MRC Management Information booklet series
No. 2

The Flow of the Mekong

November 2009

Meeting the needs, keeping the balance

INTRODUCTION

Integrated basin flow management (IBFM) is designed to provide information and knowledge to decision-makers on the impacts of water-resource developments in the Lower Mekong Basin. These developments involve modifying the flow of the Mekong and/or its tributaries. Therefore, knowledge of the hydrology of the river, the distribution and seasonal fluctuations in flow, including the size of discharge and the extent of flooding, is the technical foundation on which IBFM rests. In order to predict the possible consequences of development activities, we must first understand the hydrology of the river as it is today. This knowledge provides the baseline data for modelling potential changes to the flow of the Mekong River and the resulting impact on its physical, environmental and biological character. Modifications to the biophysical features will in turn have implications for the socio-economic fabric of the four countries, Cambodia, Lao PDR, Thailand and Viet Nam, that share the basin.

This booklet is the first in a series of information booklets that provide background information on IBFM in the Lower Mekong. It presents a review of the hydrology of the Lower Mekong Basin[1].

BACKGROUND

By any set of measures, such as length, mean annual flow, the diversity of its plant and animal life or the size and diversity of the aquatic resources, the Mekong is one of the world's great river systems. The livelihoods of 40 million of the basin's inhabitants in some way involve fishing, and the tremendous power of its tributaries provides the economies of countries that share the basin income through the development of large-scale hydropower projects.

Many of these water resources stem from the river's regular 'flood-pulse' hydrological regime. This means that the seasonal pattern of flood and recession are predictable even though their magnitude and extent can vary significantly from year to year. The rich animal and plant life that comprise the river's diverse ecosystems have evolved in tune with the seasonal hydrological cycle, as have the societies and cultures of the people who live beside it. This booklet examines the factors that contribute to the Mekong's unique hydrological characteristics

CATCHMENT GEOGRAPHY

The catchment of the Lower Mekong Basin comprises numerous smaller sub-catchments, each drained by one of the Mekong's larger tributaries. For the purposes of IBFM, the Lower Mekong Basin has been divided into six reaches or zones (Figure 1) based on:

- hydrology/hydraulics (occurrence, movement and properties of water);
- physiography (the form of river channels and how they connect);
- land use and vegetation.

These 'hydro-geographic' zones fall into broad two groups; those above Kratie, where the river usually remains within the confines of its banks and those below Kratie where the river meanders over a broad floodplain that is inundated annually during the flood season.

