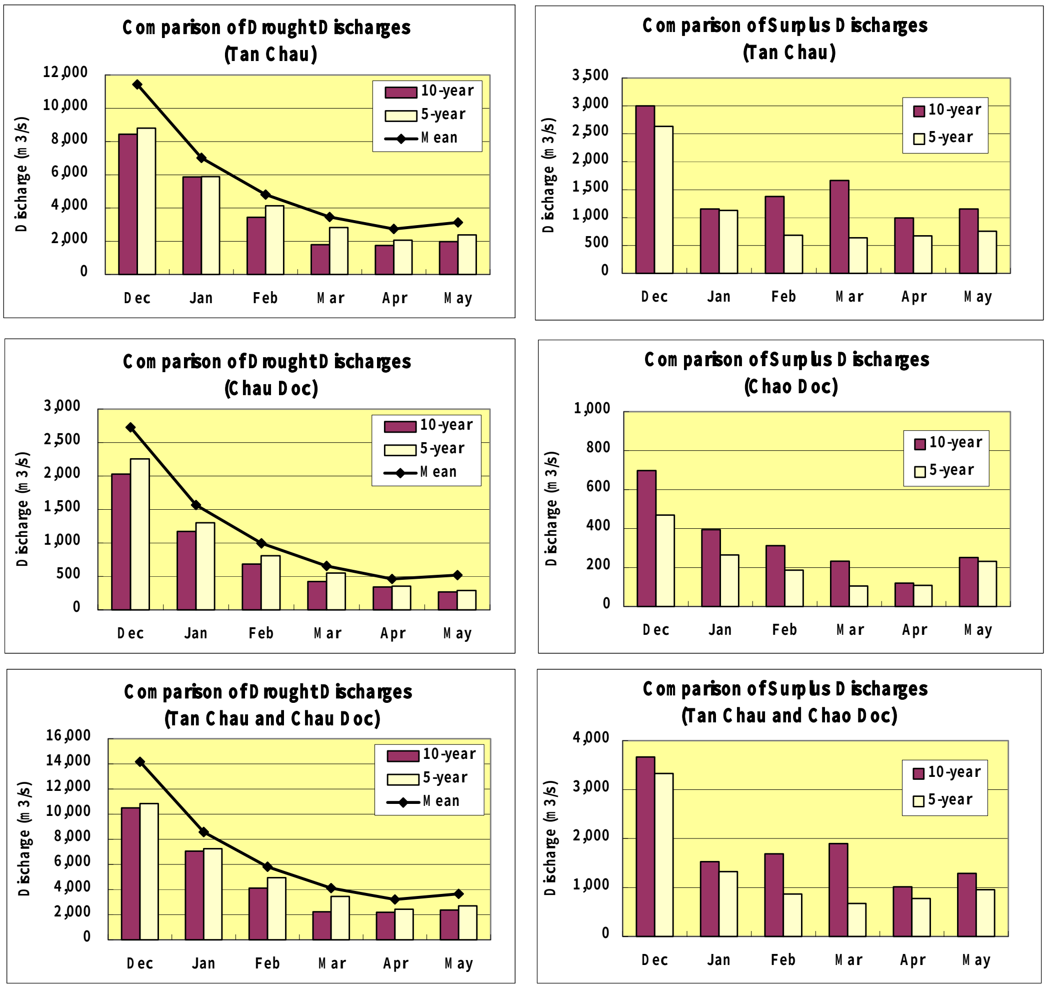


Fig. 6.28 Comparison of Surplus Discharges at Tan Chau and Chau Doc

These two cases of the mean surplus water above are on the premise that probable drought discharges are respectively applied to the acceptable minimum monthly natural flows. Table below shows the estimated monthly surplus quantities of water in the dry season. It is noted that the estimated surplus water means the expected total available water in the entire Lower Mekong Basin.

Table 6.28 Preliminary Estimation of Expected Monthly Surplus Quantities of Water in Lower Mekong Basin

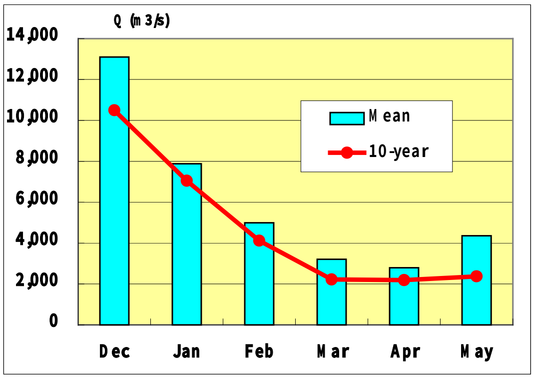
(Unit: m^3/s)

	Location	Dec	Jan	Feb	Mar	Apr	May
Mean Monthly	Tan Chau	11,438	7,012	4,812	3,462	2,742	3,135
	Chau Doc	2,726	1,568	995	657	462	520
	Mekong Delta	**14,165**	**8,580**	**5,807**	**4,120**	**3,204**	**3,656**
10-year Drought Discharge	Tan Chau	8,440	5,870	3,440	1,800	1,750	1,990
	Chau Doc	2,030	1,180	690	430	350	270
	Mekong Delta	**10,500**	**7,060**	**4,120**	**2,230**	**2,200**	**2,380**
Surplus for 10-year Drought	Tan Chau	2,998	1,142	1,372	1,662	992	1,145
	Chau Doc	696	388	305	227	112	250
	Mekong Delta	**3,665**	**1,520**	**1,687**	**1,890**	**1,004**	**1,276**
5-year Drought Discharge	Tan Chau	8,810	5,890	4,140	2,830	2,080	2,390
	Chau Doc	2,260	1,310	810	560	360	290
	Mekong Delta	**10,840**	**7,260**	**4,950**	**3,450**	**2,440**	**2,710**
Surplus for 5-year Drought	Tan Chau	2,628	1,122	672	632	662	745
	Chau Doc	466	258	185		102	230
	Mekong Delta	**3,325**	**1,320**	**857**	**670**	**764**	**946**

Note: Mean monthly discharges are in 1980-2001, which contains the preliminary estimation applying the simple linear regression for the data non-available period 1980-1996.
Source: WUP-JICA Study Team

Fig. 6.29 shows the comparison of surplus water at upstream hydrologic stations on the Mekong, but for reference only. It is noted that the surplus discharges in the graphs only show the total available surplus discharge in the upper reaches at the respective stations.

As noted in the table above, the monthly discharges applied at Tan Chau and Chau Doc are forced to include the data gap filling since the available data periods are both only five years in 1997-2001. Thus the estimated surplus quantity of water is very preliminary because the correlation between the daily mean discharges and water levels is affected by strong tidal fluctuations (see Fig. 6.11 and 6.12). Figures below show the preliminary quantification of surplus water using the observed data in 1997-2001. As seen, the surplus quantity of water in April is reduced to around 600 m^3/s from 1,013 m^3/s. Further data collection in the period 1980-1996 is strongly required if available.



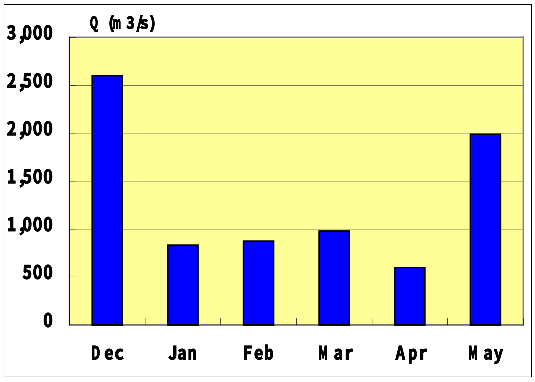


Fig. 6.31 Preliminary Quantification of Surplus Discharges at Tan Chau and Chau Doc (1997-2001)

6.6 Relationship between Drought Discharge and Selected Annual Flows

Maintaining dry-season flows on the Mekong mainstream is one of the most crucial management decisions confronting the MRC with respect to Articles 6 and 26. Some straightforward trials were made using the selected low flow regimes in the foregoing Section 6.4 in order to foresee the relationship between various low flow regimes and the resulting surplus discharges.

Subsequent dry-season daily-basis hydrographs of selected typical annual flow regimes were respectively compared to both the10-year and 5-year drought discharges tentatively assumed as the acceptable minimum monthly natural flow at the mainstream stations. The results are shown in Fig. 6.30. Following summary observations are made from the comparison results:

Table 6.29(1/2) Summary of Observations from Comparison

Type	Subsequent dry season (Dec-May)	Observation and Implications
Type-A: Water rich year	1970/71	- Due to delay of starting of subsequent wet season, both drought discharges exceed the daily discharge partly in May at all the stations. - Apart from the Khong Chiam, the daily discharge is far over the drought discharges for the recession period from the end of wet season (Dec to Mar). - In spite of the subsequent dry season after the water rich wet season, drought discharges exceed dry-season discharges at the Luang Prabang, Mukdahan, Khong Chiam and Pakse in March and April when the Mekong flow becomes the lowest.
Type-B: Normal water year	1974/75	- Same tendency as shown in the Type-A above resulting from the delay of starting of subsequent wet season is observed at all the stations. - In the recession period, there are several months when drought discharges exceed the daily discharge at all stations

Table 6.29(2/2) Summary of Observations from Comparison

Type	Subsequent dry season (Dec-May)	Observation and Implications
Type-C: Basin-wide drought	1992/93	- In the whole recession period of December to May, the daily discharges become lower than the drought discharges in considerable days within a month at all the stations. - Same tendency as shown in the Type-A above resulting from the delay of starting of subsequent wet season is observed at all stations.
Type-D: Partially drought	1998/99	- Low flow regimes (recession period) are most severe among selected flow regimes at Chiang Saen, Luang Prabang, Vientiane, Nong Khai, Khong Chiam and Pakse, although drought comditions at Chiang Saen and Luang Prabang are evaluated not so severe (to be occurred once in 2-3 years) in terms of comparison of the total flow volume in the wet season.
Type-E: Partially drought	1972/73	- Although drought conditions at Chiang Saen and Luang Prabang are evaluated so severe (to be occurred once in 5-20 years in the preceding wet season), low flow regimes at these stations are not so severe compared to those in the Type-D case. - On the contrary at the downstream stations from Nong Khai to Pakse, drought conditions become more severe in spite of decreasing drought probability thereof (once in 2-3 years in the preceding wet season).
Type-F: partially drought	1993/94	- Almost the same tendency as in the case of Type-C is observed at all stations except the Nakhon Phanom (where unreasonably high low flows have occurred just from January 1st).

