Floods in the Mekong River basin

Literature reviews

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Cambo-Water partnership

Summary

The review summarises flood characteristics and impacts they cause to the communities in different places in the Mekong river basin through the years of existing records with increasing negative impacts from rapid pace of economic development to meet the need for increasing demography and better living conditions. The flood risk reduction strategies evolved with time where the Mekong River Commission is the leading organization in the region supported by communities of scientists throughout the world. Cumulative negative impacts from development and climate change surpassed the traditional capacity of community in living with floods and taking maximum advantage of floods. Results from different studies conducted by the MRC's Regional Flood Risk Management and Mitigation Center particularly the "Council Study" clearly indicated that the level of damages caused by flood will increase by 5 to 10 times in the future with the level of invested assets particularly during extreme floods and member countries need to develop a long term integrated flood risk management and mitigation strategy based on strong scientific based approaches.

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Abbreviation and Acronyms

AAD: Annual Average Damage
ALU: Agriculture, Land Use Change
AIP: Agriculture and Irrigation Programme (of the MRC)
BDP: Basin Development Plan
BDP2: BDP Programme, phase 2 (2006 –10)
BDS: (IWRM-based) Basin Development Strategy
BioRA: Biological resource assessment team (under Council Study)
CCAI: Climate Change and Adaptation Initiative (of the MRC)
CDRI: Cambodian Independent Development Policy Research Institute
CIA: Cumulative Impact Assessment
CNMC: Cambodia National Mekong Committee
DIW: Domestic Industrial Water Use
DMP: Drought Management Programme (of the MRC)
DSF: Decision Support Framework
EDS-2007: Early Development Scenarios 2007
EP: Environment Programme (of the MRC)
FMMP: Flood Mitigation and Management Programme (of the MRC)
FP: Fisheries Programme (of the MRC)
FPF: Flood Protection Infrastructure
IKMP: Information and Knowledge Management Programme (of the MRC)
IWRM: Integrated Water Resources Management
IRR: Irrigation
ISH : Initiative for Sustainable Hydropower (of the MRC)
ITC: Institute of Technology of Cambodia
JC : Joint Committee (of the MRC)
HPP: Hydropower
LMB: Lower Mekong Basin
LNMC: Lao National Mekong Committee
M&E : Monitoring and evaluation
MIWRMP: Mekong Integrated Water Resources Management Project (of the MRC)
MRC: Mekong River Commission

MC: Mekong Countries
MRCS: Mekong River Commission Secretariat
MRC-SP: MRC Strategic Plan
MWRAS: Mekong regional water resources assistance strategy (of the World Bank)
NIP: National Indicative Plan (C-NIP: Cambodia, L-NIP: Lao PDR, T-NIP: Thailand, V-NIP Viet Nam)
NMC: National Mekong Committee
NMCS: National Mekong Committee Secretariat
NAP: Navigation Programme (of the MRC)
OAA: Other Aquatic Animal
PFS-2040: Planned Future Scenarios 20140
PMFM: Procedures for Maintenance of Flow on the Mainstream
PWUM: Procedures for Water Use Monitoring
RDA: Regional distribution analysis
SIMVA: Social Impact Monitoring and Vulnerability Assessment
TCU: Technical Coordination Unit (of the MRCS)
TNMC: Thai National Mekong Committee
TRG: Technical Review Group (of the MRC)
UMB: Upper Mekong Basin
VNMC: Viet Nam National Mekong Committee

1. Background

The MRC replaces the Mekong Committee (1957-1976) and the Interim Mekong Committee (1978-1992), and was formed following the signing of the 1995 Agreement on "Cooperation for the Sustainable Development of the Mekong River Basin". The Mekong Committee (MC) or the Committee for Coordination of Investigations of the Lower Mekong Basin was composed of four riparian states of Cambodia, Laos, Thailand, and the Republic of Vietnam.

During the early decades of Mekong cooperation, the focus was largely on economic development activity. Considerations for social and environmental aspects were minimal. Work was undertaken on a project and national basis and the transboundary impacts of development (social and environmental) were not considered. Flood risk management and mitigation focused only on flood forecasting which covered the whole stretch of the Lower Mekong mainstream from Chiang Saen to the Mekong Delta. The planned large reservoirs such as Luang Prabang, Pamong and Sambor multi purposes projects that included flood control were not implemented due to increased concerns on socio and environmental impacts. The need for regional development that was sustainable and holistic in nature and managed and decided upon by the political masters of the region emerged only at the end of the cold war and the Cambodia decade of conflict in the early 1990's when regional cooperation was once again a real possibility. At the same time the concept of sustainable development emerged in international policy and law making, and became a means of synthesizing conflicting needs. This concept is at the core of the '95 Agreement. With the signing of the '95 Agreement, increased importance was put on ensuring the delicate balance between socio-economic development and the need for environmental protection and maintenance of the ecological balance of the river basin.

1.1. **Introduction**

The Yangtze, Salween, Irrawaddy, Red and Mekong rivers all begin their long journeys on the Tibetan Plateau at 4,500 or more metres above sea level. Here, this family of great rivers are separated by only a few hundred kilometres before moving off in different directions. The Yangtze flows across all of central China, the Red River runs through Viet Nam to the Gulf of Tonkin, and the Salween and Irrawaddy through Myanmar into the Indian Ocean. From its source, the Mekong continues south for approximately 4,800 km to the South China Sea, draining a total catchment area of 795,000 km^2 within the six countries of China, Myanmar, Lao PDR, Thailand, Cambodia and Viet Nam (Figure 1). The Mekong ranks 10th amongst the world's great rivers on the basis of mean annual flow at the mouth (MRC, 2005).

The Greater Mekong can be divided into two parts: the Upper Basin in Tibet and China (where the river is called the *Lancang Jiang*), and the Lower Mekong Basin from Yunnan downstream from China to the South China Sea (Figure 1).

The Upper Basin makes up 24 per cent of the total area and contributes 15 to 20 per cent of the water that flows into the Mekong River. The catchment here is steep and narrow. Soil erosion has been a major problem and approximately 50 per cent of the sediment in the river comes from the Upper Basin. It is now prohibited to plant crops on land that exceeds a 25 per cent slope. Therefore, any future development must come from hydropower generated on the mainstream because there are no major tributary systems flowing into this reach of the river.

Major tributary systems develop in the Lower Basin (MRC 2005). These systems can be separated into two groups: tributaries that contribute to the major wet season flows, and tributaries that drain low relief regions of lower rainfall. The first group are left bank tributaries that drain the high-rainfall areas of Lao PDR (Figure 1). The second group are those on the right bank, mainly the Mun and Chi rivers, that drain a large part of Northeast Thailand (MRC, 2005). These two groups of tributaries are also marked by different levels of resource development. For example, in Thailand there is little room for further expansion of irrigation development. In Lao PDR, there is a lot of potential for water resources development of all kinds.

As the Mekong enters Cambodia over 95% of the flows have already joined the river. From here on downstream the terrain is flat and water levels rather than flow volumes determine the movement of water across the landscape. The seasonal cycle of changing water levels at Phnom Penh results in the unique "flow reversal" of water into and out of the Great Lake via the Tonle Sap River (MRC, 2009).

Phnom Penh also marks the beginning of the delta system of the Mekong River. Here the mainstream begins to break up into an increasing number of branches. Agriculture is most developed in the delta and the population density is the highest in the entire Greater Basin. The growing influence of tides from the South China Sea and the effects of saltwater intrusion on the water in the river shows up more strongly towards the downstream.

The Mekong flows for almost 2,200 km from its source and decreases in altitude by nearly 4,500 metres before it enters the Lower Basin where the borders of Thailand, Lao PDR, China and Burma come together in the Golden Triangle. Downstream from the Golden Triangle, the river flows for a further 2,600 km through Lao PDR, Thailand and Cambodia before entering the South China Sea via a complex delta system in Viet Nam (MRC, 2005).

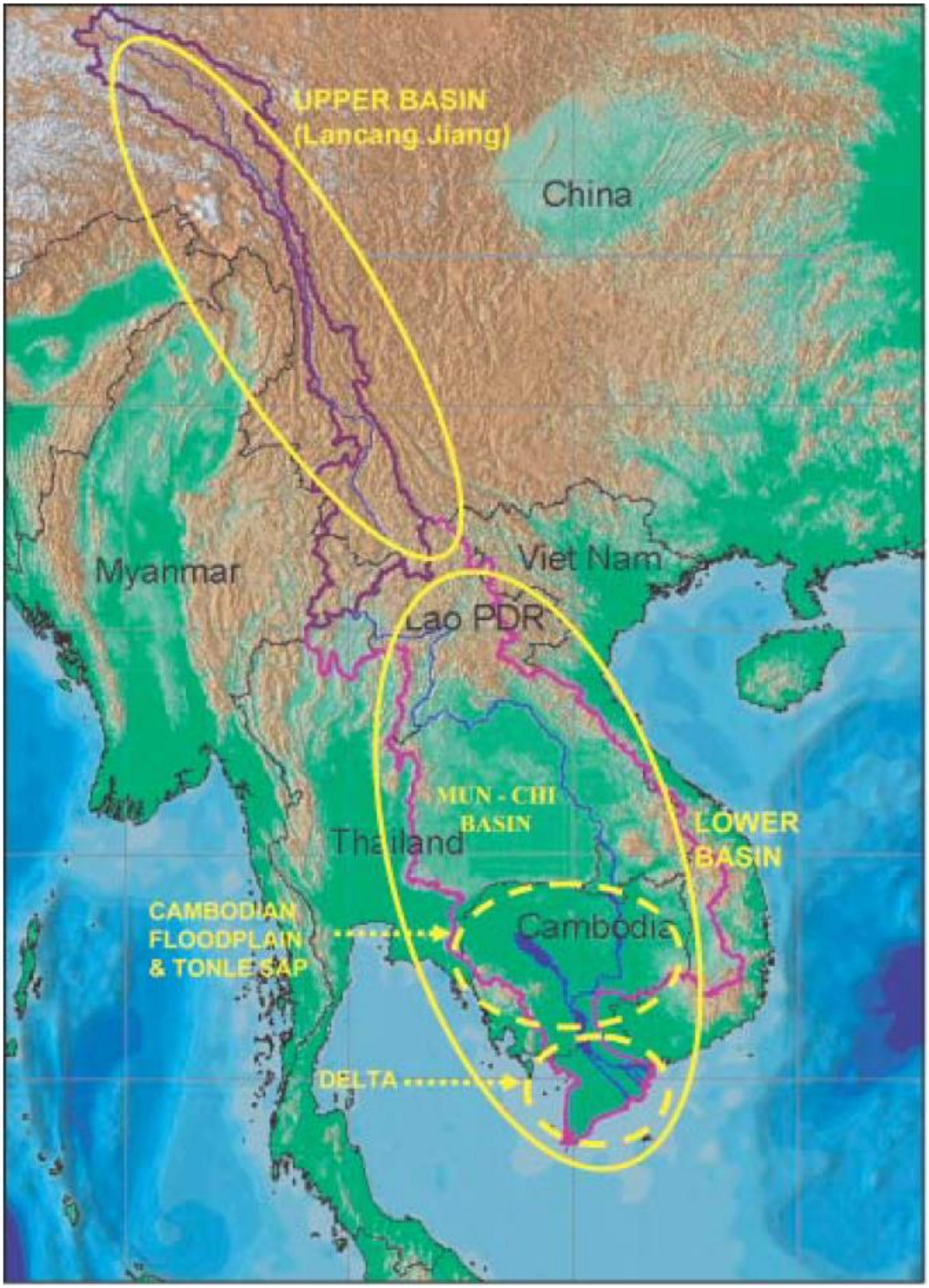


Figure 1: The Mekong River Basin broad geographical region (MRC, 2005)

In Yunnan province in China (where the river is called the Lancang Jiang), the river and its tributaries are confined by narrow, deep gorges. The tributary river systems in this part of the basin are small. Only 14 have catchment areas that exceed 1,000 km^2. In the south of Yunnan, in Simao and Xishuangbanna Prefectures, the river changes as the valley opens out, the floodplain becomes wider, and the river becomes wider and slower. The major concern here is soil erosion. As recently as 1998, up to 28 per cent of the Mekong Basin in Yunnan was classified as "erosion prone". Cultivation is now restricted in favour of reforestation.

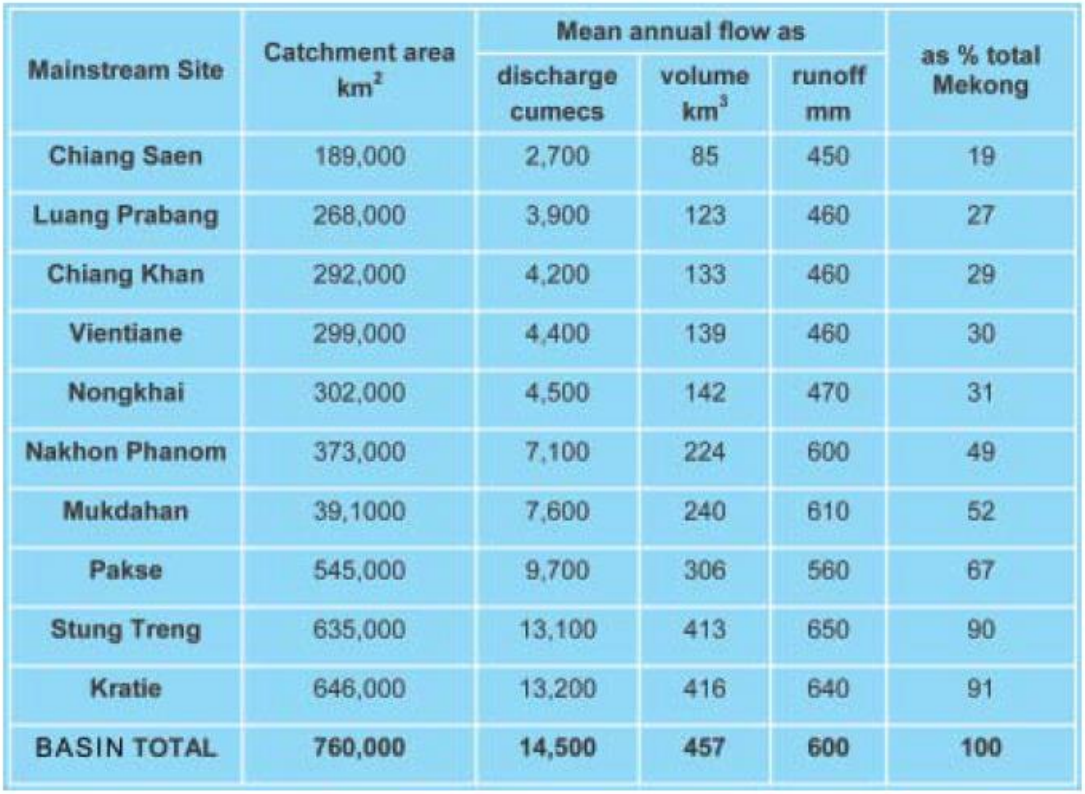
Lao PDR lies almost entirely within the Lower Mekong Basin. Its climate, landscape and land use are the major factors shaping the hydrology of the river. The mountainous landscape means that only 16 per cent of the country is farmed under lowland terrace or upland shifting cultivation. With upland shifting agriculture (slash and burn), soils recover within 10 to 20 years but the vegetation does not. Shifting cultivation is common in the uplands of Northern Lao PDR and is reported to account for as much as 27 per cent of the total land under rice cultivation (Lao Agricultural Census, 1998-9, 2000). As elsewhere in the basin, forest cover has been steadily reduced during the last three decades by shifting agriculture and permanent agriculture. The cumulative impacts of these activities on the river regime have not yet been measured.