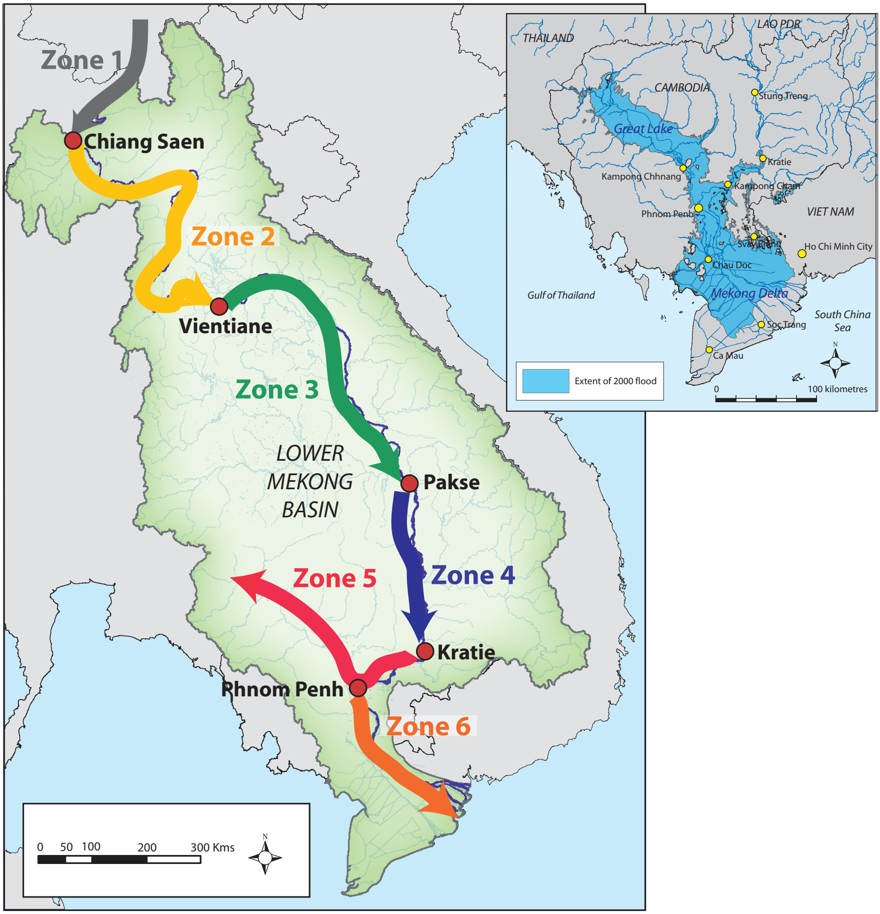


Figure 1. Major hydrological/geomorphological zones of the Mekong River in the Lower Mekong Basin

CLIMATE

In addition to geographic factors, the climate of the basin (particularly its rainfall patterns) plays an important role in controlling the Mekong's seasonal flow. The Southwest Monsoon, which generates wet and dry seasons of more or less equal length, dominates the climate of the Mekong Basin[2]. Tropical typhoons in the Pacific Ocean also make a significant contribution to rainfall during the later parts of the wet season (August to early October).

Significant local variations in rainfall exist within this broad picture[3]. As a result, parts of the basin, like the Khorat Plateau in Thailand are subject to frequent droughts, while other regions, such as the Central Highlands of Viet Nam, are more heavily affected by tropical storms.

FLOWS IN THE MAINSTREAM MEKONG

The average annual discharge of the Mekong is approximately 475 cubic kilometres. This volume is equivalent to an area of 700 x 700 kilometres inundated to a depth of just under one metre. At Kratie, during September at the peak of the flood, the monthly discharge averages in excess of 36,000 cumecs (cubic metres per second)[4].

Although the Mekong rises in the Tibetan Plateau, the contribution to the river's flow from the Upper Mekong Basin in China (Yunnan component) is relatively small (16%) by the time the river discharges through the Mekong Delta into the South China Sea. By far the major contribution comes from the two major 'left-bank' (eastern) tributaries between Vientiane – Nakhon Phanom and Pakse-Stung Treng, that together contribute more than 40% of the flow (Figure 2).

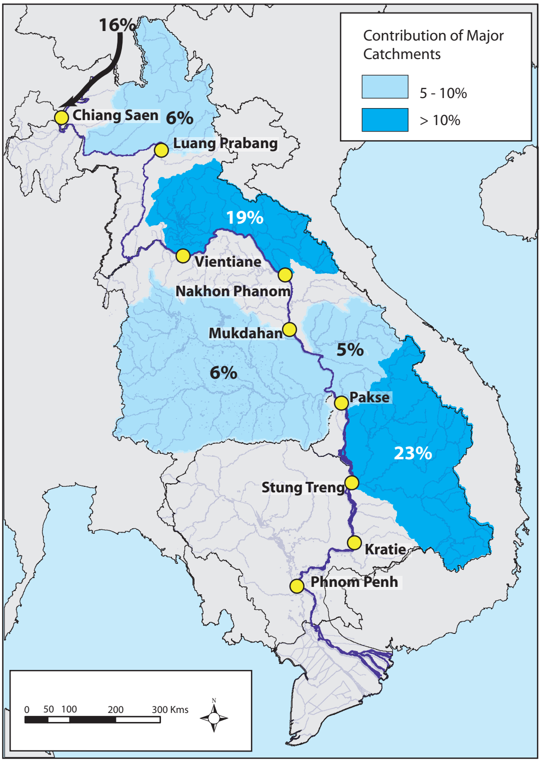


Figure 2. Major contributions to flow

Seasonal variations in flow overprint this basic pattern. During the dry season (December to May), the contribution from the Upper Mekong basin is proportionally much greater, while the input from the major east-bank tributaries declines[4].

