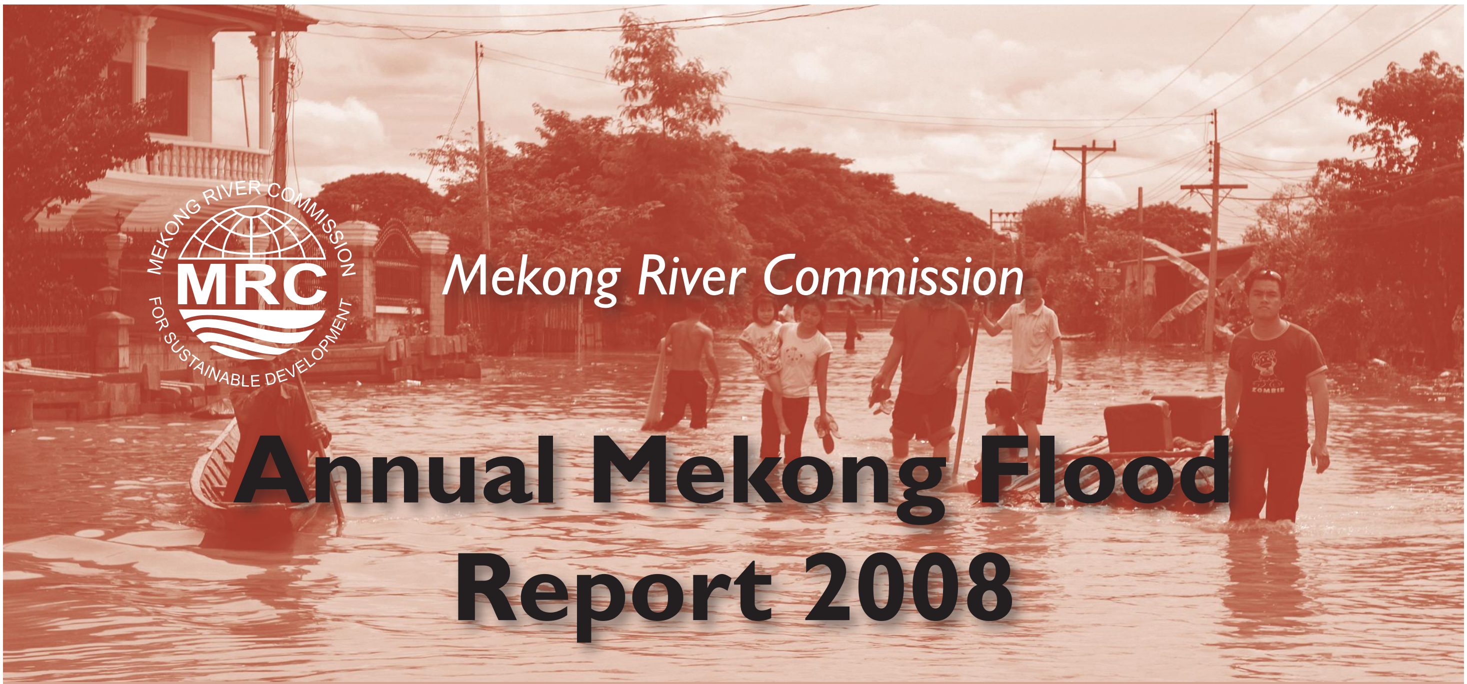
Mekong River Commission



Annual Mekong Flood Report 2008

September 2009

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Summary

Conventionally, floods and flooding are perceived as geophysical hazards within a common framework of natural disasters that also covers storms and hurricanes, earthquakes, volcanic eruptions, landslides and tsunami. In each case, socioeconomic losses and damage increase exponentially with event magnitude and as a function of civil exposure and vulnerability. Such hazards are perceived as random events that have entirely negative impacts, ignoring the fact that floods also have a positive ecological and socioeconomic function. Great civilizations have developed within flood plains where, on the face of it, exposure and vulnerability have been high. Such societies have included Sumerian Mesopotamia along the Lower Tigris and Euphrates Rivers, ancient Egypt along the Nile, the Harappan culture of the Indus valley in Pakisan and India, the founding cultures of China in the Yellow River Valley and the Angkor civilization of the Lower Mekong Basin itself. Exploiting the benefits and avoiding the risks brought by the annual flood stimulated such societies to put greater efforts into social organization and water management systems, which endorsed them as landmark civilizations.

The use of the term 'flood' in large tropical rivers and others such as the Nile refers to a highly predictable seasonal hydrological response to rainfall. The regime comprises two basic seasons, the 'flood' season and the 'low flow' season. Issues of scale mean that 'flood' conditions, when flows are considerably above the average for the year as a whole, last for several months. On much smaller rivers a 'flood' lasts only for several days, a duration that is more consistent with definitions of a 'flood' as a short duration geophysical hazard. The annual Mekong flood, in response to the SW Monsoon, does in some years reach peak discharges which cause considerable losses and damage. In other years the 'flood' is benign and benefits accrue. Here the term 'flood' is used to refer to the several months of increased discharge conditions, which may or may not in any given year result in large scale economic loss. The annual Mekong flood has been pivotal to the cultural and socioeconomic evolution of the region and despite the fact that some loss and damage occurs in most years, those that are significant at the regional and national scales have a frequency that is low enough to ensure that over time flood benefits exceed the flood costs by a very considerable margin.

Flood damage arises from a combination of direct losses due to the fact of inundation and secondary losses as a result of the suspension of normal economic activities in the commercial and service sectors which can accumulate long after the end of the event itself and until such time as damage is repaired and stocks and inventory replaced. Assessing these figures in dollar terms reasonably accurately requires detailed surveys of pilot areas the results of which are then applied to the flood affected region on a loss per unit area basis. This is the methodology adopted in each country in the basin and from data available from the relevant National Disaster Management Agencies the losses that are estimated to arise in an average year amount to a regional total of US$ 76 million. The most destructive regional flood conditions of recent decades occurred in 2000 in the south of the basin and in 2008 in the northern parts. By far the

larger overall damages occurred in 2000 and amounted to US$811 million, those of 2008 being much less at US$135 million.

The major economic flood benefits arise in the agricultural and fisheries sectors, though by maintaining wetlands the annual flood also ensures that the products and services that such areas provide are maintained from year to year, though these are difficult to value in financial terms. On the basis of the value of production the main agricultural region in the basin is the delta in Viet Nam which contributes 30% of national GDP and is the major source of export rice, Viet Nam being the second largest contributor to the international rice trade.

In Cambodia flood inundated areas of the Delta are also amongst the most fertile regions for agricultural production, with extensive double cropping. Rice occupies 90% of the total cultivated land of which 32% lies in flood prone areas. Because of the fact that only 7% of the land is irrigated it is only in these naturally flooded areas that a second crop is possible on any large scale using receding water around lakes and rivers. In Lao PDR and Thailand the link between agriculture, rice cultivation in particular, and the benefits of the annual flood on the Mekong is less evident since most crops are rain fed or irrigated.

The link between the regional fisheries production and the annual flood is now well established. Current estimates regarding the annual value of the regional aquatic resources exceed US$2.8 billion, though not all of this figure is directly attributable to flood induced processes.

Other flood benefits accrue but they are much more difficult to value in financial terms. This applies in particular to wetlands which provide ‘goods’, such as fish and aquatic products, and ‘services’ such as flood attenuation and the retention, recovery and removal of excess nutrients and pollutants.

The theme of the AFR 2008 is not to set out a detailed economic analysis of the benefits and costs of the annual Mekong flood but to compare the two in financial terms based upon the generally available macro-data. These data, such as those with respect to the annual value of the Mekong fishery, are widely accepted not least by the MRC’s Fisheries Programme itself. In addition, the annual value figure for the fishery of US$2.85 billion refers only to that at the first point of sale. In comparison, the estimated average annual costs of flood damage only amount to US$76 million or just 2.5% of the fisheries benefit alone.

The additional figures for the agricultural benefits are harder to assess since the linkage between the annual flood is not as clear as it is with the fishery. Flood recession rice production in Cambodia is reported to account for 32% of national production, valued at US$3.1 billion in 2006 (based a February 2009 international price of US$500/tonnes). The value of the agricultural benefit accruing directly from the flood in Cambodia is therefore US$3.1 billion x 0.32 = US$1 billion.

In the Mekong Delta in Viet Nam agricultural production in 2004 had a reported market value of US$3.5 billion. That this is a benefit of the flood is based on the argument that the

9 to 13 millions tonnes of sediment deposited annually across the delta, most of it during the flood season, has over millennia resulted in some of the most productive agricultural land in Southeast Asia, thus establishing the link.

Separating the proportion of the total benefits in any of the sectors that accrue directly from the annual flood is simply not possible, but even if they are half of the figures quoted here with regard the value of the annual Mekong fishery alone, the 'benefits' still far outweigh the 'costs'. The major conclusion to be drawn is that in large tropical monsoonal rivers the annual flood cannot be perceived exclusively in terms of being a geophysical hazard. The comparative benefit and cost figures presented here should not be seen in any way as a direct economic comparison but interpreted as broadly indicative measures of the potential socioeconomic value of flood induced processes.

The 2008 flood season across the Lower Mekong Basin illustrated a common feature of the regional flood hydrology, that is extreme flooding in one part of the basin and average to below average conditions elsewhere. In 2008 it was the northern parts between the Chinese border and Vientiane that witnessed flood levels not seen for almost 50 years, while further downstream in Cambodia and Viet Nam discharges and water levels were average at best.

Volumes of flood runoff, discharges and water levels in the northern part of the region up until mid July had been average but an intensification of the SW Monsoon saw repeated tropical storms and higher flood runoff. The storm situation then intensified dramatically during the first week of August with the passage of tropical storm Kammuri across the northern provinces of Lao PDR. Only satellite indications of the associated 3 to 5 day rainfalls are available (the rain gauge network here being very sparse) but cumulative rainfalls considerably in excess of 500 mm are indicted. Volumes of flood runoff in the large northern Lao tributaries such as the Nam Ou and Nam Khan increased to extreme levels.

Maximum discharges at Luang Prabang and Vientiane/Nong Khai occurred on the 14th and 15th of the month and were in the region of 23,000 cumecs or 50% above the annual average. The associated water levels were comparable to those of 1966, when both city centres were flooded. Some urban flooding again occurred at Luang Prabang since water levels were elevated due to backwater effects on the Nam Khan upstream of the Mekong confluence. At Vientiane large scale urban flooding was avoided principally due to the sandbagging of the river bank adjacent to the central business district, but large areas of suburbs and peri-urban area were flooded to depths locally exceeding 1.5 m.

These conditions soon dissipated downstream of Vientiane/Nong Khai since flood flows into the mainstream from the large left-bank tributaries in Lao PDR, starting with the Nam Ngum, were quite average. This becomes quite clear from the flows at Pakse and Kratie which come close to those for an average flood season overall, while water levels in the Delta at Tan Chau and Chau Doc were below average throughout most of the season.

Apart from these events on the mainstream local, and often seriously damaging, flash floods occurred as they do in most years. In Lao PDR such conditions occurred in Bolikhamxay province during June with over 800 mm in 10 days and as much a 200 mm in 1 day. In the Thai Mekong region during September in the Khon Kaen area heavy rainfall of almost 160 mm. on the 17th caused of flood inundation and damage to property and crops and the deaths of two people. In Cambodia no significant flood damage was reported for the year while in Viet Nam the only events to cause any significant damage occurred in the Upper Sre Prok during May and in the upper Se San Basin during the first week of August. The former saw two lives lost and the latter resulted in some bridges being damaged and about 100 ha of rice paddy lost or seriously damaged. Overall damage from flash floods for the year in Viet Nam amounted to US$1 million. Regionally, however, the number and severity of flash flood episodes was well below average.

The events of August 2008 provided the first real opportunity to assess the performance of the RFMMC's flood forecasting models and expertise and in general they performed reasonably well, though obviously room for improvement is recognised. The major constraint to accuracy over lead times in excess of two to three days is the emerging conclusion that the storm rainfalls indicated by satellite images are probably too low and that the network available for 'ground truthing' needs to be improved in key areas of Lao PDR in particular.

Otherwise the lessons and recommendations put forward in the four country reports generally repeat those of earlier years and focus up such issues as strengthening community based flood risk management and self reliance and building capacity within local communities with regard to flood preparedness and emergency response. A need is also recognized to improve the channels of communication between the local communities and the relevant flood forecasting, mitigation and response agencies. In Viet Nam once again attention is drawn to diverting more financial support for dealing with flash floods in the Central Highlands. Finally, a call is once more made to consider translating the Annual Flood Report into each of the four riparian languages.

1. Introduction

Consistent with the format established in the Annual Flood Reports for 2006 and 2007, this 2008 document comprises the following major sections:

Chapters 2, 3, and 4 present the annual theme, which this year considers the benefits and costs of the annual Mekong flood. The aim is not in any way to provide an in depth economic assessment but rather to establish the fact that the regional benefits that accrue from the flood far exceed the losses and damage, which in the past have been the almost exclusive focus of attention.

Chapter 5 reviews the hydrological aspects of the flood season, which in 2008 witnessed extreme discharges and water levels in the northern areas of the Lower Mekong Basin between Vientiane/Nong Khai and the Chinese border.

Chapter 6 gives a brief summary of each of the four annual country reports, for Cambodia, Lao PDR, Thailand, and Viet Nam.

Chapter 7 details the major lessons learnt over the year, and provides recommendations for improving the RFMMC's flood forecasting system.

2. Flood benefits

2.1 Introduction and historical context

Conventionally, floods and flooding are perceived as geophysical hazards within a common framework of natural disasters that also covers storms and hurricanes, earthquakes, volcanic eruptions, landslides and tsunami. In each case, socio-economic losses and damage increase exponentially with event magnitude and as a function of civil exposure and vulnerability. Such hazards are perceived as random events that have entirely negative impacts, ignoring the fact that floods also have a positive ecological and socio-economic function. Great civilizations have developed within flood plains where, on the face of it, exposure and vulnerability have been high. Such societies have included Sumerian Mesopotamia along the Lower Tigris and Euphrates Rivers, ancient Egypt along the Nile, the Harappan culture of the Indus valley in Pakisan and India, the founding cultures of China in the Yellow River Valley and the Angkor civilization of the Lower Mekong Basin itself. Exploiting the benefits and avoiding the risks brought by the annual flood stimulated such societies to put greater efforts into social organization and water management systems, which endorsed them as landmark civilizations.

Historically cultures that exploited the benefits of floodplains and contemporary societies which continue to do so, such as those in the Lower Mekong, have to face a two-tailed flood hazard (Webby *et al*., 2007). Either the annual flood is too small, leading to reduced agricultural output or too large, resulting in inundation, crop losses and general socio-economic damage. The dis-benefits arising from the 'failure' of the flood season must not therefore be ignored or even made light of. As will be seen, historically some of these deficiencies in the flood season hydrology of the Mekong have been quite spectacular.

The Mekong Delta and Cambodian floodplain are the site of one of the earliest civilizations in mainland Southeast Asia. Called Funan by visiting Chinese dignitaries, by the 3rd Century AD it was centred around two major urban centres, namely Oc Eo in Viet Nam and Angkor Borei in Cambodia (Jacques, 1979). It has been argued that dry season flood recession rice cultivation formed the agricultural basis of Angkor Borei and may have dictated the location of the city itself (Fox and Wood, 1999). The link between the rich agricultural possibilities provided by the annual Mekong flood and the genesis of such pre-Angkor civilizations is clear from (Figure 2.1) which compares the location of 2nd and 3rd Century archaeological sites with the flood recession rice growing areas (see Fox and Wood, 1999). It is entirely likely that this farming system became the future basis for later Lower Mekong civilizations such as that of Angkor itself which has its classic period between 800 and 1300 AD. Angkor eventually evolved into a true 'hydraulic civilization' organised around the need to manage water through a vast system of irrigation canals.

The ability to maintain soil fertility over time has been a major challenge to Asian civilizations. The Chinese, for example, developed a sustainable agricultural system based on meticulous schemes for recycling organic waste; agriculture in Japan, Java and the Philippines was based on rich volcanic ash soils (Ng, 1979). In Cambodia most soils are not naturally fertile (Delvert, 1961) but farmers recognised over 1800 years ago that, being located within a flood plain and deltaic system that allowed rising floodwater to spread out across the landscape and deposit millions of tonnes of fertile sediment annually, they could develop a highly productive and sustainable system of agriculture. The enhanced crop yields achievable from flood recession agriculture are clear from the figures in (Table 2.1).

Figure 2.1 The distribution of flood recession rice cultivation areas and pre-Khmer archaeological sites in Cambodia. (Source: Fox and Wood, 1999)

Figure 2.2 This bas relief at Angkor Wat is indicative of the importance of fish in the socioeconomics and culture of the Khmer Empire (800 – 1300 AD)

Table 2.1 *Cambodia – comparative seasonal rice yields.*

Land use system	Yield (tonnes per hectare)
Rain-fed paddy rice – wet season	1.6
Flood recession rice cultivation – dry season	3.0

These benign effects of the annual Mekong flood with their attendant benefits extend to the regional fishery which is an imperative component of the basin's economy. The first records of the importance of fish and fishing is provided by the Bas Reliefs in the temples of Angkor, dating from the 11th Century (Fox and Wood, 1999). Fish are represented in daily activities in markets and also appear in agricultural scenes pointing perhaps to early aquaculture. Accounts provided by Chinese travellers over 700 years ago indicate that fishing practises and the economic importance of the Mekong fishery have changed little. The next accounts of capture fisheries come from French and English travellers in Indo China and Thailand during the late 1800s. They identified the important areas as the Great Lake in Cambodia, the Mekong mainstream to Khone Falls, and the surrounds of Vientiane and Luang Prabang.

Over this period, the Mekong fishery developed to take advantage of annual fish migrations at the beginning and end of the flood season. The annual mono-modal flood pulse of large tropical rivers such as the Amazon, Congo and Mekong is the dominant 'trigger' in the annual cycle of ecological processes within the fluvial system, bringing about a distinct seasonality in the annual hydro-biological cycle between an aquatic phase and a terrestrial phase (Junk *et al*. 1989). As a consequence there are highly seasonal bio-geochemical cycles, growth rhythms and life cycles amongst the many species of ecosystem system biota such as algae, macrophytes, trees, fish and invertebrates (Junk, 1997; Junk *et al*., 2000; Junk and Wantzen, 2004) and these have been exploited much to the benefit of the riparian societies.

This pivotal role that the annual Mekong flood has played in the evolution of the cultures and economy of the basin therefore negates the concept of a flood exclusively as a (usually) disastrous overflowing of water onto previously dry areas. In a hydrological, ecological, economic and social environment such as that which prevails in the Lower Mekong Basin the annual flood only becomes a hazard if certain hydrological benchmarks are exceeded. Although important, it would be incorrect to define these thresholds simply in terms of water level or the associated discharge since these variables only describe one aspect of what is a multivariate random process. The annual flood in the Mekong arises from the complex interaction between meteorological conditions and the basin response which generates a seasonal hydrograph which needs to be defined in much wider terms.

The weight of the evidence, both historical and contemporary, suggests that the benefits of the annual Mekong flood far outweigh the costs in most years. The balance between the two is not static, however. When critical hydrological thresholds are exceeded the value at risk is increasing annually since there is rapidly accelerating development within the flood plain, its population is increasing and the crops, property and inventory at risk are becoming more valuable. Such circumstances are in common with those world wide where there appears to be a systematic growth in the exposure and vulnerability of society to flooding, particularly in developing countries, such that annual costs and losses are growing even though there is little evidence (so far) to suggest that the incidence and severity of the events themselves is on the increase.

The economic dimension as to whether there is an overall regional cost or benefit accruing to the annual flood in any given year is complex and fuzzy. The very size of the Lower Mekong Basin is such that the synoptic events which cause extreme runoff have an area of impact that can only cover a part of the region, such are the consequences of scale. While the strength of the SW Monsoon defines the overall character of the flood season it is typhoons and tropical storms that typically generate the extremes and most damaging events. Historically, there have been no flood seasons during which the whole basin has been affected by critical conditions. Hence there can be considerable geographical variation across the region in the annual flood situation, a fact emphasised during the events of 2008 (details in Chapter 6).

The picture that clearly emerges is that the annual flood has been pivotal to the cultural and socioeconomic evolution of the Mekong region and that despite the fact that some loss and damage occurs in most years, those that are significant at the regional and national scales have a frequency that is low enough to ensure that over time flood benefits exceed the flood costs by a considerable margin. Arguably therefore, the logical approach is to set out the benefits first and then consider the losses, which helps to moderate the perspective of floods as an entirely negative process. This is not to underplay the importance of the need to develop strategies to manage and mitigate flood losses and damage. In some years they can be catastrophic to the extent of causing a significant fall in GDP.

2.2 Flood benefits — agriculture

A key feature of the annual Mekong flood is that in terms of its timing it is highly predictable, particularly in terms of its onset in early July. This feature it shares with the Nile flood, for example, which enabled Egyptian society to develop a planned and highly seasonal form of agriculture with a relatively high level of crop security leading to food surplus in most years. This said, however, the periodic failure of the annual flood over consecutive years led to famines of which several are chronicled in the annals of Ancient Egypt. There is little doubt that droughts would also have occurred and caused food shortages at the time of the ancient Mekong civilizations, but such events are unrecorded. In Cambodia these societies were largely rural, supporting ceremonial centres with rice and labour. It has been argued that the later states and kingdoms that evolved there and in Thailand and Lao PDR took the form of social systems based on cooperative villages which had a common form of agricultural production based on monsoon rainfall and to some degree on various forms of flood irrigation. They are referred to as ‘agro-cultural complexes’.

This type of rural balance between a subsistence form of agriculture and the provision of food to political and religious centres largely prevailed in the Mekong region until the colonial era and the beginning of large scale commercial resource development. French statistics (Van Liere, 1980) suggest rapid agricultural growth and environmental change during this period. From 1880 to 1930, the total volume of earth dredged in the Mekong Delta totalled 165 million cubic metres which compares with 210 million for the Panama Canal and 260 million for the Suez. These new canals drained large areas and complemented the demands from an increasing population of ethnic Vietnamese farmers migrating from the north. Cultivated land area rose from 200,000 hectares in 1879 to 2.4 million in 1929. This represented an increase from roughly 5% to 60% of the total surface area in the Vietnamese portion of the Mekong Delta.