Loss of forest cover in the Thai areas of the Lower Basin has been the highest in all the Lower Mekong countries over the past 50 years. On the Korat Plateau, which includes the Mun and Chi tributary systems, forest cover was reduced from 42 per cent in 1961 to 13 per cent in 1993. Although this part of Northeast Thailand has an annual rainfall of more than 1,000 mm, a high evaporation rate means it is classified as a semi-arid region. Consequently, although the Mun and Chi Basins drain 15 per cent of the entire Mekong Basin, they only contribute 6 per cent of the average annual flow. Sandy and saline soils are the most common soil types, which makes much of the land unsuitable for wet rice cultivation. However, in spite of poor fertility, agriculture is intensive. Glutinous rice, maize and cassava are the principal crops. Drought is by far the major hydrological hazard in this region.

The mean annual discharge of the Mekong is approximately 475 cubic kilometres (km^3). Of this amount, about 16 per cent comes from China and only 2 per cent from Myanmar. Most of the remainder comes from Lao PDR and the major left bank tributaries, particularly the tributaries that enter downstream of Vientiane-Nongkhai (Table 1).

The geography of the runoff in the Basin is shown in (Figure 2) and Figure 3. The figure shows the major flow contributions from the left bank tributary systems in Lao PDR and the Se Kong and Se San Rivers, which enter the mainstream between Pakse and Kratie.

Table 1: Lower Mekong Mainstream mean annual flow (1960-2004)



Mainstream Site	Catchment area km^2	Mean annual flow as			as % total Mekong
		discharge cumecs	volume km^3	runoff mm	
Chiang Saen	189,000	2,700	85	450	19
Luang Prabang	268,000	3,900	123	460	27
Chiang Khan	292,000	4,200	133	460	29
Vientiane	299,000	4,400	139	460	30
Nongkhai	302,000	4,500	142	470	31
Nakhon Phanom	373,000	7,100	224	600	49
Mukdahan	39,1000	7,600	240	610	52
Pakse	545,000	9,700	306	560	67
Stung Treng	635,000	13,100	413	650	90
Kratie	646,000	13,200	416	640	91
BASIN TOTAL	**760,000**	**14,500**	**457**	**600**	**100**

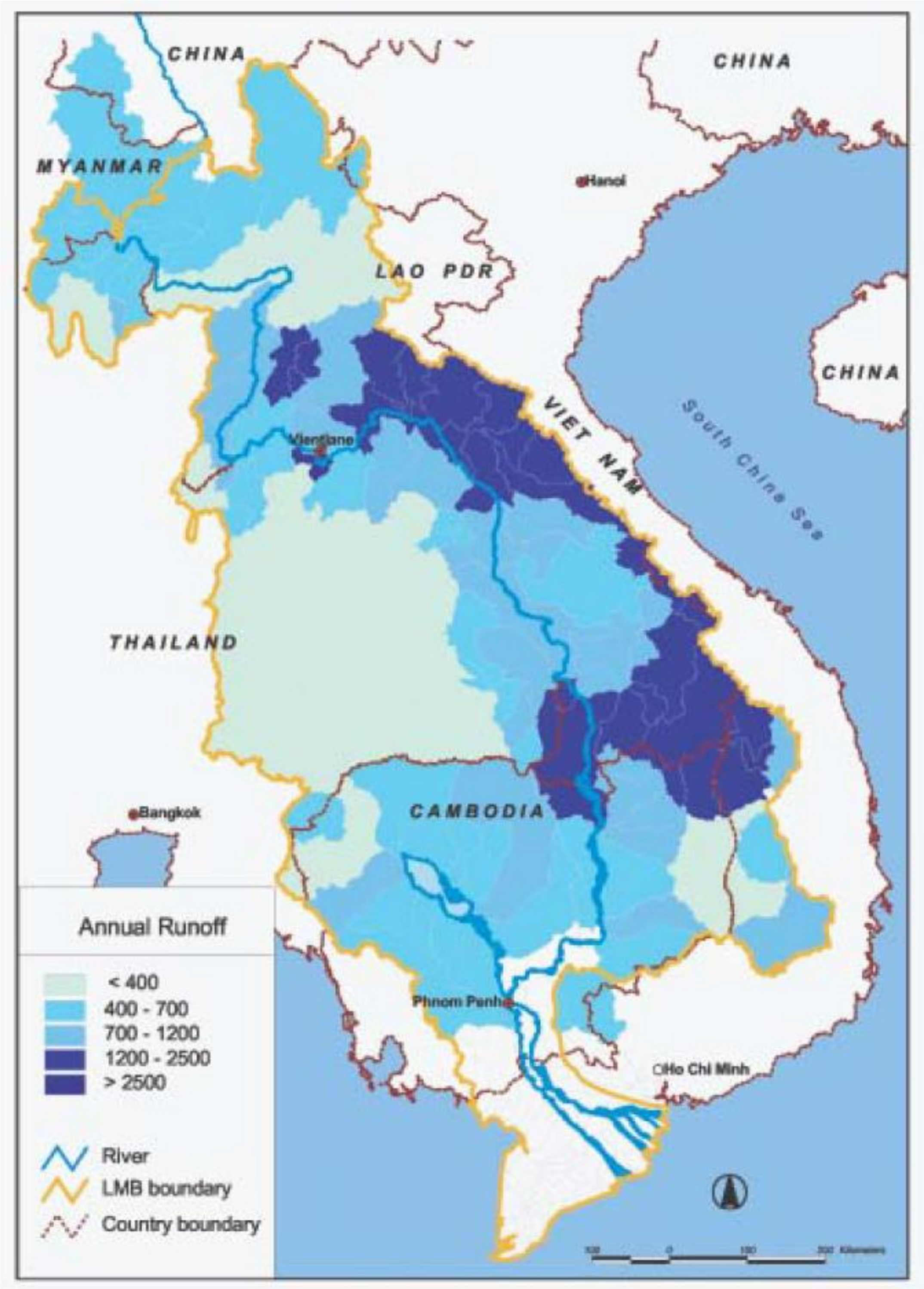


Figure 2: The Basin mean annual depth runoff (mm)

Table 1 summarises the mean annual flows along the mainstream. The mean annual flow entering the lower Mekong from China is equivalent to a relatively modest 450 mm depth of runoff.

Downstream of Vientiane this increases to over 600 mm as the principal left bank tributaries enter the mainstream, mainly the Nam Ngum and Nam Theun. The flow level falls again, even with the right bank entry of the Mun-Chi system from Thailand. Although the Mun – Chi basin drains 20 per cent of the lower system, average annual runoff is only 250 mm. Runoff in the mainstream increases again with the entry from the left bank of the Se Kong from southern Lao PDR and Se San and Sre Pok from Viet Nam and Cambodia.

Flows at Chiang Saen entering the Lower Basin from Yunnan make up about 15 per cent of the wet season flow at Kratie. This rises to 40 per cent during the dry season, even this far downstream. This key seasonal feature of the mainstream hydrology is illustrated in(Figure 4.4 of MRC, 2005) for the length of the Lower Mekong. The concern is that large-scale reservoir regulation on the mainstream in Yunnan would have a significant impact on the dry season hydrology of the lower system (MRC, 2005).

During the wet season, most of the flow comes from the large tributaries in Lao PDR, so any regulation effects coming from China will be less noticeable in the wet season.

Sources of flow in the wet season (June to November) and dry season (December to May) months are 10ummarized in Figure 4.5 of MRC, 2005). During the wet season, the proportion of average flow coming from Yunnan rapidly decreases downstream of Chiang Saen, from 70 per cent to less than 20 per cent at Kratie. The dry season contribution from Yunnan is much more significant. The major portion of the balance comes from Lao PDR, which points to a major distinction in the low-flow hydrology of the river. One fraction comes from melting snow in China and Tibet and the rest from over-season catchment storage in the Lower Basin. This has implications for the occurrence of drought conditions. For example, if runoff from melting snow in any given year is very low, then flows upstream of Vientiane-Nong khai would be lower.

In a large river system like the Mekong, seasonal flows can be quite variable from year to year. Although the pattern of the annual hydrograph is fairly predictable, its magnitude is not. The average monthly flows along the mainstream are listed in (Table 4.3 MRC. 2005). An indication of their range and variability from year to year is presented in(Figure 4.6, MRC, 2005). At Pakse, for example, flood season flows during August would exceed 20,000 cubic metres per second (cumecs) 9 years out of 10, but exceed 34,000 cumecs only 1 year in ten (MRC, 2005).

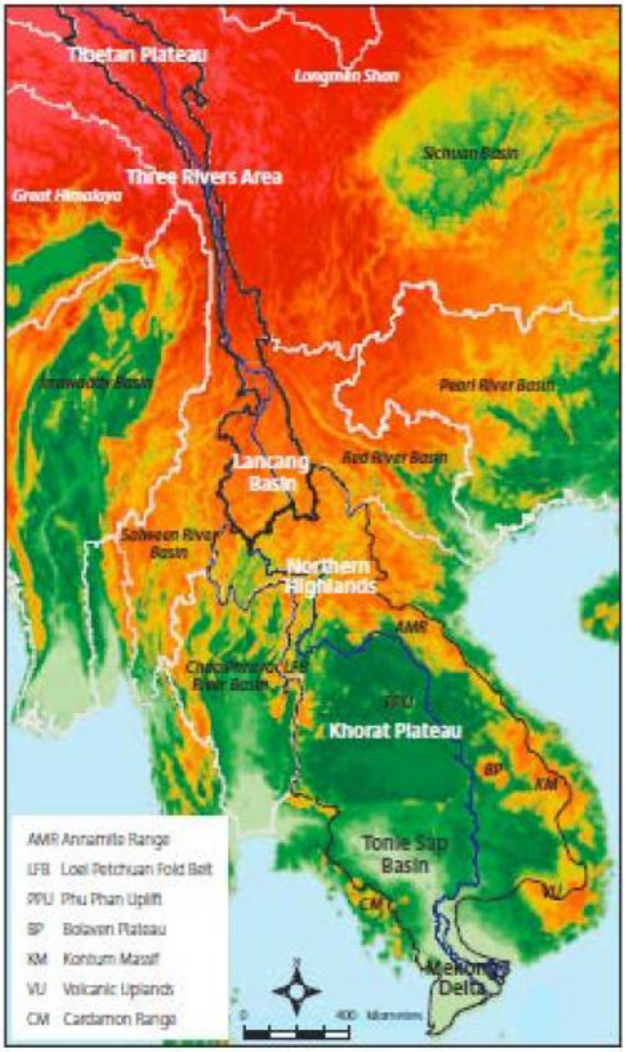


Figure 3: Topography and physiographic regions of the MRB (MRC 2010)

The UMB is characterized by high mountains, steep slopes, deep gorges, and narrow catchment areas. The Mekong cascade down more than 4000m over a distance of 2000 km from its headwater in China to Chiang Saen in northern Thailand, with an average slope of 2 m /km (Laurie et sl., 2912). The LMB of Laos, Thailand, Cambodia and Vietnam (76% of total Basin area) includes the Northern Highlands, Korat Plateau, Tonle Sap Basin, and Mekong Delta physiographic regions (MRC 2010). From Chiang Saen at China, Laos border the Kratie in central Cambodia, the Mekong has moderately steep slope, falling about 500 m over a course of 2000 km, with average slope of 0.25 n/km (Laurie et al.). Further downstream the river is nearly flat, losing only 15 m in elevation over the final 500 km of the Mekong Delta region to South China Sea (MRC 2005).

The LMB has a tropical climate, with high heat and humidity. The minimum average monthly temperature is never lower than 20º C (MRC, 2010). Mean Annual evaporation across the region is 1500 mm, and ranges from 1000 mm in the Northern Highlands in Laos to more than 2000 mm over the Khorat Plateau of northeast Thailand – one of the driest regions of Southeast

Asia. Variability of evaporation is low from year to year due to high relative humidity (MRC 2010.)

Due to the strong regional influence of the monsoon system, the seasonal distribution of rainfall in the UMB and LMB is quite similar with distinct wet and dry seasons. Peak annual rainfall occurs during June-October. The distribution of rainfall in the UMB varies from north to south, and with elevation, from 1,600-1,700 mm in the mountains to 900-1,100 mm on the valley floor. Snow is rare in the valley but increases significantly at higher altitudes and especially on the Tibetan Plateau, where most winter precipitation occurs as snowfall and rainfall is less than 600 mm per year (MRC 2010).

The distribution of mean annual rainfall over the LMB shows a distinct east west gradient. The mountain regions of Laos receive the highest rainfall (> 2500 mm/year). The greatest contributions to mainstream flows during the summer monsoon season thus originate within the large Mekong tributaries in Laos. (Figure 4).

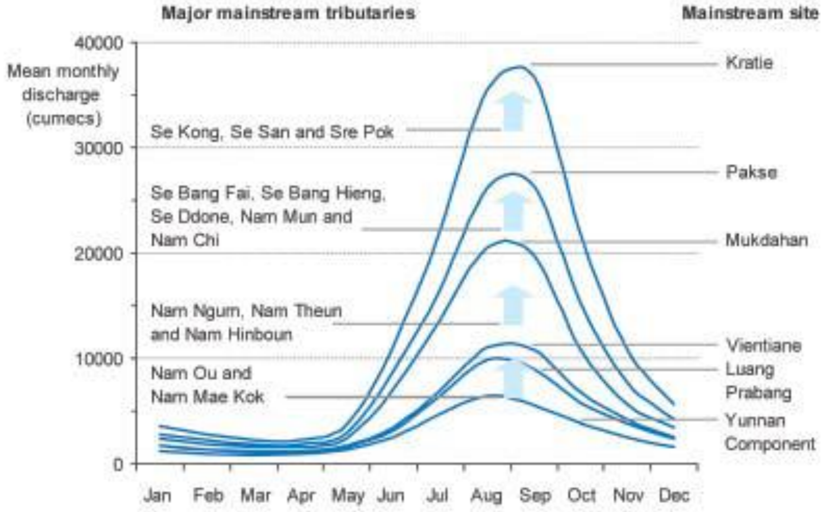


Figure 4: Mean monthly discharges at various sites on the mainstream and the major tributary sources in each reach (MRC, 2005)

The hydrology of the MRB is largely controlled by snowmelt from Tibetan plateau and monsoon rainfall-runoff from tropical tributaries of Laos (Adamson et al. 2009).