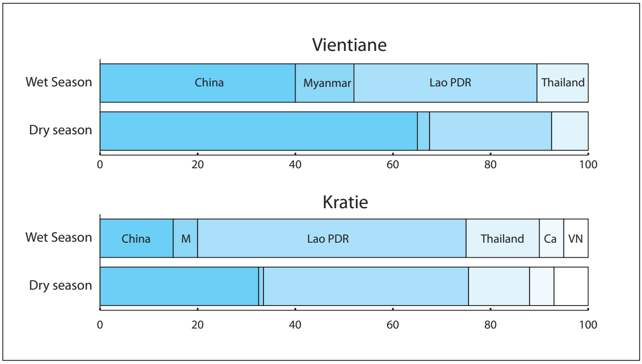


Figure 3. Variation in the contribution between wet and dry seasons

BIO-HYDROLOGICAL SEASONS

Because of the close linkage between the annual wet and dry season cycle, ecosystems and animal and plant life, hydrologists and biologists working in IBFM describe the flood–recession pulse in terms of 'bio-hydrological' seasons. These take into account both the flow of the river, and the biological communities that depend on the flow, and thus provide a framework on which to model the impacts of man-made modifications to the flow of the Mekong.

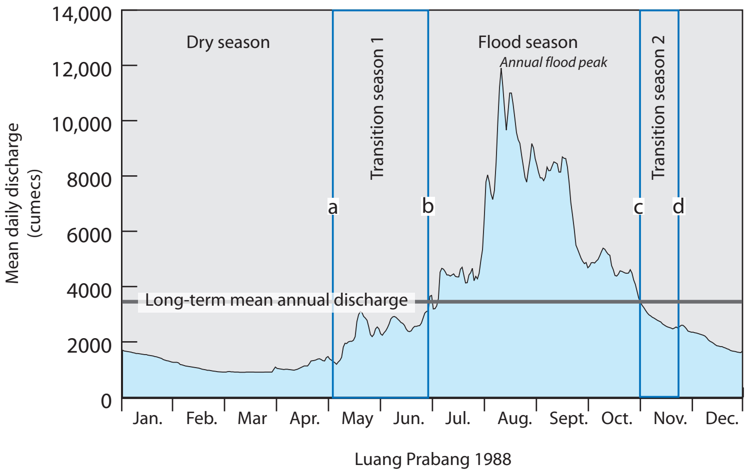
Many of the Mekong's important ecosystems have developed in response to the seasonal fluctuation of the river. The extensive wetland habitats on the river's floodplains, for example, are a direct consequence of the annual flood. Likewise, the animal and plant life these ecosystems support have adapted to the seasonal cycle of flood and recession. The life-histories of many Mekong fish species have evolved to take benefit from the river's hydrological regime. Large numbers of these fish migrate to deep pools in the mainstream where they take refuge during the dry season. At the onset of the flood season they migrate back to spawning and feeding grounds on the Mekong's extensive floodplains.

There are four bio-hydrological seasons in the annual hydrological cycle of which each has distinct attributes[5]:

- Dry season
- Transition season 1
- Flood season
- Transition season 2

The start and end of each season is defined by specific flow thresholds rather than by particular calendar days and the date of the onset of seasons may vary from year to year. The recognition of transition seasons between the dry and flood seasons is also particularly important because the changes in flow during these times have great biological significance. Changes in flow occurring during Transition Season 1, for example, are thought to trigger migration in certain species of fish.

Hydrographs provide a good visual representation of the seasonal variation in the flow of the river. The criteria that define the onset of the bio-hydrological seasons are given in Figure 4, which is a hydrograph of the flow of the Mekong recorded at Luang Prabang during 1988. This simple chart plots the volume of flow (expressed as cumecs—cubic metres per second) through the year. The peak and duration of the flood stand out clearly. The area under the plot represents the annual discharge.



a) End of the dry season/beginning of first transition season. This occurs the first time the flow increases to twice the minimum discharge of the preceding dry season.

b) End of transition season/beginning of flood season. The definition of this event is the first time the flow exceeds the long-term mean annual discharge. Typically the discharge remains above this average for several months.

c) End of flood season/beginning of second transition season. Conversely, this is defined as the last time the flow drops below the value for long-term mean annual discharge.

d) End of second transition season/beginning of dry season. This occurs at the first day of the first 15-day period when the recession of the flow averages less than 1%.