Source: WUP-JICA Study Team

As observed above, it is likely that non-exceedance probabilities of seasonal flow volumes both in the wet season and subsequent dry season do not always coincide with each other. For example, in the 1992 flow regime that was a memorable historically extreme drought in the last four decades, drought probabilities of wet-season flow volume are around 0.025 (to occur once in 40 years) at almost all stations along the mainstream. However, the subsequent dry season flows from December to May in 1992/93 have not dropped so much showing the non-exceedance probabilities of around 0.1-0.2 (once in 5-10 years).

This finding is explicitly observed from Fig. 6.32 that presents the correlation between non-exceedance probabilities of seasonal volumes at the stations. Fig. 6.33 shows a good correlation between the annual volume and wet-season volume. Table below presents the variation of seasonal volumes of annual flow regime in the recorded period at each station. Seasonal volumes of annual flow regime at the nine stations from Chiang Saen to Pakse are given in Table 6.30 and summarized below.

Table 6.31 Variation of Seasonal Volumes of Annual Flow Regime

(Unit: billion m3)

Station	Wet (Jun-Nov)	Dry (Dec-May)	Annual (Jun-May)
Chiang Saen	41-108	13-22	57-127
Luang Prabang	52-145	16-29	73-174
Chiang Khan	65-152	20-30	86-176
Vientiane	65-162	17-32	87-194
Nong Khai	64-189	21-32	87-189
Nakhong Phanom	109-254	25-44	135-293
Mukdahan	132-271	28-45	162-310
Khong Chiam	161-340	31-53	198-380
Pakse	180-360	30-58	219-405

Source: WUP-JICA Study Team

6.7 Comparison of Drought Discharges in 1992 and 1998

With respect to MRC's new approach for deciding the initial minimum flows to an agreeable and acceptable level, how to incorporate past drought episodes into the decision process would be one of great importance. Historic extreme droughts in the last decade were in 1992 and 1998. Comparisons of dry-season flows in both droughts are summarized as follows:

Table 6.32 Comparison of Drought Discharges in Terms of m^3/s (1/2)

Station	Drainage Area (km2)	Dec					Jan					Feb				
		Mean	10-year Drought	5-year Drought	1992/93	1998/99	Mean	10-year Drought	5-year Drought	1992/93	1998/99	Mean	10-year Drought	5-year Drought	1992/93	1998/99
Chiang Saen	189,000	1,597	1,200	1,310	1,371	1,085	1,156	940	1,000	1,025	907	936	780	800	910	717
Luang Prabang	268,000	2,409	1,950	2,010	1,983	1,742	1,695	1,390	1,450	1,449	1,135	1,284	1,060	1,130	1,149	776
Chiang Khan	292,000	2,472	2,120	2,160	2,281	1,739	1,738	1,490	1,540	1,562	1,326	1,280	1,070	1,140	1,069	1,078
Vientiane	299,000	2,551	1,930	2,110	2,126	1,556	1,755	1,420	1,490	1,550	1,100	1,362	1,120	1,210	1,117	856
Nong Khai	302,000	2,522	2,000	2,120	2,009	1,892	1,791	1,500	1,580	1,633	1,428	1,384	1,210	1,290	1,274	1,167
Nakhon Phanom	373,000	3,318	2,550	2,810	2,439	2,545	2,384	1,920	2,030	1,774	1,871	1,858	1,480	1,580	1,287	1,610
Mukdahan	391,000	3,403	2,650	2,830	2,769	2,199	2,390	2,010	2,090	2,052	1,751	1,886	1,610	1,680	1,651	1,502
Khon Chiam	419,000	4,059	3,040	3,390	3,464	2,597	2,864	2,220	2,410	2,403	1,935	2,221	1,830	1,890	1,954	1,727
Pakse	545,000	4,200	3,150	3,460	3,119	2,921	2,812	2,220	2,380	2,324	1,982	2,183	1,740	1,890	1,731	1,734
Delta Inflow (Tan Chau + Chau Doc)	756,000	14,165	10,500	10,840	10,496	9,640	8,580	7,060	7,260	7,413	5,199	5,807	4,120	4,950	4,941	3,190

Table 6.32 Comparison of Drought Discharges in Terms of m^3/s (2/2)

Station	Drainage Area (km2)	Mar					Apr					May				
		Mean	10-year Drought	5-year Drought	1992/93	1998/99	Mean	10-year Drought	5-year Drought	1992/93	1998/99	Mean	10-year Drought	5-year Drought	1992/93	1998/99
Chiang Saen	189,000	835	660	730	801	702	915	700	820	824	645	1304	910	1,090	1,112	1,035
Luang Prabang	268,000	1,065	890	920	1,025	673	1,112	900	990	1,011	625	1,588	1,160	1,300	1,362	1,155
Chiang Khan	292,000	1,043	870	910	962	969	1,056	890	920	881	943	1,578	1,230	1,310	1,314	1,661
Vientiane	299,000	1,167	960	1,030	1,046	755	1,194	970	1,030	974	766	1,717	1,250	1,340	1,474	1,462
Nong Khai	302,000	1,176	1,020	1,090	1,214	971	1,215	1,030	1,100	1,110	991	1,758	1,290	1,490	1,581	1,878
Nakhon Phanom	373,000	1,548	1,230	1,310	1,224	1,454	1,526	1,160	1,230	1,108	1,692	2,292	1,360	1,800	2,022	3,859
Mukdahan	391,000	1,600	1,300	1,450	1,548	1,343	1,569	1,290	1,430	1,453	1,514	2,334	1,620	1,900	2,298	4,089
Khon Chiam	419,000	1,903	1,520	1,640	1,845	1,616	1,839	1,520	1,610	1,775	1,789	2,759	1,940	2,200	2,626	4,317
Pakse	545,000	1,852	1,490	1,650	1,575	1,502	1,819	1,520	1,600	1,449	1,778	2,960	2,020	2,200	2,451	4,907
Delta Inflow (Tan Chau + Chau Doc)	756,000	4,120	2,230	3,450	4,024	1,852	3,204	2,200	2,440	2,856	2,191	3,656	2,380	2,710	2,710	5,868

Table 6.33 Comparison of Drought Discharges in Terms of m^3/s/100km2 (1/2)

Station	Drainage Area (km2)	Dec					Jan					Feb				
		Mean	10-year Drought	5-year Drought	1992/93	1998/99	Mean	10-year Drought	5-year Drought	1992/93	1998/99	Mean	10-year Drought	5-year Drought	1992/93	1998/99
Chiang Saen	189,000	0.84	0.63	0.69	0.73	0.57	0.61	0.50	0.53	0.54	0.48	0.50	0.41	0.42	0.48	0.38
Luang Prabang	268,000	0.90	0.73	0.75	0.74	0.65	0.63	0.52	0.54	0.54	0.42	0.48	0.39	0.42	0.43	0.29
Chiang Khan	292,000	0.85	0.72	0.74	0.78	0.60	0.60	0.51	0.53	0.53	0.45	0.44	0.37	0.39	0.37	0.37
Vientiane	299,000	0.85	0.64	0.70	0.71	0.52	0.59	0.47	0.50	0.52	0.37	0.46	0.37	0.40	0.37	0.29
Nong Khai	302,000	0.84	0.66	0.70	0.67	0.63	0.59	0.49	0.52	0.54	0.47	0.46	0.40	0.43	0.42	0.39
Nakhon Phanom	373,000	0.89	0.68	0.75	0.65	0.68	0.64	0.51	0.54	0.48	0.50	0.50	0.40	0.42	0.35	0.43
Mukdahan	391,000	0.87	0.68	0.72	0.71	0.56	0.61	0.51	0.53	0.52	0.45	0.48	0.41	0.43	0.42	0.38
Khon Chiam	419,000	0.97	0.72	0.81	0.83	0.62	0.68	0.53	0.57	0.57	0.46	0.53	0.44	0.45	0.47	0.41
Pakse	545,000	0.77	0.58	0.63	0.57	0.54	0.52	0.41	0.44	0.43	0.36	0.40	0.32	0.35	0.32	0.32
Delta Inflow (Tan Chau + Chau Doc)	756,000	1.87	1.39	1.43	1.39	1.28	1.13	0.93	0.96	0.98	0.69	0.77	0.54	0.65	0.65	0.42

Table 6.33 Comparison of Drought Discharges in Terms of m^3/s/100km2 (2/2)

Station	Drainage Area (km2)	Mar					Apr					May				
		Mean	10-year Drought	5-year Drought	1992/93	1998/99	Mean	10-year Drought	5-year Drought	1992/93	1998/99	Mean	10-year Drought	5-year Drought	1992/93	1998/99
Chiang Saen	189,000	0.44	0.35	0.39	0.42	0.37	0.48	0.37	0.43	0.44	0.34	0.69	0.48	0.58	0.59	0.55
Luang Prabang	268,000	0.40	0.33	0.34	0.38	0.25	0.41	0.33	0.37	0.38	0.23	0.59	0.43	0.49	0.51	0.43
Chiang Khan	292,000	0.36	0.29	0.31	0.33	0.33	0.36	0.30	0.31	0.30	0.32	0.54	0.42	0.45	0.45	0.57
Vientiane	299,000	0.39	0.32	0.34	0.35	0.25	0.40	0.32	0.34	0.33	0.26	0.57	0.42	0.45	0.49	0.49
Nong Khai	302,000	0.39	0.33	0.36	0.40	0.32	0.40	0.34	0.36	0.37	0.33	0.58	0.43	0.49	0.52	0.62
Nakhon Phanom	373,000	0.42	0.33	0.35	0.33	0.39	0.41	0.31	0.33	0.30	0.45	0.61	0.36	0.48	0.54	1.03
Mukdahan	391,000	0.41	0.33	0.37	0.40	0.34	0.40	0.33	0.36	0.37	0.39	0.60	0.41	0.49	0.59	1.05
Khon Chiam	419,000	0.45	0.36	0.39	0.44	0.39	0.44	0.36	0.38	0.42	0.43	0.66	0.46	0.52	0.63	1.03
Pakse	545,000	0.34	0.27	0.30	0.29	0.28	0.33	0.28	0.29	0.27	0.33	0.54	0.37	0.40	0.45	0.90
Delta Inflow (Tan Chau + Chau Doc)	756,000	0.54	0.29	0.46	0.53	0.24	0.42	0.29	0.32	0.38	0.29	0.48	0.31	0.36	0.36	0.78