The aim was, through public works, to drain the delta's swamps, marshes and forests to exploit the fertile alluvial soils that were the legacy of thousands of years of the flood regime of the Mekong and transform the landscape into one dominated by highly productive rice paddies. This impressive rate of growth meant that by the 1930s the delta has already become one of the world's major rice exporting regions. It was still, however, largely uncontrolled in hydraulic terms, particularly with regard to flooding and salinity intrusion, which were seen as major obstacles to the development of intensive farming and multi-cropping systems (Kakonen, 2008).

It was not until the 1980s that the necessary intake and outflow structures were constructed on a large scale to regulate flows to and from the fields and not until the 1990s that hydraulic infrastructure was completed that reduced dependence on natural hydrological conditions and which enabled the control of floods, salinity and the cropping limitations imposed in some areas by acid sulphate soils. Consequently, by 1997 Viet Nam had become the world's second largest rice exporter, shipping some 3.5 million tonnes to the global market. A statistical summary of the contribution that the agricultural outputs of the delta currently make to the Vietnamese economy (General Statistics Office, 2004) is set out below. It produces:

- About half of the national food output;
- 51% of the total rice paddy production;
- 55% of the national inland fisheries and fruit output;
- 60% of the country's exported aquaculture products;
- 61% of the total national export value.

Of course it would be quite wrong to suggest that these contributions to the national economy are entirely the result of the Mekong flood regime — they are the outcome of converting the natural floodplain into a highly controlled and intensive agricultural landscape. But the nature of the landscape that provided the opportunity to do so is the result of the hydrology of the river and the benefits that have accrued from the annual flood over thousands of years.

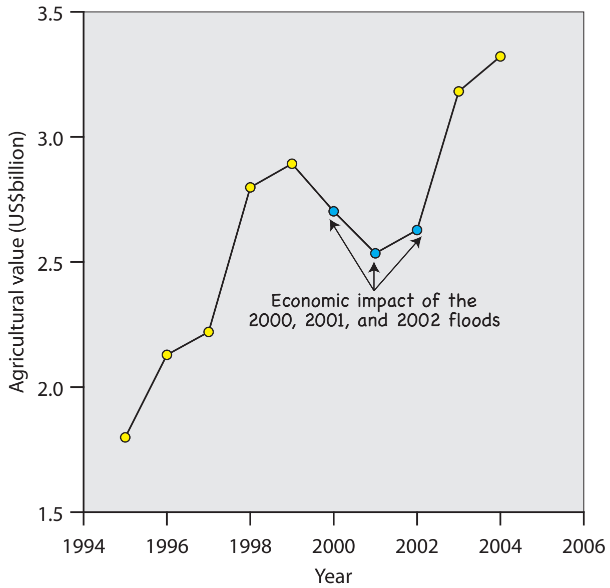

Figure 2.3 The value of agricultural production in the Mekong Delta (1995 – 2004) in Viet Nam. The chart shows significant annual growth over period, but also that this growth can be disrupted during years of extreme flood conditions.

Figure 2.3 shows the significant rates of annual growth in agricultural production in the Mekong Delta to 2004, when its total value reached US$3.3 billion. The figures also illustrate, however, that this systematic increase in monetary value can be interrupted in years when flood discharges and water levels exceed critical thresholds, as they did between 2000 and 2002.

These figures refer only to that part of the delta in Viet Nam, though it is generally regarded as beginning at Phnom Penh in Cambodia, where the Mekong divides into its two main distributaries, the Bassac and the Mekong (Tien). It comprises a vast triangular plain of approximately 5.5 million ha of which 1.6 million are in Cambodia and mostly lies below 5 masl. The 9 to 13 millions tonnes of sediment deposited annually, most of it during the flood season, has resulted in some of the most productive agricultural land in Southeast Asia.

Unsurprisingly therefore the flood inundated areas of the delta are amongst the most fertile regions for agricultural production in Cambodia, with extensive double cropping. Rice occupies 90% of the total cultivated land of which 32% lies in flood prone areas. Because of the fact that only 7% of the land is irrigated it is only in these naturally flooded areas that a second crop is possible on any large scale using receding water around lakes and rivers. Interestingly this second dry season flood recession crop usually gives higher yields than the wet season crop due to more controllable water management, the lower risk of crop losses due to excessive water depth and the benefits obtained from the deposition of fertile sediment during the flood itself.

Cambodia harvested more than 6,264,000 million tonnes of rice in 2006. Taking current 2008 price of US$ 500/million tonnes and the fact that of the 2006 figure 32% was harvested from the floodplain areas then the flood benefit value is US$1 billion.

In Lao PDR 80% of the cropped area is planted to rice, of which 75% is rain fed lowland paddy in areas of low flood risk. The balance is made up of rain-fed upland rice which has quite low yields. Only about 10% of the planted area is irrigated contributing about 14% to national production. Although overall, rice production accounts for 20 to 25% of GDP there isn't the strong linkage between the annual flood in the Mekong Basin and agricultural production that there is in Cambodia and the Delta in Viet Nam. FAO figures indicate that in 2005 rice production in Lao PDR totalled 2,600,000 tonnes, of which only 5% is marketed commercially. The planted area was 736,000 ha giving a yield of 3.5 tonnes/ha.

Figure 2.4 Flood recession rice cultivation on the Cambodian floodplain.

There are local areas of rice paddy close to the Mekong mainstream and in the lower reaches of the large tributaries in Lao PDR that are inundated during most years and which are exploited for agricultural production, including the growing of vegetables and maize as well as rice. Most of the islands in the mainstream are used in this way. Although in total the area is probably substantial and the economic benefit significant, this sector of the agricultural economy is not identified separately in the compilation of agricultural statistics since it is generally informal, with outputs traded locally, if at all. The wider commercial benefits of agriculture in Lao PDR may therefore be considered to be independent of the Mekong flood.

In the Thai Mekong region traditional forms of agriculture that exploit seasonal floodplain and wetland inundation are now increasingly scarce, as more intensive forms oriented towards external markets have taken over from subsistence and small scale farming. According to Fukui and Hoshikawa (2003) the shift towards large-scale rain-fed production in Isaan only began during the 1950s, prior to which a flood dispersion system known as *Tham Nop*, was generally used, an example of which is illustrated in Figure 2.5. Earthen bunds were constructed across small tributaries to divert early season floodwater onto pre-prepared paddy fields typically covering a 300 – 500 ha area on the flood plain and low lying riparian lands. According to the first village economic survey in Thailand in 1930–31 (Zimmerman,1931), the average yield of rice in the northeast of the country, based on this limited system, was most probably higher than in the central region, which had become Thailand's rice-bowl for export production (Fukui and Hoshikawa, 2003). The report goes on to describe the very low density of population in the northeast and its concentration along rivers where the local economy centred around the exploitation of aquatic resources.

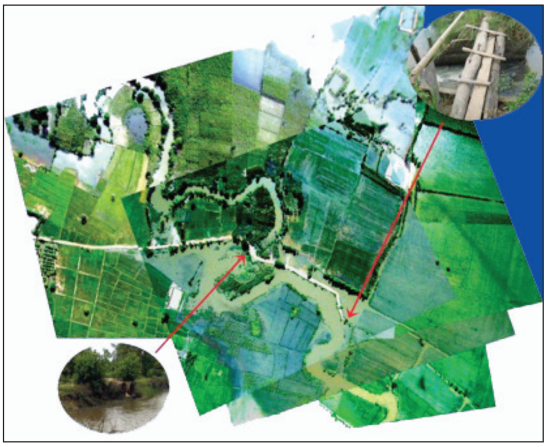

Figure 2.5 An example of the 'Tham Nop' flood diversion system from North East Thailand. (Fukui and Hoshikawa, 2003). A bund is constructed across the river and early season flood water diverted onto riparian rice paddy. Water levels are controlled by simple timber gates. Typically these tradition water control schemes provided flood irrigation to 200 to 500 ha.

Post 1950 rural development policies in the Thai Mekong region, particularly in the Mun–Chi basin, focused on agriculture and the provision of reservoir storage for direct gravity fed and pumped irrigation from regulated rivers. The population grew five fold in 50 years from 5 to 25 million, of which 70% remains rural and involved to some degree in agriculture. Rain fed rice production dominates the rural landscape, covering 75% of the agricultural land. In 2006 total rice production in the Thai provinces that lie within the Mekong Basin totalled 10.5 million metric tonnes (FAO Figures), with a current (February 2009) value of US$5.25 billion.

With less than 1% of the regional land classified as flood plain the role of the annual flood in generating this agricultural benefit in the Thai Mekong region is minimal. Small scale rice growing systems using flood recession trap ponds do still exist along with instances of traditional mixed crop farming using flood recession terraces on riverbanks, for example in the Nam Songkhram river basin. Such activities are, however, usually uncommercial and generate benefits only at the household or village level.

Summarizing the annual agricultural flood benefit gives a total regional figure of US$4.5 billion, which is generated in Cambodia and Viet Nam alone. In relative terms the outputs of floodplain agriculture in Lao PDR and Thailand are considered to be insignificant compared to rain fed and irrigated production (Table 2.2). The overall figure is probably conservative since, although it is based on a rice price of US$/500 a tonne, which represents a significant recent increase, the value of other crops has not been included. To do so would be complex since production and market value figures are not generally available in a form that permits a breakdown in a way suitable for the present purposes. It is also true to say that fruit, vegetables and other crops that are grown on a commercial scale are produced in areas not directly at risk from flood inundation except under the most extreme hydrological conditions. Rice on the other hand is the archetypical flood plain crop and production clearly benefits from the annual flood in most years.

Table 2.2 *Summary value of regional agricultural output which benefits directly from the annual Mekong flood.*

Country	Estimated annual agricultural value accruing from the annual Mekong flood (US$ billion)	Comments
Cambodia	1.0	2006 figures. Based on rice occupying 90% of agricultural area of which 32% lies in flood prone areas.
Lao PDR	Not significant	Only local flood recession agriculture – most production combines rain fed summer and irrigated winter crops.
Thailand	Not significant	
Viet Nam	3.5	2004 figures for production in the delta, which is itself a long term product of the annual flood.
Total	4.5	

Note: The estimates are based on rice production valued at US$500 per tonne (February, 2009 prices).

2.3 Flood benefits — the Mekong fishery

The annual mono-modal flood-pulse of large tropical rivers such as the Amazon, Congo and Mekong is the dominant 'trigger' in the annual cycle of ecological processes within the fluvial system, bringing about a distinct seasonality in the annual hydro-biological cycle between an aquatic phase and a terrestrial phase (Junk *et al*., 1989). As a consequence there are highly seasonal biogeochemical cycles, growth rhythms and life cycles amongst the many species of ecosystem system biota such as algae, macrophytes, trees, fish and invertebrates (Junk, 1997; Junk *et al.*, 2000). The annual inundation of the floodplain, particularly in Cambodia and specifically around the Tonle Sap and Great Lake, makes available a huge biomass to the aquatic food web which boosts aquatic productivity and results in a prolific ecosystem.

The major manifestation of this virtually unrivalled level of aquatic productivity is the Mekong fishery, amongst the largest of its type in the world. Hortle (2007) estimated that in 2000 the yield of fresh water fish in the basin, minus the aquaculture component, was approximately 1,860,000 tonnes. Combining this figure with an estimate of the size and first sale vale of the fish of between US$1.0 and US$1.8/kg, the total value of the fishery is indicated to be US$2,600 million if a median figure of US$1.4/kg is adopted. Using a proportional breakdown of estimated fish yield by country given in (Hortle, 2007), the following national estimates are obtained:[1]

Table 2.3 *Estimated value of fish production in the Lower Mekong Basin.*

Country	Value of national inland fishery based on 2000 estimates (US$ million)
Cambodia	608
Lao PDR	212
Thailand	900
Viet Nam	880
Total Lower Mekong Basin	2 600

Note: Base on figures in Hortle (2007).

The figure for Viet Nam reflects the role of aquaculture production, which in effect is independent of the annual flood pulse. Elsewhere, it is clear that the flood regime plays a pivotal role, most particularly with regard to migrant fish capture which accounts for 71% of the total fish yield (Barlow *et al.*, 2008), no more so than in Cambodia. In Thailand the major basin fishery lies in the Mun/Chi Basin and in tributaries such as the Nam Songkhram while in Lao PDR it is a significant element in socioeconomics throughout the country, both on the mainstream and within the tributary systems.

Other aquatic animals (OAAs) such as frogs, crabs and molluscs are also very important in terms of their contribution to regional diet and livelihoods and their breeding cycle and yield is closely allied to the seasonal flood cycle. Hortle (2007) provides annual yield estimates which can be converted to a US$ value by assuming an average sale price, a figure of US$0.50 kg being a reasonable one according to the MRC Fisheries Programme. As the figures in Table 2.4 indicate their annual regional value could be close to US$250 million.

Table 2.4 *Estimated value of other aquatic animals (for example, frogs, crabs and molluscs) in the Lower Mekong Basin.*

Country	Estimated annual yield of other aquatic resources (tonnes)	Value based on an average sale price of US$0.50 kg (US$ million)
Cambodia	105 500	52.75
Lao PDR	40 500	20.25
Thailand	191 000	95.50
Viet Nam	161 000	80.50
Total Lower Mekong Basin	498 000	249.00

Note; Based on figures in Hortle (2007).

1 Though these national yields figures are derived from fish consumption data and therefore ignore cross-border trading they are nonetheless broadly indicative of production value.

That there is a very strong link between the annual fish catch and the extent and duration of flooding is intuitively clear. The most researched component of the overall Mekong fishery is the so called *dai,* or bagnet, fishery that exploits the annual migration of fish out of the Great Lake in Cambodia towards the Mekong via the Tonle Sap towards the end of the flood season (Figure 2.6).

Figure 2.6 The *dai,* or bagnet fishery, on the Tonle Sap, Cambodia.

Halls *et al.* (2008) propose a flood index based upon the sum of the number of days that a given area is flooded during around the Great Lake each flood season, which provides an indicator in units of km^2 days. Figure 2.7 shows the relationship between this statistic and the annual *dai* catch in terms of fish biomass.

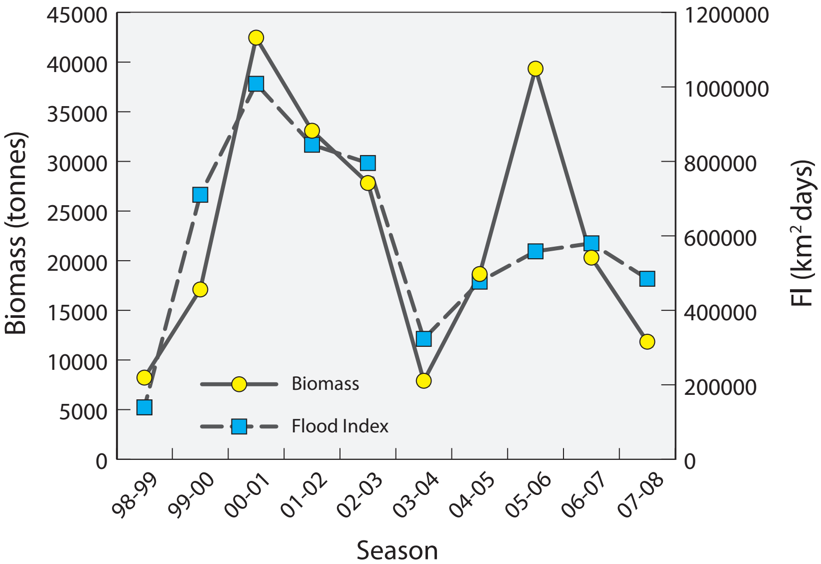

Figure 2.7 Estimates of fish biomass arriving at the *dai* fishery and the annual flood index proposed by Halls *et al.* (2008).

The higher fish biomass during years of extensive and longer duration flood inundation, as in 2000, 2001 and 2002, reflects that under such conditions the fish caught are bigger on average which in turn indicates the longer that they have to breed and feed amongst the rich organic resources of the flooded areas the larger they grow and the more mature they are once they begin to migrate.

These huge figures regarding the estimated value of the Mekong aquatic resources, particularly fish, are regarded as conservative as they do not take account of the economic benefits that flow from the trade, processing and preservation of fish products. Nor do they include the very considerable indirect values of the fishery such as its contribution to the nutrition, employment and well being of millions of rural people who generally have few other income earning and livelihood options (Barlow *et al.*, 2008).

2.4 Flood benefits – the creation and maintenance of natural wetlands

Floodplain and wetland areas which are flooded part of the year or which expand greatly in area during the flood season can produce much far more aquatic resources than permanent water bodies of the same size, such as lakes and reservoirs (Figure 2.8). In fact, according to Ringler and Xai (2006) natural wetlands are amongst the most productive ecosystems in existence and the benefits from wetland products are often considerably higher per unit area than from other land uses. The benefits in terms of the regional fishery and other aquatic resources have already been considered and identified as huge, but wetlands also provide a wide range of additional ecological goods and natural services as specified in Table 2.5. These include physical benefits such as natural flood storage and flood attenuation, improved water quality through pollution control and waste dilution, habitat provision for resident and migratory species and the maintenance of important biochemical equilibria.

Figure 2.8 Mekong wetlands at Sipandone, Lao PDR.

Table 2.5 *Functions and services provided by natural wetlands.*

Services	Comments and examples
Provisioning	
Food	Production of fish, wild game, fruits, grains.
Fresh water	Storage and retention of water, provision of water for irrigation and drinking.
Fibre and fuel	Production of timber, fuel wood, peat, fodder, aggregates.
Biochemical products	Extraction of materials from biota.
Genetic materials	Medicine, genes for resistance to plant pathogens, ornamental species etc.
Regulating	
Climate regulation	Regulation of greenhouse gases, temperature, precipitation and other climatic processes.
Hydrological regime	Groundwater recharge/discharge, water storage.
Pollution control	Retention, recovery and removal of excess nutrients/ pollutants. Waste dilution.
Erosion protection	Retention of soils and prevention of channel erosion
Natural hazards	Flood storage, retention and attenuation
Cultural	
Recreational	Opportunities for recreational activities.
Aesthetic	Appreciation of the natural environment.
Educational	Opportunities for formal and informal education and training
Supporting	
Biodiversity	Habitats for resident and migratory species.
Soil formation	Sediment retention and accumulation of organic matter.
Nutrient cycling	Storage, recycling, processing and acquisition of nutrients.
Pollination	Support for pollinators.

Note: Based on Mekong Wetlands Conservation and Sustainable Use Programme. (www.mekongwetlands.org)

Wetland goods and services are particularly difficult to value, because:

- Many goods are not marketed but traded or consumed directly:
- Wetland services, such as water quality or groundwater recharge often occur in areas away from the physical location of the wetland and may not be easily attributable to the wetland itself;
- Many wetlands are trans-boundary resources and data on the use and consumption of goods and services are difficult to obtain, and;
- Many wetlands are public property.

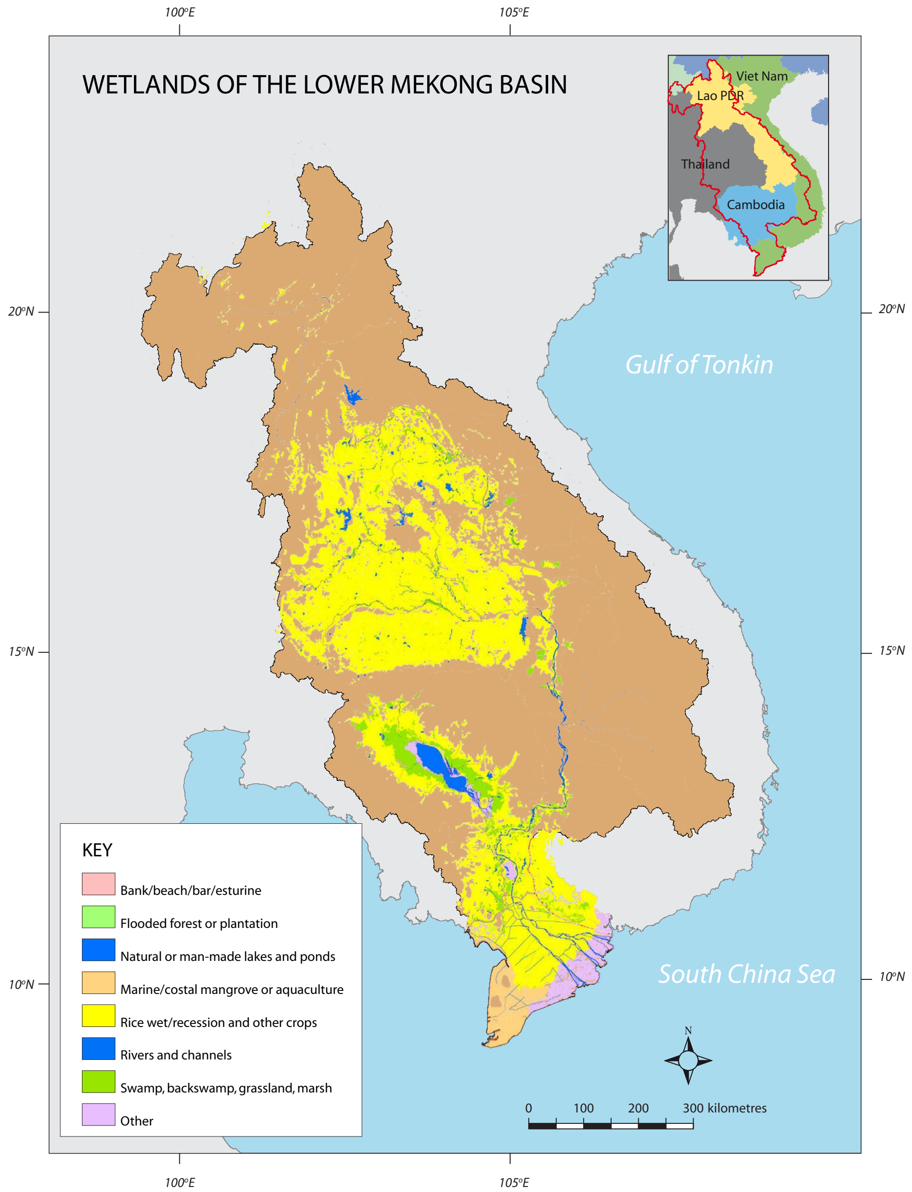

Figure 2.9 Distribution of 'wetlands' in the Lower Mekong Basin – though here no distinction is made between natural flood inundated wetlands and rain fed rice paddy. The latter would account for most of the area specified in the Mun – Chi Basin in Thailand.