Figure 4. A typical hydrograph from the Mekong River illustrating the bio-hydrological seasons

FLOOD AND DROUGHT HYDROLOGY

Definitions

Floods and droughts are subjective phenomena, most often identified by the impacts they cause on people's lives. However, from a hydrological perspective, there is a continuum between so-called 'flood' and 'drought' years. Hydrologists often define floods in terms of maximum, or peak discharge. However, this definition is not useful for the purposes of IBFM, as the duration of the flood is often equally as important as the height of the peak discharge (Rice paddies, for example, die if they are submerged for more than 8 –10 days).

A more useful definition takes into account both the peak flow rate and the total volume of the flood. Figure 5 is a scatter chart that displays the annual flood peak and annual flood volume of the Mekong at Kratie between 1924 and 2005. The plots show that, while there is some correlation between the annual flood peak and the annual flood volume there is also a wide scatter of points on either side of the central trend.

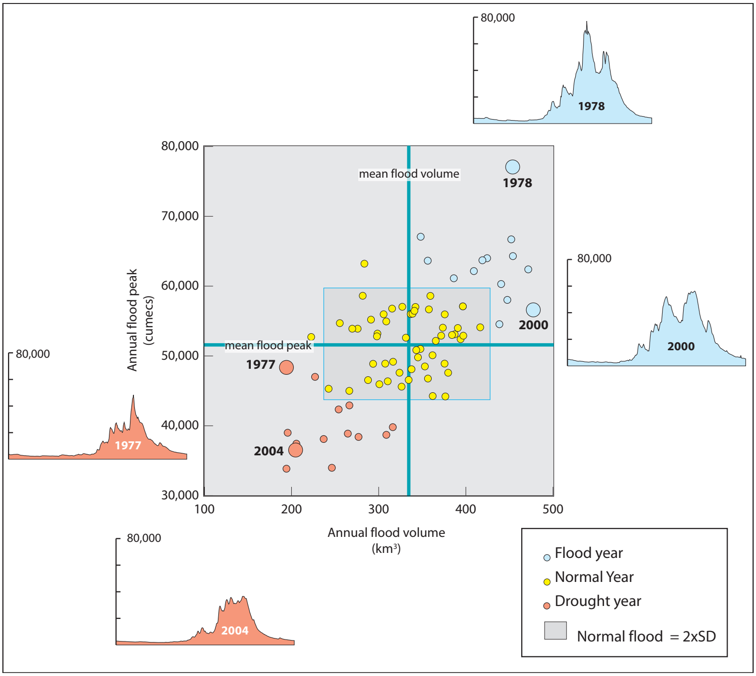


Figure 5. Flood and drought years at Kratie – with example Hydrographs

The ranges of annual flood peak and flood volume in Figure 5 shows the natural variability of the hydrological cycle and is a vital characteristic of the river system. Reducing the variability or shifting it in any direction will cause the character of the river to change.

From a statistical perspective, a 'normal year' occurs when both values are within two standard deviations (2xSD) of the mean. A 'flood year' occurs when both the annual flood peak and the annual flood volume are greater than 2xSD of the mean, and 'drought years' when these measures are less than 2xSD of the mean.

For comparison, the figure also presents the hydrographs of two flood years (1978 and 2000) and two drought years (1977 and 2004). The difference in the annual discharge (the area under the plot) between flood and drought years is stark. Interestingly, while 1997 was a drought year, it has a pronounced annual flood peak. In contrast in 2000, a flood year, two peaks occurred rather than forming a distinct single spike. These plots emphasise that, both the shape and size of the hydrograph provide important information regarding the severity of the flood or drought.

The cause of flood and drought years is a complex interaction between snow melt in the headwaters of the Mekong and geographic and temporal rainfall patterns. As a result, prominent flood and droughts years have their own unique origin and character. Likewise, the impacts of these extreme years may vary at different locations in the basin.

Broadly speaking however, below Vientiane wet season runoff from the large left bank tributaries dominates the flood hydrology, while upstream the input from the Upper Mekong Basin (Yunnan component) has more influence. For example, the extreme flood in 1978 largely affected reaches downstream of Pakse, while the hydrograph in Vientiane was more typical of a 'normal' year.