The UMB contributes 15-20% (averaged 18%) of MRB annual flow (MRC 2005, Adamson et al. 2009).The Mekong is initially fed by melting snow in the Tibetan Highlands. Numerous studies of MRB hydrology consider snow storage and snowmelt to be important components of UMB runoff and dry season flows in the MRB (MRC 2005, Kiem et al. 2005, Adamson et al. 2009), although snow cover less than 5% of the Mekong Basin during November- March and is negligible at other times. Recent studies by Institute for Water Management Institute (in press) suggest the contribution of snowmelt may be relatively insignificant, other than in the highest reaches of the UMB, contributing less than 1% of total annual runoff. UMB drains rapidly through steep slope, narrow tributaries with most catchment smaller than 1000 km^2 (Adamson et al. 2009). UMB runoff –whether sourced from snowmelt or groundwater baseflow-sustains dry season flows in the northern portions of the LMB. UMB runoff also provided most of the floodwater during the majority of the years. At Vientiane, for example average contribution range from over 75% during the low-flow months in Apri-May, to over 50% during the peak-flow months in July, August and September – although year-to-year contributions are highly variable (Adamson et al., 2009). Far downstream at Kratie, near Tonle Sap confluence in Cambodia, the contribution of the UMB to Mekong flood-season flows is reduced to 10-20%, but the UMB still provides over 40% of the dry season flow in April (Adamson 2006).

The LMB contributes 75-80% of MRB annual flows (MRC 2005, Adamson et al. 2009). The majority of LMB runoff is derived from the Mekong eastern riverbank tributaries of Laos that drain the high-rainfall areas of the Northern Highlands (Adamson et al.. 2009) (Table 1). The large western river bank tributaries (mainly the Mun and Chi rivers) drain the low relief, lower rainfall regions of the Khorat Plateau in northeastern Thailand, and contribute relatively little to mean annual discharge. In the flat, low-lying terrain of the Tonle Sap and Mekong Delta regions, flow contribution is minimal and water levels rather than flow volumes determine the movement of water across the landscape (Adamson et al. 2009). Figure 4 gives the average annual hydrographs for the Mekong basin at various gaging stations. Overall, the catchment of Laos contributes 43% of LMB runoff (and more than 35% of total MRB runoff), generating most of the wet- season peak discharge and significantly contributing to downstream flooding events (Adamson 2006). Thailand and Cambodia contribute 21-23% of LMB runoff, respectively, and the Vietnamese catchment contributes about 13%.

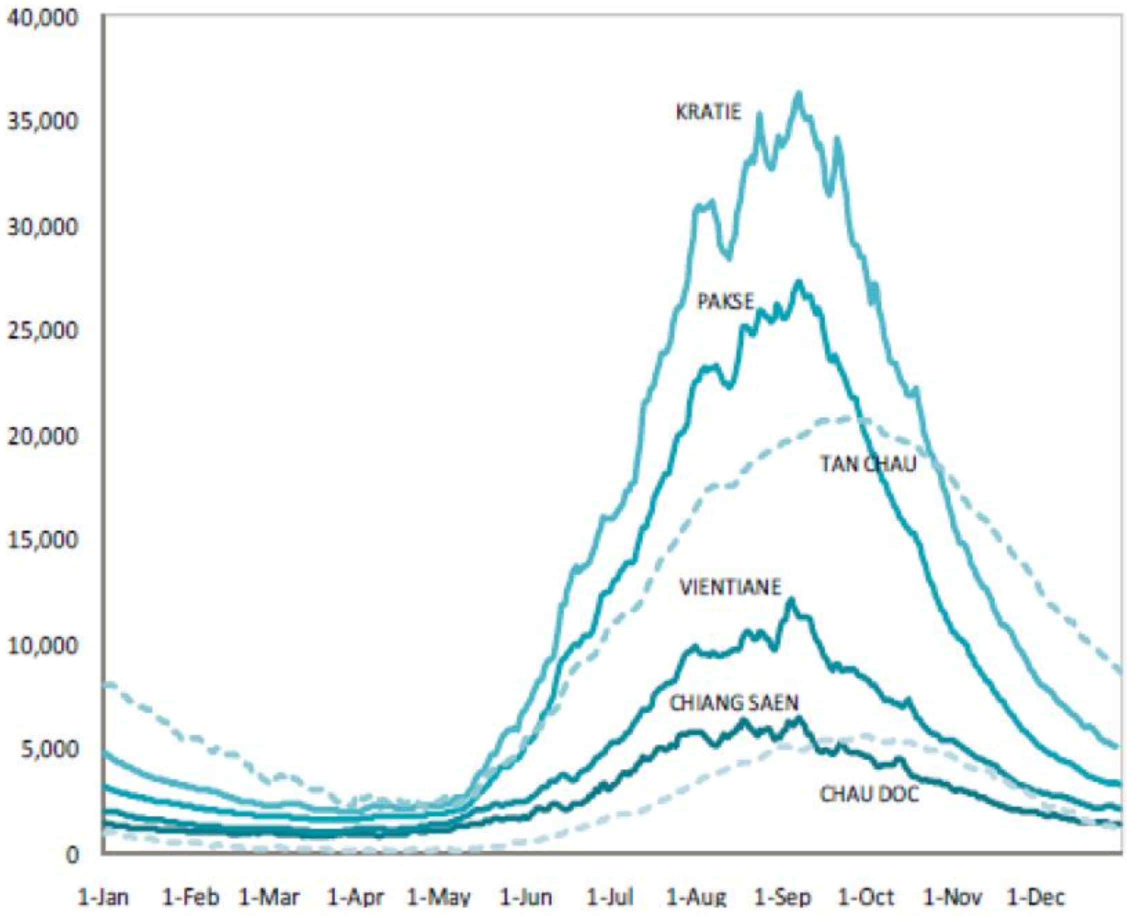


Figure 5: Average annual hydrographs for Mekong River Basin, Chiang Saen captures runoff from UMB (about 65 mk^3). Runoff increases to 350 km^3 at Kratie, below which it enters the Tonle Sap floodplain of Cambodia (ICEM 2010)

The basin-wide influence of the monsoon climate and steepness of the Mekong river channel give rise to the single-peak hydrograph, with large seasonal differences between high and low flows. The defining characteristics of Mekong River hydrograph, of particular relevance to assessing the influence of climate change and hydropower in the basin, are the regularity in the timing of the beginning and the end of the wet season; the single smooth wet-season peak of consistent size and regularity, and the pronounced low-flow season (Adamson et al. 2009), MRC 2010, ICEM 2010).

Adamson (2006) divided the Mekong hydrograph into four seasons over the hydrological year (figure 6). The timing of the onset and the duration of these seasons is virtually identical for the UMB (measured at Chiang Saen) and LMB (measured at Kratie), as shown in Figure 5). The annual minimum daily discharge usually occurs in early April. The doubling of this discharge, generally in late May, defines the start of the first transition season (point 2). This ends when the flood season starts (point 3). The onset of the flood season (the point at which the discharge exceeds the mean annual discharge for that station) occurs within a few days each year and the end of June. The timing of peak flooding is very consistent overtime, with a standard deviation of about 23 days. The second transition season defines the period between the end of flood season (point 4) and the start of the dry (point 5), which occurs when rates of daily flow decrease become typical of "base flow" recession. On average, the dry season onset is in late November. The flood season lasts for just over 130 days. The fact that the start and end of the annual flood can be guaranteed to occur within a period of just two weeks is a remarkable and defining characteristic of the Mekong system (Adamson et al. 2009). As discussed in chapter 5, the regularity of the seasonal onset and duration of flooding over the millennia has given rise to a biota that is finely tuned that "acceptable" hydrological conditions, and, consequently, a river system that likely is very sensitive to any changes in these characteristics resulting from climate change of river regulation (Adamson et al. 2009).

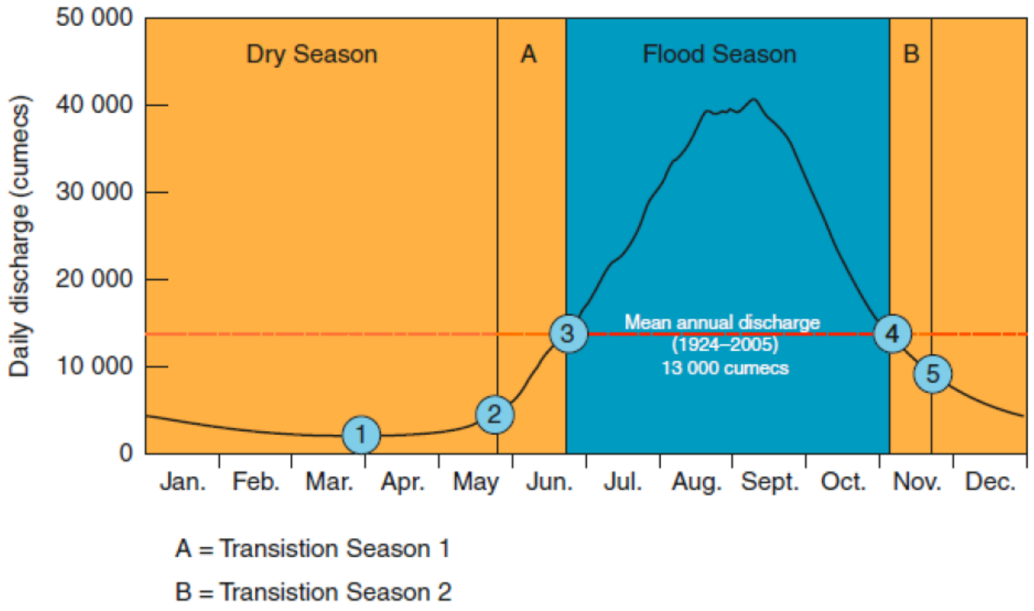


Figure 6: Mekong River average annual hydrograph with key transition seasons, with a single smooth annual peak and prolonged period dry season flow (Adamson et al 2009)

Historically, cyclones and severe tropical storms have generated the most significant Mekong flooding events (Adamson, et al. 2009). The largest flood recoded in 1966, occurred when tropical storm Phyllis struck the UMB. At the downstream end of the basin, these severe tropical storms combine with the southwest monsoon to produce floods in Cambodia and the Mekong Delta (Adamson et al. 2009).

Pronounced dry season low-flows, sustained by UMB snowmelt and LMB baseflows, occur annually between November and May, and facilitate the seasonal transition from aquatic (flooded) to terrestrial (dry lands) environment (ICEM 2010). Groundwater sources in the Mekong River Basin have not been assessed comprehensively, but regional aquifers are considered to be substantial (MRC and UNEP 1997; MRC 2003, Eastham et al. 2008) and Hapuadchchi et al. (2008) noted shallow aquifers of recent alluvium 1-20 m deep flanking the mainstream Mekong river in Northeast Thailand.

1.2. Regional Impacts of tropical Storms

In average year 4 to 6 typhoons or severe tropical storms make landfall in Vietnam, a number of which will track across the LMB and cause significant to extreme flooding. There are many years when far more systems make landfall incursion, for example 1964 (18), 1973 (12), 1978 (12), 1989 (10) and 1996 (10) (MRC/FMMP 2013) (Figure 7). The incursion of these storm systems into the Mekong region has historically been associated with most of the largest flood peak discharge on the mainstream. This said it has to be acknowledged that the annual Mekong flood is in its greater part a response to the SW monsoon and is a multivariate event defined by both only the seasonal maximum discharge but also by the volume of floodwater and the duration of flows above critical thresholds. The events of 2000 illustrated quite clearly that extreme floods cannot be defined exclusively in terms of annual maximum discharge. (MRC-FMMP, 2013).On that occasion the flood peak was no more than average but the volume of floodwater over a prolonged flood season was critical and had d devastating impact across the Cambodia floodplain and within the Mekong Delta (see Figure 8).

The role of typhoons and tropical depressions in the flood hydrology of the Mekong is well established (MRC/FMMP, 2013). However, there has never been a detailed systematic study nor an inventory of their annual incidence and impacts. The challenge lies with the fact that in meteorological term the severity of tropical low pressure systems is indicated according to wind speed, while the hydrological extent the focus of interest lies with the consequent storm rainfall maps and resulting flood runoff. Prior to the introduction of the Annual Flood Reports by the FMMP in 2006/7, supported by the four National Reports, assembling the relevant historical data is a considerable task since ideally storm rainfall maps are required for each of the key events. The further back in time one goes the more difficult it is to put together sufficient rainfall data to accurately depict the geography and intensity of the storm rainfall. This arises because the observation network becomes increasingly sparse.

The exercise undertaken has proved to be useful and informative, with the linkage between tropical low pressure systems and the regional flooding examined back to early 1950’s. In a sense though, it should be seen as “explanatory” and setting the framework for a more detailed research assessment. The importance of undertaking the latter lies within the context of potential climate change impacts upon regional floods and flooding. Due to warming sea temperatures the incidence and severity of tropical low pressure systems is forecast to intensify with secondary consequences with regard to the frequency of intense storms and flooding. There is to suggest that the regional annual count of storm systems has increased in recent years, although it may be the case that their scale and severity has intensified, of at least the occurrence of super typhoons such as HAIYAT in 2013, has become more frequent. This thought could be difficult to establish to any degree of statistical satisfaction. Super typhoon and extreme tropical storm are hardly a contemporary development. Chinese historical annals and Vietnamese records chronicle a long history of tropical storms impacts. Among these the Haiphong super typhoon in 1881 which killed a reported 300, 000 people and is regarded as the third most deadly tropical storms in recorded world history.

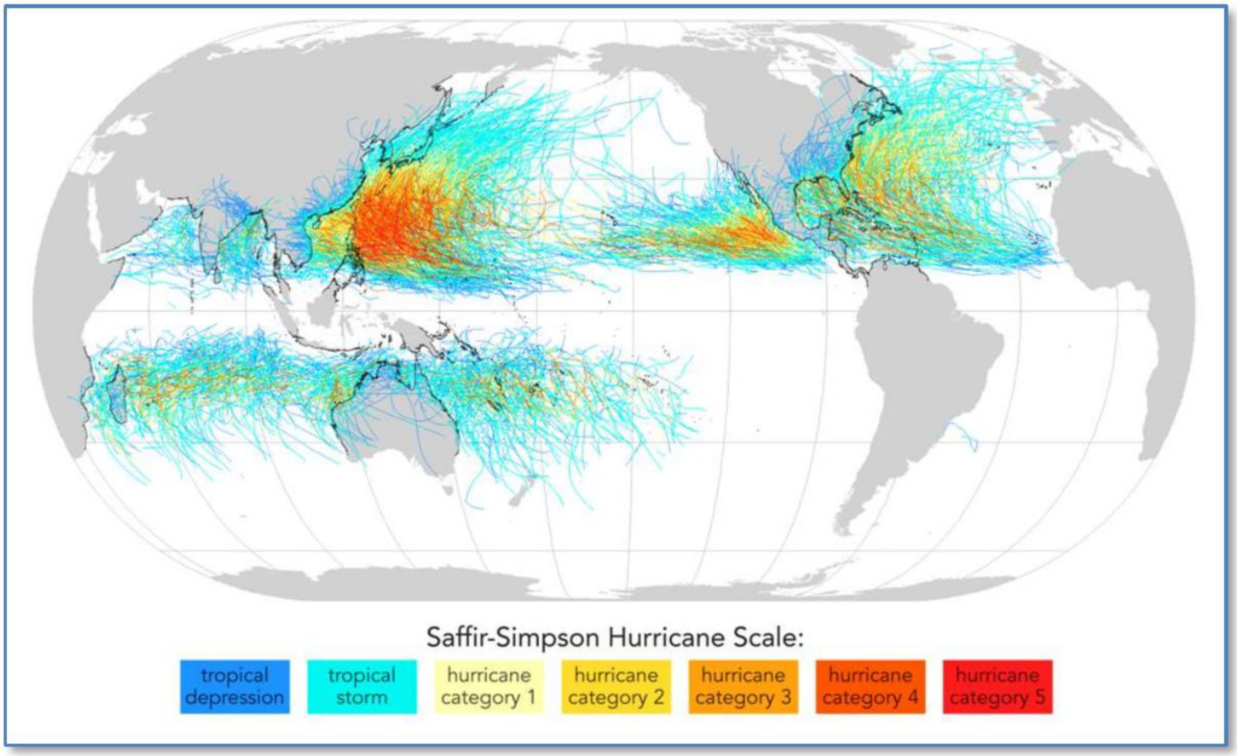


Figure 7: Global tropical cyclones 1945 to 2006, their tracks and classification. (Data from the Joint Typhoon Warning Centre and the US National Oceanographic and the US National Oceanographic and Atmospheric Administration, March, 2008).