Source: WUP-JICA Study Team

Table 6.34 Comparison of Drought Discharges in Terms of liter/s/km^2 (1/2)

Station	Drainage Area (km2)	Dec					Jan					Feb				
		Mean	10-year Drought	5-year Drought	1992/93	1998/99	Mean	10-year Drought	5-year Drought	1992/93	1998/99	Mean	10-year Drought	5-year Drought	1992/93	1998/99
Chiang Saen	189,000	8.4	6.3	6.9	7.3	5.7	6.1	5.0	5.3	5.4	4.8	5.0	4.1	4.2	4.8	3.8
Luang Prabang	268,000	9.0	7.3	7.5	7.4	6.5	6.3	5.2	5.4	5.4	4.2	4.8	3.9	4.2	4.3	2.9
Chiang Khan	292,000	8.5	7.2	7.4	7.8	6.0	6.0	5.1	5.3	5.3	4.5	4.4	3.7	3.9	3.7	3.7
Vientiane	299,000	8.5	6.4	7.0	7.1	5.2	5.9	4.7	5.0	5.2	3.7	4.6	3.7	4.0	3.7	2.9
Nong Khai	302,000	8.4	6.6	7.0	6.7	6.3	5.9	4.9	5.2	5.4	4.7	4.6	4.0	4.3	4.2	3.9
Nakhon Phanom	373,000	8.9	6.8	7.5	6.5	6.8	6.4	5.1	5.4	4.8	5.0	5.0	4.0	4.2	3.5	4.3
Mukdahan	391,000	8.7	6.8	7.2	7.1	5.6	6.1	5.1	5.3	5.2	4.5	4.8	4.1	4.3	4.2	3.8
Khon Chiam	419,000	9.7	7.2	8.1	8.3	6.2	6.8	5.3	5.7	5.7	4.6	5.3	4.4	4.5	4.7	4.1
Pakse	545,000	7.7	5.8	6.3	5.7	5.4	5.2	4.1	4.4	4.3	3.6	4.0	3.2	3.5	3.2	3.2
Delta Inflow (Tan Chau + Chau Doc)	756,000	18.7	13.9	14.3	13.9	12.8	11.3	9.3	9.6	9.8	6.9	7.7	5.4	6.5	6.5	4.2

Source: WUP-JICA Study Team

Table 6.34 Comparison of Drought Discharges in Terms of liter/s/km² (2/2)

Station	Drainage Area (km2)	Mar					Apr					May				
		Mean	10-year Drought	5-year Drought	1992/93	1998/99	Mean	10-year Drought	5-year Drought	1992/93	1998/99	Mean	10-year Drought	5-year Drought	1992/93	1998/99
Chiang Saen	189,000	4.4	3.5	3.9	4.2	3.7	4.8	3.7	4.3	4.4	3.4	6.9	4.8	5.8	5.9	5.5
Luang Prabang	268,000	4.0	3.3	3.4	3.8	2.5	4.1	3.3	3.7	3.8	2.3	5.9	4.3	4.9	5.1	4.3
Chiang Khan	292,000	3.6	2.9	3.1	3.3	3.3	3.6	3.0	3.1	3.0	3.2	5.4	4.2	4.5	4.5	5.7
Vientiane	299,000	3.9	3.2	3.4	3.5	2.5	4.0	3.2	3.4	3.3	2.6	5.7	4.2	4.5	4.9	4.9
Nong Khai	302,000	3.9	3.3	3.6	4.0	3.2	4.0	3.4	3.6	3.7	3.3	5.8	4.3	4.9	5.2	6.2
Nakhon Phanom	373,000	4.2	3.3	3.5	3.3	3.9	4.1	3.1	3.3	3.0	4.5	6.1	3.6	4.8	5.4	10.3
Mukdahan	391,000	4.1	3.3	3.7	4.0	3.4	4.0	3.3	3.6	3.7	3.9	6.0	4.1	4.9	5.9	10.5
Khon Chiam	419,000	4.5	3.6	3.9	4.4	3.9	4.4	3.6	3.8	4.2	4.3	6.6	4.6	5.2	6.3	10.3
Pakse	545,000	3.4	2.7	3.0	2.9	2.8	3.3	2.8	2.9	2.7	3.3	5.4	3.7	4.0	4.5	9.0
Delta Inflow (Tan Chau + Chau Doc)	756,000	5.4	2.9	4.6	5.3	2.4	4.2	2.9	3.2	3.8	2.9	4.8	3.1	3.6	3.6	7.8

Source: WUP-JICA Study Team

Dry-season flows into the Mekong Delta are partly dependent on the amount of wet-season mainstream flows stored in the Great Lake. As seen above, specific discharges at the Mekong Delta inflow (combined flows at Tan Chau and Chau Doc) in the dry season show higher values than those at the upstream stations on the Mekong. This is due to the flow contribution from the Tonle Sap River. In the dry season, the stored water in the Great Lake is gradually released into the Tonle Sap River despite the decreasing low flows in the Mekong mainstream. Using the estimated flow contribution rates, specific discharges are divided into two discharges from the Mekong mainstream and the Tonle Sap River as summarized below.

Table 6.35 Comparison of Flow Contribution of Great Lake

	Month				
	Jan	Feb	Mar	Apr	May
Mean Monthly Discharge (m3/s):					
Pakse (for reference)	2,812	2,183	1,852	1,819	2,960
Delta Inflow (Tan Chau + Chau Doc)	8,580	5,807	4,120	3,204	3,656
Specific Discharge (liter/s/km2):					
Pakse (for reference)	4.1	3.2	3.4	3.3	5.4
Delta Inflow	9.3	5.4	5.4	4.2	4.8
Distribution Ratio (%):					
Mekong mainstream	41.5	42.2	48.8	62.8	86.4
Tonle Sap	58.5	57.8	51.2	37.2	13.6
Estimated Discharge of Delta Inflow (m3/s):					
Mekong mainstream	3,561	2,451	2,011	2,012	3,159
Tonle Sap	5,019	3,356	2,109	1,192	497
Estimated Specific Discharge of Delta Inflow (liter/s/km2):					
Mekong mainstream	3.9	2.3	2.6	2.6	4.1
Tonle Sap	5.4	3.1	2.8	1.6	0.7

Source: WUP-JICA Study Team

Figures below show the longitudinal plots of specific discharges in March and April along the Mekong mainstream.

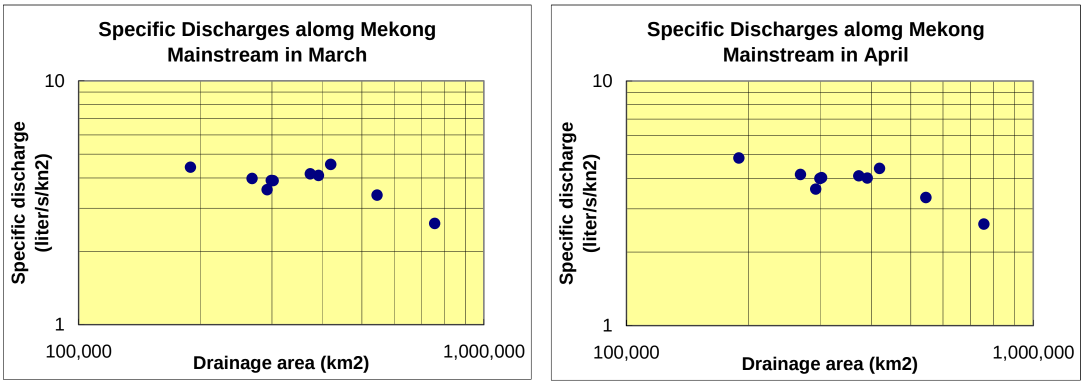


Fig. 6.34 Relationship between Specific Discharges and Drainage Area along Mekong Mainstream

6.8 Simulation of Monitoring for Annual Flow Regime

Fig. 6.35.22 to 6.46 show comparisons of the selected annual flow regimes to the drought discharges with non-exceedance probabilities of 10% (once in 10 years) and 20% (once in 5 years) at the mainstream stations from Chiang Saen to Chau Doc.

7. RECOMMENDATIONS ON THE FUTURE FRAMEWORK OF MEKONG RIVER HYDRO-METEOROLOGICAL MONITORING SYSTEM

7.1 Development of the Rules for the Maintenance of Flows on the Mainstream

The Mekong 1995 Agreement had already recognized the potential of conflicts arising from water scarcity on the Mekong mainstream in the dry season as well as the need to manage high flows during the wet season. It had also identified the need for the protection of other water uses and important ecosystem from the effects of water utilization. Thus the Agreement commits the riparian countries to maintain the quantity and quality of flows of the Mekong mainstream in accordance with the guidelines currently being prepared by MRC. In order to meet this commitment, the "Water Utilization Rules" covering both quantity and quality must be negotiated and agreed upon.