For these and other related reasons, the economic benefits generated by wetlands and the economic costs associated their degradation or loss are usually unknown and omitted in project and policy analysis. As a result, the potential of wetlands to be used as contributors to economic growth, income generating activities and as sources of goods and services has been underestimated in many parts of the world resulting in the loss of valuable species, services, and livelihoods.

The only detailed economic assessment of the value of the goods and services provided by natural wetlands within the Mekong region is that undertaken of the That Luang marsh in Vientiane municipality, Lao PDR by Gerrard (2004). Although it collects urban storm water runoff and some wastewater from the city, has a major flood control role and is not directly connected to the Mekong in terms of seasonal flood inflow, the results for That Luang provide an important pointer towards the potential wider regional economic value of natural wetlands. The total value of the goods and services provided by the 2000 ha marsh on an annual basis is summarised in terms of direct and indirect use values in Table 2.6:

Table 2.6 *Summary of the annual value of wetland economic benefits from the That Luang marsh, Vientiane municipality.*

That Luang Wetland Uses and Services	Annual value (US$)
Wetland Resources – Direct use	
Rice cultivation	350 000
Garden cultivation	55 000
Aquaculture production	180 000
Capture fisheries.	1 100 000
Other aquatic products	354 000
Sub total	2 040 000
Wetland services – Indirect use.	
Flood protection	2 850 000
Wastewater purification	70 000
Sub total	2 920 000
Total	4 960 000

Note: figures are rounded from Gerrard (2004).

Gerrard based the monetary value of the flood protection service provided by the marsh on figures available from the JICA feasibility study on the improvement of the drainage systems in Vientiane which was undertaken in 1990. This involved the assessment of inundation damage that would occur as a result of a 10 year storm without an improved drainage system for the city using unit cost values of damage to property, services and inventory based on surveys and land use. JICA recommended the construction of urban drainage canals (now completed) into the marsh as part of the overall plan and calculated the benefit of doing so in terms of the damage avoided within those areas of the city that would be drained of storm water in this way. Gerrard updated the cost benefit figures on the basis of the growth in the Gross Regional Domestic Product of the city over the years since 1990 and obtained the estimate for the flood protection services provided by That Luang given in Table 2.6.

Since the value of direct wetland uses has already been included in the analysis of regional agriculture and fisheries the focus here lies with wetland services. For That Luang the annual monetary benefit of flood protection and wastewater purification is estimated to be US$2,920,000, giving an annual unit area benefit of US$1,460/ha over the 2,000 ha of the marshland. In a study of one hundred and ninety wetland valuation studies worldwide Brander *et al.* (2006) observed that socioeconomic variables such as income and population density are important factors in explaining wetland value. Since in effect That Luang is providing municipal services directly to a large population its service value is estimated in terms of replacement costs, for example the construction of sewage treatment facilities and alternative flood protection and drainage infrastructure. Consequently the service value figure of US$1,460/ha would be higher than the average for regional wetlands as a whole.

Even so the average value of wetland services at this regional scale is not likely to be insignificant particularly with regard to their role in mitigating floods. It may seem to be a circular argument that, since the mainstream and tributary wetlands are by and large a product of the annual Mekong flood pulse, that one of their key benefits lies with flood attenuation. This, however, could be seen as positive feedback and simply as one sub-component of the hydrological dynamics of the system.

Other than the problem of placing a meaningful financial benefit on the services provided by regional wetlands another complication arises since it is difficult to derive the total area in the Lower Mekong Basin classified as such. Estimates vary. MacAlister and Mahaxay (2008) report that 40 million ha are mapped but that the thematic accuracy is poor, which precipitated their much more detailed mapping though no final figures were quoted for the Basin as a whole. The figure of 40 million ha is quite clearly unrealistic since it represents more than 60% of the Lower Basin area. Keskinen *et al.* (2008) quote a figure of five million hectares for the basin between Kratie and the South China Sea, which is consistent with estimates available from the Asean Regional Centre for Biodiversity and those quoted in Do and Bennet (2008). Of this total area the Cambodian floodplain comprises almost three million hectares.

Determining figures for Lao PDR and Thailand is more problematical. As MacAlister and Mahaxay (2008) found the categorization of wetlands and floodplain is complex upstream of Cambodia. Taking a wider view of the available data for the two countries then, excluding ‘closed’ wetland systems that are not directly connected to the Mekong drainage system, a figure of 250,000 ha seems reasonable. On this basis the overall regional figures can be broken down as shown in Table 2.7.

As a working assumption, if a minimum unit area value of the services provided by this area of floodplain and wetland is set at US$100/ha and a maximum figure of US$500 selected then the total regional benefit that accrues each year is as reported in Table 2.8.

The natural regulation of floodwater and reduction in peak discharges and water levels is the major service benefit. Floodwater is in effect stored on the flood plain and in the wetlands and released once the peak flow has occurred with the effect that flood recession is slower and therefore longer. This is of advantage particularly in the delta since the period of the year during which tidal influences dominate the diurnal pattern of water levels and therefore the risk of extensive saline intrusion is significant becomes shorter.

Table 2.7 *Estimated wetland and floodplain areas in the Lower Mekong Basin (LMB) contiguous with the Mekong drainage system.*

Sub area of LMB	Key wetlands	Area (ha)
Lao PDR and Thailand	Nam Songkhram	100 000
	Se Champone	24 000
	Siphandone	6 000
	Se Kong	35 000
	Se Pian	30 000
	Other	55 000
Cambodia and Viet Nam	Cambodian floodplain	3 000 000
	Delta floodplain	2 000 000
Regional Total		5 250 000

Note: Compiled from figures in Keskinen *et al*, (2005) and the Mekong Wetlands Biodiversity and Sustainable Use Programme statistics.

Table 2.8 *Estimated minimum and maximum value of the services provided by the flood plain/wetland area in the Lower Mekong Basin.*

Flood plain/wetland area (million ha)	Annual value of services (US$ million)	
	Minimum based on a unit area service value of US$100/ha	Maximum based on a unit area service value of US$500/ha
5.25	525	2 625

Other service benefits include the retention of sediment and organic matter within the floodplain and wetlands to the obvious advantage of agriculture and the aquatic ecosystem, pollution control and groundwater recharge and storage.

3. Flood costs

3.1 Introduction

The major challenge to any systematic review of the financial costs of flood damage in the Mekong region is that national guidelines and methodologies vary, such that building up a consistent regional database is difficult. The accuracy of the estimates is effectively unknown since they depend upon the valuation of private property, public infrastructure, crops and livestock which can vary in line with the economic climate prevailing at the time, though in general the total value at risk increases from year to year as repair and replacement costs rise. In addition the property and inventory exposed to flood inundation is growing year on year as areas at risk are developed.

Primary flood damage arising from the fact of inundation is probably easier to assess. Less straightforward to evaluate are secondary losses, principally those that accumulate during the time that normal economic activity is suspended and production and services are suspended. These secondary losses can accumulate over a very long period after the flood has receded, usually months and sometimes a year or more depending on the time it takes to fully repair the damage and for normal services to be resumed.

Issues of scale dictate that in the Lower Mekong Basin flood damage and the associated financial costs are best considered at the macro level since extreme flooding tends to be regional in extent. So much so that the impact of the losses can often be measured in terms of reduced GDP. The major component of total economic damage varies. In rural Lao PDR, for example the agricultural sector usually suffers the major losses, though the consequences for structural economic assets such as houses, schools, roads and bridges can also be significant. In the more densely populated and urbanised delta damage to infrastructure typically exceeds that to crops.

The economics of flood damage are complex since there are a number of damage categories that have to be valued differently:

- Residential – includes physical damage to the structure, clean-up, and damage to the contents of the house.

- Commercial – includes structural damage to shops and industrial premises and the losses in terms of stock and equipment.

- Agricultural – refers not only to crop damage and losses but also to livestock losses and damage to irrigation infrastructure and on farm property. Also included is the fish farming sector which in parts of the Mekong region is extensive and a key local economic activity.

- Communications and transport – covers structural damage to roads, railways and bridges.
- Service facilities – encompasses damage to power supply and telecommunications, for example.

Figure 3.1 Flooded rice fields near Pakse, September 2008.

To these potential sectoral costs and losses must be added the additional costs incurred during flood emergencies for evacuation, temporary housing, medical supplies, food and clothing, A significant diversion of resources from other activities during the emergency response also carries a cost with it. Finally, the secondary losses in terms of ongoing post flood disruptions to economic activity and reduced agricultural, commercial and industrial production can in the case of extreme regional events accumulate over time to become a significant proportion of total damage (Anderson *et al.*, 1993).

3.2 Flood damage assessment in the Lower Mekong region

In the Mekong region flood damage data are collected by the national disaster management organisations that have been established in each of the four countries. The data are obtained on the basis of surveys, interviews and questionnaires and are therefore not available for some time after the event, though early rapid assessments are undertaken to inform governments of the expected scale of economic loss and damage. For most structural damage categories, the financial loss increases as a function the depth of inundation though the duration of flooding also plays an important role, for example damage to building foundations in expansive clay soils rises exponentially with increasing duration of saturation. Earth flood protection levees fail not only as a result of overtopping but also because of extreme durations of high water level causing saturation and collapse.

Crop damage is related to both the depth and duration of flooding as are livestock losses. Costs in the communications sector are also related to both with erosion of embankments an additional factor which is linked to flow velocity. Throughout all damage sectors sediment deposition is a major factor.

At the broadest level flood losses are measured in financial terms though there are important intangible social consequences including distress, health issues and ultimately loss of life. The nature and severity of the flood conditions provide one set of variables that determine overall damage while the land use makes up the balance. The depth of inundation, its duration above critical thresholds, the velocity of overland flow and the amount of sediment deposited comprise the major hydrological and hydraulic factors. These, however, exert varying types of impact depending on land use factors. Flood depth is often used exclusively to define damage in the residential sector on the basis of damage – depth curves. The relationship between depth and damage in the industrial and commercial sectors is more complex and can only be meaningfully established on the basis of detailed surveys. In the agricultural sector the relationship between depth and damage is related to the time of the year, the stage of development of the crop, the type of crop and the length of time that critical water levels are exceeded.

Depth – damage relationships can be extended to encompass frequency aspects such that the overall value at risk can be expressed within an annual probability framework. However, drawing indirect and secondary damages into such a model is extremely difficult while the depth of inundation is simply just one aspect of the nature of the flood event that requires consideration in the evaluation of overall costs. Some authors, for example Smith (2004), argue that the other components of the flood hydrograph, such as duration, flow velocity and turbulence are so highly correlated with inundation depth that they can be ignored. This may be so for floods smaller river systems but as scale increases the argument becomes less tenable. The 2000 flood in the Lower Mekong, which caused the most damage in decades was characterised not by its peak discharge and maximum water levels, which were not extreme, but by huge volumes of flood runoff throughout the flood season which resulted in unprecedented durations of flooding which determined by far the greater proportion of the total losses.

Depth – damage curves have not been applied to the assessment of flood costs and losses in the Mekong region by the relevant national agencies who provide data based on surveys and a loss per unit area approach. Meanwhile, research and pilot studies have been limited. Das Gupta *et al*. (2004) estimated curves for flood damage assessment in the delta in Viet Nam based on modelling the annual flood hydrograph on the Mekong mainstream at Kratie for various recurrence intervals and then predicting the area inundated. Land use was classified into four groups, namely residential, commercial, agriculture and infrastructure. Losses were based on field surveys and included secondary costs such as those arising from the suspension and reduction of commercial and industrial production. Potential agricultural losses were determined using yield and average market crop value figures.

Despite what appeared to be a sound experimental design the damage figures obtained by Gupta et al for flood conditions of various risks of occurrence are huge and bear no relationship at all to those provided by the Vietnamese disaster management agencies. For example, they indicate that a 1:10 year event would generate damages to a total of US$54 billion, which is indefensible. This figure compares to the official estimate of losses during the extreme flood conditions of 2000 of US$50 million. The research results contend that 97% of these huge potential losses lie in the commercial sector and it is here that the major errors appear to mainly lie. For example, the authors propose that the economic value of commercial output losses after the event amount to over 50% of annual production, which seems extreme.

Even the rate at which damage increases as an inverse function of flood frequency appears to be unrealistic. Figure 3.2 shows the growth in agricultural flood damage in relation to flood magnitude expressed in annual risk terms. The authors suggest that damage arising from a 100 year flood is just 15% higher than that for a 10 year event. Australian data on the other hand indicate that flood damage in the agricultural sector arising from a 1:100 year event is at least 15 times larger than that for a 10 year event (Agricultural and Resource Management Council of Australia and New Zealand).

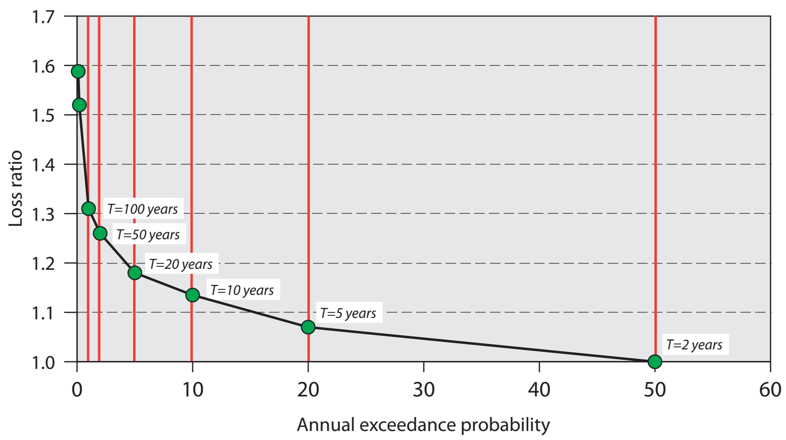

Figure 3.2 Growth in agricultural losses in the Mekong delta in Viet Nam as a function of flood frequency, according to Das Gupta *et al*. (2004). These results imply that the losses during a 100 year event are only 15% higher than those during a 10 year event, which seems too low. Comparable results in Australia indicate a difference of the order of 15 times.

Haskoning (2008) undertook pilot socioeconomic surveys in nine focal districts in Cambodia, Lao PDR and Viet Nam in order to establish depth damage data and provide a basis upon which the potential cost benefits of flood management and mitigation measures could be assessed. The Vietnamese provinces of Dong Thap and An Giang provide data for the perennially flooded areas of the delta bordering Cambodia for which the depth damage relationships are shown in Figure 3.3.

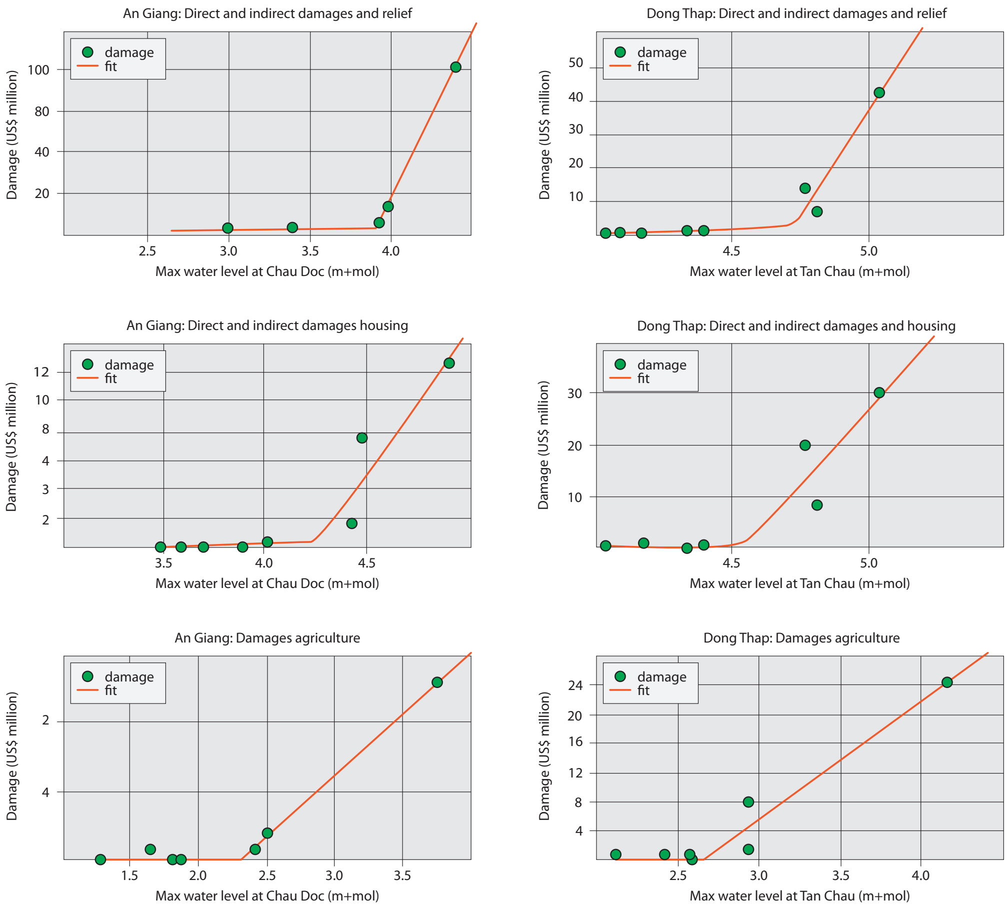

Figure 3.3 Sectoral flood damage curves for the Mekong Delta. (Source: Haskoning, 2008.)

- In each sector there is a threshold water level at which damage begins to accumulate, which for infrastructure and residential properties is when levels observed at Tan Chau and Chau Doc exceed 4 to 4.5 masl.

- Damage to agriculture begins at water levels that are 2 to 2.5 m lower indicating that in these areas where the annual flood risk is high, property and service facilities are generally elevated either on columns or more widely on embankments.

- The major component by far of overall damage is that caused within the infrastructure sector.

- These damage curves were used to develop annual time series of flood costs back to 1910 using historical water levels observed in the delta, which in turn permitted an estimate of the frequency distribution of annual flood damage to be derived (Figure 3.4) for the two delta provinces.

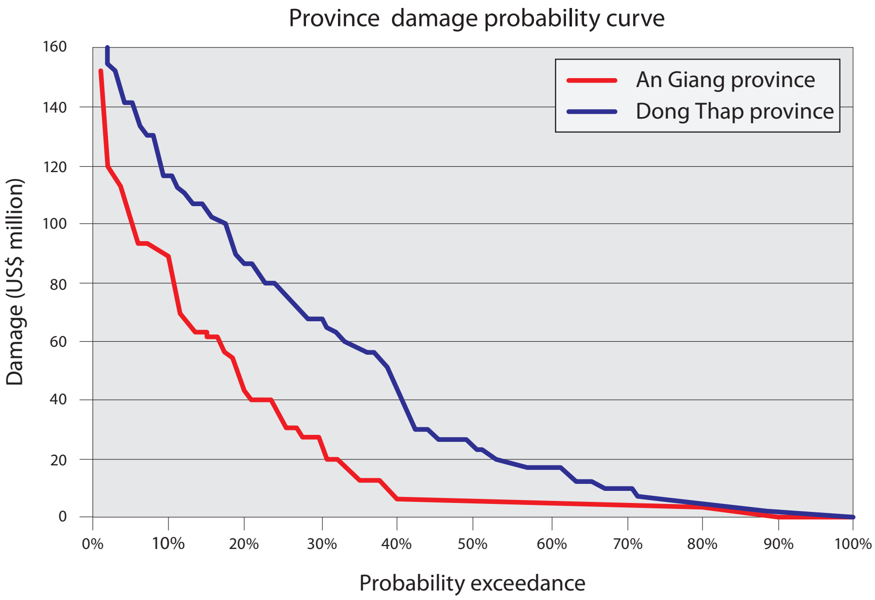

Figure 3.4 Frequency distribution of annual flood damage in the Mekong Delta.
(Source: Haskoning, 2008)

Similar results are available for the pilot study areas in Cambodia and Lao PDR. Such is the spatial complexity of flood conditions in the Mekong region and the geographical variation in land use that these results cannot realistically be generalised. They do, however, provide far reaching insights into the nature and structure of flood damage within key areas such as the delta in Viet Nam, the Cambodian flood plain and those extensive areas in Lao PDR that are vulnerable to backwater flood effects between the large tributaries and the Mekong mainstream. Not least they enable the cost benefits of flood mitigation measures within these vulnerable areas to be established with a considerable degree of confidence.

3.3 The regional history and pattern of flood damage

For the Lower Mekong Basin as a whole history reveals that some order of flood damage occurs in almost every year on a scale which varies between that caused by local flash flooding to that arising from large scale regional events, often classified as natural disasters, such as the flood of 2000 and to a lesser extent that of 2008. Even though annual damage data have been systematically collected for quite a number of years assembling them into a coherent series on the basis of which, for example, trends in regional flood losses could be reliably evaluated is difficult. The historical figures have to be adjusted to net present value, damage and loss surveys are improving constantly, the value of the property and inventory at risk is increasing, the improved levels and therefore the financial costs of emergency response are growing and as the regional socio-economy and services provision develops the order of secondary damage is increasing year by year as a proportion of total damage.

Figure 3.5 to Figure 3.8 show the annual flood damage for each of the four riparian countries over the years for which data are available.

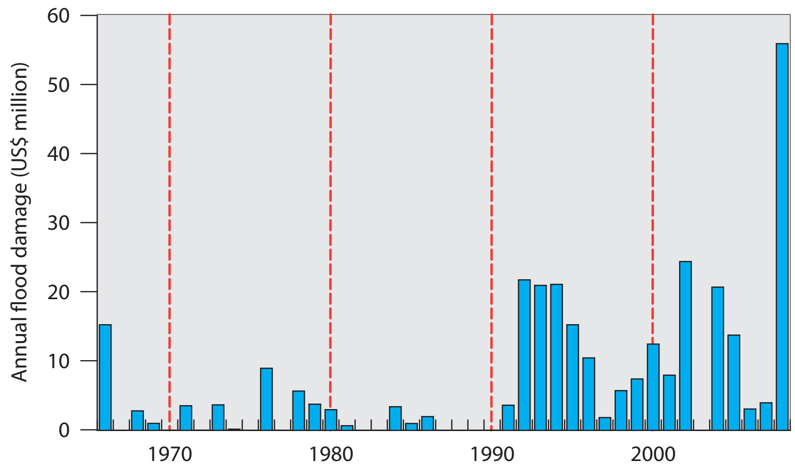

Figure 3.5 Lao PDR, annual flood damage 1966–2008. (Sources: www.internationalfloodnetwork.org and Lao National Flood Report, 2008.)