1.3. Flood in the LMB

Floods can be classified into the following three categories: Rainfall floods, Dam related floods, and Maritime floods (MRC, 2009, 2010).

Rainfall Floods are caused by excessive rainfall and comprise:

- M*ainstream floods* in the LMB occur when the Mekong River overflows its banks, typically in the wet season from June to November. In the Upper and Middle Reaches of Lao PDR and Thailand, mainstream floods typically inundate a narrow floodplain for several weeks; in the flatter reaches of the Cambodian Lowlands and Cuu Long Delta, mainstream floods inundate vast areas for several months. The Great Lake modifies flooding in downstream areas, reducing the flood peak but extending flood duration.
- *Tertiary floods* occur in the LMB when Mekong tributaries overflow their banks. Three types of tributary flood can be distinguished: flash flood, combined flood, landslide. Flashflood refers to sudden and unexpected flooding that occurs within 6 hours of the onset of the flood-producing rains. They typically occur in the steep, narrow Upper Reaches of tributaties. The Lower Reaches of tributaries are suseptible to combining flooding: the interaction of mainstream and tributary flood flows rises tributary flood levels higher than otherwise would be the case. Landslide occur because of sloe

instability and happen abruptly and with little warning. Although not floods per se, they are often in tributary catchment and in concert with tributary floods and can be more deadly than the latter.

- *Local floods* occur when heavy rainfalls overwhelm the capacity of local drainage systems Typically in urban areas)
- *Dam related floods* are caused by the operation or failure of dams and dikes and comprise:
- *Dam related floods* are caused by the operation or failure of dams and dikes and comprise:
- *Dam release floods* occur when releases from a dam overtop the banks of the receiving waterway. Sudden and large releases may have to be made to cater for incoming flood. Dam release floods can results in sudden and unexpected rises in downstream water levels.
- *Dam break floods* occur when a dam embankment fails because of overtopping, structural failure or the undermining of its foundations. Dam break floods are extremely hazardous, being characterized by rapid (instantaneous) increases in water level, high velocities and rapid progress downstream.
- *Dike breach floods* occur when a dike breaches because of overtopping structural failure or undermining of its foundations. A dike breach flood is similar to a small dam break flood, but not as hazardous or destructive because of the generally low nature of dikes.

Finally, Maritime floods refer to the inundation of coastal and estuarine lands by seawater and comprise storm surge floods (Linda, 1997) and tsunami floods.

- Storm surge flooding occurs when a storm typically a tropical weather system, raises coastal and estuaries water levels through the action of low atmospheric pressures and storm driven waves. In the LMB, only the coastal and estuarine areas of the Cuu Long Delta are exposed to storm surge flooding.
- *Tsunami floods* are caused when the ocean floor is thrust up or down by tectonic plate movements or undersea landslides occur. Again, in LMB, only the coastal area of the Cuu Long Delta and its estuaries are subject to tsunami risk, which is considered to be samll to very small because of the small size of locally generated tsunami (less than 0.5 m high) and protection of the coastline of the Cuu Laong Delta.

In terms of flood risk, which embraces the population at risk, together with the frequency, severety andhazard of flooding, the greatest flood risk in Cambodia and Viet Nam is mainstream flooding (a very high risk), where in Lao PDR it is tributary flooding (a high risk), and in Thailand it is inferred that mainstream and tributary floods have about the same risk (medium)

Te economic cost of floods varies significantly from country to country. The floowing table show the estimated average annual cost of flooding in the LMB.

Estimated Average Annual Flood Damage, Lower Mekong Basin

Table 2: Estamate Average Annul Flodd Damage in Lower Mekong Basin

Country	Average Annual Flood Coast (USD)
Cambodia	18
Lao PDR	11
Thailand	7
Vietnam	25
TOTAL	61

Source: MRC 2013

Floods also provide significant benefits to the LMB, including susaining the annual fish catch, especially in the Great Lake, sustaining the 5. 24 M ha of flooded wetlands in the LMB with associated socio-economic benefits, providing water supply for dry season irrigation, fertilizing the floodplains with an annual deposit of silt, etc. The average annual benefit of flooding in the LMB has been estimated at between USD 8 and 10.1 B i.e. over 100 times the average annual cost of flooding.

1.4. Past extreme floods

Extreme floods in the LMB occurs at different locations and different times and scale in terms of peak, voume and extent. The table depicts extreme peak flood at two locations (Vietiane in Lao PDR and Kratie in Cambodia)

Table 3: Extreme floods events at selected location along the Mekong mainstream

Vientiane		Kratie	
Year	Maximum peak discharge cumecs	Year	Maximum peak discharge cumecs
1966	25900	1978	77100
1924	25600	1939	66700
2008	23600	1991	67100
1929	23500	1940	64000
2002	23200	1941	60300
Mean annual average	16600		51000

Source: MRC 2013

1.5. Flood characteristics in the LMB

Floods are most often measured in terms of maximum or peak discharge. On large rivers such as the Mekong, this is not a good enough measure since there are other aspects of a flood that are often as important or more important. For example, the duration of the flow above a critically high threshold can cause long periods of inundation and cause the collapse of protection dykes. Rice paddies can be submerged in water for 8 to 10 days but longer than that and the crop begins to die. Flood volume is also an important indicator of the extent and length of time that natural wetlands are flooded and the degree to which a flood event can be modified by natural over-bank storage. The Figure.8 illustrates the relationships between historical flood peaks and flood volumes at different locations along the course of the LMB.

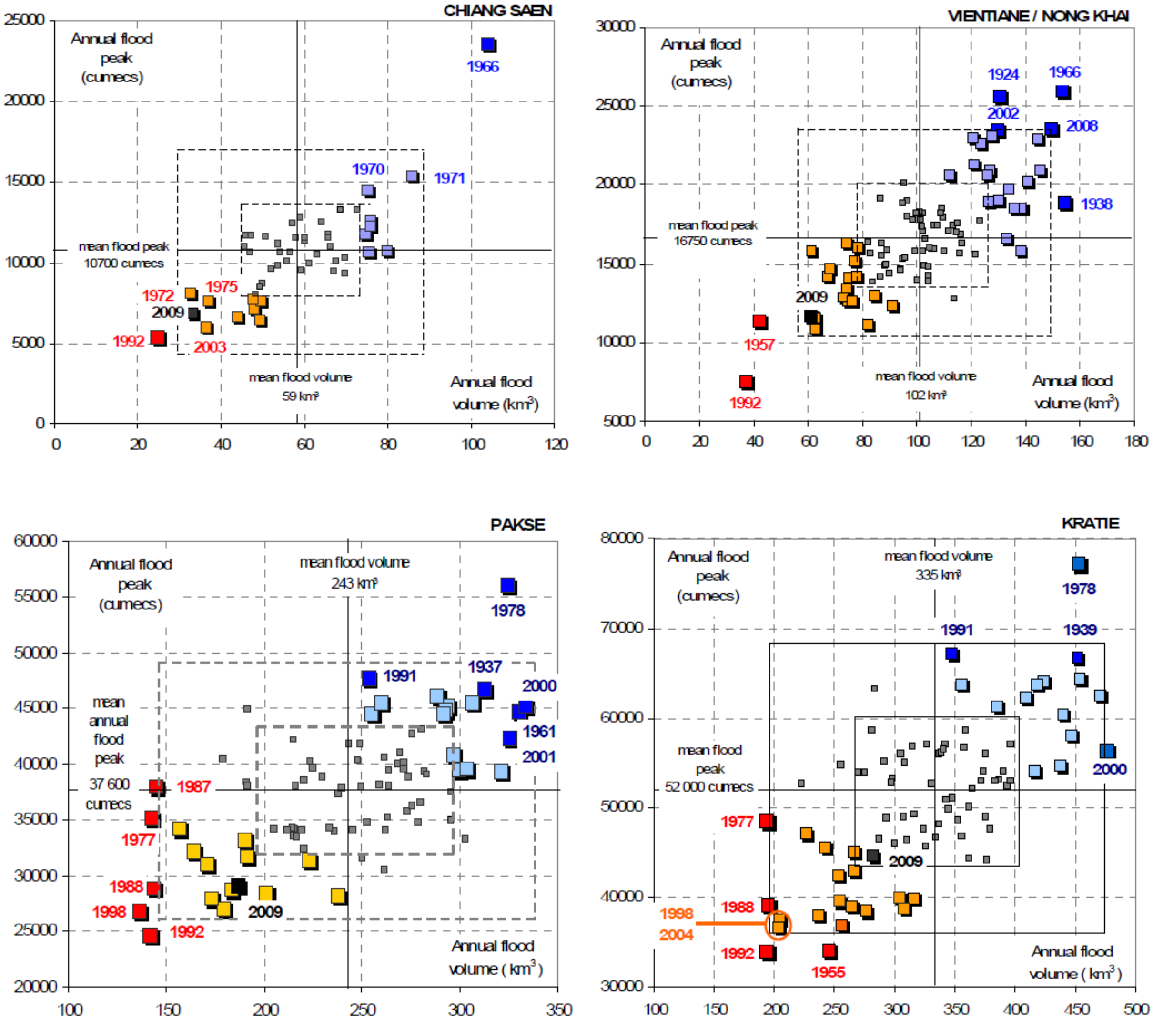


Figure 8: Scattered plots of the joint distribution of annual maximum flood discharge (cumecs) and the volume of the annual flood hydrographs (km^3) at selected sites on the Mekong mainstream. The 'boxes' indicate one (1σ) and two (2σ) standard deviations for each variable above and below their respective means. Events outside of the 1σ box might be defined as 'significant' flood years and those outside of 2σ box as historically 'extreme' year.

1.6. Droughts in the Lower Mekong Basin

Droughts, like floods can occur anywhere in the LMB. We can distinguish three different types of drought:

- *Meteorological droughts* occurs when rainfall over some prescribed period are significantly less that the long-term average. The most meteorologically drought-prone locations of the LMB are the western area of the Khorat Plateau in Thailand and the South-eastern area of cambodia.
- *Hydrological drought* occurs when water resources are significantly depleted because of meteorological drought e.g. stream flows over some prescribed period are significantly less than the long-term average.
- *Agricultural drought* occurs when meteorological and hydrological droughts reduce crop yields and livestock and fisheries production. As far as agriculture is concerned, an agricultural drought occurs when soil moisture is insufficient to meet crop water requirements. (The actual reduction in crop yield depends on the type of crop, its growth stage and the water holding properties of soil). As far as fishereis and livestock production is concerned and agricultural drought occurs when the supply of water and/or the condition of the water are inadequate to maintain fodder supplies and normal growth.

Drought severity depends upon drought intensity, i.e. the magnitude of the rainfall, water or soil moisture deficits, along with the extent, timing and duration of the deficits, and its socio-economic impacts. Typically, a drought is deemed to be severe if the rainfall, streamflow or soil moisture deficit is greater that 20% of the average annual value.

The likelyhoo of an annual meteorological drought is greatest in Lao PDR and Thailand (about 0.4 to 0.45 per year) and is least in Cambodia and Vietnam (0.30 to 0.35 per year).

Definitive data for the cost of drought in the LMB are lacking. However, it is apparent that meteorological drought will have a major impact of rainfed rice production (which accounts for over 75% of the total LMB rice production in Lao PDR. Thailand and Cambodia). A recent study estimated the average annual drought loss of rice production in northeastern Thailand (the western area of the Khorat Plateau) at 78,000 T/pa valued at USD 10 M pa. Drought also has a significant impact on fishery production in the Great Lake, with an estimated average annual loss of sround USD 15 M pa. Figures available at the time of writing this report do not lend themselves to s definitive estimate of annual drought costs in the LMB. However, given the relatively high frequency of droughts (2 years in 5 in Lao PDR and northeast Thailand, and one year in three in Cambodia and Vietnam), coupled with the high costs of individual droughts (the 2004-05)and 2015-2016) droughts drought cost some USD 45 M in the Cuu Long Delta and significant and amounts in the other riparian countries), it is expected that the average annual cost of drought in the LMB is greater that the average annual cost of flood damage, perhaps markedly so.

Unlike floods, there are no benefits associated with the concurrence of droughts, and the droughts have only a limited impacts (if any) on public infrastructure.

1.7. Impacts from Hydropowerdevelopment upstream

In the UMB, the large elevation drop of the Lancang River (80% of the total Mekong decline) offers significant potential for hydropower generation, and many dams are in operation, construction, or planning on the mainstream Mekong (Figure 9 and 10). The first phase of the Lancang River development consists of a seven dam cascade in Yunnan Province, China. The seven dams have a total generation potential of 15,450 MW, and include, from upstream to downstream, Gonguoqiao (completed in 2012; 750 MW), Xiaowan (completed in 2010; 4200 MW), Manwan (completed in 2007; 1550 MW), Dachaoshan (completed in 2003; 1350 MW), Nuozhadu (completed in 2012; 5850 MW), Jinghong (completed in 2009; 1750 MW), and Ganlanba (in planning; 155 MW) (Figure 9). An eight dam (Mengsong) was originally planned for the cascade, but has been cancelled. Two of the dams have very large reservoir live storage capacity, Xiaowan (9,895 Mm^3) and Nuozhadu (11,340 Mm^3) (MRC 2009b), that will significantly regulate the downstream Mekong flow regime (MRC 2001). The other dams are configured as run-of-river with relatively small reservoirs (MRC 2009b). The full cascade will have a live storage capacity of more than 23.2 km^3, corresponding to 28% of the mean annual flow that enters the LMB from Yunnan (Rasanen et al. 2012).