There are five sets of Rules now being formulated under the WUP Project within MRC. These rules are used in a general sense to refer to the obligations of the MRC member states with respect to Articles 5 and 6 of the Agreement. Out of them, the technical drafting process for developing the "Rules for the Maintenance of Flows on the Mainstream" (so-called Water Quantity Rules) will soon be commence by Technical Drafting Group 5 (TDG5) of WUP Working Group 3.

As detailed in Section 2.8, MRC has just launched a new approach of Integrated Basin Flow Management (IBFM) Project. Over 2003 and 2004, the MRC will establish a panel of experts in the fields of hydrology, fisheries, river ecology, human use of the river and computer-based modeling of scenarios, to provide the best judgments available as to what "critical values" of the river must be protected. "Critical values" are those that the member riparian states agree should not be lost. These values are from an interpretation of what is "acceptable" with respect to Article 6. All available relevant information on the Mekong will be collected for use in decision-making, and public input will be sought. These information and recommendations will provide the basis for an Interim Flow Plan (IFM) to be presented to the MRC Council in 2004. The IMF would ensure that the present condition of the river is maintained until a more comprehensive and empirically based strategy for establishing flow management (a Comprehensive Flow Plan) can be carried out during the period 2004-2006.

In formulating the draft "Rules for the Maintenance of Flows on the Mainstream", the highlights to be addressed are:

(1) To establish the timeframe for wet and dry seasons as an overall guideline with close relation to Articles 5 and 6;

(2) To establish the location of hydrological stations, and to determine and maintain the flow level requirements at each station as definitive guidelines stipulated in Article 6;

(3) To set out the criteria for determining surplus quantities of water during the dry season on the mainstream as a guideline to ensure reasonable and equitable utilization of the waters of the Mekong River System in accordance with Article 5;

(4) To improve upon the mechanism to monitor intra-basin use as a guideline in accordance with Article 26 that would help to ensure that the most reliable water use data are collected and to regularly assess the situation of intra-basin water uses; and

(5) To set up a mechanism to monitor inter-basin diversions from the mainstream as a guideline in accordance with Article 26.

The timeframe is closely related with the procedural rule of Procedures for Notification, Prior Consultation and Agreement. This procedural rule was just agreed upon on November 30, 2003.

Under this rule, establishment of the timeframe for the wet and dry seasons was also agreed in terms that the wet season is to start during mid-May to mid-June and end from mid-November to mid-December. The Joint Committee will make the final decision on the actual dates of the start and the end of the wet and dry seasons. Items (2) and (3) above would be analyzed and discussed by MRC under the ongoing Integrated Basin Flow Management (IBFM) project and then technically drafted by TDG5. The rules for both "improvement of the mechanism to monitor intra-basin use" and "setting up of a mechanism to monitor inter-basin diversions" have been formulated by TDG3 for drafting the procedural rule of Procedures for Water Use Monitoring. Through significant amounts of discussions, this rule was finally approved on November 30, 2003.

7.2 Two Basic Aspects in the Implementation of the Rules for the Maintenance of Flows on the Mainstream

Basically, there are two technical aspects in the implementation (or operation) of the Rules for the Maintenance of Flows on the Mainstream. They are: (i) the planning aspect for water resources development, and (ii) the management (operational) aspect for monitoring and coordination among the various water users. They are briefed as follows:

Planning aspect:

Almost any project of water resources development might more or less change river flow regimes. Changes in river flows might affect the river conditions in different ways, and so there might be physical, biological, ecological and social impacts. In this sense, the 1995 Mekong Agreement requires to maintain the pre-determined flow levels on the Mekong mainstream of not less than the acceptable minimum monthly natural flow throughout the dry season. This requirement aims at maintaining a certain or acceptable level of the health of the Mekong River.

Once such acceptable minimum flows, which would be suggested from the ongoing IBFM Project for the time being as the agreed Interim Flow Plan, are defined and agreed upon by riparian states, any water resources development project shall be planned not to change the river flows beyond the agreed acceptable minimum flows. The proposed Rules shall guide the riparian countries to maintain the amount of future consumptive water use within such limitation. The limitation shall be derived from the acceptable flow at all representative monitoring stations longitudinally located along the mainstream.

It is however noted that the Interim Flow Plan will be agreed upon based on the predicted changes of low flow regimes affected by the several future basin development scenarios selected. Selection of an acceptable flow regime is through the stakeholder consultation and negotiation between all four member riparian countries, ultimately at the Joint Committee level. The predicted flow changes associated impacts from social, economical and ecological aspects will be from the DSF basin simulation models and impact assessment tools. Future basin development scenarios (as being not a combination of specific or planned projects but a realistic possible future situation in the level of basin development) are selected with the collaboration of BDP. At the future implementation stage of the rules, the DSF will enable decision makers to discover in advance whether or not the individual development proposals in each country will modify the river flows beyond the agreed flow limits.

Management (Operational) aspect:

In general actual hydrological events are changeable and of large fluctuation. Hydrological events may vary from season to season, from year to year and from place to place. This is easily understandable in terms of difference of occurrence probabilities along the mainstream stations under the same hydrological event. Thus maintaining dry-season flows on the Mekong mainstream in accordance with the agreed Rules might be of the most crucial management issue confronting

MRC and the riparian countries. There is a possibility for an emergency situation to occur induced by the extreme drought resulting in extremely low flows beyond the agreed acceptable flow limits. Likelihood of such extreme droughts even after formulation of the Rules is mentioned in Article 6 as "To cooperate in the maintenance of the flows on the mainstream from diversions, storage releases, or other actions of permanent nature; *except in the cases of historically severe drought* and/or floods: ....".

In the light of the above, some coordinated and joint activities coping with severe drought shall be necessary to curtail basin-wide water uses among the riparian countries and to make other actions as required in advance. Such drought management response preferably shall come into effect when the river flow levels has passed down the pre-determined trigger levels, or predicted to lower the agreed acceptable flow limits. Drought management measures would vary by degrees of the economical, social and ecological impacts arising from human use of water and related resources. The necessity of drought management shall be justifiable from Article 10 of the Agreement as stipulated below.

Article 10: Emergency Situations

Whenever a Party becomes aware of *any special water quantity or quality problems constituting an emergency that requires an immediate response*, it shall notify and consult directly with the party(ies) concerned and the Joint Committee without delay in order to *take appropriate remedial action*.

Moreover, Article 6 stipulates: "The Joint Committee shall adopt guidelines for the locations and levels of the flows, and monitor and *take action necessary for their maintenance* as provided in Article 26."

These provisions were agreed upon by all parties as beneficial to the efforts of cooperation in addressing emergency situations. It emphasizes the importance of notifying any party that would potentially be endangered by the emergency and simultaneously notifying the Joint Committee so that appropriate remedial action can be taken through the combined efforts of the riparian country governments and MRC. In an event of severe basin-wide drought or flooding, drought or flood management action shall be taken up to cope with such emergency situations with the collaboration of the riparian states and MRC. In this sense, MRC is keenly expected to implement as the core of action arrangements as well as collection of the related information on the emergency situations and basin-wide hydrologic data.

7.3 Necessity of Hydro-meteorological Monitoring System for Water Quantity Rules

According to Articles 5 and 6 of the Agreement, new water uses on the mainstream will be proposed not to infringe on the acceptable minimum monthly natural flow (see Table 2.1: Summary of Provision of Article 5), that is, for the time being, the Interim Flow Plan. However, new water users in the tributary can develop with only issuing the Notification to the Joint Committee both in the wet and dry seasons. It is superficially interpreted that the current and future water uses can be independently managed by the water right system of each riparian country. From the hydrological viewpoints, the water use in tributary has a more or less effect on the river flows of the Mekong mainstream. Water abstraction from a tributary might reduce the Mekong mainstream flows. It shall be discussed and mutually agreed that the acceptable change of flows should be divided between the countries based on a number of factors such as flow contributed, current investment in water use and socio-economic factors.

Overall, it is expected that development pressures are likely to be so far relatively low or moderate, but large-scale development pressure will possibly occur on some tributaries in the near future. All four countries agreed on the general principle that water of the Mekong River is a shared resource, whereas the states have a higher priority on the use of tributary waters within their territory. It is considered that the Agreement allows flexibility for each country to undertake development activities in tributaries. In the future as a consequence of excessive water use and abstraction in tributaries in the dry season, this will sooner or later create issues that low flows on the mainstream will decrease and especially in case of severe drought serious water shortage and conflicts might arise.

In this sense, establishment of hydro-meteorological monitoring system for water quantity rules will be urged to ensure effective implementation of the water utilization rules based on the hydrological network as proposed for river flow monitoring in Article 26.

7.4 Basic Composition of Hydro-Meteorological Monitoring System for Water Quantity Rules

The proposed Hydro-meteorological Monitoring System for Water Quantity Rules comprises six system components as illustrated below.

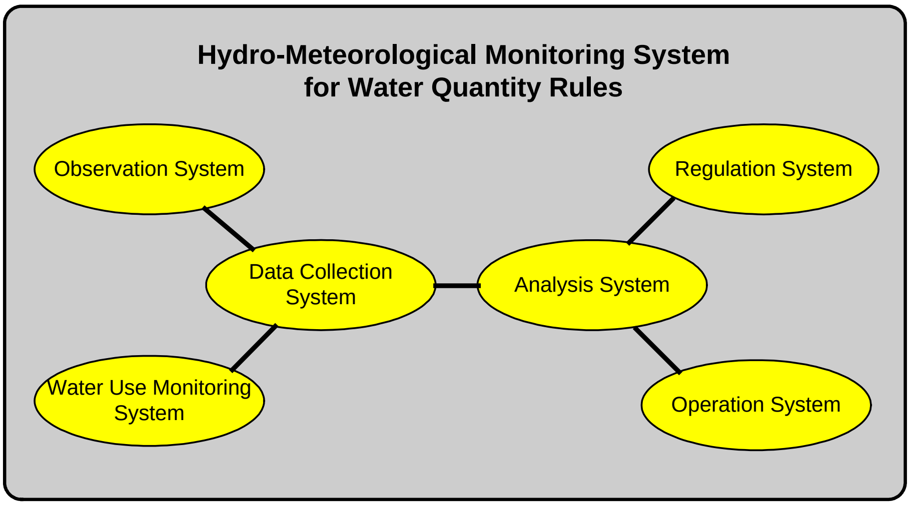


Fig. 7.1 Basic Components of Hydro-Meteorological Monitoring System for Water Quantity Rules

The proposed System will be preferably in the future integrated into the Mekong River Integrated Basin Flow Management System together with the ongoing Flood Forecasting System that is to be strengthened under the Flood Management and Mitigation Program, and the Water Quality Monitoring System for Water Quality Rules.