The early arrival of the flood season can also lead to extreme flooding. In 2000, the onset of this season occurred four to six weeks early, causing wetlands to fill long before they normally do. Flood waters arriving later were forced into areas that do not normally flood. Overall, the annual flood peak in 2000 was only slightly above the mean flood peak, but the flooding in this year was more extensive than in most years.

Drought years are less easy to characterise than flood years. While the 'less than 2xSD' measure is a fair guide, a variety of factors controls the severity of the impacts caused by drought. These factors include the time of year, crop and water demands, soil type, resistance of vegetation to moisture stress, and the infrastructure available for water storage. As a result, a hydrological drought defined by an extremely low water level is different from an agricultural drought, which is in turn different from a meteorological drought. Much depends on the occupations or livelihoods of the people suffering the drought. However, the dry season hydrology is a key factor because during this time the competition for water resources becomes critical if there is any shortage.

SPECIAL ISSUES FOR THE CAMBODIAN FLOODPLAIN AND MEKONG DELTA

Unlike the upstream reaches of the Mekong, the extent, duration and timing of the annual flood is the dominant factor in the hydrology of the Cambodian floodplain (including the Tonle Sap–Great Lake System) and the Mekong Delta (Figure 1). For this reason alone, these two unique hydrological systems merit special mention.

Most of the population of Cambodia relies on the natural resources supported by the Tonle Sap–Great Lake system for their livelihoods. It is one of the world's most productive ecosystems. The hydrology of the system is characterised by the unique seasonal reversal of the Tonle Sap River. This occurs in the wet season, when increased flow in the Mekong causes water to flow back up the Tonle Sap River and into the Great Lake. The impacts of the reversed flow on the lake are dramatic;

- The area of the lake increases six-fold, from 2,500 km^2 to 15,000 km^2.
- The mean depth increases from 1 m to 6–9 m depending on the year in question.
- The volume increases from less than 1.5 km^3 to between 60 and 70 km^3.

The vast inundated floodplain created around the lake is a huge natural resource, which, among various other benefits, provides rich feeding grounds for many commercially important species of fish on which Cambodia's prolific inland fishery depends.

The Tonle Sap–Great Lake system, which acts as a large natural reservoir, has a major influence on the flow of the Mekong downstream to the Delta region in southern Viet Nam. At the end of the wet season, when the flow in the Mekong begins to drop off, the flow of the Tonle Sap switches back. Water drains off the extensive floodplains around the Great Lake through the Tonle Sap river into the mainstream of the Mekong and then into the Delta. The unique reversal of flow brings significant benefits to the people downstream of Tonle Sap. These include:

- reducing the severity of flooding downstream of Tonle Sap by moderating peak flow rates during the wet season;
- providing additional water for irrigation during the dry season;
- increasing the amount of fresh water flowing into the South China Sea thereby reducing the extent of salt water intrusion into the Delta during the dry season;
- bringing a large recruitment of juvenile fish that have spent the months of the wet season feeding and growing on the highly productive floodplains around the Great Lake.

THE NEXT STEPS

The Mekong is special in that it is one of the few major river systems in the world whose water-resources have yet to be developed extensively. Much of the river is in unaltered condition in terms of its flow, ecosystems, animal and plant life. Unlike many rivers systems which are already heavily developed, we can try to predict and manage changes to the natural condition of the Mekong as development occurs rather than after the event.

Understanding the present day flow of the river is the first and most fundamental step in forecasting these potential changes. The hydrology and hydraulics of the Mekong are now well understood and the large amount of historical data on rainfall, climate and land form that is available basin wide, means that the flow can be described mathematically and modelled using computer simulations. These models, which are calibrated against real measurements, can be used to forecast modifications to the flow regime that result from changing any of these input parameters. As such, they can be used to simulate how the system will behave if the regime is altered as a result of human activities, such as hydropower development, or global factors, such as climate change and rises in sea level.

The MRC Management Information Booklet—*Modelling the Flow of the Mekong*—describes how these models work and some of the impacts that modified flow will have on the physical characteristics of the river system such as its channels and floodplains. This provides a platform for assessing the consequences that changing the natural character of the river will have on its animal and plant life and on the people who live by and off the river.