A second cascade consisting of eight additional hydropower dams is under construction or in planning for upstream of Gongguogiao, including Gushul (2600 MW), Wunonglong (990 MW), Lidi (420 MW), Tuoba (1400 MW), Huangdeng (1900 MW), Dahuaqiao (900 MW), and Miaowei (1400 MW) (HydroChina 2010; Grumbine and Xu 2011; www.internationalrivers.org). As many as 14 additional hydropower dams are planned for the Tibetan Plateau. If fully realized, the total installed capacity of the UMB would be greater than the massive Three Gorges Dam project on Scoping Study on Climate Change and Hydropower in the Mekong River Basin Page 35 the Yangtze River, and 13 times greater than the total capacity of the Tennessee Valley Authority system in the United States (Hori 2000). Cumulatively, the dams would regulate more than 30% of Mekong mean annual flows from the UMB, significantly increasing dry season flows and reducing wet season flows. Substantial changes in downstream flow volumes and seasonal patterns are anticipated as far downstream as Kratie, where unregulated UMB runoff contributes as much as 40% of dry-season flows and 15% of wet season flows (MRC 2009b).

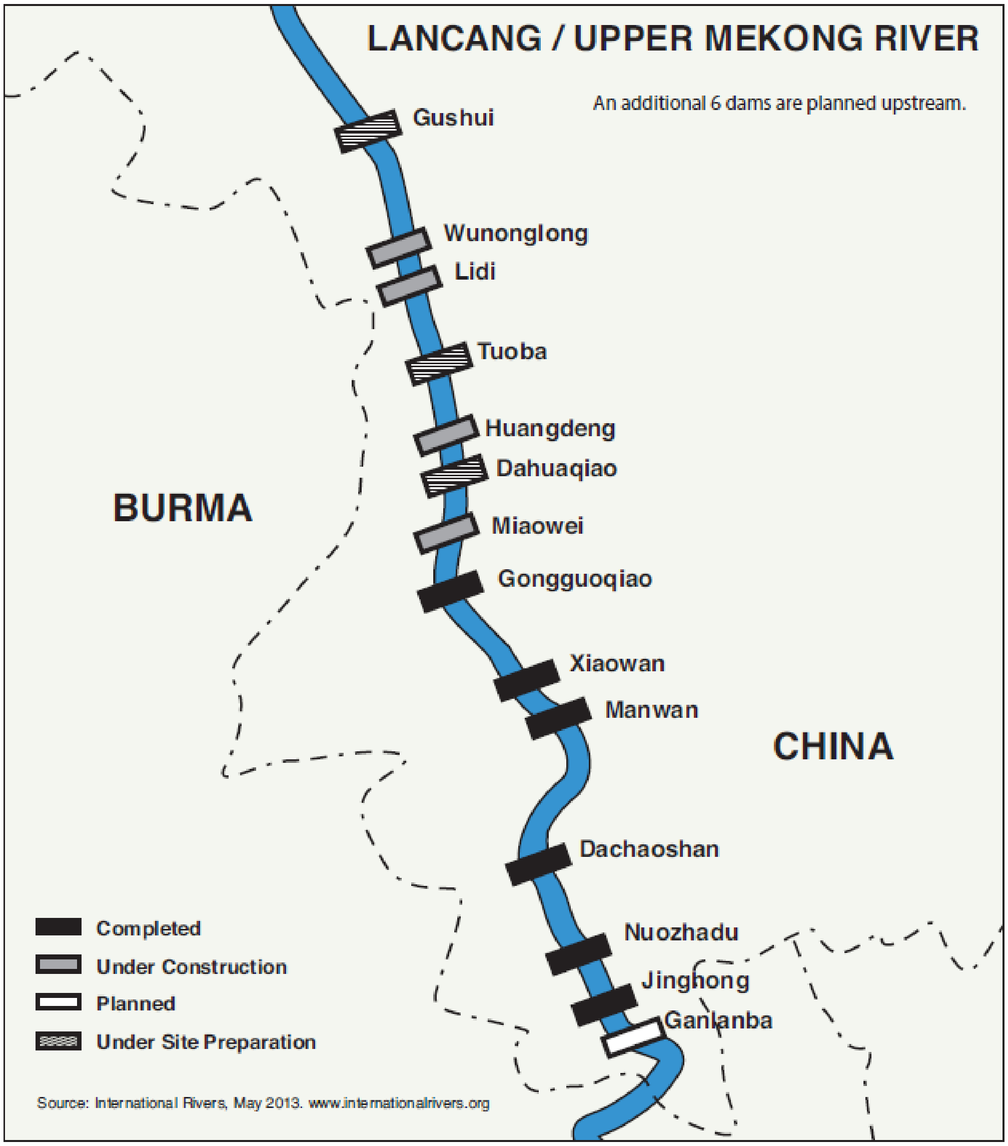


Figure 9: Hydropower projects in the Lancang/Upper Mekong River

In the LMB, one mainstem dam is under construction, and an additional 11 mainstream projects are proposed – eight in Laos, two on the Lao-Thai border, and two in Cambodia, with a total installed capacity of 13,000 MW (MRC 2009b) (Figure 10). The total capacity of tributary dams, including those in operation, under-construction, and proposed, is nearly 29,000 MW, bringing the total capacity of hydropower generation in the LMB to nearly 42,000 MW from more than 130 hydropower projects (MRC 2009b).

The first six LMB dams are proposed above Vientiane, with the upper 5 dams connected in a cascade such that the tail waters of each dam flows directly into the headwaters of the next dam, creating a linked stepped reservoir of nearly 800 km (ICEM 2010). The five dam cascade is located in Laos, while the lowest dam, Pak Chom, is shared by Laos and Thailand.

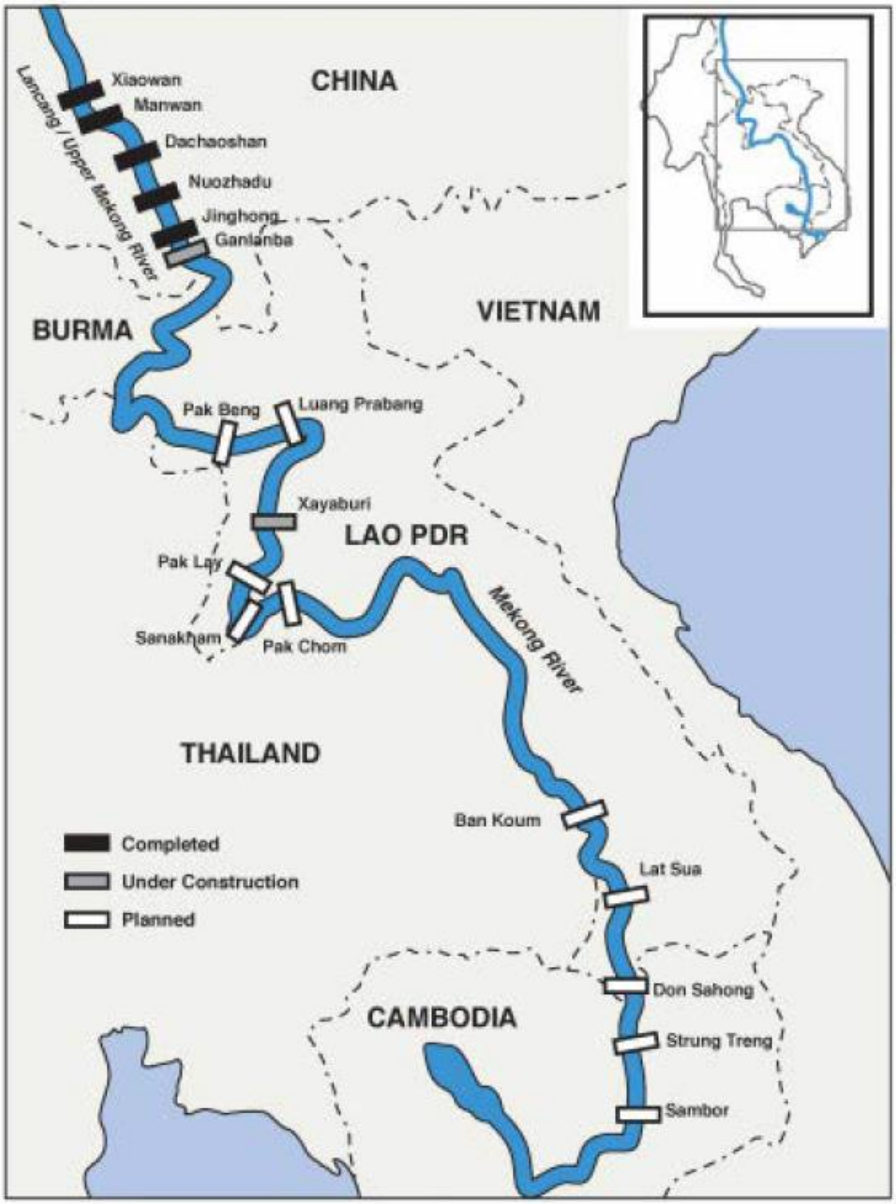


Figure 10: Large hydropower dams existing, under construction, or in planning on the mainstream Mekong River including the lower cascade of the UMB and all proposed mainstream dams in the LMB (www.internationalrivers.org)

1.8. Impacts of climate change on exiting and potential hydropower generagtion

According to the World Commission on Dams (WCD 2000), climate change has the potential to affect global hydropower installations in at least five important ways:

1. Changes in reservoir inflows in a seasonal and annual basis, due to increase or decreases in basin runoff and altered frequency and duration of runoff conditions, affecting energy generation capacity;
2. Increased surface water evaporation, especially from upstream reservoirs, and floodplains, reducing energy generation capacity;

3. Altered timing of the wet season flows especially delayed onset of the rainy season, affecting dam operations as well as downstream release patterns;
4. Increased extreme flooding (inflow) events due to higher rainfall intensity and more frequent and intense tropical cyclones, affecting dam safety and operational rule curves designed to prevent over-topping;
5. Increase sediment loads to resevoirs, resulting from higher rainfall intensity and correespinding erosion, resulting in reduced reservoirs capacity (lifespan) and water quality.

1.9. Exteme flooding events and hydropower

The effects of climate change on hydropower dams are not limited to production patterns; extreme flood volumes may exceed dam design limitations, over-topping dam walls and increasing the risk of structural failure, or delivering sediment dan debris that block dam spillways and damage important structural components (Hauenstein 2005). Eastham et al. (2008) recommend that failure MRB dam design take into account changing probalities of rainfall and runoff events of different magnitudes to ensure structural stability.
ICEM(2010) notes that the hydropower sector will faace an increasing complex severe risk profile. The projected increase in extreme wet events and incidence of flood events brings a risk of catastrophic failure. Climate chage might turn into1 in 10,000 year floodrisk into a more frequent event.-

2. Flood Management and Mitigation Programme of the MRC

MRC is now established to holistically manage policy, technical and administrative matters of river basin management. It is guided by a programme approach to development and does so through three core programmess: (i) Water Utilization Programme, currently under the M-IWRM Programme; (ii) Environment Programme and (iii) Development Plan Programme, seven sector programmess: (i) Water Resources Management; (ii) Agriculture, (iii) Irrigation and Forestry; (iv) Fisheries; (v) Navigation; (vi) Tourism and (vii) Flood Risk Management and Mitigation (FMMP) currently established at the Regional Flood Management and Mitigation Center in Phnom Penh; and (v) one Support Programme: Capacity Building Programme.

After the devastating floods of 2000 and 2001 the MRC Member Countries of the of the LMC took drastic steps towards the reduction of damage to infrastructure, economic losses and the loss of lives and livelihoods as result of extreme floods. The Flood Management and Mitigation Strategy was endorsed in 2001which was followed by the design and implementation of a dedicated Flood management and Mitigation Programme (FMMP) in 2004. The FMMP was designed as an integrated programme (FMMP 2004-2010) consisting of five components:

Component 1: The Establishment of a Regional Flood Management and Mitigation Centre (in Phnom Penh)
Component 2: Structural Measures and Flood Proofing
Component 3: Enhancing Cooperation in Addressing Trans-boundary Flood Issues
Component 4: Flood Emergency Management Strengthening
Component 5: Land Management

The main achievements of FMMP 2004-2010 can be summarized as follows:
- The establishment of a fully operational RFMMC, complete with flood forecasting systems, staff and equipment. The improved flood forecast and broadened flood related information on the flood pages on the MRC website have been very much appreciated by its users. The Annual Mekong Flood Forums have been considered valuable by local, regional and international organizations and agencies for its achievements in sharing flood related information;
- The development of five sets of best practice guidelines (BPGs) that address various aspects of flood risk management at the national level. There were also created opportunities for investment banks to consider some example flood risk management plans for further development and investment;
- Flood management and mitigation knowledge, capacities and skills in addressing trans-boundary flood issues have been strengthened at the national agency level, in educational institutes and in National Mekong Committees, while administrative and technical tools have been developed, tested, applied with outcomes documented. Knowledge and skills have been built through innovative pilot studies, applying administrative and technical tools within the framework of the 1995 Mekong Agreement.
- Flood preparedness and emergency management in the MRC Member Countries has been strengthened through targeted capacity building and training programmes at national, provincial, district and commune levels. Annually-updated flood preparedness plans have been embedded in provincial and district administrative systems; best practices have been documented and shared with MRC Member Countries.
- The development and use of flood probability information has been demonstrated for better land management.

2.1. FMMP 2011-2015

All MRC Programmes developed their programme documents for the period 2011-2015 in line with the goals of the MRC Strategic Plan for this period. FMMP is one of the twelve MRC Programmes and, since 2012, has developed strong ties with the Climate Change Adaptation Initiative (CCAI), the Information and knowledge Management Programme (IKMP) and the Basin Development Programme (BDP), while links have become increasingly stronger with Integrated Capacity Building Programme (ICBP) and the drought Management Programme (DMP). FMMP is also in close contact with the Mekong integrated Water Resources Management Project (Mekong-IWRM), while the interaction with Navigation Programme (NAP), the Environment Programme (EP), the Agriculture and Irrigation Programme (AIP), the Fisheries Programme (FP) and the Sustainable Hydropower Initiative (ISH has been more and more ad-hoc character. The linkages between FMMP and other MRC Programmes have been well identified (MRC/FMMP, 2014).

The Programme Objectives:

Basin management and development in the Lower Mekong Basin is guided by up to date flood risk management and mitigation practices aimed at reducing the negative impacts of floods, while maintaining the environmental benefits of floods. There are five major outcomes:
1. IFRM principles are incorporated in the regional basin plan and strategy and in national (long-term) strategies and planning processes;

2. Flood forecasting, impact assessment, modelling, monitoring and knowledge management (and drought monitoring and forecasting) is occurring on a routine, year round, basin-wide basis;

3. Member Countries and Dialogue Partners address trans-boundary flood issues, differences and disputes in an efficient, effective and coordinated way;

4. The ability of relevant line agencies and NMCs to use IFRM knowledge and principles to better manage flood risk is strengthened;

5. The transition of RFMMC to a financially sustainable and professionally capable institution is initiated.

2.2. The FMMP- Initial Studies

The Initial studies is an important component of the FMMP 2011-2015, which has been designed to deliver Outputs 1.2, 2.4, and 3.2 of FMMP 2011-2015:

Output 1.2	Demonstration of the formulation of IFRM Plans and Strategic Directions to manage future and residual flood risks, including the impacts of possible future climate change, for the Nam Mae Kok Basin of Thailand and Xe Bag Fai Basin in Lao PDR;
Output 2.4	Impact of Climate Change on short and long-term flood behaviour and forecasting and climate change adaptation are systemized in RFMMC and member countries
Output 3.2	Demonstration of the formulation of an IFRM Plan and strategic directions to manage future and residual flood risks, including the impacts of future climate change and sea level rise, across the transboundary floodplains of Cambodia and Vietnam’s Cuu Long Delta (joint project).