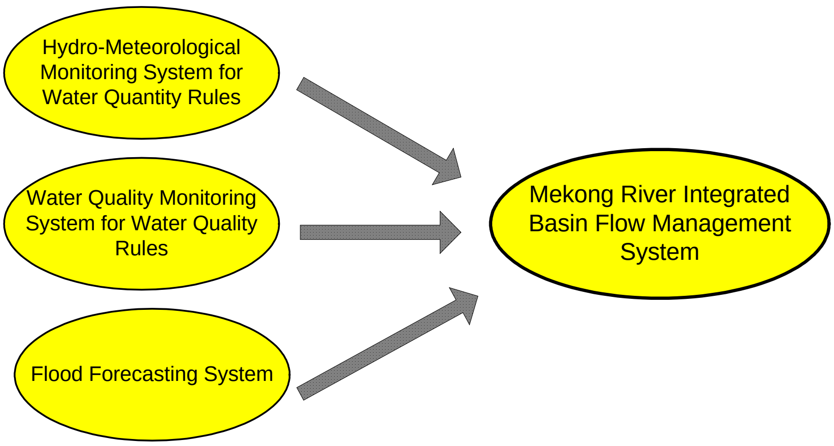


Fig. 7.2 Future Integration into the Mekong River Integrated Basin Flow Management System

7.4.1 Observation System

The observation system aims at monitoring of hydro-meteorological conditions in the Mekong Basin. The system consists of mainly two observation networks; the hydrological monitoring station (river water level) and rainfall station networks. In accordance with the provision of Article 26, hydrological monitoring stations shall be firstly proposed from the viewpoints of river flow management under the Rules for the Maintenance of Flows and the future basin development planning.

(1) Hydrological Monitoring Station Network

At the beginning of the year 2001, the number of hydrological stations in the entire Lower Mekong River Basin reached 432 in total. The Strategic Master Scheme for Hydro-Meteorological Network in the Mekong River Basin was established by MRC in March 2001. One of the purposes of this study was to classify the existing hydrological stations in view of the network improvement goal that "The network of hydro-meteorological stations shall provide timely, sufficient and reliable data and information to water management and water-related programmes and projects in both the regional and national levels." The network classification is as follows:

Table 7.1 Classification of Network Hydrological Station in the LMB

Classification	Thailand	Lao PDR	Cambodia	Vietnam	Total
Key	7	5	8	5	**25**
Primary	4	4	3	8 (1)	**19**
Basic	12	23 (1)	23 (6)	13 (2)	**71**
Sub-Total	***23***	***32***	***34***	***26***	***115***
Local	157	107	35	28	**327**
Total	**180**	**138**	**63**	**51**	**432**

Note: Number of station in parenthesis is planned to be newly installed and included in the total number. Number of station in only the category "Local" does not include the planned new station installation. "Total" does not include the planned new station installation.

Source: Strategic Master Scheme for Hydro-Meteorological Network in the Mekong River Basin, MRC, March 2001

Network classification is shown below.

Table 7.2 Classification and Objectives of Network Station

Classification	Objectives
Key	- To facilitate real-time coordination and forecasting activities - To monitor long term trend in quantity and quality of river hydrological conditions - To provide data/information for major project planning on the mainstream and major tributaries
Primary	- To monitor long term trend in quantity and quality of river hydrological conditions - To provide data/information for major project planning on the mainstream and major tributaries
Basic	- To provide data/information for medium-scale projects, research and management works to meet short/medium term needs including those for high accuracy purposes
Local	- To provide data/information for small-scale projects, monitoring operation for medium/small-scale projects to meet local needs

Source: Strategic Master Scheme for Hydro-Meteorological Network in the Mekong River Basin, MRC, March 2001

Table below summarizes the flow contribution of major sub-basins to the annual runoff of Mekong River deprived from the water balance study in 1980s. This table notes the existing major large-scale reservoirs that might cause impacts on the Mekong low flow regimes.

Table 7.3 Major Tributaries and Flow Contribution

No.	Tributary	Flow Contribution to Annual Runoff (%)	Drainage Area to Entire Basin (%)	Existing Major Large Reservoirs/Water Use
1	Se Kong-Se San	16.7	9.4	Ialy Dam; Houay Ho Dam
2	Tonle Sap	6.4	10.7	Natural release to the Mekong mainstream in the dry season
3	Nam Muc-Chi	6.0	15.0	Many large-scale dams and many irrigation schemes
4	Nam Theun	5.2	1.8	
5	Nam Ngum	4.5	2.1	Nam Ngum Dam
6	Se Bang Hiang	4.0	2.5	
7	Se Bang Fai	2.5	1.2	
8	Nam Ou	2.2	3.3	
9	Nam Songkhram	1.7	1.8	
10	Se Done	1.6	0.9	
11	Nam Nhiep	1.5	0.6	
12	Nam Mae	1.2	1.4	

Source: Fig. 6.19, Annual Water balance of Lower Mekong River

On the other hand, the Appropriate Hydrological Network Improvement Project (AHNIP) has been ongoing, from 2001 to 2005, to upgrade the current hydrological network using the telemetry data transmission system. Under the project, 15 hydrological stations in the Lower Mekong Basin will be improved to a telemetry network system. The location map of the stations is shown in Fig. 7.2. Further, an agreement with China on the provision of hydrological information during the flood season at two stations, Yunjinghong and Man'an stations on the Lancang River, was signed at the MRC Secretariat on April 1, 2002. The contents of hydrological information are: (i) rainfall and water level data of two stations, (ii) regular provision of the latest rating curves/table and related cross-sections of two stations, (iii) flood season from June 15 to October 15 every year,(iv) water level on hourly basis, and (v) 12 hourly rainfall data (at 20:00 and 08:00 Beijing time). Satellite communication system equipment will be installed at both stations to transmit hydrological information to the MRCS from the data centre in Kunming by e-mail at 09:00 Beijing time.

Fig. 7.3 Telemetry Stations Established under AHNIP

Based on the information above and the flow regime analysis results under the current study, recommendable twenty-seven stations were selected for implementation of the Water Quantity Rules as listed below. Further, the stations for setting of IFP for maintaining the mainstream flows are recommended, although they are subject to discussion and final selection under the ongoing IBFM Project.

Table 7.4(1/2) Selected Hydrological Monitoring Station of the Proposed Hydro-Meteorological Monitoring System

No.	Station (Nation)	River	Drainage Area (km^2)	Classi-fication	Setting of IFP	Remarks
1	Man'an (China)	Mekong (Lancang)	114,500	-	X	Monitoring of outflow from the Manwan dam
2	Yunjinghong (China)	Mekong (Lancang)	160,000?	-	X	Trans-boundary station. Monitoring of inflow into the LMB
3	Chiang Saen (Thailand)	Mekong	189,000	Key	O	Trans-boundary station. Monitoring of inflow into the LMB and navigation management
4	Luang Prabang (Lao PDR)	Mekong	268,000	Key	O	Trans-boundary station. Monitoring of inflow into Lao PDR territory
5	Chiang Khan (Thiland)	Mekong	292,000	Key	O	Monitoring of Mekong flow at the border between Thailand and Lao PDR territories
6	Vientiane (Lao PDR)	Mekong	299,000	Primary	O	Monitoring of Mekong flow at the border between Thailand and Lao PDR territories
7	Nong Khai (Thailand)	Mekong	302,000	Key	O	Monitoring of Mekong flow at the border between Thailand and Lao PDR territories
8	Pak Kagnung (Lao PDR)	Nam Ngum	14,300	Key	X	Monitoring of Nam Ngum inflow into the Mekong including the Nam Ngum dam
9	Nakhon Phanom (Thailand)	Mekong	373,000	Key	O	Monitoring of Mekong flow at the border between Thailand and Lao PDR territories
10	Mukdahan (Thailand)	Mekong	391,000	Key	O	Monitoring of Mekong flow at the border between Thailand and Lao PDR territories
11	Ban Keng Done (Lao PDR)	Se Bang Hiang	19,400	Key	X	Monitoring of Se Bang Hiang inflow into the Mekong
12	Khong Chiam (Thailand)	Mekong	419,000	Key	O	Monitoring of Mekong flow at the border between Thailand and Lao PDR territories
13	Ubon (Thailand)	Nam Mun-Chi	104,000	Key	X	Trans-boundary station. Monitoring of Nam Mun-Chi inflow into the Mekong including many large dams
14	Pakse (Lao PDR)	Mekong	545,000	Key	O	Trans-boundary station. Monitoring of outflow to Cambodia territory
15	Ban Komphoun (Cambodia)	Se San	48,200	Key	X	Monitoring of Se San Inflow into the Mekong
16	Cham Tangov (Cambodia)	Se Kong	29,600	Primary	X	Monitoring of Se Kong Inflow into the Mekong
17	Stung Treng (Cambodia)	Mekong	635,000	Key	O	Trans-boundary station. Monitoring of inflow into Cambodia territory

Source: WUP-JICA Study Team

Table 7.4(2/2) Selected Hydrological Monitoring Station of the Proposed Hydro-Meteorological Monitoring System