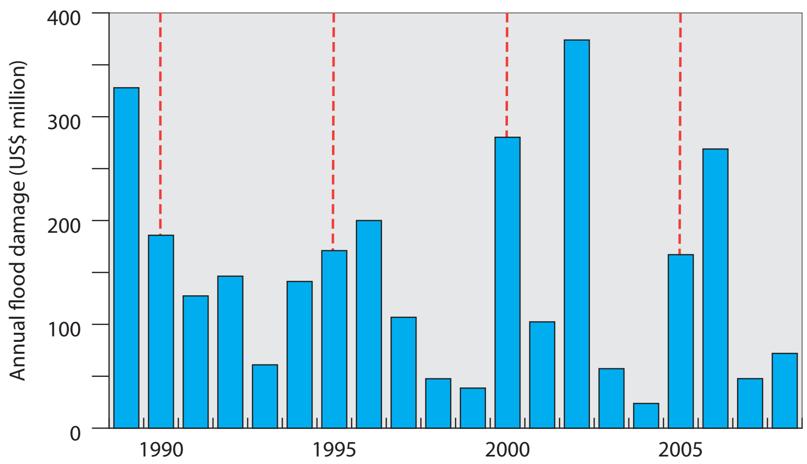

Figure 3.6 Thai Mekong region, annual flood damage 1989–2008. (Sources: Thai Disaster Mitigation Centre, Department of Disaster Prevention and Mitigation and Ministry of Interior.)

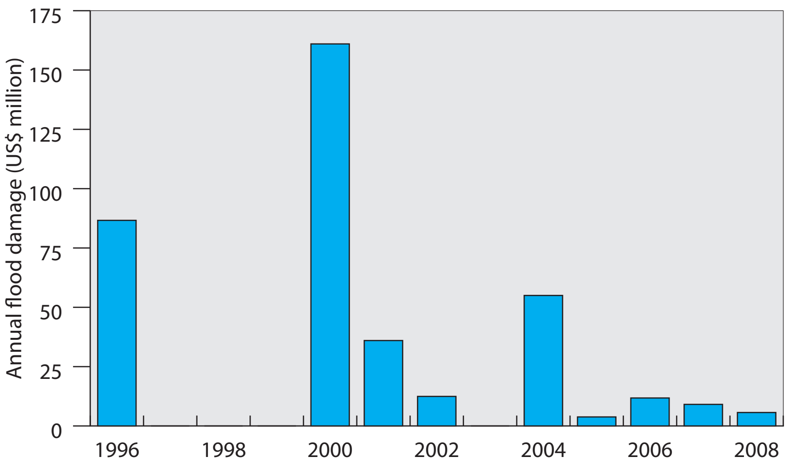

Figure 3.7 Cambodia, annual flood damage 1996–2008. (Source: Cambodian National Committee for Disaster Management.)

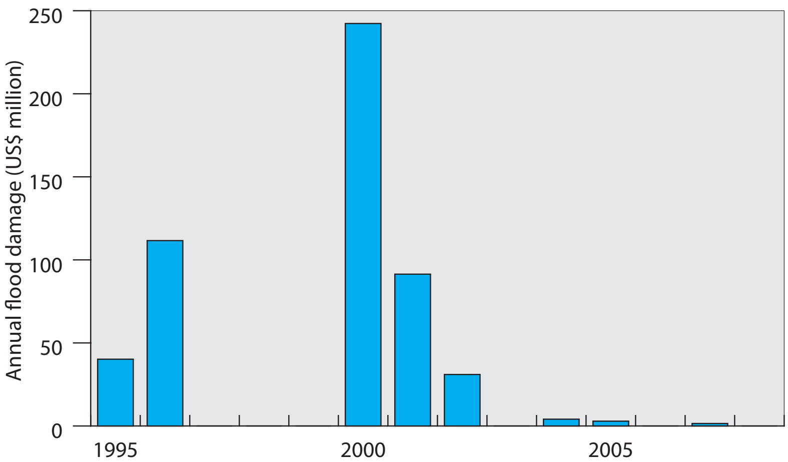

Figure 3.8 Mekong Delta, Viet Nam, annual flood damage 1995–2008. (Sources CCFSC, MARD and MONRE)

- Although data for Lao PDR are available since 1966 it is unlikely that those prior to 1990 are particularly reliable. There is certainly a break in their pattern and magnitude at this point. Since 1990 the average annual flood costs have been of the order of US$10 million. The cost of the 2008 event are estimated to be US$55 million, by far the largest over the period and far larger than those of 1966 when the central business districts of Vientiane were flooded. If these 1966 figures were adjusted to contemporary values they would probably be at least comparable to or possibly exceed those of 2008.

- The data for the Thai Mekong region from 1989 onwards indicate an average annual flood damage figure of US$16 million. The fact that significant flood damage occurs almost every year reflects the perennial incidence of flash floods in the northern provinces around Chiang Rai and the fact that considerable areas of the low lying Mun – Chi Basin are inundated annually to some extent.

- In Cambodia and the delta in Viet Nam the financial losses related to the 2000 event is the dominant feature in the recent history of flood damage. Though average annual losses are difficult to assess from the available data, as a tentative estimate a figure of US$25 million is adopted for both.

These figures translate into an annual average total figure for regional flood damage of US$76 million, close to the figure for 2004 which may be considered to be an average flood year. The figure is distributed as indicated in Figure 3.9.

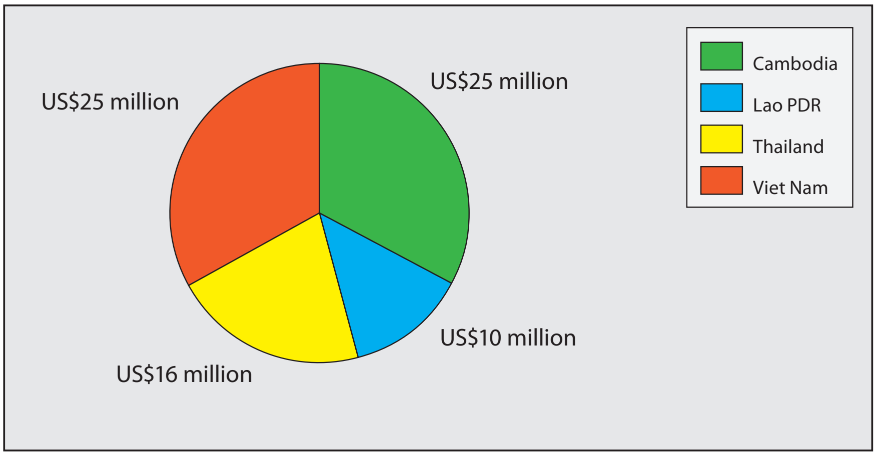

Figure 3.9 Indicative distribution of average annual regional flood costs of US$76 million.

The picture changes if the figures are expressed as a proportion of regional GDP (the total annual value of all goods and services produced) in that part of each country that lies within the Lower Mekong Basin (Table 3.1).

On this basis the average annual flood damage inflicted on the national economies is highest in Cambodia and Lao PDR, the least developed countries. This would appear to confirm the widely held view that the proportional economic losses to natural hazards such as floods is greater in poorer societies which are more vulnerable.

Table 3.1 *Average annual flood damage occurring within the Mekong region as a proportion of national GDP.*

Country	National GDP (US$ billion)	Lower Mekong Basin GDP (US$ billion)	Average annual flood damage as a proportion of National GDP generated in the Lower Mekong Basin
Cambodia	8.7	8.0	0.29%
Lao PDR	4.0	4.0	0.25%
Thailand	246.0	22.0	0.07%
Viet Nam	85.0	25.5	0.09%
Total LMB		60.2	

Notes: (i) National GDP is based on World Bank figures for 2007. (ii) GDP for Lower Mekong Basin were computed as follows. Since they lie almost entirely within the LMB it can be assumed that the national figures for Cambodia and Lao PDR apply. For Viet Nam 30% of national GDP is generated in the Delta (General Statistics Office, Viet Nam). In the case of Thailand the figure is based upon statistics given in Huang and Bocchi (2008) that show that in NE Thailand per capita GDP is 30% of the national average of US$2,500. Given a population of 25 million in the NE provinces within the Mekong Basin plus a further US$1.5 million in the area of northern Thailand within the basin then the estimate Thai Mekong GDP becomes US$22 billion, less than 10% of the national figure.

Losses as a proportion of GDP under extreme flood conditions obviously cause even greater economic damage, the benchmark measure for which in recent times were the events of 2000 which were centred on the southern areas of the basin in Thailand, Cambodia and Viet Nam. Total damage was estimated to be US$695.5 million, or 1.34% of regional GDP. The flood of 2008 was less extensive, confined to the northern parts of the basin and generated far less damage in value terms. Never the less the costs to Lao PDR of US$56 million amounted to 1.4% of GDP.

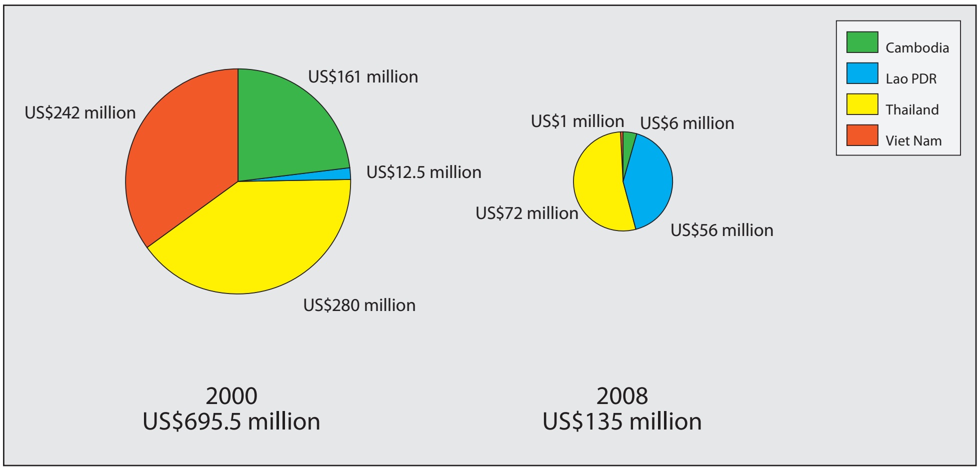

Figure 3.10 Mekong floods in 2000 and 2008 – proportional and total damage.

Although the major flood events of recent history and the associated losses are linked to extreme flows on the Mekong mainstream it would be wrong to suggest that they have exclusively determined the historical pattern of annual flood damage. Throughout the region annual damage is linked to a diversity of flood conditions and cannot be related to a single regional hydrological or meteorological index as Figure 3.11 confirms. The annual cost of flood damage in Lao PDR is clearly not simply a function of the magnitude of the Mekong flood expressed in terms of peak discharge, though the exceptional mainstream peak flows and water levels of 2002 and 2008 did account for the largest losses in recent decades. During other years, however, the national costs of flood damage are independent of hydrological conditions in the Mekong mainstream and might arise from local tributary floods, upland flash flooding or simply an accumulation of damage during a strong SW Monsoon when a larger than average number of severe tropical storms might occur.

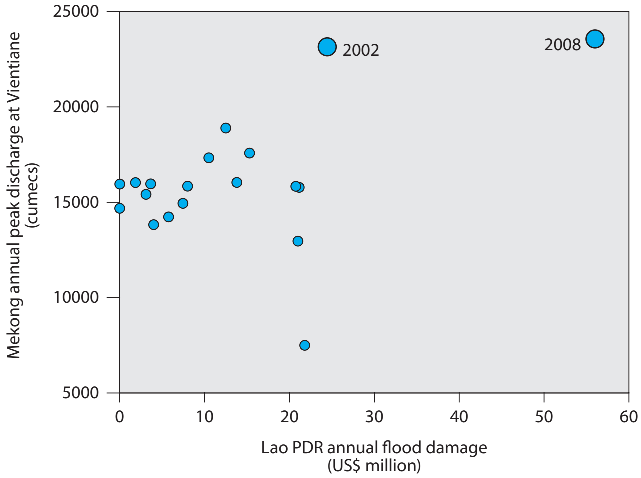

Figure 3.11 Scatter plot of the ‘relationship’ between annual maximum discharge on the Mekong at Vientiane and the reported annual flood damage in Lao PDR over the years from 1990 to 2008.

Figure 3.12 Urban flooding – Vientiane, Lao PDR, August 2008.

Even in Cambodia and the Delta where annual flood damage would be expected to be more directly linked to flow conditions on the mainstream there is no single hydrological measure that can be systematically linked to the losses (Figure 3.13). Factors other than peak and volume play an important role such as the duration of water levels above critical thresholds and the time of the year that crops are submerged.

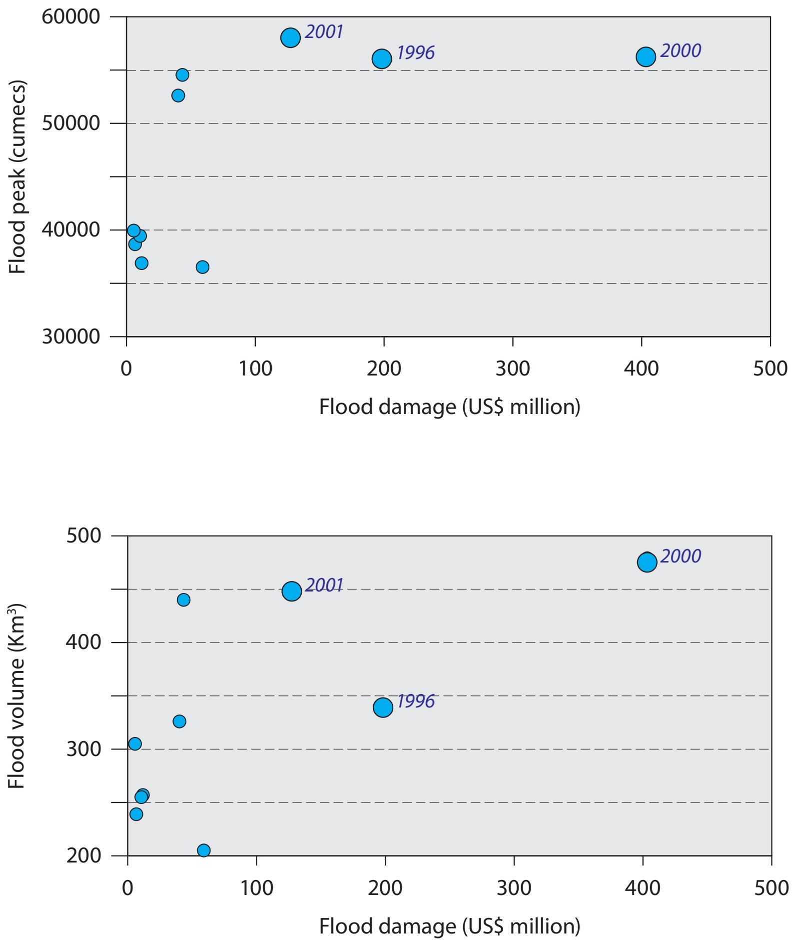

Figure 3.13 Total annual flood damage (1996 – 2008) in Cambodia and the delta in Viet Nam in relation to the peak and volume of the annual flood hydrograph recorded at Kratie.

3.4 The composition of flood losses

It is standard practice to breakdown total flood damage into that occurring within the various economic sectors, usually domestic, commercial and agricultural:

- The domestic category includes private housing and small commercial businesses carried out from home such as family shops.

- Commercial/services covers industrial premises, schools, hospitals, roads, bridges and services such as power and telecommunications facilities.

- Agriculture covers crops, livestock, aquaculture losses and damage to irrigation infrastructure.

Although based on local but detailed surveys, the results available in Haskoning (2008) clearly indicate that there are significant regional distinctions in the composition of overall damage which reflect differences in population density, the degree of urbanisation and the structure of local socioeconomics(Figure 3.14).

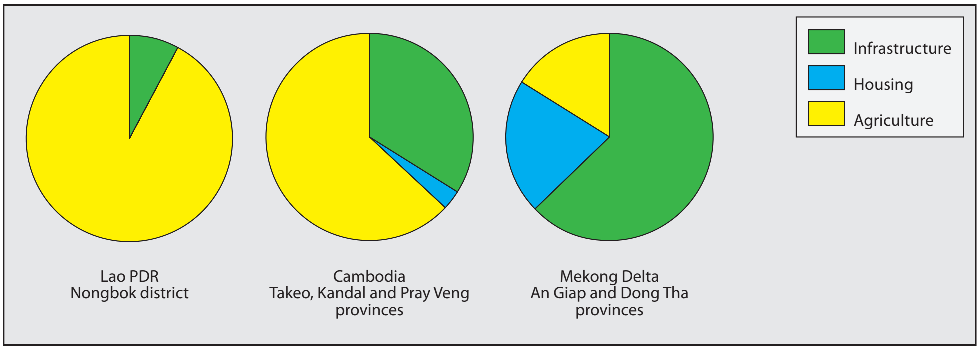

Figure 3.14 Proportion (%) of total flood damage by sector during 2000. Source: local survey data given in Haskoning (2008).

- In Lao PDR the result refers to Nongbok district at the confluence of the Se Bang Fai River and the Mekong. The data therefore represent the composition of overall flood damage in rural areas where 'backwater flooding' of riparian lands is a major hazard and which is a major cause of annual flood losses in the country in most years. Damage to agriculture accounts for over 90% of the total in these less well developed rural areas where commercial and service infrastructure is limited. The result is probably indicative of the composition of flood damage costs over the greater part of Lao PDR with the exception of the larger towns and cities adjacent to the Mekong such as Vientiane and Luang Prabang. The distribution of losses during the August 2008 event would not therefore follow this pattern since the major impacts were felt in these large urban centres.

- In Cambodia the data were aggregated from surveys undertaken in three provinces and again the pattern of the overall loss is arguably indicative for the country as a whole outside of major urban centres. Since the surveyed districts have a higher population than Nongbok in Lao PDR the proportional losses to infrastructure and housing are that much higher but damage to the agricultural sector (63%) still dominates.

- In the Mekong Delta in Viet Nam the picture changes completely. Here the population density is extremely high with a large proportion living in urban centres at risk from regular flood inundation. Commercial and service infrastructure losses (62%) predominate with agricultural damage falling to just 16% of the total. One major contributory factor is that the secondary commercial and industrial losses, that is the financial costs due to the suspension of economic activity and reduced levels of service provision, are high and continue for a considerable period after the floodwaters recede. Another factor that contributes to the lower relative agricultural losses is that drought and salinity are now considered to be a greater threat to rice yields and production than floods in the delta due to the adoption of hybrids that can withstand longer periods of submergence (Buu and Thi Lang, 2003).

A survey of businesses in the same sample districts sought to estimate the relative levels primary and secondary losses, the results for which are shown in Figure 3.15. The higher to replace it and repair any structural secondary losses in Cambodia possibly reflect the fact that stock and inventory values are lower than in Viet Nam and once stock is lost the ability to replace it takes much longer given greater financial constraints. Consequently ongoing secondary damage accumulates over a longer period of time and therefore comprises a higher proportion of the total loss.

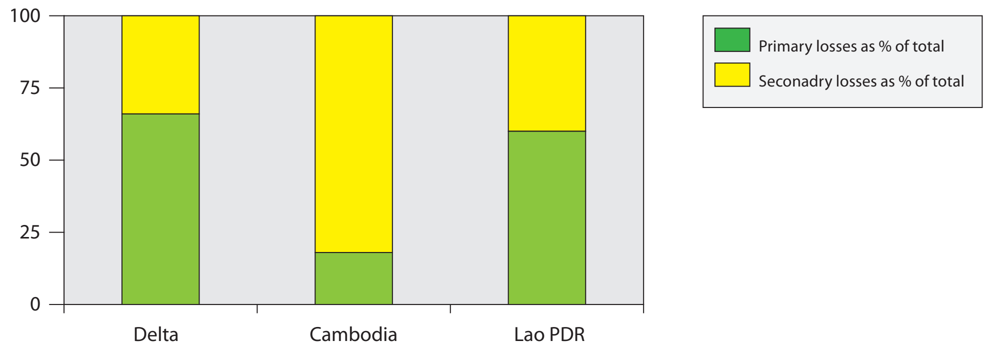

Figure 3.15 Primary and secondary flood losses as a proportion of total damage for business enterprises. Source: district survey data available in Haskoning (2008).

4. Comparing the costs and benefits of the annual flood

4.1 General observations

Comparing the costs and benefits of the annual Mekong flood is difficult. Some level of benefit accrues in all years but significant costs do not. For costs to arise the flood, in terms of peak discharge and water levels, has to exceed a certain threshold. The costs are then a function of the magnitude of the exceedance and the consequent depth of inundation, its duration and areal extent and the value at risk in the flooded areas. The latter is highest over the Cambodian flood plain and the delta. Average annual regional flood costs do not therefore provide a statistic that is directly comparable to the financial benefits, which in any case are systematically increasing, particularly in the agricultural sector.

However, a generalized comparative assessment is useful in that it reveals just how much larger the benefits are compared to the much more often quoted figures regarding costs. For example, the annual value figure for the regional fishery of US$2.85 billion refers only to that at the first point of sale. In comparison, the estimated annual costs of flood damage in an average year such as 2004 only amount to US$76 million or just 2.5% of the fisheries benefit alone.

The additional benefit figures for the agricultural benefits are harder to assess since the linkage between the annual flood is not as clear as it is with the fishery. Flood recession rice production in Cambodia is reported to account for 32% of national production, valued at US$ 3.1 billion in 2006, based on a February 2009 international price of US$ 500/tonne The value of the agricultural benefit accruing directly from the flood in Cambodia is therefore US$3.1 billion x 0.32 = US$1 billion. Even if the value figure is reduced to a farm gate price of (say) US$100/ tonne the benefit still amounts to US$200 million

In the delta in Viet Nam agricultural production in 2004 had a reported market value of US$3.5 billion. That this is a benefit of the flood is based on the argument that the 9 to 13 millions tonnes of sediment deposited annually across the delta, most of it during the flood season, has over millennia resulted in some of the most productive agricultural land in Southeast Asia, thus establishing the link.