In addition to climate change, upstream development (dams) and future change to the basin’s flood plain will affect flood behaviour and flood risk in the Lower Mekong Basin. Future floodplain changes include the development of new infrastructure, increased population, changes to land-use, a higher standard of living, etc. The Initial studies address the impacts of all these factors on future flood behaviour and flood risk in the Lower Mekong Basin.

Eight tasks to deliver the above outputs are listed below and described in the Project Proposal document, which was accepted by the Regional Consultation Meeting of 19 September 2014 in Hanoi, Vietnam. The initial studies built upon work and results obtained under FMMP 2004-2010 for the three flood focal areas (FFAs) described in Outputs 1.2 and 3.2 above.

Task 1	Simulation and assessment of existing flood behaviuor and possible future flood behaviour under climate change across the LMB and the three FFAs and their hotspots.
Task 1-C	Existing Flood Behaviour and Possible Future Flood Behaviour under Inferred Climate Change in transboundary floodplains in Cambodia and Vietnam Mekong Delta, including the Tonle Sap Lake area;
Task 2.	Delivery of Pilot Projects to identify and implement non-structural climate change adaptation measures, including indicative IFRM Plans;
Task 3	Formulation of future floodplain development scenarios, embracing population growth, increase in standard of living, changes to land-use and new floodplain infrastructure developments (Council Study)
Task 4	Assessment of possible future flood behaviour under conditions of inferred future climate change, future upstream development (dams) and future floodplain development. (Council Study)
Task 5	Formulation of existing and future flood damage estimation relationships. (Council Study)
Task 6	Assessment of existing and future event damage and average annual damage (Council Study)
Task 7	Delivery of pilot studies to demonstrate the formulation of strategic directions to manage existing, future and residual flood risks in the three FFAs, including indicative IFRM Plans.
Task 8	Preparation of flood maps for existing and future flood situations (Council Study)

The Initial Studies contributes directly to the Council studies

The study conclu*ded that:*

The simulation of Climate Change in the Cambodian Floodplain and Mekong Delta has highlighted the significant changes that may occur leading to higher water levels in extreme floods, longer duration of flooding and increased flows leading to potential erosion and flood damages.
The role of the floodplain in terms of Conveying Flow and for Storage is seen to be critical as naturally functioning river helps to offset downstream increases. However in terms of stress testing, it is already apparent that the floodplain system even with the current infrastructure cannot absorb the increases in extreme floods that most of the climate scenarios indicate.
The relative fragility of the flood control system for cities such as Phnom Penh, Long Xuyen and Can Tho and secondary towns such as Kampong Cham, Tan Chau and Chau Doc indicates that flood risks could increase dramatically. It is found that conveyance on the Mekong left bank in Cambodia and Vietnam is especially significant at the present time and that potentially increased flow could cause large rises in water level in the West Vaico basin. Sea level rise will cause more flood issues in the coastal zones in particular and change in the drainage systems may be needed including more use of pumping. The next stages of the Initial Studies will define the likely trends in floodplain development but at the same time it is recommended to look at how the functioning of the floodplain can be maintained and even improved (for example extra flood conveyance through major roads, reservation of key conveyance and storage) as well as how flood risk can be reduced. More detailed analysis of the flood behaviour and options for improving flood risk management should go together with the analysis of combined floodplain development scenarios and climate change impacts so that firm recommendations for future floodplain development can be made.

2.3. Mekong Adaptation Strategy Action Plan (MASAP)

The Mekong Adaptation Strategic Action Plan (MASAP) is an initiative of CCAI) to formulate a basinwide plan that identifies and prioritizes adaptation options to lessen impacts of future CC on the following water-related sectors of the LMB: Sector 1: Flow; Sector 2: Floods; Sector 3: Drought; Sector 5: Ecosystem and biodiversity; Sector 6: Food security; and Sector 7:Socio-economics.

Of specific interest of this review is the result of the Task 1-C: Initial studies to demonstrate the formulation of strategic direction to manage existing, future & residual flood risks in the LMB:

Flood flow distribution below Kratie in Cambodia to the Mekong Delta is very complex and is governed by water level in a complex natural and man-made networks river/canal branches, roads, dike embankment for urban areas flood protection across the vast floodplains. The Study subdivides the whole floodplain into 8 flood zones in Cambodia and 5 flood zones in Vietnam. The MRC's Decision Support Frameworks (DSF) consisting of set of models was used (SWAT, IQMM and ISIS models).

2.4. The Council Study

All MRC Programmes contribute to the Council Study, which has been assigned ‘high priority’ by MRCS. Theme 3 is relevant to FMMP, namely the likely impacts of existing and future floodplain infrastructure on behaviour, especially activities under task 1 (existing flood behaviour), Task 3 (the formulation of future floodplain development scenarios for 2040), Task 4 (future floodplain behaviour), and Task 5 and 6 (existing and future flood damage and flood risk).

To this end FMMP has incorporated CS outputs into it IS project and will deliver to the Council Study a broad assessment of existing flood behavior/risk across the major floodplain of the Lower Mekong Basin, along with a broad assessment of strategic directions and options to manage existing, future and residual flood risks in the LMB, taking into account likely future changes to floodplains infrastructure, land-use, land cover, urbanization, etc.

Study focuses on Sustainable Management and Development of the Mekong River including Impacts of Mainstream Hydropower Projects is aimed to provide an objective scientific assessment of the environmental, social and economic costs and benefits of existing and planned water resource developments in the Lower Mekong Basin to inform decision makers.

The Council Study used a sequence of qualitative and quantitative models to examine a set of water resource development scenarios. The modelling outputs were integrated as a systematic framework to describe outcomes for selected environmental, social and economic indicators and to carry out assessments. These, in turn, informed the social and economic analysis of six thematic sectors. The framework provides a coherent, scientific foundation for the assessment of water resource developments and is complemented with accessible, practical methodologies and modelling tools, and a knowledge base to support further studies, deliberations and decision processes. The Study examines three development scenarios:

(i) The early development scenarios
(ii) The medium term definite scenarios, and
(iii) The long term plan scenarios

The Council Study (CS) covers 10 themes:

1. Summary and Cumulative Impact Assessment
2. Thematic Report 1: Irrigation
3. Thematic Report 2: Non-Irrigated Agriculture and Land Use Change
4. Thematic Report 3: Domestic and Industrial Water and sand mining
5. **Thematic Report 4: Flood Protection Structures and Floodplain Infrastructure (This Report)**
6. Thematic Report 5: Hydropower Development

7. Thematic Report 6: Navigation

8. Discipline Report: Social and Economics Assessment

9. Discipline Report: Modelling: Hydrological Assessment, Geomorphology and Sediment Modelling, Nutrient Modelling and Assessment

10. Discipline Report: Biological Resource Assessment (BioRA)

2.5. The main outputs of the Council study

Objective 1: Further develop/establish a reliable scientific evidence base on the environment, social and economic consequences (positive and negative) of development in the Mekong River Basin.

Output 1.1: *Review the past scientific knowledge base and databases in terms of use as a basis and baseline for the study.*

Output 1.2: *Critical knowledge gaps in understanding of the Mekong River Basin system and the impacts of development of the main thematic topics of infrastructure and water use are closed.*

Output 1.3*: Climate change impacts are analysed in the context of the sector development impacts to assess opportunities and risks.*

Objective 2: Results of the study integrated into the MRC knowledge base to enhance the BDP process providing support to the Member Countries in the sustainable development of the Mekong River Basin.

Output 2.2: *The Basin development scenario assessment for the Basin Development Strategy 2016-2020 uses the information and knowledge generated from the Study.*

Objective 3: Promote capacity building and ensure technology transfer to Member Countries in the conduct of the Study.

Output 3.1: *Comprehensive capacity on scientific assessments, survey and analysis are strengthened among Member Country study team members*

Output 3.2: *Member Countries' staff participating in the study is able to undertake major thematic studies and possible tools and guidelines are documented for future use of similar studies.*

This will result in a decentralized, targeted, incremental and accessible assessment methodology that incorporates emerging issues and supports new approaches to adaptive management for climatic variability and change available for use by riparian countries.

The approach of the Council Study is unique in the way that water resources and external development impacts in the river basin have been considered as a whole in an integrated fashion rather than taking a narrow sectoral basis as in many planning and project studies. The analysis has also gone further than earlier MRC basin planning to integrate models and predictive tools for economics and social impact and though incomplete it is suggested that the work is progressively improved and the lessons learnt are made widely available to member countries for future planning.

2.6. Development Scenarios for Flood Protection and Floodplain Development

Formulation of 'Main Scenarios"

The SWAT, IQQM and ISIS models reflecting 2007 development conditions are available with IKMP and were used as a basis for simulation runs. These models have been checked and modified as necessary to incorporate more recent modelling improvements, for example improvement in channel representation. These improvements, however, are not related to infrastructure or floodplain development. The reference scenario M1 'Early Development' uses this condition.

2.7. 2020 M2 and 2040 M3 Development Scenarios

The SWAT, IQQM and ISIS models were updated to include land use change, irrigation and dam developments that have already occurred and are planned to be implemented by 2020. The modelling team did not include changes in the lower model for floodplain development and this is instead included in a sub scenario.

Table 4: Key aspects of the three development scenarios

Scenario		Level of Development for water-related sectors*						Climate
		ALU	DIW	FPF	HPP	IRR	NAV	
M1	Early Development Scenario 2007	2007	2007	2007	2007	2007	2007	Historic Climate
M2	Definite Future Scenario 2020	2020	2020	2020	2020	2020	2020	Historic Climate
M3	Planned Development Scenario 2040	2040	2040	2040	2040	2040	2040	Historic Climate
M3CC	Planned Development Scenario 2040 Under Climate Change	2040	2040	2040	2040	2040	2040	Seasonal Change for 2040 Climate
M1960	1960 Development*							

*ALU = Agric/Landuse Change; DIW = Domestic and Industrial Water Use; FPF = flood protection infrastructure; HPP = hydropower; IRR = irrigation; and NAV = Navigation. Floodplain development

*1960 – Historic Development Scenario not implemented yet

2.8. Main water resources development scenarios

Formulation of "flood thematic sub-scenarios"

There are three flood thematic sub-scenarios as follows:

- PF1: Planned Development 2040 without Flood Protection: No change in flood protection i.e. M3C3 without flood protection;
- PF1: Planned Development 2040 with likely Flood Protection: Flood Protection for all urban areas to 1:100 years ARI, floodplain development scenarios 1 (most likely floodplain protection to 2040);
- PF2: Flood Protection 1+ floodplain development and loss of floodplain storage.

Review of SIMVA findings for villages in the mainstream corridor (Table 5) for different corridor zones (the corridor impact zone is presented in Figure 11 below.

Table 5: Social Impact Monitoring and Vulnerability Assessment project, flood situation at village level, with an average also shown. The results indicate a very high level of impact of flooding along the Impact corridor (source: Council study).

		Villages with households that experienced losses or damages from any floods in the last 3 years		**% HHs experienced damages from flooding in last 3 years**
Country	**Sub-Zone**	**N**	**Row %**	**Mean % of HHs**
Cambodia	Zone 4 A - Subzone Cambodia - Khone Falls to Kratie	20	90.91%	39.33%
	Zone 4 B - Subzone Cambodia - 3S	3	75.00%	49.73%
	Zone 4 C - Subzone Cambodia - Kratie to Vietnam border	12	66.67%	52.60%
	Zone 5 A - Subzone Cambodia - Tonle Sap river	15	68.18%	49.15%
	Zone 5 B - Subzone Cambodia - Tonle Sap lake	18	81.82%	58.78%
	All	***68***	***77.27%***	***49.45%***
Lao PDR	Zone 2 A - Mainstream - Lao	1	2.27%	.
	Zone 3 A - Subzone Lao - Mainstream	0	0.00%	.
	All	***1***	***1.14%***	***.***
Thailand	Zone 2 C - Subzone Lower Thailand	9	40.91%	24.74%
	Zone 2 B - Subzone Upper Thailand	19	86.36%	22.83%
	Zone 3 C - Subzone Thailand - Songkhram	18	81.82%	45.17%
	Zone 3 B - Subzone Thailand - Mainstream	14	63.64%	26.64%
	All	***60***	***68.18%***	***30.71%***
Vietnam	Zone 6 A - Subzone Vietnam - Mekong Delta - freshwater	8	18.18%	30.16%
	Zone 6 B - Subzone Vietnam - Mekong Delta - saline	3	6.82%	34.10%
	All	***11***	***12.50%***	***32.13%***
All		**140**	**39.77%**	**38.96%**

The FMMP has assessed changes in flood characteristics primarily in term of changes to the frequency distribution of Flood Risk (Damage). Baseline distribution developed for:

- The EDS-2007 development situation, which will be used to assess future exchanges under the DFS-2020 and PFS-2040 cumulative development situations; and
- The PFS-2040 cumulative development situation, which will be used to assess changes under the various thematic sub-scenario development situations.

The FMMP terms ‘flood risk’ as average annual damage (AAD). Changes to flood risk are given in terms of changes to AAD between the baseline and future periods (cumulative scenarios) and between the PFS-2040 cumulative scenario and perturbed variations of that scenarios (thematic sub-scenarios).
In addition to formulating flood protection works and floodplain development components of the cumulative scenarios and thematic sub-scenarios, the need for flood protection works for the cumulative scenarios (other thematic areas) and thematic sub-scenarios (all thematic areas)

An example of flood risk calculation for the transboundary floodplain in the framework of the Initial Studies is shown in (Figure 2.1 of the Council Study). The districts shown in this Figure are those for which district based damage function can be calculated.

2.9. Flood Damage Estimation for Council Study

Specifically, for the flood sector the flood damages calculation is key to determining impacts especially with regards to flood defenses. A process diagram in shown in Table 2.1 (page 12) and in figure 2.2 (page 21) the method for integration of all components of flood damages described above is shown. The calculation techniques are based on probabilistic analysis of the modelling results rather than looking at specific years.