No.	Station (Nation)	River	Drainage Area (km^2)	Classi-fication	Setting of IFP	Remarks
18	Kratie (Cambodia)	Mekong	646,000	Key	O	Monitoring of Mekong flow. Key representative station for the Acceptable Natural Reverse Flow of the Tonle Sap during the wet season
19	Kompong Cham (Cambodia)	Mekong	660,000	Key	O	Monitoring of Mekong flow and mainstream inflow to the Chak Tomuk junction at Phon Penh
20	Kompong Luong (Cambodia)	Great Lake	43,800	Key	X	Monitoring of water level at the Great Lake
21	Prek Kdam (Cambodia)	Tonle Sap	84,400	Key	O	Monitoring of inflow & outflow of the Great Lake
22	Phnom Penh Port (Cambodia)	Tonle Sap	?	Primary	X	Monitoring of inflow & outflow of the Great Lake. Monitoring of flow distribution at Phnom Penh (Chak Tomuk junction)
23	Chroui Changvar (Cambodia)	Mekong	663,000	Primary	X	Monitoring of flow distribution at Phnom Penh (Chak Tomuk junction)
24	Neak Luong (Cambodia)	Mekong	?	Key	X	Trans-boundary station. Monitoring of inflow into the Mekong Delta
25	Tan Chau (Vietnam)	Mekong	?	Key	O	Trans-boundary station. Monitoring of inflow into the Mekong Delta
26	Chak Tomuk (Cambodia)	Bassac	?	Key	X	Monitoring of flow distribution at Phnom Penh (Chak Tomuk junction)
27	Chau Doc (Vietnam)	Bassac	?	Key	O	Trans-boundary station. Monitoring of inflow into the Mekong Delta

Source: WUP-JICA Study Team

The location map of the proposed hydro-meteorological monitoring stations is shown in Fig. 7.4. Nineteen stations are located on the Mekong mainstream. The selection above is based on the following considerations:

(a) It is expected that modernization will provide for automatic data collection and real-time transmission of data to MRC and the riparian countries. Telemetry network stations under establishment of the ongoing AHNIP are fully utilized for the proposed observation network. Data will be required for both the mainstream and tributaries that would cause significant impacts to mainstream flow regimes.

(b) The DSF basin simulation models developed by WUP-A consists mainly of two parts; hydrological model (SWAT and IQQM models are applied) for the upper basins of Kratie and hydro-hydraulic model (ISIS model applied) for the lower basins of Kratie. Major representing stations used for model calibration shall be covered by the proposed hydrological monitoring network for future calibration use for betterment of the simulation model.

(c) There are several major tributaries contributing to the low flow regimes of the Mekong mainstream. On some of these tributaries, existing are large-scale seasonal regulation reservoirs that might affect the Mekong flows in the dry season. Supplementary monitoring stations might be necessary in major tributaries. Referring to Table 7.3 above, significant tributaries contemplated are the Tonle Sap River including the Great Lake, Nam Ngum River, Nam Mun-Chi River, Se Kong River, Se San River, and Se

Bang Hiang River. In these tributaries, representative stations shall be selected considering the locations and record length.

(d) The hydrological observations at Stung Treng and Kratie have been completely suspended throughout the two decades of 1970s and 1980s due to political unrests. These stations were restored and the observation was resumed in the early 1990s, although rating curves have not yet been properly established. Nevertheless these stations are of great importance for monitoring the low flow regimes in the Cambodian territory.

(e) At the Chak Tomuk junction at Phnom Penh, the Mekong River joins the Tonle Sap River and then bifurcates into the Mekong mainstream and the Bassac River. In spite of hydraulic flow complexity, monitoring of flows at this junction is necessary to monitor the flow distribution into both these two rivers and then the total inflows (the sum of discharges at Chak Tomuk and Koh Norea) into the Mekong Delta in the Vietnam territory. Moreover, inflows at the Chak Tomuk from both the Mekong and Tonle Sap rivers shall be measured at Chrui Changvar and Phnom Penh Port.

(f) In the dry season, the stored water in the Great Lake is gradually released into the Mekong River via The Tonle Sap River. The released flows play a key role to the low flow regimes into the Mekong Delta. The Konmpong Luong and Prek Kdam stations are necessary to monitor the Great Lake water level fluctuation, and the inflow and outflow of Great Lake, respectively.

(g) The Mekong River enters Vietnam from Cambodia via two rivers; the Mekong River and the Bassac River. Discharges monitored jointly at Tan Chau on the Mekong and Chau Doc on the Bassac reflect the flow volume of Mekong water passed onto the Vietnam territory from the upstream Mekong riparian countries.

Fig. 7.4 Hydrological Monitoring Station Network of the Proposed Hydro-Meteorological Monitoring System

(2) Meteorological Monitoring Station Network

The number of rainfall gauging stations in the entire Lower Mekong Basin (LMB) had remarkably increased since 1960. As of 2000, the total number of rainfall stations was 569. Table below shows the chronological increase of stations in the respective member countries of MRC.

Table 7.5 Rainfall Station Network Developments in LMB

Year	Thailand	Lao PDR	Cambodia	Vietnam	Total
1960	8	4	11	5	**28**
1970	94	34	21	11	**160**
1980	152	68	41	18	**279**
1990	154	70	41	21	**286**
2000	153	143	170	103	**569**

Source: Strategic Master Scheme for Hydro-Meteorological Network in the Mekong River Basin, MRC, March 2001

Rainfall observation is currently made manually, with recording chart and data logger. The table below summarizes the current data recording method that is investigated by MRC.

Table 7.6 Present Rainfall Data Recording Method in LMB

Method	Thailand	Lao PDR	Cambodia	Vietnam	LMB
Manual	153	139	170	73	**535**
Chart	22	33	2	30	**87**
Data Logger	1	11	10	-	**22**
Total	**153**	**143**	**170**	**103**	**569**

Source: Strategic Master Scheme for Hydro-Meteorological Network in the Mekong River Basin, MRC, March 2001

Hydro-meteorological observation network stations for the MRC are part of the overall network stations operated by the various national hydrologic and meteorological service agencies of the member countries. They have been partly established with equipment provided, maintained and improved by the MRC. Part of the field data from government agencies is transmitted to the MRC for processing, archiving and publication or final verification. The MRC established the hydro-meteorological database system called HYMOS, which was provided by the Delft Hydraulic of Netherlands. The MRC compiles the hydro-meteorological data for annual publication as the Lower Mekong Hydrologic Yearbook. The records of water level, discharge and rainfall are available on the daily basis in the publication as well as the MRC HYMOS database system. Below is the summary of data availability of rainfall records at the MRC as of 2001.

Table 7.7 Number of Available Rainfall Stations at MRC

Category	Thailand	Lao PDR	Cambodia	Vietnam	Total
Existing	153	143	170	103	**569**
Yearbook	163	94	44	12	**313**
HYMOS	141	62	24	5	**172**

Note: The number of station available in the Yearbook means the accumulation of the number of available stations in all the available MRC's Lower Mekong Hydrologic Yearbooks. In Thailand, the Hydrologic Yearbooks before 1960 published by the Government agencies are also included in the accumulation.

Source: WUP- JICA Study Team

Under the Basin Modeling and Knowledge Base Project (WUP-A), daily rainfall data was collected and stored in the knowledge base of DSF. Totally the data at 358 stations were used for the modeling. In view that the knowledge base will be the central digital storage of data and knowledge for use with the DSF, all the stations in the knowledge base shall be preferably covered in the proposed observation network. The plots below show the location of rainfall stations.

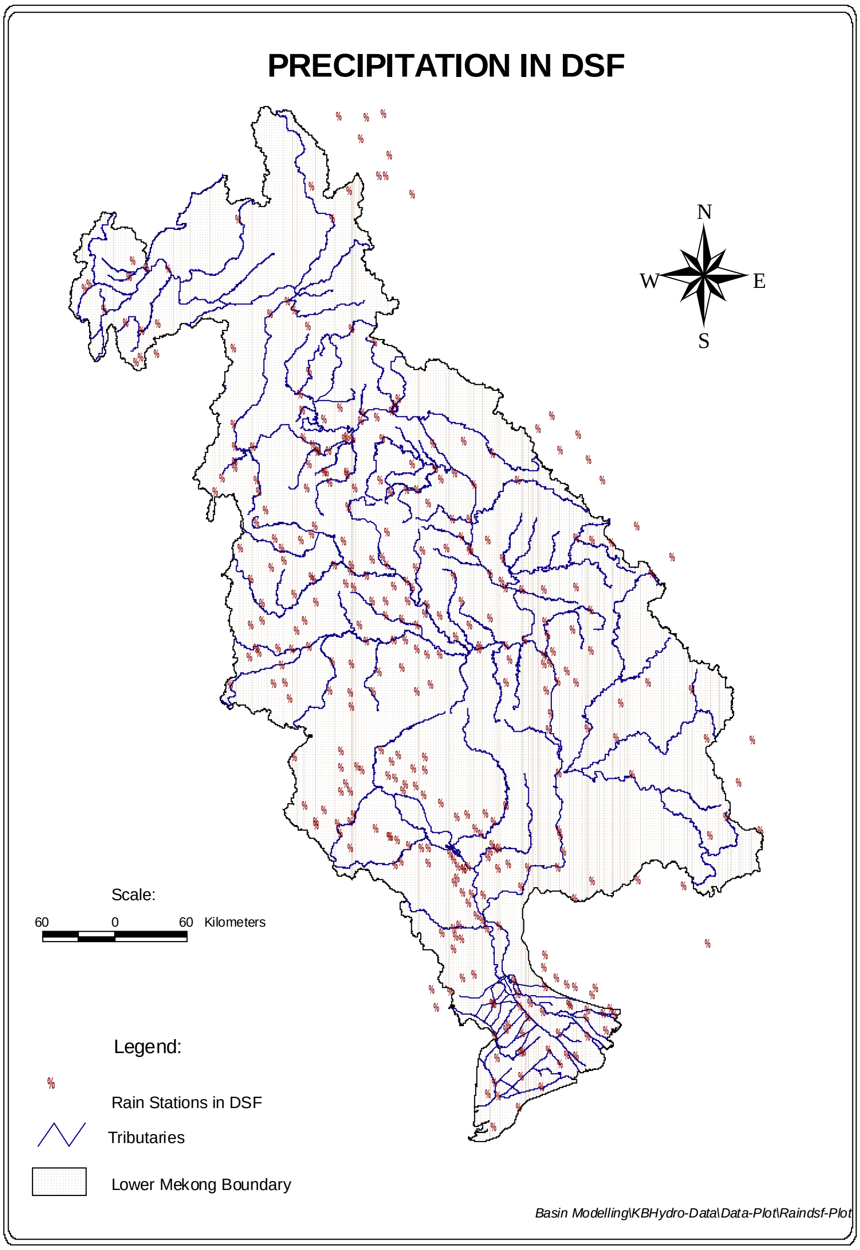


Fig. 7.5 Plots of Rainfall Stations Stored in the Knowledge Base of DSF
(Source: WUP-A Working Paper No. 14, Model Development and Calibration)

7.4.2 Water Use Monitoring System

Despite all the efforts put in data collection supported by numerous donors, there has not been a coordinated attempt to systematically and routinely collect data on the actual water uses in the Lower Mekong Basin. Data on the past or current water uses are so far not readily available. There does not exist a shared understanding among the member states of their respective use of water. Discussion of the "reasonable and equitable use" of the Mekong waters would not be possible unless water uses are identified and quantified. Moreover, it may be necessary to monitor water use to ensure that water use estimates are accurate and to provide a means of water use control during periods of droughts and extremely low flows. Monitoring the release of water from reservoirs might also be important during severe drought and/or flood events.