Table 4.1 summarises the relative benefits and costs of the annual flood on this simple basis. Costs in terms of loss and damage are quoted both for an average year (2004) and for 2000, which witnessed the most extreme regional flood losses of recent decades.

Table 4.1 *Relative costs and benefits of the annual Mekong flood*

Annual flood benefit (US$ billion)	Annual flood costs (US$ million)		Costs as % benefit	
	Average year	Extreme year (2000)	Average year	Extreme year (2000)
7.35	76	811	1%	11%

Note: he benefits refer only to the sum of the value capture fishery and other aquatic products and the annual value of flood linked agricultural output in Cambodia and Viet Nam).

4.2 Incremental figures

The comparative assessment undertaken here does not pretend to be an economic study of the costs and benefits of the annual Mekong flood. It is simply a statement of the degree to which the benefits exceed the costs by a very large margin, a fact not widely recognised. Many working assumptions have had to be made, so the figures should not be taken as definitive. Rather they should be seen in comparative rather than absolute terms.

To take these results any further would require a data base that is simply not available. Although a reasonable estimate of the total regional flood damage and losses over the last decade can be achieved this is not the case with regard to the benefit data. The major component of the overall financial benefit of the flood is the annual value of the Mekong fishery. The linkage to the annual flood is clear since the seasonal inundation of the flood plain in Cambodia provides a huge biomass for fish reproduction and growth. However, accurate year on year catch value figures for the fishery are not available. Only the annual *dai* fishery catch is monitored and this refers to just one element of the regional fishery and in fact to just one fishing gear type, namely the 'bag net'. This lack of data prescribes any incremental assessment of the benefits and losses of the flood.

5. The 2008 flood season

5.1 General observations

Flood conditions in the Lower Mekong Basin during 2008 were amongst the most extreme since records began and will be viewed along with those of 1966, 1971, 1978, 2000, 2001 and 2002 as defining the character and magnitude of severe flood conditions on the mainstream. Like the extreme events that have been observed in the past, conditions in 2008 were geographically confined to just a part of the Basin, in this case the areas upstream of Vientiane and Nong Khai. Only in 2001 were exceptional flood conditions basin-wide in any sense. The more typical pattern is for exceptionally high flows to be confined to either the reach upstream or that downstream of Vientiane, which represents a 'hydrological discontinuity' between the two. To the north the flood hydrology is determined by flows out of China and the contributions of the large tributaries systems such as the Nam Tha, Nam Ou and Nam Khan. The significance of these inflows then diminishes further downstream as the large left bank tributaries, specifically those in Lao PDR, begin to exert their dominant influence.

This hydrological discontinuity is readily apparent in Figure 5.1 which presents a classification of the annual flood at 10 sites between Chiang Saen and Kratie for the years from 1960 to 2008. The pattern comes about since factors of scale generally preclude weather generating mechanisms, even those at the synoptic scale[1] such as tropical cyclones and other intense low pressure systems, from influencing flood runoff over the Basin as a whole. The area of the Basin is many orders of magnitude greater than the area of influence of such weather systems as they pass over it from east to west. Those associated with the large flood events have historically tracked across the region either to the north or south thus bringing about the distinct geographical pattern evident in Figure 5.1.[2]

The flood of 2008 centred around events during the first half of August when Tropical Storm Kammuri moved across the northern regions of the Lower Basin and the extreme south of Yunnan. In common with most other notable flood seasons there was really only one such weather system which turned what were up to that date fairly average hydrological conditions into those that were exceptional. The point should also be made that 2008 was a strong La Niña year generally associated with enhanced tropical cyclone activity in the western Pacific.

Conditions further south in the Basin were very much below average, with peak water levels and discharges at Kratie and further downstream pointing to a relatively weak SW Monsoon.

1 Synoptic scale refers to migratory weather systems with a horizontal dimension greater than 1,000 km, such as tropical cyclones.
2This geographical pattern is discussed in further detail in the Annual Mekong flood report 2006 on pages 11 to 13

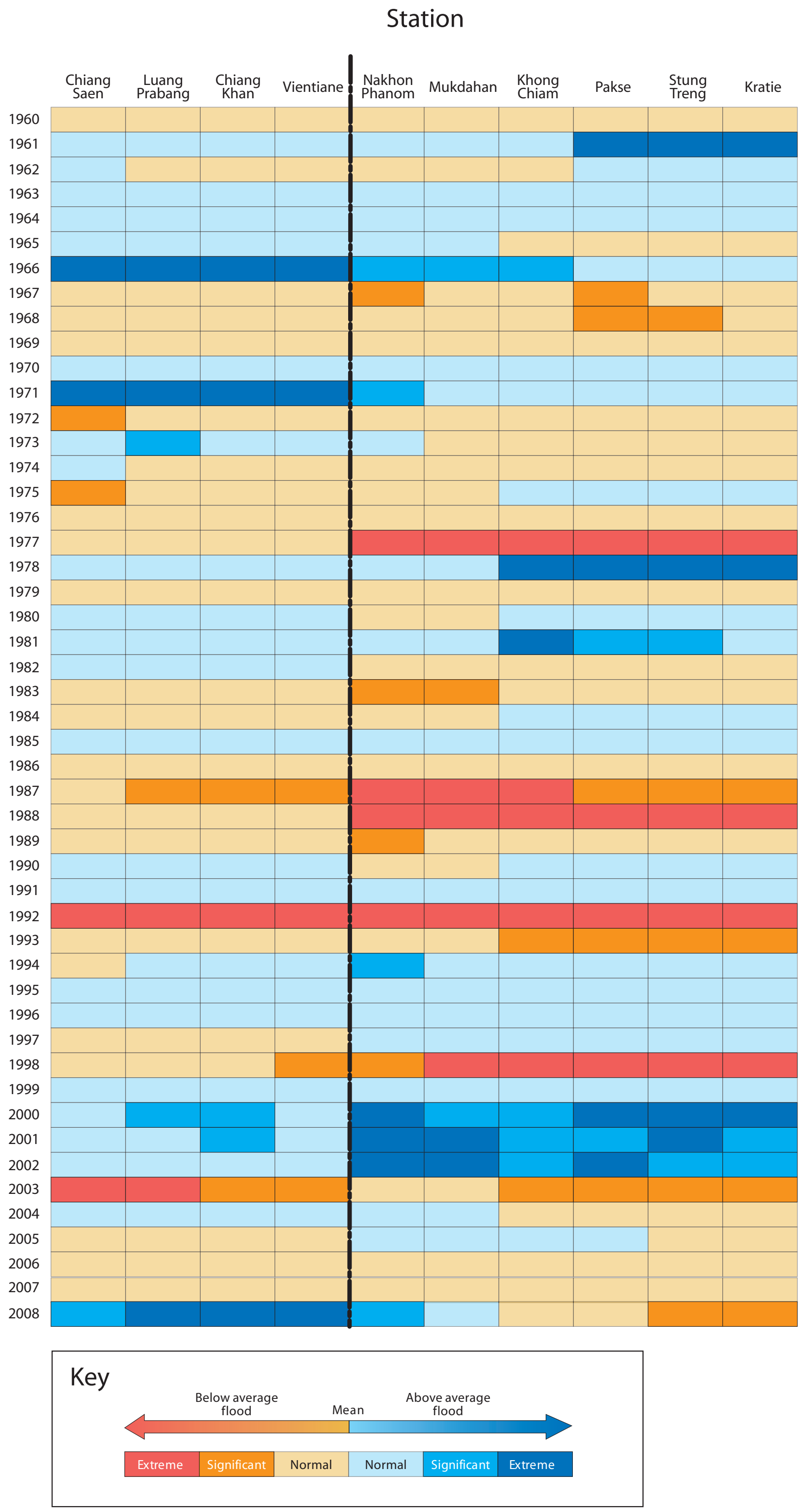

Figure 5.1 The 'historical geography' of the annual flood on the Mekong mainstream (1960–2008) between Chaing Saen and Kratie.

5.2 Meteorological conditions

From a meteorological perspective, conditions within the annual Mekong flood season should be assessed with respect to two aspects:

- The intensity of the SW monsoon in terms of cumulative rainfall and the creation of saturated soil moisture conditions which maximise flood runoff. In some years it is this effect combined with a strong Monsoon which generates exceptional volumes of floodwater and extremely damaging levels of flood inundation. This was the case in 2000, particularly across the Cambodian flood plain and the Delta in Viet Nam.

- The incursion of tropical cyclones and tropical storms into the basin which historically, given already saturated catchments, have produced most of the highest observed water levels and flood discharges. The events of 2008 are a case in point.

The timing of the regional onset and end of the SW Monsoon is remarkably consistent from year to year, with a typical standard deviation of only one to two weeks. The data for the locations indicated in Table 5.1 are based upon criteria applied in India by Khademul *et al.* (2006). The annual onset of the SW Monsoon may be defined as the week during which more than 20 mm of rainfall occurs within 1 or 2 consecutive days, provided that the probability of at least 10 mm of rainfall occurring in the subsequent week is more than 70%. The latter component of the criterion screens out isolated storm events earlier in the year that do not fully indicate the start of 'true' monsoonal conditions. The date of monsoon withdrawal is defined as the day up to which at least 30 mm of rainfall accumulates over a sequential seven day period, with no subsequent rainfall for at least 3 consecutive weeks.

Table 5.1 *The onset and end of the SW Monsoon at selected sites in the Lower Mekong Basin.*

Site	Monsoon onset			Monsoon withdrawal		
	Average Date	Standard Deviation	2008	Average Date	Standard Deviation	2008
Chiang Saen	7th May	9 days	3rd May	7th Nov	25 days	24th Oct
Luang Prabang	7th May	9 days	28th April	24th Oct	33 days	3rd Nov
Vientiane	4th May	8 days	27th April	10th Oct	16 days	3rd Nov
Pakse	5th May	11 days	28th April	15th Oct	17 days	3rd Nov
Tan Chau	11th May	7 days	7th May	17th Nov	14 days	26th Nov

The onset of the Monsoon typically occurs within a remarkably narrow period of time in May. It withdraws usually during October in the more central areas of the Basin and in November in the north (Chiang Saen) and south (Tan Chau) where there tend to be wider variability from year to year. During 2008 the onset and end dates were within the characteristic range. The early withdrawal of the Monsoon, as happened in 2004 when the rains ceased a month earlier than usual can precipitate serious drought conditions due to depleted soil moisture for crops that rely on late seasonal rainfall.

From a temporal perspective therefore, Monsoonal conditions during 2008 appear to have been typical across the region. In terms of total seasonal rainfall the general picture is one of an average year (Figure 5.2), though with the expected significant exceptions[1]. However, drawing basin wide conclusions from such a small sample of data could be misleading, particularly when the spatial variation of rainfall is high, even at the local scale. Nonetheless the indications are that:

- Total annual rainfall at Chiang Saen, Luang Prabang, Chaing Khan and Tan Chau were average and over the year as a whole accumulated according to a typical pattern;

- At Vientiane, the total rainfall for 2008 of 2,200 mm would define the year as extremely wet, while;

- At Pakse the annual total was significantly below normal.

The definitive meteorological event of 2008 was the incursion into the northern regions of the Basin of tropical cyclone Kammuri during the first week of August which produced extreme water levels and volumes of runoff in the Mekong mainstream, particularly at Luang Prabang and Vientiane. However, the rainfalls observed in August at those sites in the north for which data are available, namely Chiang Saen, Luang Prabang, Chiang Khan and Vientiane do not reflect the extreme levels of precipitation that must have occurred in the wider northern sub region. This reflects the fact that the regional rain gauge network is most sparse in those remote areas that receive the highest rainfall on average and which generate the major volumes of flood runoff.

The track of cyclone Kamurri is shown in Figure 5.3 and the associated storm rainfall, based upon satellite imagery, shown in Figure 5.4:

- In the Lao PDR most rainfall occurred upstream of Luang Prabang. Accumulated rainfall over the nine days between the 6th and 14th of August was generally between 100 and 150 mm, though locally the figures were as high as 200 – 250 mm.

- In Yunnan the cumulative rainfall was similar and generally confined the extreme south, downstream of Jinghong.

These areas therefore generated virtually all of the consequent flood runoff, while elsewhere in the Basin the rainfall was much more scattered and not directly linked to Kammuri.

Although as expected regional catchments were all saturated at this stage of the flood season (Figure 5.5) which would have enhanced the levels of storm runoff, the extend and magnitude of the rainfalls indicated in Figure 5.4 appear to be modest compared to the volumes of flood runoff that were subsequently generated. This observation may be seen as supporting the

1 Sufficient data for the year of interest, in this case 2008, in order to produce a basin-wide map of the seasonal rainfall were not available in time for this report., while issues of data quality arose for those records that were received, such that only a few could be used with confidence,

emerging view that the satellite data do indeed underestimate regional storm rainfall which makes accurate flood forecasting more difficult. There is therefore a need for improved 'ground truthing' of satellite based estimates of storm rainfall and in particular the expansion of the sparse rainfall observation network in northern and eastern Lao PDR.

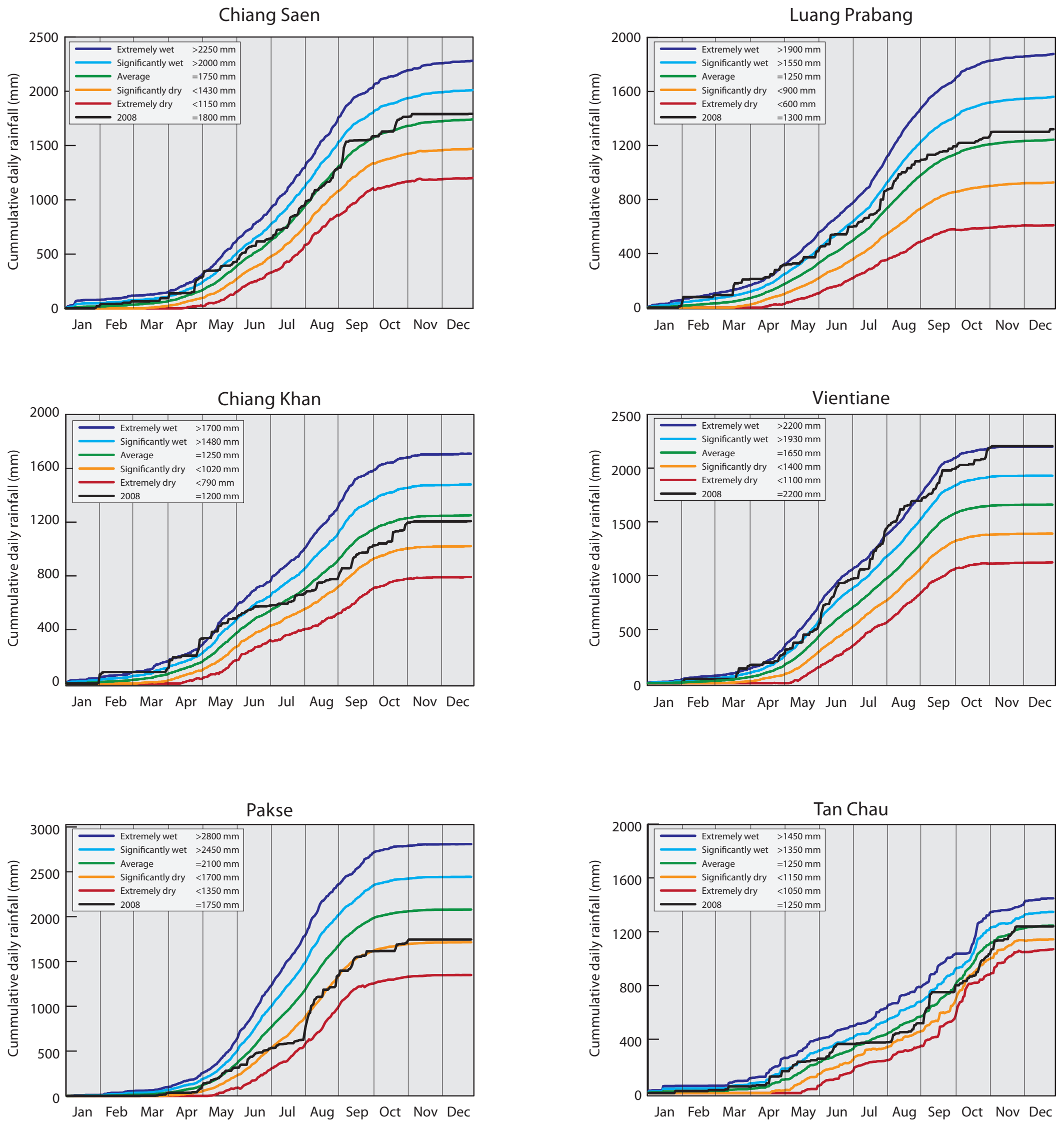

Figure 5.2 Cumulative annual rainfall during 2008 at selected sites in the Lower Mekong Basin. (Extremely wet and dry conditions are defined as plus/minus 2 SD, and significantly wet and dry as plus/minus 1 SD.)

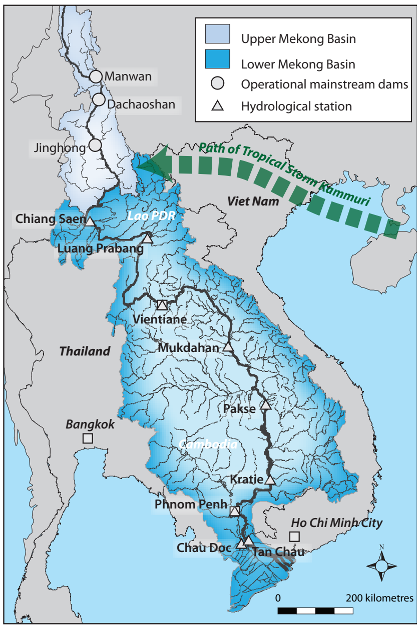

Figure 5.3 Track of tropical storm Kammuri – first week of August, 2008. (Map based upon data obtained from the Hong Kong Meteorological Bureau http://weather.gov.hk.)

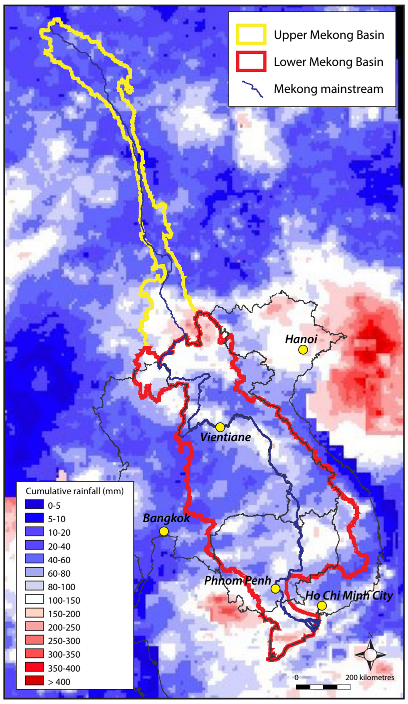

Figure 5.4 Accumulated rainfall over the Mekong Region: 6th to 14th August 2008. (Based on data provided on a daily basis by the United States National Oceanic and Atmospheric Administration to the MRC).

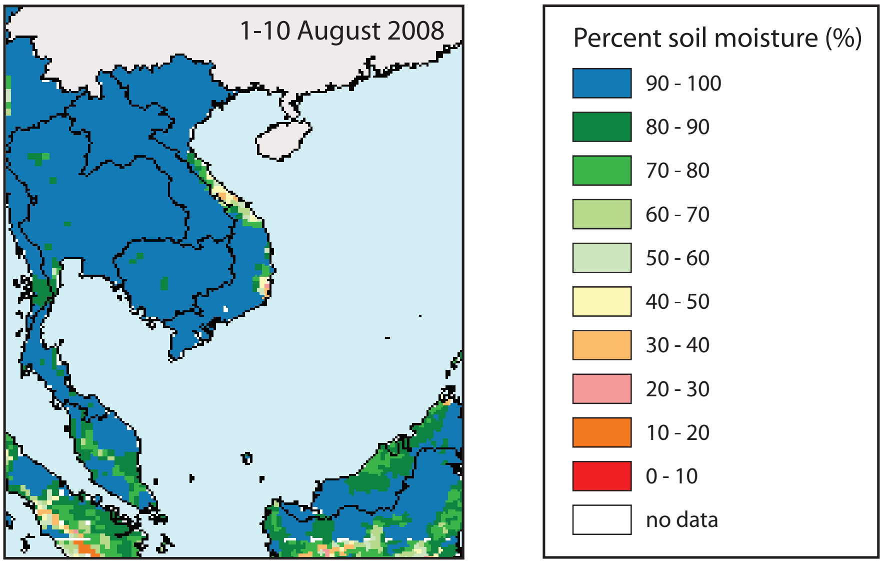

Figure 5.5 Regional soil moisture conditions during early August 2008, indicating that catchments were saturated. This would have maximised the flood runoff that resulted from tropical storm Kammuri. (Source: USDA, http://gcmd. nasa.gov/records/ GCMD_USDA_FAS_ Percent_Soil_Moisture.html.)

5.3 Temporal aspects of the 2008 Mekong flood season

Defining as usual, the onset of the flood season as the first sustained 'up-crossing' of the mean annual discharge and its end as the last 'down-crossing' the figures in Table 5.2 indicate that in the middle reaches, at Vientiane and Pakse the 2008 seasonal onset was two to three weeks early. Elsewhere, the timing of the start was 'normal' while throughout the Basin the season ended just two weeks later than average.

Table 5.2 *Start and end dates of the 2008 flood season compared to their historical mean and standard deviation at selected mainstream locations.*

Site	Onset of flood season			End of flood season		
	Historical average	Standard deviation	2008	Historical average	Standard deviation	2008
Chiang Saen	28th June	13 days	27th June	14th Nov	14 days	22nd Nov
Vientiane	3rd July	14 days	15th June	11th Nov	15 days	21st Nov
Pakse	29th June	16 days	9th June	5th Nov	11 days	20th Nov
Kratie	1st July	16 days	5th July	7th Nov	12 days	20th Nov

Note: Levels for Vientiane were recorded at the river gauge at Kilometre 4.