2.10. Strategic Indicators

Strategic indicators must take account of triple bottom line assessment and other sector analysis in the CS. For the flood sector specifically, Flood Risk is the key indicator-expressed in terms of probabilistic analysis of flood damages at different frequencies of probability of occurrence. For flood and river bank protection and assessment is required of damages avoided through improving flood defense infrastructure. People and social aspects should also be a key part including the number of people directly and indirectly affected by floods, impact on the economy etc. Five groups of indicators were thus proposed through though not all were possible at calculate at this stages:

- Hydrological
  - Change in flood frequency at key stations and Impact Assessment Locations
  - Changes in timing of flood peaks and travel time
  - Changes in flood duration and depth
- Flood Risk/Economic Damage
  - Crop damage (Annual Average and Extreme Flood)
  - Property & Infrastructure and Indirect Impact
- Socio Economic
  - Food security implication of flood
  - Number of people affected
- Environment
  - Effect of flood protection on fisheries and OAA

  - Sedimentation reduction due to flood protection
  - Length of bank at risk and Risk Erosion

The findings of Flood Protection Structures and Floodplain Infrastructure are summarized here:

1. Flood Damages will rise rapidly by a factor of 5-10 with development unless protection is provided;

2. The trapping of sediments in the proposed dams in the Mekong Basin will increase River Erosion in the LMB and significant bank protection work will be needed;

3. If uncontrolled, the loss of Floodplain storage with development will result in higher river flood levels and increase flood levels and frequency or river and surface water flooding;

4. Climate Change is highly likely to result in significant increases in floods especially in the upper part of the basin and the in the Mekong delta.

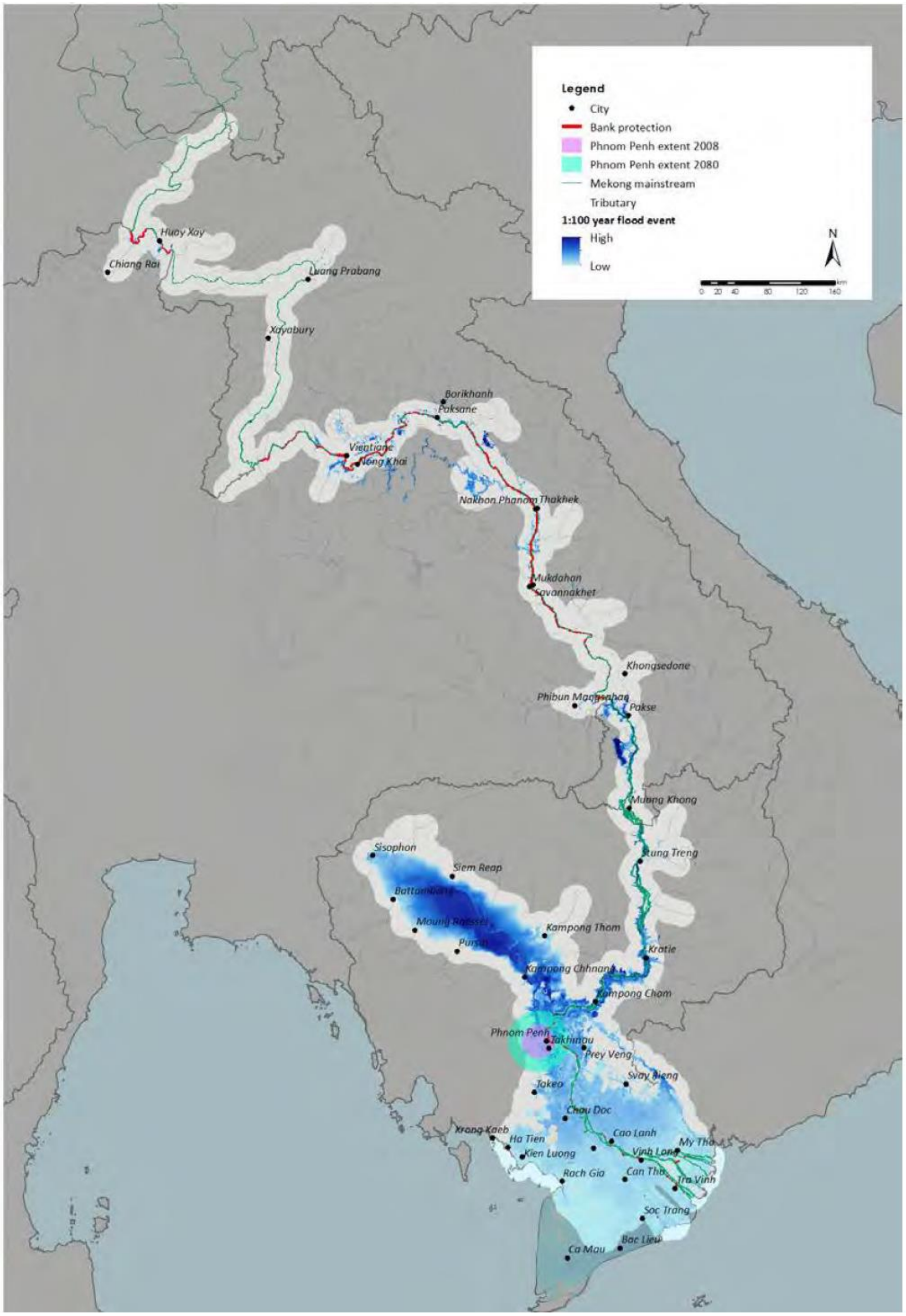


Figure 11: The Council Study Impact Corridor used for the council study to estimate 1: 100 year flood extent

2.11. Scenario results

The Council Study, as it became known, aimed to provide an objective scientific assessment of the environmental, social and economic costs and benefits of existing and planned water resource developments in the Lower Mekong Basin to inform decision makers.
The Council Study used a sequence of qualitative and quantitative models to examine a set of water resource development scenarios. The modelling outputs were integrated as a systematic framework to describe outcomes for selected environmental, social and economic indicators and to carry out assessments. These, in turn, informed the social and economic analysis of six thematic sectors. The framework provides a coherent, scientific foundation for the assessment of water resource developments and is complemented with accessible, practical methodologies and modelling tools, and a knowledge base to support further studies, deliberations and decision processes.

Three main water resources development scenarios have been examined:

(i) **The *early development scenario (EDS)*** characterizing baseline water resource developments in 2007;
(ii) **The medium-term *definite future scenario (DFS)*** characterizing existing, under-construction, and firmly-committed water related developments in 2020, including the Xayaburi and Don Sahong hydropower projects (M2) and;
(iii) **The long-term *planned development scenario (PFS)***, characterizing the planned water developments in 2040 in addition to those assigned for 2020 (M3) for implementation over the following two decades.

The main scenarios aggregate combinations of water resource developments enabling the cumulative assessment of environmental, social and economic effects in the Member Countries.

Twelve sub-scenarios were evaluated to isolate sector-specific contributions and comprise reductions or increases in sector-specific investments relative to those in the M3 scenario of agricultural land use, flood protection infrastructure, hydropower and irrigation. A set of three sub-scenarios was also devoted to isolating the impacts of Climate Change.

The assessment follows the principles of IWRM and IFRM that adopt a probabilistic approach to the analysis of floods. The Council Study has available continuous simulation modelling that covers a period of 26 years which is just sufficient for flood frequency assessment up to 50 years average recurrence interval.

The SWAT, IQQM and ISIS models reflecting 2007 development conditions are available with IKMP and were used as a basis for simulation runs. These models have been checked and modified as necessary to incorporate more recent modelling improvements, for example improvement in channel representation. These improvements, however, are not related to infrastructure or floodplain development. The reference scenario M1 ‘Early Development’ uses this condition.

2.11.1. Flood Thematic sub-scenarios

There are three flood thematic sub-scenarios as follows:

- FPF1: Planned Development 2040 without Flood Protection: No change in flood protection i.e. M3CC without flood protection.
- FPF1: Planned Development 2040 with likely Flood Protection: Flood protection for all urban areas to 1:100 years ARI, flood plain development scenario 1 (most likely flood plain development to 2040).
- FPF2: Flood Protection1 + floodplain development and loss of floodplain storage.

The FMMP has assessed changes in flood characteristics primarily in terms of changes to the frequency distribution of Flood Risk (Damage). Baseline distributions will be developed for:

- The Early Development Scenarios (EDS-2007) development situation, which will be used to assess future changes under the DFS-2020 and PFS-2040 cumulative development situations; and
- The PFS-2040 cumulative development situation, which will be used to assess changes under the various thematic sub-scenario development situations.

2.11.2. The findings

Results from this study show clearly how flood risks will increase significantly with time unless action is taken to raise the standard of flood protection where the risk is greatest. Those flood risks have been translated into flood damages within the **assessment corridor** for the main and flood scenarios considered by the Council Study.

2.11.3. Flood damages

Cambodia

The approach used for damage assessment is a top down one similar to be used by the FMMP for which training and tools are provided to Member Countries. The principle is for working with the observed damages divided into categories and water level for events at key locations 'Impact Assessment locations'. Data was collected from member countries for flood events and damage and analysed. The data supplied did not cover the whole corridor especially in Cambodia and Vietnam so it is not possible to have a complete analysis of the whole corridor.

The data available from member countries cover the transboundary area of Cambodia and Vietnam well but this is only part of the corridor. The detailed calculation can be done only for the transboundary area which is then treated as a representative sample and the data presented is factored up to the whole corridor.

In Cambodia it can be seen that relative to population very high losses can occur and there is a tendency for some scenarios to increase greatly the flood risk i.e. M3CC 2040 increases from 2010 by $42m from $5m at risk in 2010.
Agriculture remains an important component though in future average damages increase sharply for the infrastructure and property with development and commercial activity in this flood prone area. The important impact of flood defenses on reducing the annual average damages can be seen comparing F1 and F2. See table 3.4 and 3.5 of the Consult Study (scenario F2 includes additional defense to urban areas to give 1:100 year protection and 1:10 years for agricultural areas.
A high extreme flood could also set the country development back as it causes up to $557m of damage in a single event which a high proportion of the government budget for the country to afford.

Lao PDR

The corridor for Lao and PDR used in the assessment are relatively limited but include both rural and urban areas. Results summarised for Lao PDR case as an example show that with 2007 socioeconomic condition (Table 3-6) the damages to crops dominate the flood risks. However, with development and urbanisation the Urban Risks become more dominant (Table 3-7) though flood defenses can significantly reduce and manage these risk (Scenario F2).

Thailand

For Thailand similar results are obtained as for Lao PDR in 2007 and 2040 condition as shown in Tables 3-8 of the Consult Study. The relatively modest current AAD of $9m increases slightly with M2 and M3 Scenarios but with climate change there is potentially a rapid rise in damage for extreme events for the 2007 condition largely because of agricultural losses though a rise in property/infrastructure is also noted. With the 2040 socioeconomic scenario damages increase further due to the greater value of assets at risk. The F2 scenario show though that a combination of urban and rural flood defenses can mitigate the loss significantly though there is still a residual risk.

Vietnam

It can be seen that from the difference between F2 in 2040 and F1 in 2040 especially additional flood defenses could be used very effectively to reduce the damages especially in urban areas where it is expected that the major growth in risk will occur. In Vietnam this may take the form of a safe urban platforms raised above the flood level. The difficulty with such an approach though is the high fill requirement from the limited supply of sand transported in the Mekong River and if there is a higher flood design level due to climate change and sea level rise then additional banks may be needed. The agricultural damages are relatively high in Vietnam due to the high productivity of the system.
If flood defenses were incorporated in other scenarios similar to the 1:100 year protection for urban areas and 1:10 for agriculture then the difference in average annual damage may be estimated as shown in Table 3-9.
The extreme flood will always potentially be greater than the defense level and for Disaster Risk Management the total flood risk is shown also in Table 3-10 of the Council Study. It can be seen that a major flood in 2010 would have caused a fairly high loss of $155m in 2040 with Climate Change that could increase to over $3billion dollars.

It is recognised within the analysis that there are components of flood impact that will change relatively going into the future and thus should be separated in the analysis;

1. *Flood Damage to Agriculture*
2. *Flood Damage to Infrastructure, including roads, banks, irrigation and government facilities including schools and health*
3. *Damage and loss to Private and Commercial Properties and their contents*
4. *Indirect Impacts such as the cost of relief measures, impact on health or loss of factory production*

A further significant effect considered was the large increase in urbanisation, development and the increasing value of assets at risk going forward into the future due to more affluent societies. Previous studies have established this as a major factor and thus future change in flood damage should consider:

a) Change in flood risk due to hydrological changes due to infrastructure and climate

b) Change in flood risk due to socioeconomic change

The results for the main flooding areas of Cambodia and Vietnam are shown in Tables S1 and S2

2.12. Changes in Flood Regime

The main and sub scenarios related to the flood sector have been analysed for change both for mean flow and for extremes through flood analysis of return periods up to and below 1:100 year events. There is a small decrease in flooding for the M2 and M3 scenarios but with climate change there is a significant increase in peak water levels, expected annual and peak event damages etc. The more extreme C2 Climate Change scenario more than doubles the flood risk in Cambodia and Vietnam. Allowing for socioeconomic change results in a significant increase in assets at risk and associated infrastructure/property and indirect damages that by 2040 will outweigh the agricultural loss**.**

2.13. Effect of Mainstream Dams

The storage within mainstream dams is small compared to the high flood volumes and thus the impact of mainstream dams on flooding downstream is very small. The scenario results for M2 and M3 indicate expected small reductions in flood risk in Cambodia and Vietnam especially though this is more than offset by climate change and sea level rise.

The possible local impacts upstream of mainstream dams in the backwater areas need to be considered on a case by case basis but is limited at high floods and if found to be an issue then mitigation measured would be adopted. A more significant effect may occur due to releases of flow at critical times, again this has not been assessed but could be studied further in the available models. The flood management using dams scenarios F3 was unsuccessful and gave a small increase in flood risk showing that the responses of multiple cascade systems within the basin in the future will be a challenge to coordinate and further study is needed to prepare for emergency drawdown eventualities.

The impact of mainstream dams on sediment regime and hence potential bank erosion downstream is significant as the mainstream dams play a significant role in the deprivation of sediment load downstream. Ultimately there is little doubt that the expected reductions in sediment load due to Upper basin dams and tributaries will necessitate significant expenditure on bank protection in Cambodia and the Vietnam delta in particular where over 300km of bank is at risk in the main Mekong and its six delta arms.

2.14. Development on the Floodplain

Loss of floodplain has been shown to raise peak flood levels and many urban and rural assets are already exposed to comparatively high risk of increasing damages. Combined with climate change, it is essential that the requirement for flood defenses of certain areas is considered strategically, ensuring that steps to manage the essential functioning of the floodplain are set into land use planning and development control. Future Socioeconomic Development is already resulting in development pressures on the floodplain and steps to protect essential services of storage and conveyance are needed at the earliest opportunity. Additionally the impact of rising sea level will impact on flooding in the Vietnam delta. The Council Study considers only a short horizon to 2040 and without doubt sea level rise and climate change will continue to build with progressively higher impacts after this time period.

2.15. Floods damages and increased assets at risk with development

Flood Damages will increase substantially as countries develop and more assets are at risk.
Future Flood Damages will rise rapidly due to climate change and development putting more assets at risk. This can be offset substantially through sensitive flood protection works at the areas of most risk. At present much of the impact corridor is dominated by the potential risk of agricultural losses due to flooding. These risks will rise in time with the increased agricultural productivity also with developing economies there will be larger increase in assets at risk especially in urban areas. Increases in risk and thus potential losses may be a factor of 3 to 5 higher than current day. Mapping standard of service for urban areas and crops in particular are needed as is clear planning guidance for flood risk when developing infrastructure.