END NOTES

1. Much of the data presented in this booklet is taken from the MRC publication *Overview of the Hydrology of the Mekong Basin*.

2. Generalised climatic seasons in the Lower Mekong Basin.

Cool / Cold			Hot / Dry		Wet						Cool / Cold	
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
NE Monsoon			Transition		SW Monsoon						NE Monsoon	

3. Mekong Basin annual and seasonal rainfall (mm) for representative sub-regions

Month	Northern Region (Chiang Rai Thailand)	Central Region (Pakse Lao PDR)	Khorat Plateau (Khon Kaen Thailand)	Central Highlands (Pleiku Viet Nam)	Floodplain (Phnom Penh Cambodia)	Delta (Viet Nam)
Jan	13	2	5	6	8	8
Feb	10	7	15	6	3	3
Mar	20	20	35	25	15	15
Apr	85	70	60	85	65	75
May	190	220	170	225	115	165
Jun	210	380	180	350	125	110
Jul	310	390	160	360	160	140
Aug	390	500	185	460	160	170
Sep	280	320	260	360	265	160
Oct	140	100	120	220	255	250
Nov	60	20	10	75	130	160
Dec	20	3	3	20	20	40
ANNUAL	1730	2050	1210	2200	1320	1300

4. Lower Mekong mainstream monthly discharge 1960 to 2004 (cumecs)

Month	**Mainstream Site**						
	Chiang Saen	Luang Prabang	Vientiane	Nakhon Phanom	Mukdahan	Pakse	Kratie
Jan	1150	1690	1760	2380	2370	2800	3620
Feb	930	1280	1370	1860	1880	2170	2730
Mar	830	1060	1170	1560	1600	1840	2290
Apr	910	1110	1190	1530	1560	1800	2220
May	1300	1570	1720	2410	2430	2920	3640
Jun	2460	3110	3410	6610	7090	8810	11200
Jul	4720	6400	6920	12800	13600	16600	22200
Aug	6480	9920	11000	19100	20600	26200	35500
Sep	5510	8990	10800	18500	19800	26300	36700
Oct	3840	5750	6800	10200	10900	15400	22000
Nov	2510	3790	4230	5410	5710	7780	10900
Dec	1590	2400	2560	3340	3410	4190	5710

5. Characteristics of bio-hydrological seasons

Hydro–Biological Season	"Normal" Start Period	"Normal" End period	Significant hydrological parameters	Ecosystem Influence
Dry season	Late November to early December on the mainstream upstream of Kratie. Further downstream, floodplain storage and the regulating influence of the Tonle Sap system delays the typical dry season start to January	Typically May, throughout the Lower Basin	• Minimum flow and date. • Mean daily dry season discharge. • Coefficient of variation (%) of dry season daily flows	Dry season minimum indicates potential magnitude and timing of maximum stress. Mean specifies overall conditions while the coefficient of the variance indicator offers a way to detect non-natural influences on dry season hydrology.
Transition season 1	In a 'normal' year would typically be confined to a few weeks in May/June		Number and magnitude of pre-flood season spates or freshes.	Early spates offer spawning cues for migratory fish and have positive impacts upon water quality, particularly dissolved oxygen, and other variables.
Flood season	Typically June throughout the Lower Basin	From year to year can be quite variable, but generally early November in the upper reaches, and later further downstream.	Each flood season is classified into one of four quartiles dependent upon whether the peak and volume are above / below their respective means (Figure 5)	The relationship between the peak and volume of the annual mainstream flood hydrograph is a key indicator of the extent, depth and duration of floodplain inundation and habitat provision for fish and other aquatic organisms.
Transition season 2	A generally brief one to two week season during mid November in the upper reaches but tending to be longer and occur later downstream as over-bank, wetland and lake storage influences emerge.		The average daily rate of flow recession (cumecs/day)	Indicates the rate of post flood drainage riparian wetland which triggers downstream fish migration and influences vegetation changes.

Other publications available in this series:

MRC Management Information Booklet No.1: Adaptation to climate change in the countries of the Lower Mekong Basin

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