Article 26 calls for the MRC to "improve the mechanism to monitor the intra-basin uses" and "set-up a mechanism to monitor inter-basin diversions". Along this line, Procedures for Water Use Monitoring is drafted by TDG3 and approved by the Joint Committee in November 2003. This procedural rule stipulates to establish a Water Use Monitoring System by MRC and member countries to monitor water use in the Mekong River basin and inter-basin diversion into another river basin. Although the details of the System component are subject to determination by a technical support team within MRC, the proposed Monitoring System consists of the following three components:

(1) **Physical equipment and related structures, which are normally located in and managed/owned by the respective states:** i.e. relevant water measuring devices such as: streamflow/level and reservoir gauges, water quality monitoring stations, meteorological facilities. Data transmission means by telephone, telemetry and satellite, and data gathered through remote sensing technologies.

(2) **Various technological procedures:** i.e. relevant monitoring methodologies, operation and maintenance requirements and processes, calibration standards and verification protocols, and data collection and communication procedures.

(3) **Related personnel/institutions/organizations:** i.e. those directly involved in operation and maintenance of the physical equipment and related structures through the various procedures.

The Water Use Monitoring System by MRC and member countries to be proposed by the Procedures above will become an integral part of the proposed Hydro Meteorological Monitoring System for Water Quantity Rules. Recommendable points to be reflected in the future guidelines for the Procedures for Water Use Monitoring are enumerated below.

(1) Existing large scale seasonal regulation reservoirs such as the Nam Ngum dam and Houay Ho dam in Lao PDR, the Sirindhorn dam, Lam Takong dam, Lam Phra Ploeng dam, Nam Pong dam, Chulabhorn dam, Ubolratana dam, Lam Pao dam, Huai Luang dam, Nam Oon dam and Nam Pung dam in Thailand, and the Yali dam in Virtnam shall be monitored with focus on the release of water and reservoir water level as well as the remaining water volume in the reservoir.

(2) An inventory of the major off-stream users that might cause impacts on the low flow regimes shall be established.

(3) In addition to providing information on water use, mechanism shall be formulated so that water use reporting in each riparian country is accurate and acceptable by the other member countries. Ensuring transparency in reporting would be of great importance and certified reporting system shall be established. Furthermore, some verification procedures shall include empowered on-site field inspections by MRC whenever required.

(4) Formulating and reviewing water use monitoring procedures will be a long term and continuous process through modification of the procedures and management mechanism periodically as required.

7.4.3 Data Collection System

(1) Hydrological Data

As for the transmission method of hydrological data observed at all of the proposed monitoring stations, the telemetry system shall be preferably established. As mentioned in Subsection 7.4.1, some of the monitoring stations are now being upgraded under the AHNIP by the provision of telemetry data transmission system as summarized below. Continuous effort for the establishment of a basin-wide telemetry system under a new project shall be recommended.

Table 7.8 Upgrading of the Proposed Hydrological Monitoring Station

No.	Station	River	Classi-fication	Status of Upgrading
1	Yunjinghong	Mekong (Lancang)	-	Telemetry by AHNIP
2	Man'an	Mekong (Lancang)	-	Telemetry by AHNIP
3	Chiang Saen	Mekong	Key	Telemetry by AHNIP
4	Luang Prabang	Mekong	Key	Telemetry by AHNIP
5	Chiang Khan	Mekong	Key	Telemetry by AHNIP
6	Vientiane	Mekong	Primary	
7	Nong Khai	Mekong	Key	Telemetry by AHNIP
8	Pak Kagnung	Nam Ngum	Primary	Automatic equipment by WUP-JICA
9	Nakhon Phanom	Mekong	Key	Telemetry by AHNIP
10	Mukdahan	Mekong	Key	Telemetry by AHNIP
11	Ban Keng Done	Se Bang Hiang	Primary	Automatic equipment by WUP-JICA
12	Khong Chiam	Mekong	Key	Telemetry by AHNIP
13	Ubon	Nam Mun-Chi	Key	Automatic equipment by WUP-JICA
14	Pakse	Mekong	Key	Telemetry by AHNIP
15	Ban Komphoun	Se San	Key	Automatic equipment by WUP-JICA
16	Cham Tangoy	Se Kong	Primary	Automatic equipment by WUP-JICA
17	Stung Treng	Mekong	Key	Telemetry by AHNIP
18	Kratie	Mekong	Key	Telemetry by AHNIP
19	Kompong Cham	Mekong	Key	
20	Konpong Luong	Great Lake	Key	Telemetry by AHNIP
21	Prek Kdam	Tonle Sap	Key	Telemetry by AHNIP
22	Phnom Penh Port	Tonle Sap	Primary	
23	Chroui Changvar	Mekong	Primary	
24	Neak Luong	Mekong	Key	Automatic equipment by WUP-JICA
25	Tan Chau	Mekong	Key	Telemetry by AHNIP
26	Chak Tomuk	Bassac	Key	Automatic equipment by WUP-JICA
27	Chau Doc	Bassac	Key	Telemetry by AHNIP

Source: WUP-JICA Study Team

(2) Meteorological Data

The current transmission system of meteorological data is different from country to country. Table 7.9 below presents the current data collection system and summarized as follows:

Thailand:

The Department of Energy Development and Promotion (DEDP) collects data by post once a month from stations for data processing purposes. For the forecasting purpose, provincial centers send data to the DEDP daily by e-mail. The Thai Meteorology Department (TMD) collect data from stations once a month for data processing. Further, the TMD has established a telemetry system for the acquisition of real time rainfall and air temperature data from 50 stations in the Bangkok Metropolitan area.

Lao PDR:

In both line agencies of the Waterways Administration Division (WAD) and the Department of Meteorology and Hydrology (DMH), field stations send data to their provincial centers at an interval of 3 to 6 months by manpower or the postal service. The provincial centers of both agencies send collected data to their higher authorities or the departments at an interval of 3 to 6 months by manpower or post for data processing. On the other hand, for the forecasting purpose, stations under the provincial centers of WAD send data daily during the wet season, whereas those of DMH send on a daily basis all year round by the single side band (SSB) radio telephone or public telephone.

Cambodia:

There are no provincial centers under the Department of Hydrology and River Works (DHRW). Therefore, provincial coordinators are assigned to collect data from the data observers at stations who send data once a month to the provincial coordinators either by manpower or postal service. Provincial coordinators send the collected data from stations to the DHRW at intervals of 1 to 3 months by manpower or mail for data processing purposes. In the Department of Meteorology (DOM), for data processing purposes, key stations send data daily to DOM by SSB radio or telephone all the year round.

Vietnam:

Under the Southern Regional Hydro-Meteorological Center (SRHMC), for data processing purposes, stations send data directly to the SRHMC once a month by postal service. For forecasting purposes, stations send data to provincial centers daily by telephone in the morning. Provincial centers send collected data from stations to the SRHMC daily by telephone, e-mail or fax in the afternoon. In the Highland Regional Hydro-Meteorological Center (HRHMC), for data processing purposes, stations send data directly to the HRHMC daily during the wet season and at 10 days interval during the dry season by e-mail or fax.

Table 7.9 Current Meteorological Data Transmission System

Country	Agency	Current Data Transmission System
Thailand	DEDP	Once a month by mail from stations via provincial center to DEDP for data processing. Daily from provincial centers to DEDP by e-mail for forecasting.
	TMD	Once a month from stations to TMD by post for data processing. Real time rainfall and air temperature data by telemetering system in Bangkok Metropolitan area.
Lao PDR	WAD	3-6 months interval from stations to a provincial center by man or post. 3-6 months interval from provincial centers to WAD by man or post and sometimes by fax. Daily during rainy season, from provincial centers to WAD by SSB or telephone.
	DMH	3-6 months interval from stations to provincial centers by man or post. 3-6 months interval from provincial centers to DMH by man or post and sometimes by fax. Daily throughout the year, from provincial center to DMH by SSB or telephone.
Cambodia	DHRW	Monthly from stations to provincial coordinator by post or man. 1-3 months interval from provincial coordinators to DHRW by man except one coordinator who sends by post.
	DOM	**For Forecasting: Daily from provincial center's stations (one from each province) to DOM by SSB or telephone.** For Data Processing: Monthly by post or man from stations to provincial centers. Monthly by post or man from provincial centers to DOM.
Viet Nam	SRHMC	**For Forecasting: Daily from stations to provincial center by telephone. Daily, from provincial centers to SRHMC, by telephone, e-mail or fax.** For Data Processing: Once a month from stations to SRHMC by post
	HRHMC	**For Forecasting: Daily from stations to regional center by telephone, e-mail or fax during rainy season; at 10 days interval from stations to regional center by e-mail or fax during dry season.** For Data Processing: Once a month from stations to HRHMC by post.