2.16. Transboundary erosion increase with numbers of dams

Transboundary Erosion Issues will increase rapidly with completion of dams in the LMB
An erosion problem along the whole of the Lower Mekong is steadily developing and will accelerate quickly once the planned dams are put in place. It is estimated that there is around 3450km of bank at risk along the mainstream channels, nearly 1400km within the Mekong Delta. It can be envisaged that bank protection works will be needed along the alluvial reaches of the main river. Further modelling work is needed to define how quickly the erosion will occur, but it is likely to be progressive as dams are developed and be realised within decades

after completion. As the banks are developed the erosion will move downstream more quickly due to the ‘hungry’ river effect of rapid bed erosion causing degradation, followed by erosion of banks and lateral instability. With major infrastructure along the river as well as areas of international border between Lao and Thailand there is already a significant length of bank protective work in place on the Thai side of the river and increasingly on the Lao side. Further protection will require substantial investment to contain the problem, estimated at around $6 billion. The rate at which these bank protection works will be needed will depend on the mitigation measures adopted at the mainstream dams and how rapidly other bank protection works are developed upstream. The upstream bank protection is significant as it further starves the downstream reaches of sediments that might have been liberated by erosion. Major rivers such as the Mississippi are known to be still adjusting to changes over 100 years earlier though rapid change can also be expected as evidenced by the increasing loss of banks in the Vietnam delta following the major loss of sediments from the Upper Riparian catchment in 2010/11.

2.17.Biological Resources

There are positive impacts of flooding that must be incorporated into cost benefit assessments as well as flood damages. The BioRA Assessment shows changes mainly relative to the effect of dam development but for areas that will be behind flood defenses in the future a loss of biological resource is also predicted. Further work is needed to be able to compare this expected loss with the benefit of flood protection which is shown to be high in the F2 scenario.

The integrated approach of the Council Study has brought a sharp focus on the four main flood issues of:

1. Flood Damages will rise rapidly by a factor of 5-10 with development unless protection is provided;
2. The trapping of sediments in the proposed dams in the Mekong Basin will increase River Erosion in the LMB and significant bank protection work will be needed;
3. If uncontrolled, the loss of Floodplain storage with development will result in higher river flood levels and increase flood levels and frequency or river and surface water flooding;
4. Climate Change is highly likely to result in significant increases in floods especially in the upper part of the basin and the in the Mekong delta.

Consultation with member countries revealed a lack of long term strategic planning for improving flood protection works in the Council Assessment Corridor. This is primarily due to the expected rise in the value of asset at risks as the economies develop, especially in the urban areas with high exposure but also influenced by climate change and development on floodplains.

2.18. Key recommendation of the Consult Study

1. Better information must be collected on the current flood defenses, bank protection and damages and made available in a more useable form

2. The prediction of the change in future Flood Damages with development must receive more attention and improved methodologies made available.

3. Floodplain management guidelines utilizing flood zone mapping are needed in each country and wider sharing of data for transboundary areas

4. Further study is needed to reduce the uncertainty on trapping of sediments in the proposed dams and the effectiveness of possible mitigation measures. This could also include nutrient cycle analysis and potential for harmful algal blooms.

5. Further study is needed on the impact of the reduction of sediment on bed and bank erosion, coastal erosion and river morphology and a costed sediment management plan developed for erosion protection measures to be taken for the whole LMB over the next 20 years. This plan should include the management of sediment for navigation dredging, the need for building materials and land raising that goes with development as well as sand mining for construction and land raising.

6. Modelling of the interactions between flooding, sediment movement, nutrient and agriculture development needs to be continued and improved with linkage to planned irrigation schemes and the effect on the biological resource and environment.

7. Pilot Studies of Flood Protection works should be undertaken to a level that demonstrates the economic feasibility of flood defense improvement and to establish guidelines for the economic and social standards of protection that should be aimed for in rural and urban areas.

8. Planning of Climate Change adaptation for floods must be closely linked to the changes in situation due to development.

9. Longer Term Strategic Planning for flood Protection and River Bank protection should be incorporated in the next MRC Basin Plan or a specific basinwide flood sector plan.

10. Hydrometric data improvements in terms of better quality of data and longer time series for simulation are strongly needed to support the planning.

11. Improvements in the MRC modelling and assessment system that can provide transparent and more robust outputs and decision support should be made. It is important to continue to improve the basic data, the core DSF models, incorporate the social, biological resource and economic impact tools into a more streamlined system and further develop tools for agriculture simulation, flood damage assessment etc.

12. The MRC Flood team's 'Initial Studies' should be advanced rapidly to define in better detail the impact of likely floodplain developments and the possible solutions. This should lead onto the first draft of a strategy for management of the floodplains of Cambodia and the Mekong delta as identified in the MRC Strategic planning in 2010. The plan should link closely to the planning of member countries and address the opportunities and constraints of the transboundary impacts identified.

13. The methodology for calculation of flood damage where there is rapid development should be advanced and improved and capacity built in the use of the tools and techniques through 'bottom up' approaches using unit calculations for housing, industry, infrastructure and agriculture that are more adaptable than the rigid bottom down approach that inevitably assumes a similar condition to the present.

14. Further to flood damage estimates the economic value of flood benefits is also required.

15. The MRC DSF tools and datasets should be updated to incorporate fully the assessments required in studies such as the Council Study and made available to a wider audience to ensure better accountability and transparency.

3. Other related MRC Strategies

3.1. IWRM-based Basin Development Strategy 2016-2020

The Basin Development Plan Programme (BDP)'s Assessment of Basin-wide Development Scenarios completed in 2011 assessed four future basin development scenarios against 42 economic, environment and social criteria that were selected to provide an overall picture of socio-economic development and environment protection parameters of importance for decision making in the basin.

The Basin Development Strategy 2016-2020 takes stocks of implementation experiences, lessons learned, and progress achieved under the Strategy 2011-2015, much of it through the implementation of MRC Strategic Plan and the National Indicative Plans of the Member Countries by a broad range of regional, national and local stakeholder.

The BDS 2016-2020 maintain the development opportunities prioritized in the previous Strategy as follows: tributary hydropower development; expansion of irrigated agriculture; mainstream hydropower development; and other opportunities. These development opportunities will be updated in greater detail based on the results of implementation of defined actions for 2016-2020 in this Strategy.

The priority recognize that cooperative or joint investment, involving deal structures and possibly cost and benefit sharing, will lay the foundation for a long term, sustainable and peaceful basin development. The strategic priorities are:

- Reduce remaining knowledge gaps to minimise risks;
- Optimise basin-wide sustainable development and cost and benefit sharing;

- Strengthen the protection of mutually agreed environmental assets;
- Strengthen basin-wide procedures and national implementation capacity;
- Improve national water resources development;
- Enhance information management, communication and tools; and
- Increase cooperation with partners and stakeholders

3.2. The Mekong Integrated Water Resources Management Project (M-IWRM)

Transboundary dialogue can help reduce tension and increase cooperation among countries. The Mekong River Commission (MRC) supports its four member countries in the Lower Mekong Basin – Cambodia, Lao PDR, Thailand and Viet Nam – to enhance transboundary cooperation through the Mekong Integrated Water Resources Management Project (M-IWRMP). The project promotes IWRM practices of coordinated planning and management with the application of MRC's procedural rules, known as Procedures, and technical tools on water use planning, data sharing and flow monitoring.

The project originally began in 2009 with three inter-linked regional, transboundary and national components to increase IWRM-based water cooperation among the four countries at both basin-wide and local levels. The regional component, funded by the Australian government, was completed in 2015 after it advanced the application of the MRC Procedures and their technical guidelines and developed a package of modeling tools for basin-scale water utilisation. While the transboundary component focuses on bilateral water cooperation, the national component supports each member country to improve governance mechanisms and build technical capacity to carry out coordinated planning and utilisation of water within the national boundaries. The World Bank finances both the transboundary and national components.

The MRC Procedures are five sets of procedural rules to govern the utilisation of shared water resources among the member countries, in support of the implementation of the 1995 Mekong Agreement on water cooperation. The rules include:

1. Procedures for Data, Information Exchange and Sharing (PDIES)
2. Procedures for Water Use Monitoring (PWUM)
3. Procedures for Notification, Prior Consultation and Agreement (PNPCA)
4. Procedures for the Maintenance of Flows on the Mainstream (PMFM)
5. Procedures for Water Quality (PWQ)

These rules, together with MRC's research data, technical guidelines and modeling tools, are expected to facilitate IWRM practices in the region.

Under the transboundary component, the four Mekong countries have set up five bilateral projects focusing on fisheries, wetland, delta, lake and river basin management to tackle transboundary water issues such as pressures from urbanisation, infrastructural development and climate change that affect riverine communities across borders.

Through transboundary dialogue, the four countries build a common understanding of key cross-border water issues, find durable solutions to work together, and share best practices in water resources management. Altogether, these projects are designed to strengthen national and provincial capacities for coordinated water utilisation, and create a better institutional framework for IWRM-based joint management of water resources beyond borders.

Launched in 2013 and 2014, these bilateral projects are slated for completion in March 2018. It is expected that IWRM-based bilateral collaboration continue beyond the projects' completion with new national development plans that incorporate lessons from the projects. It will bring benefits to the livelihoods of the riparian communities and foster more sustainable development in the region.

The five projects are:

1. **Mekong and Sekong Rivers Fisheries Management Project** between Cambodia and Lao PDR that addresses the issue of declining migratory whitefish species to improve transboundary management;

2. **Sesan and Srepok River Basins Water Resources Management Project** to improve transboundary cooperation between Cambodia and Viet Nam in the face of hydropower development;

3. **Mekong Delta Water Resources Management Project** in the bordering provinces of Cambodia and Viet Nam to address challenges from upstream development and climate change;

4. **Xe Bang Hieng and Nam Kam River Basins Wetland Management Project** between Lao PDR and Thailand to strengthen wetland resources management through knowledge sharing;

5. **Tonle Sap Lake and Songkhla Lake Basins Communication Outreach Project** between Cambodia and Thailand that promotes healthy lake governance through communication activities.

4. Mekong-Lancang Cooperation

In April 1995, Thailand, Vietnam, Laos, Cambodia signed the Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin in Chiang Rai, Thailand and announced the establishment of the new MRC. In 1996, China and Myanmar became the MRC's dialogue partners, but China has not formally joined the MRC.

In recent development China regards the Lancang-Mekong Cooperation as focal point of promoting new cooperation mechanism in the GMS.

In water resources management, practical cooperation has started since 2002 when China has provided hydrological and rainfall data from two stations one on the mainstream at Jinghong and one on the main tributaries at Man An's. The provided data are considered of vital importance for flood early warning for the UMB parts namely Chiang Saen in Thailand and Luong Prabang in Lao PDR.

During the extreme drought period of 205 and 2016, a joint evaluation of the water emergency supplement from China to the Mekong River was formed to monitor the water release from hydropower reservoir.

The navigation channels in the upper part of the LMB connecting the Lancang River in China

The project, known as the Development Plan for International Navigation on the Lancang-Mekong River (2015-2025) is set in three phases, with an initial survey, design, and environmental and social assessments.

The navigational "improvements" cover 630 kilometers from China to Myanmar boundary marker 243 to Luang Prabang. The aim is to make the river passable for 500-ton cargo vessels.

A second phase, starting in 2020, includes navigational improvements over a distance of 259 kilometers, as well as the construction of cargo and passenger ports.

In 2015 an estimated 3,500 commercial ships, largely between 100 and 300 tons, were making the journey bringing goods to Thailand.

On **31 March 2016** The Mekong River Commission (MRC) has welcomed the First Lancang-Mekong Cooperation (LMC) Leaders' Meeting as an important new initiative for regional cooperation. Leaders of China, Myanmar, Lao PDR, Thailand, Cambodia and Viet Nam – the MRC's four member countries and its official dialogue partners – following the meeting in Sanya, a city of China's Hainan Island, for the first time to discuss regional cooperation for sustainable development of the basin along the Mekong River, which is called in China the Lancang River.

Earlier, at the First LMC Ministerial Meeting in November 2015, the Foreign Ministers of the six LMC countries formally endorsed the LMC Concept Paper and launched the Framework. In their Joint Press Communique they stated that "LMC will adhere to the spirit of openness and inclusiveness and complement and work in tandem with other sub-regional frameworks such as the Greater Mekong Subregion (GMS) Economic Cooperation Program, ASEAN Mekong Basin Development Cooperation (AMBDC) and the Mekong River Commission (MRC) to jointly promote regional integration process.

The Phnom Penh Declaration: The second Lancang-Mekong Cooperation Meeting (MLC) was organized on 10 January 2018 in Phnom Penh under the theme "Our River of Peace and Development" and to chart the future course of the MLC into the next decade. The Declaration covers four areas: (i) Political and Security Cooperation; (ii) Economic and Sustainable Development; (iii) Social, Cultural and People to People Exchanges; (iv) and Cooperation Support.

5. Conclusion and Recommendation

Up until the Year 2000s Flood, MRC flood management activities were essentially limited to the provision of mainstream flood forecasts along the Mekong River. A comprehensive Flood Risk Management and Mitigation Strategy and Programme were adopted in 2001 and implemented in 2004 (2004-2010) followed by the (2011-2015) Programme. Significant basin information tools and capacity supporting flood risk management and mitigation have been produced to support scientific evidence based for national spatial planning, including transboundary flood management at the MRC Secretariat and FMMP Center.

However the absorption capacity at national level particularly in Cambodia is extremely low affected by the riparianization of the MRC Programme related activities and insufficient awareness on inter-sectoral planning integration aiming for long term vision based on scientific evidence versus short term economic gains.

The tremendous amount of information and knowledge has not been effectively used and build in the national planning capacity of specialized agencies through normal capacity building through projects implementation. As previously reported scientific communities were not always parts of the consultative process or play any important advisory roles in water sector development planning particularly in flood management and mitigation.

To keep momentum and assure continuity of accumulated knowledge and resources the best ways is to provide greater roles of university namely ITC and the CDRI that are the only institutions with capacity to operate, maintain, disseminate and accumulate knowledge as basis for national planning and furthermore as national honest broker.

The Integrated Flood Risk Management Planning (IFRMP) has started with the FMMP-C2, the zone C4 and zone C7 in Cambodia and zone V1, V2 and V3 in Vietnam where detail flood damage data at district level have been collected supplemented with additional data collected for the Council Study. Additionally the M-IWRM Mekong Delta Water Resources Management Project significantly contributes to the MRC transboundary cooperation strengthening.

As discussed in the Task 1C- and the Council Studies report on the continuous trend of losing flood conveyance and storage capacity would further increase flood risk in the Mekong Delta in addition to the loss of sediment supply from upstream and CC would be enormous challenges for the population in the areas while the services provided by the floodplain is continuously degrading. Integrated Flood Risk Management and the IWRM must be planned for the remaining flood zone in the floodplain. There is a need for a systematic scientific basic data ranging from detail hydrological and hydraulic, topographic to socio economic and flood damage data at district and flood zone level. IFRMP and IWRM need to be integrated into the Commune, district development plans.

MRC rules and procedures faced implementation difficulties due to incomplete basin integration. It is expected that the recent initiative on Mekong-Lancang Cooperation could significantly contribute to the acceleration and strengthening of the procedures with additional technical and financial participation from upper countries.

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