The importance of employing a meaningful definition of the onset and end dates of the flood season was amply demonstrated in 2007. Then the onset of flood season conditions in the latter part of July and the first week of August was the latest observed in the last 80 to 90 years. As a consequence the low water levels observed during most of July were unprecedented and had negative impacts upon the environment, fisheries, agriculture and navigation.

5.4 Water levels

The water level at reached Vientiane on the 15th of August was the highest recorded since records began in 1913. At 171.7 masl it was 1 m more than the maximum levels achieved in 1966, 1971 and 2002 (Table 5.3). Conversely, upstream at Chiang Saen and Luang Prabang the 2008 maximum water levels were lower than those experienced in 1966 and by as much as 3 m at Chiang Saen.

The much higher 1966 water levels at Chiang Saen point to the fact that in September 1966 tropical storm Phyllis tracked further north than did Kammuri in 2008. So while much of the floodwater in 1966 originated in Yunnan, in 2008, by far the major contribution appears to have come from the large left-bank tributaries in northern Lao PDR such as the Nam Tha, Nam Ou and Nam Khan. It is also worth noting that the rapid water level rise at Luang Prabang occurred one day before water levels rose at Man An tributary station in China. This also strongly suggests that the flood event was primarily caused by heavy rainfall in the basins of the Mekong tributaries in northern Lao PDR.

Table 5.3 *Comparative annual maximum historical flood water levels at Chiang Saen, Luang Prabang, and Vientiane.*

Year	Maximum water level achieved (masl)		
	Chiang Saen	Luang Prabang	Vientiane
1924	No data	No data	170.7
1929	–	–	170.4
1942	–	–	170.2
1966	370.9	289.6	170.7
1970	366.9	285.0	170.2
1971	368.1	287.4	170.5
2002	367.5	285.1	170.6
2008	367.7	287.6	171.7

As further confirmation of this, Figure 5.7 indicates that water levels during August remained below the flood warning and inundation levels at Chiang Saen but at Luang Prabang, Vientiane and Nong Khai the flood inundation levels were exceeded for up to 10 days and by considerable margins. Downstream of Nong Khai and towards Nakhon Phanom there were no significant additional contributions to these floodwaters that largely originated in Northern Lao PDR such that at Nakhon Phanom itself the maximum water levels reached in 2008 fell well short of the alarm level.

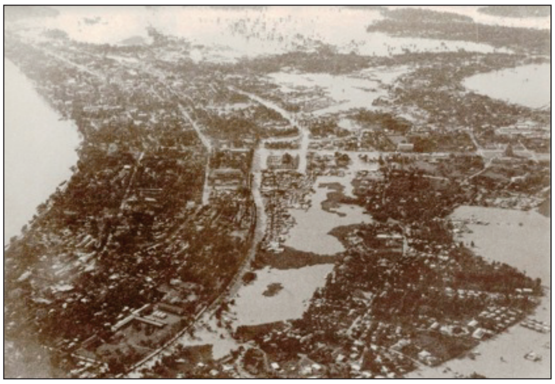

Figure 5.6 The extent of flooding across Vientiane on the 1st September 1966, indicating the potential disaster that was averted by the prompt actions taken during mid August, 2008.

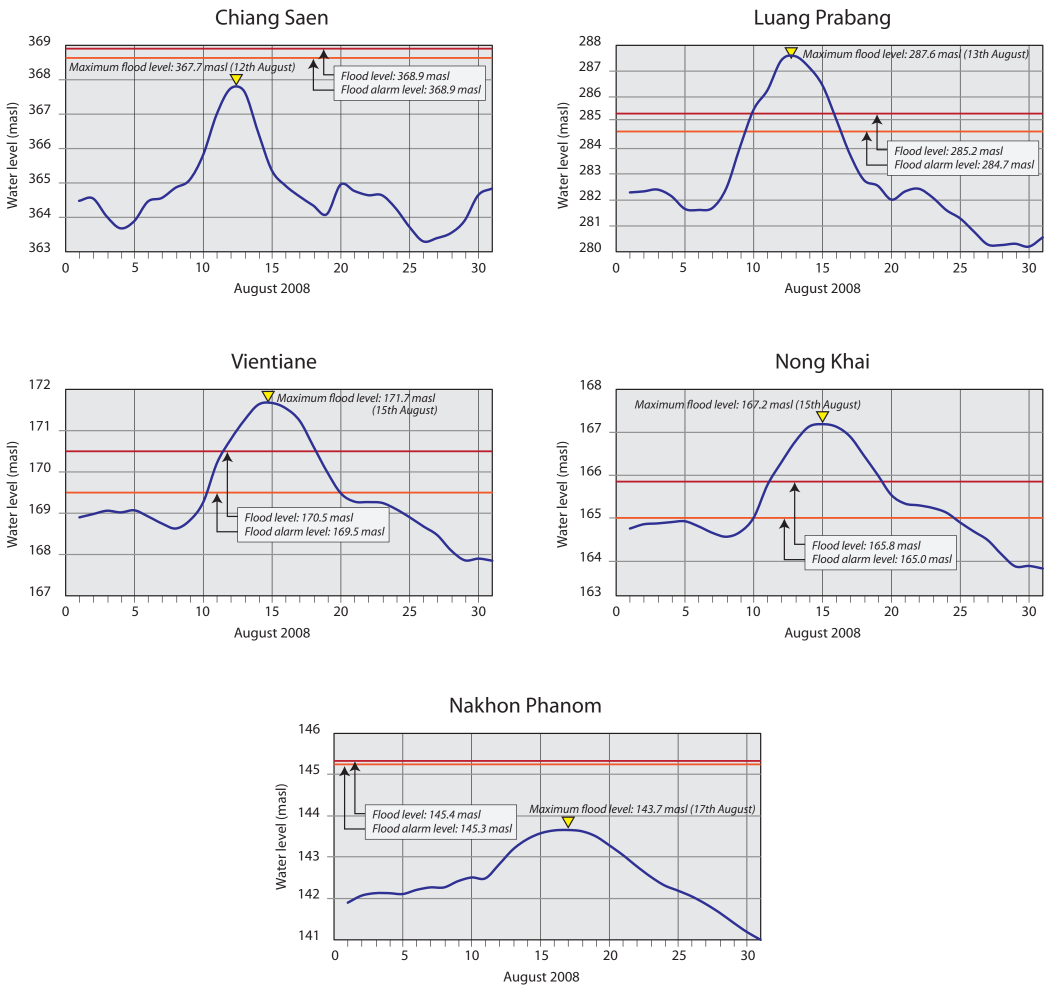

Figure 5.7 August 2008 water levels on the Mekong mainstream between Chiang Saen and Nakhon Phanom compared to flood alarm levels.

At Pakse the flood alarm level was reached for a few days following the 14th of August, whereas at Kratie maximum flood levels peaked 1 m below the alarm level. In the Delta at Tan Chau and Chau Doc the alarm stage was exceeded from early August to late November but such conditions occur even in an average flood year, given the low lying nature of the landscape.[1]

5.5 Flood discharges and flood volumes

Following up the similarity between the floods of 1966 and 2008, Figure 5.8 shows the comparative discharge hydrographs for the two years at Chiang Saen, Luang Prabang and Vientiane:

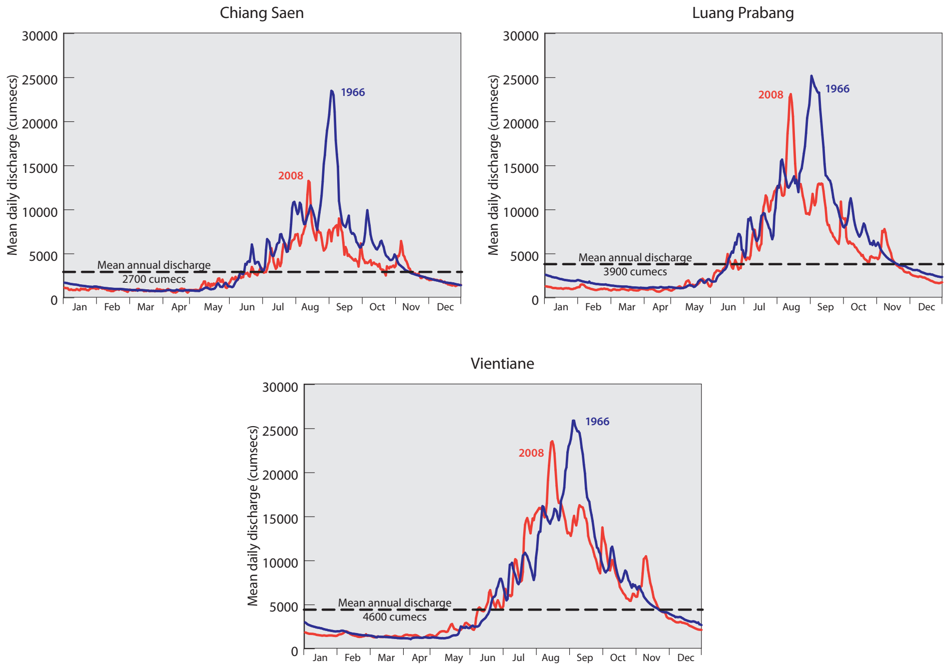

Figure 5.8 Mekong at Chiang Saen, Luang Prabang and Vientiane – comparative 1966 and 2008 daily discharge hydrographs.

- At Chiang Saen the 2008 event does not compare with that of 1966 either in terms of peak discharge or flood volume, underscoring the fact that in 2008 outflows from China were not a major contributory factor, but were in 1966. Never the less the maximum discharge reached on the 12th of August 2008 of 13,300 cumecs has only been exceeded three times in 1966, 1970 and 1971 since records began in 1960. As will be seen, the peak discharge of 23,500 cumecs in 1966 was a huge outlier in the time series of annual maxima at Chiang Saen.

1 Flood warning levels in the Delta were set before much of the flood protection infrastructure was completed. They are currently recognised as too low and are under review.

- At Luang Prabang and Vientiane on the other hand the two events are similar both in terms of peak and volume.

At Chiang Saen and Luang Prabang the relationship between peak water level and discharge is consistent, both were higher in 1966. Conversely, at Vientiane although the water level reached in 2008 was 1 m higher than that of 1966, the discharge was slightly less. In 1966 peak flood discharge was 26,000 cumecs, while that in 2008 was 23,500 cumecs. The explanation lies with the flood protection works that were undertaken after 1966 on both the Thai and Lao banks of the river, subsequent to the inundation of Vientiane, Si Chiang Mai and Nong Khai. These works involved raising flood protection levees that contain the river within its channel up to 14 m above the gauge datum or 172 masl. This explains why for a given discharge water levels are now higher and why the river did not overtop its banks and inundate central Vientiane as it did in 1966.

Further downstream the severity of the flood conditions of August 2008 dissipated since the mainstream tributary inflows downstream of Vientiane were average or below. Figure 5.9 indicated that at Chiang Saen the peak discharge in August is more than twice the average discharge for the month but with the exception of further higher periods of flow in September and November daily flows over the rest of the year were close to average. At Vientiane discharges were way above normal throughout the major part of the flood season but by the time the river reached Kratie the annual flood hydrograph as a whole for 2008 was unexceptional, with below normal flood volumes.

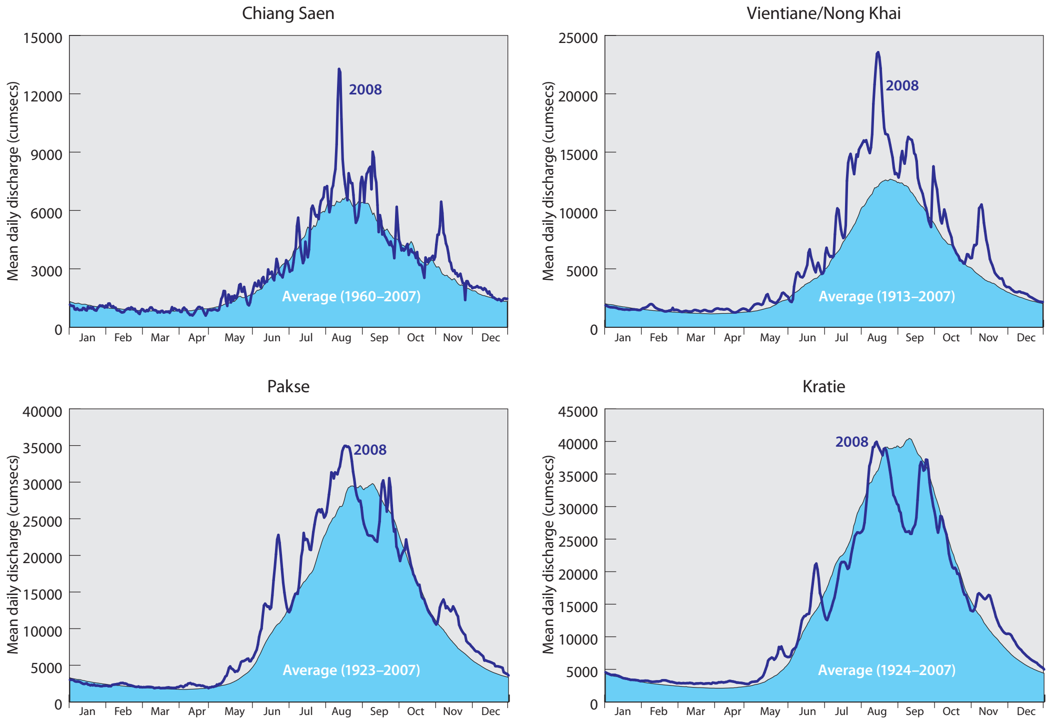

Figure 5.9 The 2008 daily discharge hydrograph at selected sites on the Mekong mainstream, compared to the long term average.

These observations are summarised in Figure 5.10 that shows the historical joint sample distribution of annual flood peak and volume.

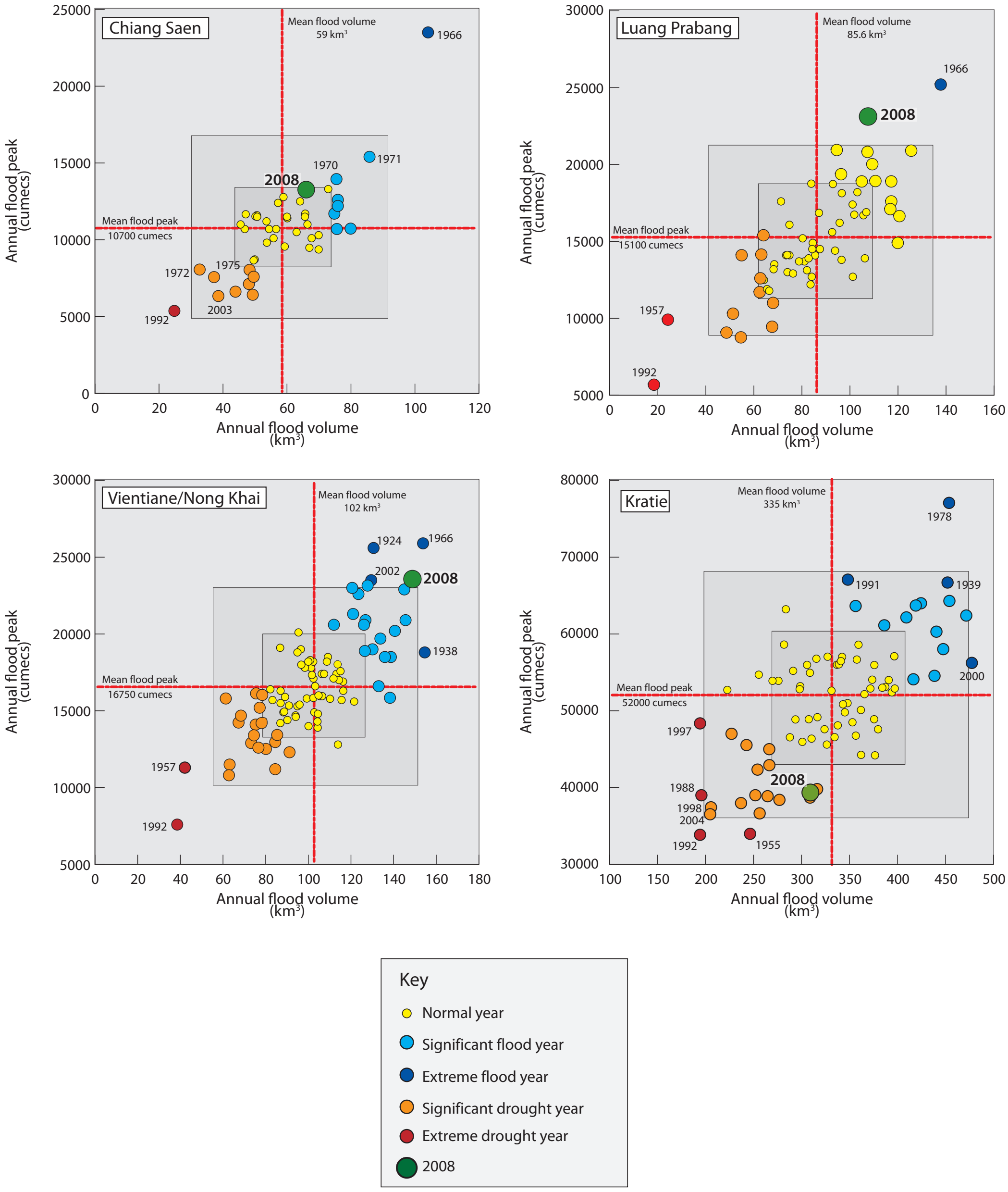

Figure 5.10 Scatter plots of the joint distribution of the annual maximum flood discharge (cumecs) and the volume of the annual flood hydrograph (km³) at selected sites on the Mekong mainstream. The 'boxes' indicate one (1δ) and two (2δ) standard deviations for each variable above and below their respective means. Events outside of the 1δ box might be defined as 'significant' flood years and those outside of the 2δ box as historically 'extreme' flood years.

- According to the criteria, 2008 at Chiang Sean would be defined as a significant flood year in terms of peak discharge but 'normal' with respect to flood volume. The fact that 1966 is a complete outlier in both respects is clear.

- At Luang Prabang and Vientiane the 2008 event was extreme in terms of both variables and exceeded only in 1924 and 1966.

- Much further downstream at Kratie the 2008 event was significantly below normal in terms of peak discharge. The annual flood volume was, however, only marginally less than average.

5.6 Aspects of probability and risk

Extreme events such as that of 2008 in the northern reaches of the Lower Mekong Basin prescribe a need to reassess the mainstream flood risk by including the event in the sample for reanalysis. Appendix A1.2 of the 2006 Annual Flood Report provided estimates of the distribution of flood risk along the mainstream at ten\ locations in terms of annual peak discharge and the total seasonal flood volume. Annual maximum water levels were considered at a further four sites in Cambodia and the Delta in Viet Nam.

For the reach of the mainstream primarily affected by the August 2008 event the annual maximum flood peak data to 2008 were statistically re-evaluated with the following results:

Table 5.4 *Annual maximum discharge (cumecs) at sites on the Mekong mainstream primarily affected by the 2008 flood.*

Mainstream site	Recurrence interval (years)					
	2	5	10	20	50	100
Chiang Saen	10 000	13 000	14 500	16 000	18 000	20 000
Luang Prabang	14 500	17 700	19 800	21 800	24 400	26 400
Chiang Khan	15 800	18 600	20 700	22 800	25 400	27 300
Vientiane	16 200	19 200	21 000	23 000	25 600	27 800

These results indicate that the annual risk of occurrence of the 2008 peak discharge at these sites is:

Table 5.5 *Estimated annual recurrence interval of the 2008 maximum flood discharge.*

Mainstream site	Peak discharge (cumecs)	Recurrence interval (years)
Chiang Saen	13 300	1:7
Luang Prabang	23 100	1:30
Chiang Khan	23 200	1:25
Vientiane	23 500	1:25

Further downstream at Pakse and Kratie the 2008 peaks were no more than average with annual return periods of the order of 1:2 years.

On large rivers a more complete statistical assessment of flood risk is obtained if the peak and volume of the event are considered jointly within a probabilistic context. This recognises the fact that the duration of flows above critical thresholds and therefore the potential period of inundation is often as important as the peak discharge, which is related to the maximum depth of flooding. Adamson *et al.* (1999) developed a method for obtaining a bivariate extreme value model of flood peak and volume which provides the type of result indicated in Figure 5.11. This may be perceived as adding the dimension of probability to the simple scatter plots shown in Figure 5.10.

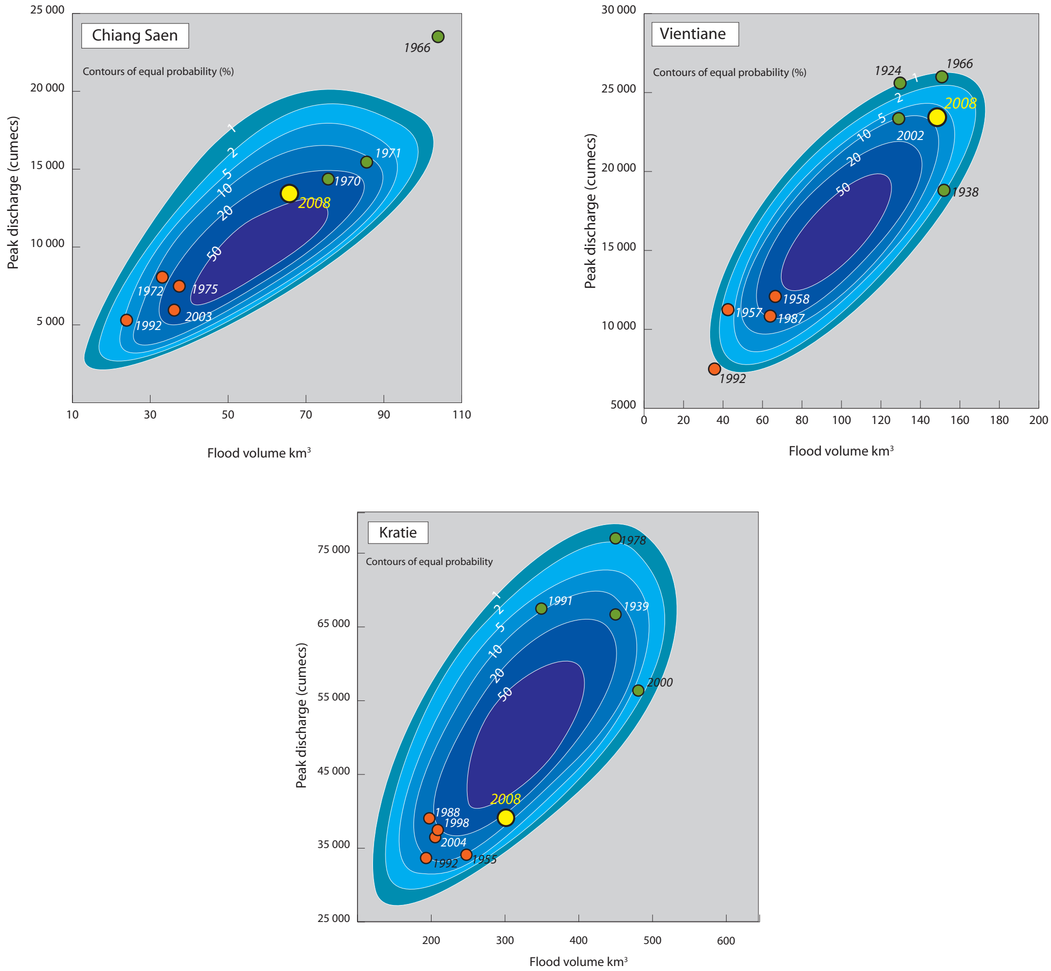

Figure 5.11 Bivariate probabilities of the joint distribution of flood peak and volume at selected mainstream sites. For example, points lying outside of the 1% isoline would have a recurrence interval in excess of 1:100 years, any outside of the 2% contour a recurrence interval in excess of 1:50 years, and so on.