Source: Strategic Master Scheme for Hydro-Meteorological Network in the Mekong River Basin, MRC, March 2001

Considering that drought and extremely low flows are predictable by hydrological monitoring, for the time being the introduction of telemetry system for real time monitoring of meteorological data may not be crucial for maintaining the minimum flow requirements. Since the establishment basin-wide telemetry system needs huge financial and technological support, a telemetry system might not be sustainable and economically affordable at present. As applied mainly in Thailand and Vietnam, data transmission by use of e-mail has become the most effective and reliable means of data transmission. If the data transmission by e-mail is more effectively applied in Cambodia and Lao PDR, the current data acquisition system to MRC will be greatly improved.

7.4.4 Analysis System

(1) Procedures for Data and Information Exchange and Sharing

The draft Procedures for Data and Information Exchange and Sharing was endorsed by the MRC Joint Committee in July 2001 and subsequently adopted by the MRC Council in November 2001, bringing the Procedures into force. The Procedures provides for a broad range of data and information to be exchanged among the member countries. The MRC Secretariat has been given responsibility under the Exchange and Sharing Procedures to be the Custodian of shared data collected, processed and stored in an integrated database. Custodianship provides an organized means of sharing agreed data with clear accountability for standards of the data, its security and its accessibility to recognized partners. Guidelines on Custodianship and Management were developed under the provisions of Clause 5.1 of the

Procedures, designed to support the operation of MRC's integrated database system, and particularly to facilitate data and information exchange and sharing to create basin-wide data and information. The Procedures provides for a broad range of data and information to be exchanged among the member countries. Data and information on water resources, topography, natural resources, agriculture, navigation and transport, flood management and mitigation, infrastructure, urbanization, industrialization, environment and ecology, administrative boundaries, socio-economics changes, and tourism, all fall within the scope of this agreement.

(2) Decision Support Framework (DSF)

WUP-A has developed a DSF for the Lower Mekong Basin. The DSF is intended to be a key tool to assist the four riparian states in developing the rules and support the decision making for basin planning and management. The main components of the DSF are a Knowledge Base, a Basin Modeling Package comprised of a number of integrated simulation models, and Impact Assessment Tools relating to the environmental and socio-economic impacts of development options. The MRC will coordinate administration and use of the DSF. The Basin Modeling Package will not only accurately and reliably simulate the hydrology and hydraulics of the basin, but also water uses, water quality, the important linkages and effects that changes or variations in water functions such as fisheries, wetlands or navigation as well as natural functions such as flows to and from the Great Lake and salinity control in the delta. The DSF will be the essential and central analysis tool, which covers the entire Lower Mekong Basin and adequately defines the present day flow regime for the purposes of implementation of the Rules.

7.4.5 Operation System

As mentioned in Section 7.2, implementation of the Rules for the Maintenance of Flows on the Mainstream has two aspects: (i) the planning aspect for water resources development, and (ii) the management (operational) aspect for monitoring and coordination among the various water users. The operation system provides a systematic and routine monitoring operation for maintaining the dry season flows on the mainstream confronting MRC and the riparian countries. Important tasks expected in the operation system are listed below.

(1) Monitoring and maintaining of the dry season flows and water levels on the Mekong mainstream in accordance with the agreed flow level requirements.

(2) Prediction of emergency situations due to extreme droughts.

(3) Dissemination of monitoring information as well as emergency situations to the line agencies, in particular in relation to drought prediction, drought management and necessary actions.

(4) Joint decisions on some actions necessary for maintaining the dry season flows in accordance with the Rules.

7.4.6 Regulation System

With regards to rights and obligations, the Agreement reflects trends in international river basin management towards greater cooperation and joint management of the basin's resources. Along with these trends, there are five sets of Water Utilization Rules now being formulated under the

WUP Project within MRC. These rules are used in a general sense to refer to the obligations of the MRC member states with respect to Articles 5, 6 and 26 of the Agreement.

Table 7.10 Five Sets of Water Utilization Rules

Category	Rule
Procedural Rules	1. Procedures for Data and Information Exchange and Sharing (approved in July 2001)
	2. Procedures for Water Use Monitoring (approved in November 2003)
	3. Procedures for Notification, Prior Consultation and Agreement (approved in November 2003)
Technical Rules	4. Rules for the Maintenance of Flows on the Mainstream (to be approved by the end of 2004)
	5. Rules for Water Quality (to be approved by the end of 2005)

For implementing the Water Utilization Rules above, more definitive technical guidelines and standards might be necessary. As for the Procedures for Water Use Monitoring, for example, under the provision of Clause 4.2, a technical support team shall determine the details of three components of the Monitoring System. Without the development of technical guidelines and standards defining the details, effective water use monitoring could not be substantially carried out. With regard to the Rules for the Maintenance of Flows on the Mainstream, several technical guidelines might be necessary in the near future as discussed in the succeeding Section 7.5.

7.5 Recommendation for Formulation of Supplementary Guidelines

7.5.1 Guideline for Water Allocation

Once the surplus quantity of water is determined, the allocation of surplus water (water sharing) among the member states might need to be agreed upon. Although the Agreement stipulates the necessity of utilization of Mekong waters in a reasonable and equitable manner, it does not provide any water allocation or more specific water allocation arrangements. Under the recently agreed rules "Procedures for Notification, Prior Consultation and Agreement", once individual development proposals in any tributary are agreed upon, each country could undertake development and use water with the opportunity to exercise sovereign powers and independence. Nevertheless, without agreed water sharing, this application might not substantially allow the countries with little developments to be given equal development opportunity with countries that already have significant developments. One of concepts is that trading or swapping of rights among riparian countries to change the agreed water sharing might be allowed.

In this respect, some guidelines to solve such water allocation issues among the member states might be necessary in the immediate future. Clarification and evaluation of historic water usages and/or flow contributions (such as low flow increase by water release from reservoir) by each riparian country would be the starting point for water allocation that shall be the basis for determination of basin development scenario under the IBFM project. This technical guideline or standard shall be formulated through a number of discussions among the member states in view of the sustainable cooperative uses of the Mekong waters preferably before completion of the ongoing Xiaowan Dam in China, because this dam is expected to cause a drastic low flow increase of 550 m^3/s on the mainstream.

7.5.2 Guideline for Drought Management

The purpose of Article 6: Maintenance of Flows on the Mainstream, is the recognition by all the riparian states of the need to cooperate in maintaining flow levels on the Mekong mainstream within the pre-determined acceptable flow levels. However, it is clearly acknowledged that Article 6 does not impose any duty upon the member states to observe the rules during emergency situations of exceptionally extreme drought ("except in the cases of historically severe droughts", as stipulated). On the other hand, because of great variations of hydrological events, it is likely that the existing flows are beyond the acceptable flow limits at some stations, but are within the limits at other stations. In this situation, Article 6 calls for undertaking some actions necessary for the maintenance of mainstream flow levels. Conceivable actions to be taken as a drought management in general may include the restriction of existing water uses and/or emergency water supply from the existing reservoirs. These actions seem to be unrealistic and impractical at the moment considering that implementation of such actions would require, in principle, the recognition and compromise of all the member states with regard to whether or not monetary compensation issues for emergency release of water as well as curtailment of water uses are agreeable. Nevertheless, the possibility and necessity of drought management are subject to discussion under the IBFM project.

In this connection, key facts and information to be noted from the hydrological point of view are as enumerated below.

(1) Every year the extent of the Great Lake varies tremendously from the dry season to the wet season. The estimated maximum water level and volume of the lake are around 6 m and 28 billion m^3 in the 1998 dry year and 9.5 m and 65 billion m^3 in the 2000 wet year.

(2) Even though the natural reverse flow of the Tonle Sap River becomes smaller than the acceptable limit (to be determined under the IBFM project), there are presently almost no effective and practical means to supplement the reverse flow into the Great Lake.

(3) On the mainstream, there are no reservoirs for emergency water release to the lower reaches except for two reservoirs in China with total effective storage of around 0.5 billion m^3. On the other hand, large seasonal regulation reservoirs would be able to supplement water, if this is effective and practical. The total effective volume is around 11.7 billion m^3 comprised of 5.4 billion m^3 in Lao PDR, 5.5 billion m^3 in Thailand and 0.8 billion m^3 in Vietnam.

(4) The preliminarily estimated current dry season irrigation demands (diversion requirements) are 4.8, 1.2, 1.8 and 11.6 billion m^3 in Thailand, Lao PDR, Cambodia and Vietnam, respectively. On the other hand, the total flow volumes during the dry season (December to May) at the Cambodia-Vietnam national border into the Mekong Delta are estimated at around 104 billion m^3 in normal years and 74 billion m^3 in the 1998/99 dry year (see Table 6.32). At the Cambodia-Vietnam national border, the water utilization ratios during the dry season are thus 7.5% (= 7.8/104x100) in normal years and 10.5% (= 7.8/74x100) in the 1998/99 dry year excluding the downstream water uses in the Mekong Delta in Vietnam. Considering that a major portion of water source for dry season irrigation in Thailand is highly dependent upon the stored water in the existing small to large reservoirs, the water utilization ratios depending on the dry season flows are around 2.9% (= 3.0/104x100) in normal years and 4.1% (= 3.0/74x100) in the 1998/99 dry year, respectively, excluding water uses in Thailand. These percentages above will become smaller if return flows into the mainstream from irrigation uses are taken into consideration.

(5) Once a dry year occurs, the available dry season flows drastically decrease. For example, the total seasonal flow volume in the 10-year drought at the Cambodia-Vietnam national border into the Mekong Delta is estimated at around 75 billion m^3, which is almost the same volume as in the 1998/99 dry year and 72% of the seasonal flow volume in normal years. On the other hand in case of an emergency situation like the 10-year drought, the current water use that might possibly be the object of drought management is only 4.0% (= 3.0/75x100).