- At Chiang Saen the 2008 flood has a bivariate probability of occurrence of less than 20% or 1:5 years and was therefore unremarkable in both respects. The magnitude of the outlier that is the 1966 flood is clear in terms of both peak and volume.

- At Vientiane the 2008 flood hydrograph an annual probability of occurrence in biforate terms of between 10 and 5% or 1:10 to 1:20 years.

- At Kratie the 2008 hydrograph was below average in terms of both variables to an extent that would be expected with an annual probability of 20% or once on the average every 5 years.

5.7 Conditions on the Cambodian floodplain and in the Delta

Consistent with the systematic diminishing of the magnitude 2008 flood downstream of Vientiane, daily water levels in Cambodia and the Delta were unexceptional during the season as can be seen from Figure 5.12.

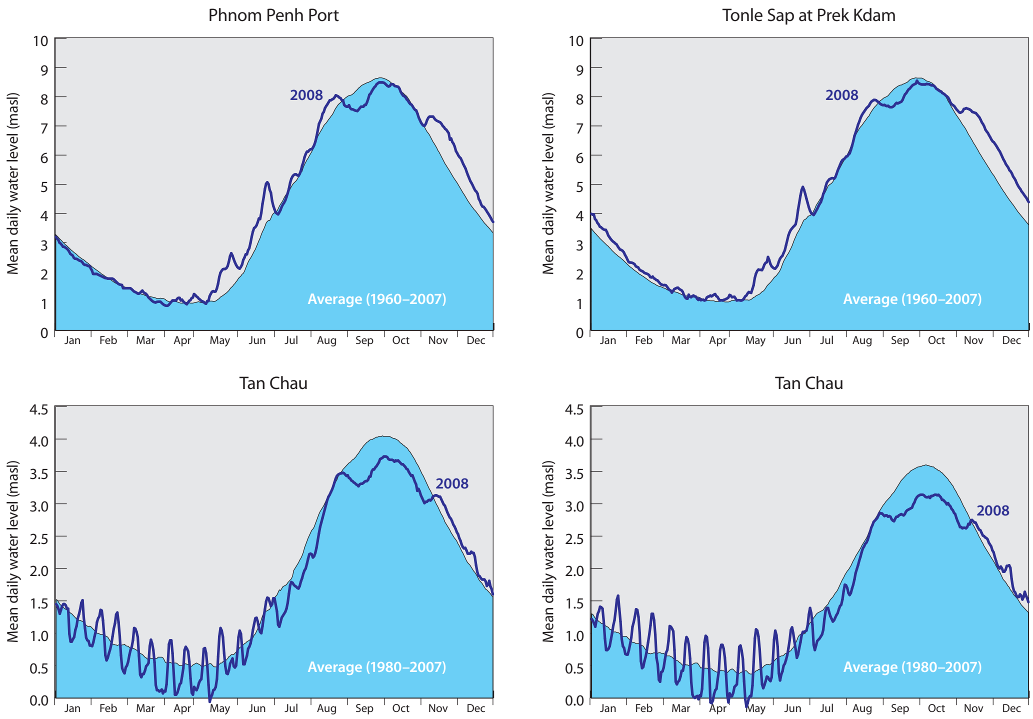

Figure 5.12 Mean daily water levels in Cambodia and the Mekong Delta for 2008 compared to their long term daily average.

In 2008 the start and end of the flood season, defined as the period of the year when water levels exceed their long term average, were typical, except at Prek Kdam where the season did not end until the first week of 2009:

Table 5.6 *Cambodian floodplain and Mekong Delta – onset and end dates of the 2008 flood season compared to their historical mean and standard deviation.*

Site	Onset of flood season			End of flood season		
	Historical average	Standard deviation	2008	Historical average	Standard deviation	2008
Phnom Penh	10th July	14 days	9th July	14th Nov	14 days	15th Dec
Prek Kdam	11th July	16 days	8th July	20th Dec	17 days	3rd Jan
Tan Chau	19th July	20 days	18th July	17th Dec	12 days	16th Dec
Chau Doc	23rd July	17 days	22nd July	19th Dec	12 days	19th Dec

Meanwhile, the maximum water levels achieved in 2008 fell well below the annual average figures:

Table 5.7 *Maximum water levels reached during 2008 in Cambodia and the Mekong Delta compared to their long term average.*

Site	Period of Record	Annual maximum water level. (masl)		
		Historical average	Standard deviation (m)	2008
Phnom Penh Port	1960–2008	9.02	0.67	8.49
Prek Kdam	1960–2008	9.08	0.73	8.63
Tan Chau	1980–2008	4.30	0.54	3.73
Chao Doc	1980–2008	3.82	0.58	3.14

6. Summary of the 2008 country reports

6.1 Cambodia

General situation

The annual report of the National Committee for Disaster Management (NCDM) for 2008 indicates there was little or no flood damage in the country during the year that could be linked to hydrological conditions along the Mekong mainstream, the Bassac and in the Tonle Sap Basin. Flood warning levels were not exceeded at any time. The only flood losses arose from flash flooding caused by a series of tropical storms during the latter part of September in Preah Vihear, Kampong Thom and Bantay Meanchey Provinces which damaged about 10 500 hectares of crops, mainly rice. The NCDM estimate of the cost of the associated damage is US$5.7 million, or about US$550 per hectare inundated. The figure for 2008 is below the average annual financial loss and less than 4% of that arising from the most extreme event of recent decades which took place in 2000:

Table 6.1 *Cambodia – total national flood damage in recent years (NDCM data).*

Year	National flood damage (US$ million)
2000	161.0
2001	36.0
2002	12.5
2003	no data
2004	55.0
2005	3.8
2006	11.8
2007	9.1
2008	5.7

Lessons learnt

Since minimal flood damage was reported for 2008 no direct lessons can be drawn specific to the year's events. The general observations and recommendations made in previous years continue to apply, however. In the main these emphasize the need for a stronger financial commitment to national disaster management and improved inter-agency coordination. Specifically it is recognized that:

Figure 6.1 Cambodian flood situation in 2000, the most extreme conditions of recent decades. Compared to this, the situation in 2008 was one of the least damaging of recent years with water levels along the Mekong, Bassac and in the Tonle Sap system not reaching the alarm stage at any time.

- There is a lack of systematic flood preparedness planning at the provincial, district and commune levels.

- At the national level there is poor coordination between the institutions and agencies concerned with disaster management.

- Hydrometric monitoring in general and during flood events in particular requires the appropriate levels of funding. Financial support for the operation and maintenance of the recording network is also inadequate.

- Effective disaster management should be based on a continuous process of data assembly and analysis including mapping areas at risk and continuously developing and testing mitigation measures. While of significant benefit the momentum and technical expertise developed during the course of short term internationally funded projects is not often sustained due to a lack of ongoing financial support. The design and implementation of such projects also requires improved coordination such that repetition is avoided and funds used in a more optimal manner.

6.2 Lao PDR

General situation

Events in Lao PDR during 2008 were obviously dominated by the August flood conditions on the Mekong mainstream, particularly between Luang Prabang and Vientiane. Though these extreme mainstream flood conditions dominated the picture at the national scale in terms of damage and losses, there were a number of other events across the country which had significant impacts at the local and provincial level. The geography of flooding in the country during 2008 is summarised in Figure 6.2. In this section the flood conditions that occurred across the country other than those of mid August are briefly reviewed, the latter having been considered in detail in Chapter 5.

Flooding in Bolikhamxay and Khammouane provinces caused by heavy monsoonal rainfall 17th – 20th June

The relatively strong SW Monsoon of 2008 saw the development of sequential periods of intense and prolonged periods of storm rainfall, particularly over the central regions of the country during June. As the figures in the Table 6.2 below show over 800 mm was recorded over the 10 days between the 11th and 20th of the month at Paksane. Although extreme and is amongst the highest that has been observed in the central and southern regions of Lao PDR, this figure has been exceeded several times and by considerable margins as indicated in Figure 6.3. On two occasions more than 1,000 mm has been observed over 10 days; 1,255 mm at Muong Tchepon in 1927 and 1,020 mm at Attapeu in 1996.

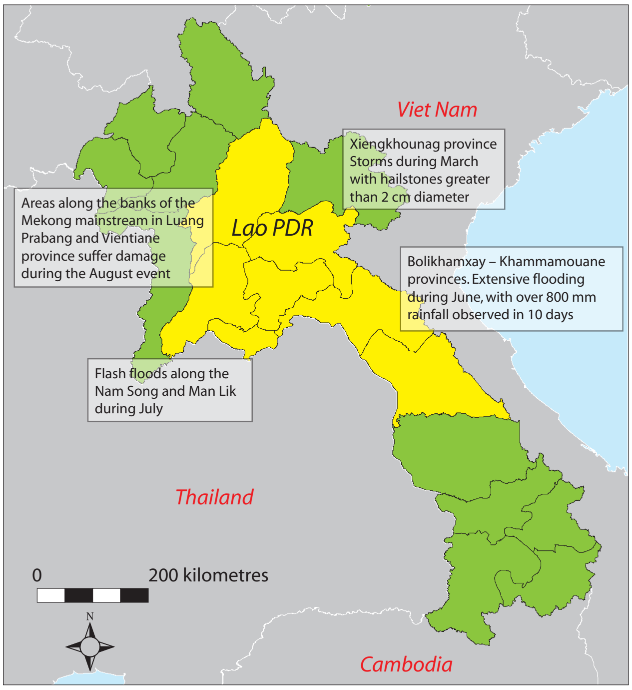

Figure 6.2 Lao PDR – provinces affected by flooding and local storms during 2008.

Table 6.2 *Daily rainfalls observed at Paksane over the 10 days between 11th and 20th June, 2008.*

June										Total
11th	12th	13th	14th	15th	16th	17th	18th	19th	20th	
35	96	110	22	98	102	196	60	83	6	808

Other than extensive rural flooding the major impact of this period of exceptional rainfall was the flooding of the major road link to the south to a depth of 0.5 m over a distance of 500 metres. This lasted for several days and caused severe disruption to inter-provincial traffic.

Flooding in the Nam Song and Nam Lik Rivers in July

Wide spread heavy rainfalls in mid July in the upper Nam Ngum basin, with a total of more than 300 mm observed on the 18th and 19th at Vang Vieng, caused extensive flooding as the Nam Ngum, Nam Lik and Nam Song rivers rose above critical levels. Flood depths widely exceeded 1m, inundating over 2,000 households in the Kasy, Vang Vieng, Hinheup, Pheuang and Thoulakhom districts. Landslides in the Kasy district caused four deaths.

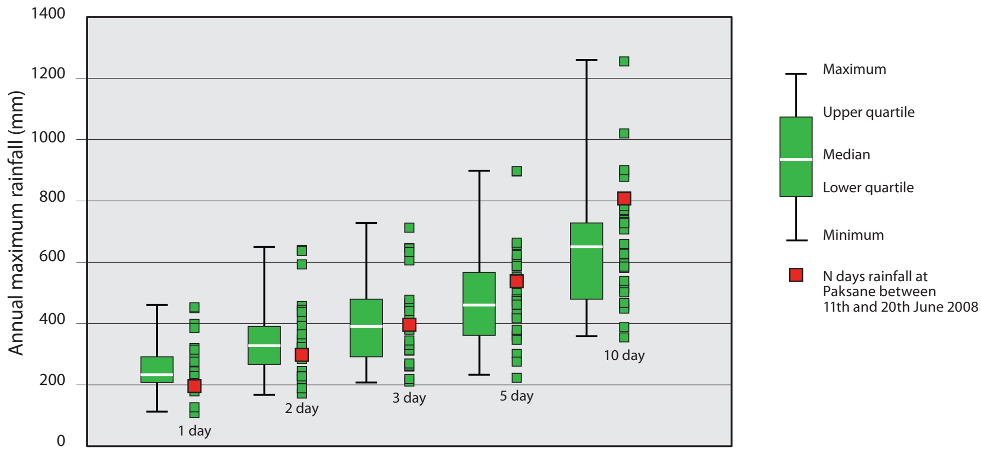

Figure 6.3 Central and southern Lao PDR – annual maximum 1, 2, 3, 5, and 10 day rainfalls observed at 29 sites with a combined total of 680 station-years of data.

Figure 6.4 Flooding in the Vang Vieng district of Vientiane province after the storms of mid July, with maximum observed rainfalls of more than 300 mm over two days.

Figure 6.5 Flooding in Luang Prabang Province as a consequence of the passage of tropical storm Kammuri in early August.

Flood damage and losses

The major damage and losses were linked to the events of mid August and the passage of tropical storm Kammuri and were centred on Luang Prabang, Vientiane capital, Bolikhamxay and Khammuane provinces. Some 664 villages and 32,610 households were affected, 3 people were killed and 28,500 hectares of rice and other crops damaged. Livestock losses were significant as was damage to national infrastructure, particularly roads, bridges and irrigation systems.

Local flash flooding in the northern and central regions of the country during June, July and September affected 11 districts, 90 villages and 2,500 households and 4 people were killed by landslides. In the agricultural sector 2,250 hectares of crops were damaged and some livestock lost.

The financial loss is currently estimated to be US$56 million, by far the highest figure since systematic damage assessments began in the early 1990s.

Lessons learnt

Given that the August flooding in Vientiane capital and Luang Prabang was the most severe in almost 50 years meant that much was learnt with regard to flood forecasting and emergency response and how the impacts of comparative events in the future might be mitigated.

- Although the short term forecasting over 1 to 2 days was reasonably accurate and provided sufficient time for the implementation of emergency measures such as sandbagging, the accuracy of the medium and longer term forecasts could be improved significantly. Improvements to hydrometric and in particular to the storm rainfall observation network in the northern regions of the country are required in order to provide the longer lead times warning of the development of critical conditions within the large northern tributaries such as the Nam Ou. This is particularly relevant as it becomes evident that the satellite images that indicate regional storm rainfall during the passage of tropical storms appear to be providing underestimates and that more ‘ground truthing’ of extreme rainfall is needed.

- Unplanned urban development and the removal of natural flood storage will contribute to increased damages and losses in the future and the issue needs to be addressed.

- The inventory of equipment available to the emergency response agencies needs improvement, particularly with regard to boats and vehicles suitable for accessing and evacuating stricken areas.

6.3 Thailand

General situation.

Two major events dominated the flood situation in the Mekong region of Thailand during 2008:

1. The consequences of cyclone Kammuri during August and the resultant extremely high water levels in the Mekong mainstream which caused over bank flooding over considerable areas in Nan, Chiang Rai, Nakhon Phanom, Sakon Nakhon, Nong Khai, Mukdahan, and Phetchabun provinces.

2. Extreme storm rainfalls caused by tropical storm Mekkhala between September 30th and 1st October. Flooding was widespread nationally but the Mekong region was affected particularly Khon Kaen and Loei provinces and the Mun Chi Basin. Earlier during the first two weeks of September at Khon Kaen more than 50 mm was recorded on most days, with more than 125 mm observed on the 13th, 16th, and 17th of the month causing severe local disruption and damage.

Tropical storm Noul passes over the southern regions of Thailand during November and caused significant losses and damage but not within the Mekong region.

Over the NE of the country the regional rainfall for the 2008 monsoon season is estimated to have been 1,650 mm, about 20% above average – largely explained by higher than normal rainfall in between September and November. However, there was considerable geographical variation caused by quite local synoptic conditions that resulted in exceptional storms over several days or weeks, such as those that were confined to Khon Khaen Province during early September. No instances of serious flash flooding were reported from the north of the country, in Chiang Rai Province for example. The tends to confirm the observation made elsewhere that the extreme rainfall associated with cyclone Kammuri that caused the Mekong flood conditions of mid August were largely confined to within the northern regions of Lao PDR.

At the national level[1] the total financial losses for 2008 flooding amounted to 75% of the average figure over the six years from 2003 to 2008. Of the 2008 losses some 40% was ascribed to the impacts of tropical storm Noul over the southern regions of the country outside of the Mekong Basin.

The Mekong floods of August

As on the left bank of the Mekong in Lao PDR, flood inundation due to extreme mainstream water levels in mid August on the right bank in Thailand was mainly in semi urban and rural areas that did not have the benefit of flood protection levees. Where these were present, in Nong Khai for example, the central urban districts suffered only minor flooding and disruption. However, even here, as in Vientiane, sand bags were strategically placed to manage the risk. In all 7 provinces and over 2,300 villages were affected in Thailand, not only those directly adjacent to the Mekong mainstream but also those along the tributary rivers such as the Nam Loei and Nam Songkhram. As in all years when water levels in the mainstream reach their peak there are tributary backwater effects which can extend far upstream such that inundation extends over wide areas beyond those immediately adjacent to the Mekong.

Intense local storms during early August intensified the impacts of the over bank Mekong flooding. For example, at Nakhon Phanom on the 11th 270 mm was recorded and almost 150 mm at Nong Khai on the same day. This combination of events resulted in six deaths.

Figure 6.6 Flooding in Nakhon Phanom Province in mid August.

1 Flood damage data at the provincial level such that a figure could be obtained for the Thai Mekong region were not made available.

Flooding in Khon Kaen province – September

If the figures are correct the total rainfall for September 2008 at Khon Kaen was 1,990 mm, which compared to the available historical records over the 55 years between 1950 and 2004:

- Is more than 1.5 times the mean annual rainfall of 1,250 mm;
- Is higher than the highest recorded annual rainfall of 1,850 mm observed in 2000;
- Is more than seven times the average September rainfall of 260 mm;
- Is more than three times the highest recorded September figure of 600 mm observed in 1982 (Figure 6.7).

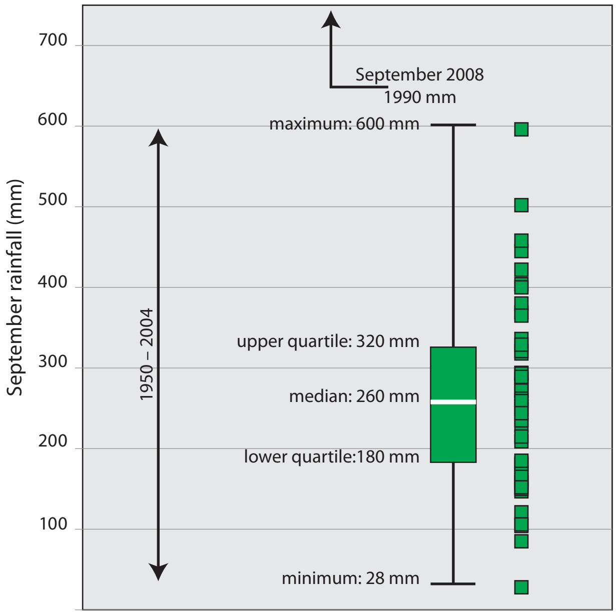

Figure 6.7 Khon Kaen: The sample distribution of September rainfall over the 55 years from 1950 to 2004 compared to the reported 2008 monthly figure of 1,990 mm.

If this is indeed the case then rainfall conditions at Khon Kaen during September 2008 were unprecedented by some considerable margin.

The consequent flooding extended over 23 provincial districts to a mean depth of 0.3 m. Two people were reported to have died.

Flood damage and losses

The total national figure for flood losses in Thailand during 2008 has been estimated to be US$72 million, of which US$28 million occurred in the far south of the country during the passage of tropical storm Noul. This flooding in the south and that in the western provinces during October would appear to account for the greater part of the national damage. Although substantially higher than those of 2007, the 2008 figures are much less than the average over recent years and less than half of those of 2005 and 2006.

The damage in the Thai Mekong region was generally confined to rural areas and the agricultural sector and although the water levels in the Mekong were the highest for almost 50 years their impact in terms of monetary loss appears to have been modest compared to events elsewhere in the country during 2008.

Figure 6.8 Flooding in Khon Kaen Province as a result of unprecedented September rainfall.

Lessons learnt

As in any emergency response activity coordination between the various agencies responsible is key to effective implementation. In Thailand a comparatively wide range of organizations provide aid such as the Rajaprajanugroh Foundation Under Royal Patronage, the Thai Red Cross Society, the Department of Disaster Prevention and Mitigation, National, Provincial and District Authorities, the Royal Irrigation Department, the army, the Department of Water Resources and so on. A need is recognized for improved planning and coordination between these bodies at the community, basin and national level.

The government's National Policy statement on Land, Natural Resources and the Environment of December 2008 heeds the lessons of recent national disasters and calls for a greater emphasis upon preventive measures, such as early warning systems and the use of geo-informatics to identify and monitor areas at risk. Amongst the approved measures is the installation of an early warning system for flash flood and landslide risk which will cover 2,300 villages by 2012, the establishment of the 'Mekhala Centre' for water crisis management which will exploit modern IT technology and Decision Support Tools and improved flood warning in the Mun Chi Basin based on an expanded telemetry system.

Figure 6.9 Emergency medical provision – Lop Buri Province. September 2008.

Figure 6.10 A component of the flash flood and landslide monitoring network.

6.4 Viet Nam

General situation

Although water levels in the Mekong Delta at Tan Chau and Chau Doc exceeded alarm levels for considerable periods of the 2008 flood season[1], flood damage in this part of the country was

1 It is recognised that the current flood alarm levels in the Delta are too low given the flood protection works that have been completed over the last decade or so. It is planned to reassess them in the coming months

limited and less than that for a typical year. In fact over the year less than 70 ha of rice paddy was reported to have been damaged. The only significant inundation occurred in mid October as a result of spring tide conditions causing widespread but brief flood inundation in a number of delta provinces and Can Tho City, and in late November as a consequence of the intense rainfall linked to the passage of tropical storm Noul over the southern regions of Viet Nam.

In the Central Highlands, specifically in the upper Se San and Sre Pok river basins, a number of local flash floods occurred, with those of mid May, early August and late November being the most damaging. Generally, however, as in the Delta, 2008 was a year that saw the lowest levels of flood losses observed in recent years.

Flash flooding in the upper Se San basin

During the first half of August, at the same time that tropical storm Kammuri was passing over the northern regions of the Lower Mekong Basin, heavy rainfall occurred over parts of the Central Highlands, particularly in Kon Tum Province in the upper Se San basin, with as much as 355 mm observed in the 7 days between the 2nd and 8th of the month.

Table 6.3 *Storm rainfall observed in the upper Se San Basin between the 2nd and 8th of August, 2008.*

Station	River basin	Rainfall (mm)
Mang Canh	Dak Bla	175
Sa Thay	Dak Bla	190
Dak Lay	Dak Bla	185
Pleiku	Dak Bla	280
Dak Mot	Se San	155
Kon Plong	Se San	285
Dak To	Dak Takan	185
Kon Tum	Se San	355

On the 7th in Dak Bla village and Kon Tum town flash flooding caused considerable damage to residential property, crops and infrastructure and included one death. Almost 100 ha of rice paddy were lost completely and 150 ha damaged, 8 rural bridges were damaged and total costs estimated to be VND 15.5 billion.

Flash flooding in the upper Sre Pok basin

During early May local monsoonal low pressure systems brought heavy rainfall to the upper Sre Pok basin and flash floods to Dak Nong province on the 11th, which resulted in four deaths. Later in the year in November tropical storm Noul caused further flash flooding and significant damage to 60 houses along with two further two deaths.

Table 6.4 *Rainfall observed in the upper Sre Pok: 14 – 6th November.*

Station	River basin	Rainfall (mm)
Buon Ma Thuot	Sre Pok	135
Buon Ho	Sre Pok	160
Giang Son	Sre Pok	225
Duc Xuyen	Sre Pok	110
Bridge 14	Sre Pok	115
Krong Buk	Sre Pok	290

Figure 6.11 Typical flash flood conditions in the Central Highlands, indicating high flow velocities and considerable erosive power. Landslides in the steep terrain add to the hazard since they can block river channels. When they collapse or are overtopped, a wave of floodwater is released containing huge amounts of sediment and debris.

Flood damage and losses

Flood damage in the delta during 2008 was insignificant. In the upper Se San and Sre Pok though flash floods did occur with some loss of life, total damages were small compared to previous years. For example, during 2008 costs were estimated to be US$1 million, compared to US$51 million in 2007.

Lessons learnt

The benign flood conditions in 2008 in the delta served to emphasise the benefits of the annual Mekong flood with regard to agriculture fisheries and the environment. Although flood protection and mitigation measures both structural and non-structural continue to be implemented in the Delta, it is recognised that more needs to be done in the Central Highlands where flash flooding is a perennial hazard. By definition such events are extremely difficult to forecast, though by monitoring levels of catchment saturation, improving the accuracy both spatial and temporal of short term rainfall forecasts, mapping the most vulnerable areas and encouraging people not to live in them would serve to reduce the significant losses in terms of both property and lives that occur year in, year out. It is acknowledged that mitigating the impacts of flash floods in Viet Nam would be a considerable and very expensive challenge, not with standing the significant social challenges that exist and the fact that such floods occur throughout the country and are a major cause of loss of life. Although qualitatively the conditions that cause them are well understood the quantitative meteorological and hydrological thresholds that trigger them within various types of landscape are not and provide an area of much needed research.

Figure 6.12 Structural flood mitigation measures implemented in the delta – schools and houses raised on piles.

The complex fluvial geomorphological consequences of ‘hard’ flood control and mitigation measures need to be better understood since bank erosion during the flood season is becoming a serious issue in parts of the delta region.

7. Summary conclusions and recommendations

7.1 Summary conclusions.

The Mekong flood of 2002 provided a classic illustration of the fact that in years when extreme water levels and discharges occur, they tend not to do so throughout the Lower Basin. The synoptic scale of the weather generating mechanisms such as typhoons and tropical storms that cause such conditions are such that their direct impacts are limited to just a part of the basin. Typically extreme annual events are confined either to the northern parts of the lower basin upstream of Vientiane, as in 1966 and 2008 or to the southern parts as in 2000, 2001 and 2002.

The events of 2008 saw the highest water levels observed at Luang Prabang, Vientiane and Nong Khai since 1966, with considerable inundation of peri urban and rural areas with flood damages, particularly in Lao PDR, the highest incurred in many years. The conditions, which peaked in mid August, were the result of the passage of cyclone Kamurri across northern Lao PDR and Thailand during the first week of the month. Analyses revealed that almost all of the floodwater originated within the Nam Tha, Nam Ou, Nam Soung and Nam Khan river basins, with only a modest trans-boundary contribution from China.

Downstream of Vientiane and Nong Khai flood conditions rapidly moderated since the flood contributions to the mainstream from the large left bank tributaries were not exceptional. As a consequence discharges and water levels across the Cambodian flood plain were average at best. Little or no damage was reported in these southern regions of the basin, though flash flooding did occur in the upper Se San and Sre Pok river basins in Viet Nam during May and August, though overall damage and losses were small compared to those of recent years

7.2 Recommendations.

The events of August 2008 provided the first real opportunity to apply and test the RFMMC's flood forecasting system, which performed tolerably well when predicting the potential situation over a one and two day lead time, but less well over the longer lead times. This suggests that the flood routing component works well once the floodwater is in the major tributaries and the mainstream. However, estimating several days in advance the volumes of flood runoff that will be generated by the storm rainfall is recognized as needing improvement.

The major constraint to bringing this about appears to be the fact that the satellite imagery used to estimate the storm rainfall depths is apparently leading to systematic underestimation. Certainly the accumulated volumes of flood runoff during the first two weeks of August, which amounted to 30 km^3 in the Mekong at Vientiane, could not have been produced by the total rainfall for the period indicated from satellite imagery. The figures are far too low and the areal coverage of maximum storm rainfall too small. There is a need therefore to extend the 'ground truthing' of the figures indicated from the satellite image.

In this context the major recommendation is the need to improve the rainfall recording network in the key river basins in Northern Lao PDR, although this need has already been recognized by the Department of Meteorology and Hydrology (DMH) in Vientiane. New gauges have been installed at Phongsali, Oudomxai and Luang Namtha.

It was also recognized during the post flood evaluation that the clarity and coverage of the flood forecasts as they are posted from day to day on the MRCS web site needs to be improved. The issue has been addressed.

Turning to the observations made in the Annual National Flood Reports:

- The August damage in Vientiane emphasized the need for improved urban planning such that residential development is controlled in flood prone areas, while the ongoing removal of natural flood storage such as wetlands will only lead to increased future losses.

- The inventory of equipment available to the emergency response agencies is inadequate.

- In Thailand, the call for greater emphasis on preventative measures such as early warning systems and the use of geo-informatics to identify and monitor areas at risk from flash floods and landslides applies regionally. The installation of the monitoring network to protect vulnerable villages provides a model that could be extended throughout the basin.

- The difficulty of mitigating the impacts of flash flooding has been long recognized in Viet Nam and a call is made for increased investment in research regarding the quantitative meteorological and hydrological thresh holds that trigger them in various kinds of landscape.

- Flood induced erosion, particularly in the Delta, and its linkage with 'hard' flood control measures is also an area that needs better understanding since it is emerging as a serious issue.

- As in previous years all four national reports recommend ongoing improvement towards effective disaster management through better inter-agency coordination and the provision of the appropriate levels of funding.

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Appendix 1. Mekong mainstream: summary hydrological statistics for the 2008 flood season

Location	Date of onset of flood season	Date of end of flood season	Maximum water level (masl)	Maximum discharge (cumecs)	Date of maximum	2006 Flood volume (km^3)
Chiang Saen	27 June	14 Nov		13 300	13 Aug	66.5
Luang Prabang	29 June	14 Nov		23 100	14 Aug	107.2
Chiang Khan	13 June	23 Nov		(25 500)	15 Aug	134.5
Vientiane	15 June	21 Nov		23 500	15 Aug	148.0
Nong Khai	2 July	18 Nov		(21 100)	16 Aug	(125.3)
Nakhon Phanom	3 June	24 Nov		32 800	18 Aug	(288.0)
Mukdahan	6 June	18 Nov		34 000	18 Aug	260.4
Khong Chiam	8 June	21 Nov		(29 400)	18 Aug	256.3
Pakse	9 June	20 Nov		37 500	17 Aug	295.4
Stung Treng	10 June	24 Nov		48 000	10 Aug	393.0
Kratie	5 July	20 Nov		(40 000)	14 Aug	(304.0)
Phnom Penh Port	9 July	14 Dec	8.49		26 Sep	
Prek Kdam	10 July	19 Dec	8.86		28 Sep	
Tan Chao	18 July	16 Dec	3.73		30 Sep	
Chao Doc	22 July	19 Dec	3.14		1 Oct	

Appendix 2. Cambodia. 2008 flood damages compared to those of recent years

Year	Total Flood Damage (US$)	Major area affected	Type of flood	Major components of loss
1996	86,500,000	Along Mekong, Bassac and around Tonle Sap Lake	Mekong flood and flash flood	Crops (250,218 ha), Livestock (327) Houses (3,768), Schools (173) Roads (802 km), Bridges (290 sites) Culverts (2,499 sites), Dams (65 sites) Dead (169 persons)
2000	161,000,000	Along Mekong, Bassac and around Tonle Sap Lake	Mekong flood and flash flood	Crop s(421,568 ha), Houses (7,086) Schools (6,620), Roads (908,710 km) Bridges (1,856 km), Culverts (17 sites) Dams (397 sites), Dead (347 persons)
2001	36,000,000	Along Mekong, Bassac and around Tonle Sap Lake	Mekong flood and flash flood	Crops (164,173 ha), Houses (2,251) Schools (911), Roads (7,976 km) Bridge s(175 sites), Culverts (44 sites) Dams (201 sites), Livestock (956) Dead (62 persons)
2002	12,450,000	Along Mekong, Bassac and around Tonle Sap Lake	Mekong flood and flash flood	Crops (45,003 ha), Houses (35) Schools (2), Health centre (7) Roads (12 km), Dams (201 sites) Livestock (956)
2004	55,000,000	Along Mekong, Bassac and around Tonle Sap Lake	Mekong flood and flash flood	Crop (247,393 ha)
2005	3,810,000	Along Mekong, Bassac and around Tonle Sap Lake	Mekong flood and flash flood	Crops (1,500 ha), Houses (1,700 flooded, 32 collapse), Schools (30 flooded), Dead (4 persons)
2006	11,800,000	Along Mekong, Bassac and around Tonle Sap Lake	Mekong flood and flash flood	Crops (13,787 ha), Roads (70 km) Dams (41 sites), Bridges (24 sites) Dead (11 persons),
2007	9,000,000	Along Mekong, Bassac and around Tonle Sap Lake	Flash flood	Crops 18,786 ha, Houses 11 Roads 34 km
2008	5,750,000		Flash flood	Crop 18,907

Appendix 3. Lao PDR: August 2008 flood damages

Description	Assessment methodology is based on data reporting from: Provincial Agriculture and Forestry Office, Ministry of Agriculture and Forestry ; Department of Meteorology and Hydrology, Water Resources and Environment Administration and the National Disaster Management Organization
Provinces affected	Luangprabang, Vientiane Capital, Bolikhamxay and Khammuane
Districts affected	26
Villages affected	664
Houses affected	32,610
People affected	95,158 persons in Bolikhamxy and Khammuane provinces
People killed	3
Agriculture	
Hectares of Rice and other Crop damaged	28.516,67
Hectares of Industry log damaged	53,54
Kilogram of seed bed / nursery	860
Livestock	
Cattle	702 head (buffalos, cows, pigs and goats) lost
Poultry	995 head lost
Fish ponds, aquaculture and Mekong fish net	44 sites fish ponds 355,59 ha aquaculture and 71 sites of Mekong fish net damaged
Infrastructure	
Schools	63 sites affected
Health Center	3 health centre of Hinboun village affected and 50 sites and medicine cabinets
Bridges damage	3 sites
Erosion along the Mekong river	18 sites destroyed 27 kilometres of length
Road damage	40 places damaged 314,38 kilometres of length
Canal systems damaged	48 sites
Drainage tubes affected	53 metres
Water wells damage	929 sites
Underground water well damage	812 sites
Natural water spring damage	1 site
Villagers toilets affected	4,954 sites

Appendix 4. Thailand: 2008 flood damages compared to those of recent years

Descriptions		2008	2007	2006	2005	2004	2003
Areas	Provinces	65	46	47	63	59	66
	Districts	584	486	482	541	337	349
	Villages	22,874	20,499	20,625	10,326	9,964	5,281
Human	People	4,494,187	3,640,978	5,198,814	2,874,673	2,324,441	1,882,017
	Households	1,197,253	940,663	1,430,085	763,847	619,797	485,436
	Casualties	97	62	340	88	31	54
Assets	House	18,258	7,369	49,611	6,040	5,947	10,329
	Fish ponds	42,424	34,767	125,683	13,664	12,884	22,339
	Live stock	504,737	38,079	142,211	696,123	71,889	301,343
	Agriculture field (rai)	3,023,477	2,645,982	5,605,559	1,701,450	3,298,733	1,595,557
Infrastructures	Roads	12,133	8,330	10,391	5,697	4,173	5,071
	Bridges	573	309	671	667	173	393
	Hydraulic structures	595	591	778	22,527	716	179
	Institute buildings	197	271	1,425	2,123	827	174
	Drains	561	163	1,085	1,482	594	282
US$ million		72	48	202	170	24	58

These figures are for the country as a whole. Of the US$72 million flood damage figure for 2008 about US$20 million occurred in the Thai Mekong region.

Appendix 5. Viet Nam: 2008 flood damages compared to those of recent years

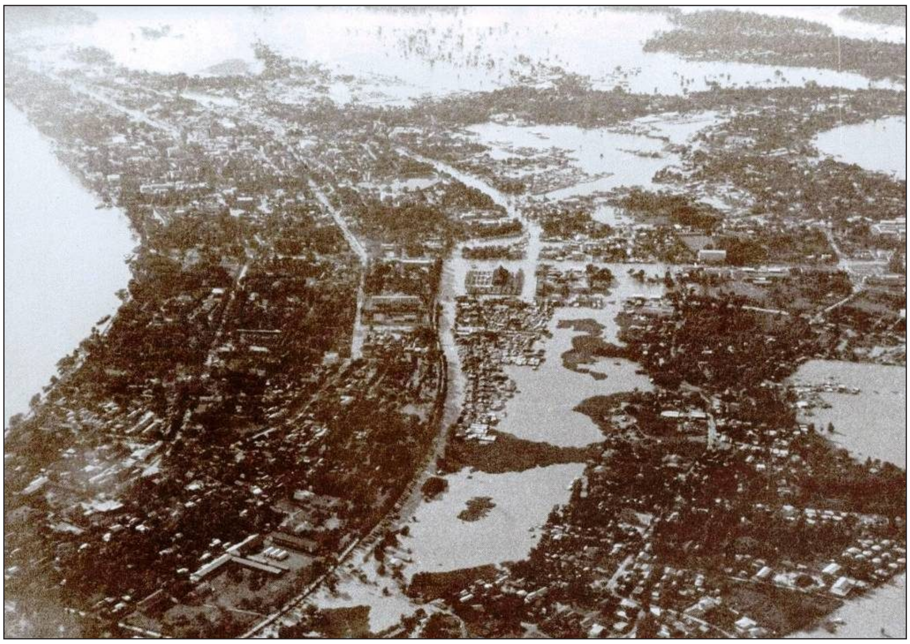
Mekong Delta

Description	Flood impacts 2007	Flood impacts 2008 *	Flood impacts 2000
Number of affected provinces	5	5	13
Number of affected families	13 500	0	800 000
Number affected people	67,500	0	10 million
Number of people killed	30	7	453
Rice & upland crop damaged (ha)	14 688	68	2.0 million
Total estimated cost (US$ million)	1.50	*	250

Central Highlands

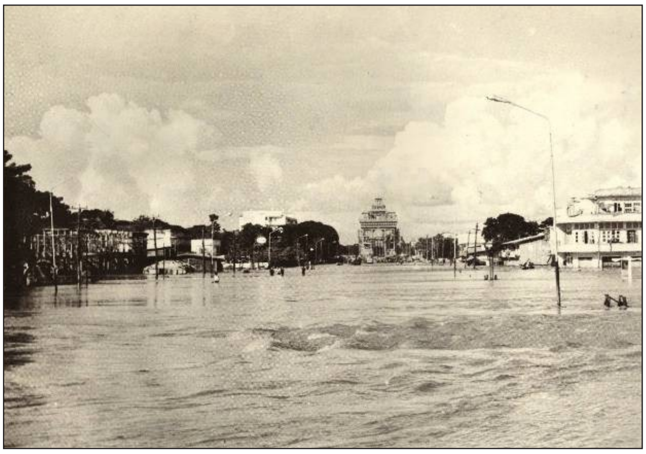
No.	1990	1994	1995	1996	1998	1999	2000	2002	2003	2006	2007	2008
People												
Killed	22	2	3	4		13	>20	2	6	0	29	6
Missing				5		41			2	0	4	1
Injured								1	1	0		
Houses												
Lost	22								7	5	166 d	
Inundated								1500			12,447	
Agriculture												
Lost		400								24	20,344	79
Inundated								9000	1000	126	24,393	
Fish ponds damaged											593	
Bridges												
Destroyed		32				10				1	59	8
Damaged											14	
Water containers												
Damaged		4									37	
Eroded											331,837	
Number of provinces effected	4	4	4	4	4	4	4	4	4	4	4	4
Total Cost (US$10 million)	0.5	1.0	n/a	n/a	n/a	0.2	n/a	3.0 .	0.5.	n/a	50.8	1.0

Appendix 6. Photograph archive of the September 1966 flood in Vientiane



Central Vientiane September 3rd, 1966.

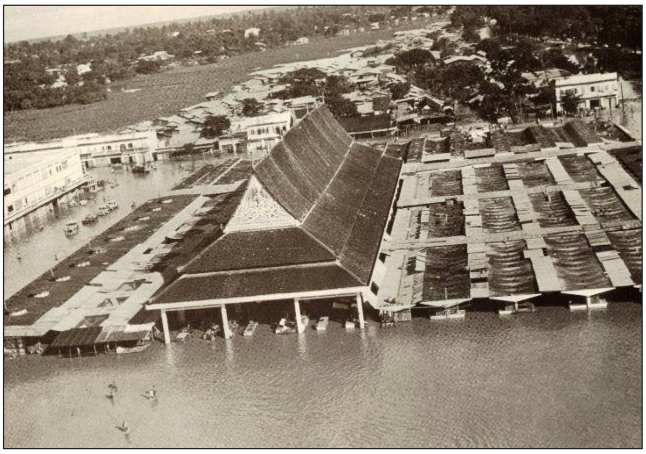
Residential inundation



Lang Xiang Avenue.

The Morning Market

Lang Xiang Avenue looking south towards the Mekong.



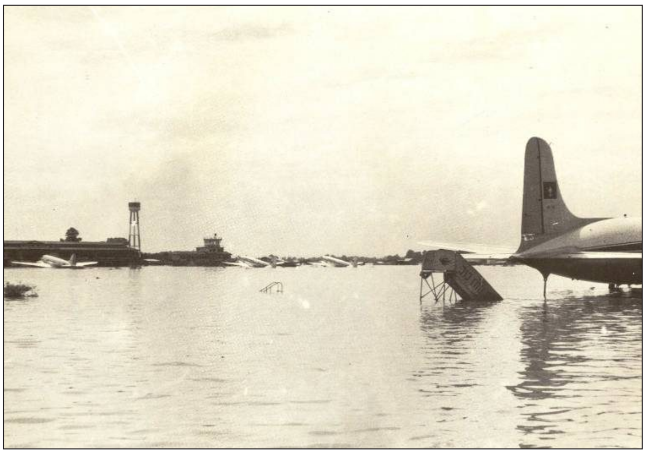
Morning Market.

Morning market – obtaining water from a tanker.

Pedestrians are help to cross the flooded Lange Xiang Avenue.

The terminal building at Wattay Airport.

The runway at Wattay Airport with a stranded Dakota.

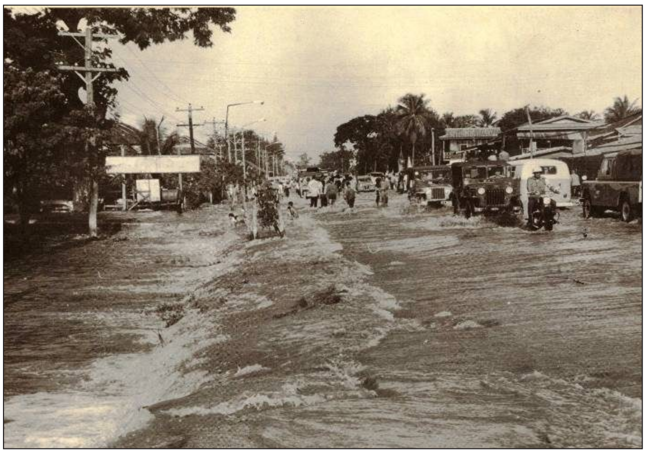


The flooded runway at Wattay Airport.

Flooded road.

Traffic struggles along the flooded Lang Xiang Avenue.

Soldiers direct traffic on Lang Xiang Avenue.



High water velocities added considerably to the infrastructure damage.

Sandbags were laid to protect the river banks.

Sandbags were laid to protect the river banks.

Mekong River Commission

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