Annual Mekong Flood Report 2011

Flood Management and Mitigation Programme

Mekong River Commission

Cambodia · Lao PDR · Thailand · Viet nam
For sustainable development

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Lesson Learnt since the Year 2000 Flood

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1. SYNOPSIS

This Annual Mekong Flood Report (AMFR) follows the established pattern since 2007 that is a review of the year's flood conditions within the Lower Mekong Basin (LMB), supplemented by an Annual Theme. The "Theme" of this Report is "What lessons have been learnt since the extreme events of 2000, given the exceptional flooding during the course of 2011?" The text considers a comparative assessment of the damage and losses during each of the two years, the flood management and mitigation initiatives adopted since 2000, supplementary flood risk management options, the roles and responsibilities in each country and so on.

The principal development has been to devolve responsibility from the national level to the provincial and village level through education and investment, though the latter needs far more financial support. The positive, is that these short comings are appreciated and that such organizational challenges need to be addressed.

The flood events of 2011 illustrated quite clearly that flood management and mitigation in the LMB requires considerable levels of investment in data management, effective forecasting and the systematic improvement of public awareness to the risks. It is not known how many people or what proportion of the regional population is exposed directly to the dangers linked both to the annual flood on the Mekong mainstream and to flash floods in the tributary uplands. The numbers though are significant and probably increasing.

The magnitude of damage and loss reported here, during what was a relatively common situation, is far beyond a local or regional issue. The damage to the national riparian economies, not only in terms of economic loss, but probably more significantly in terms of replacement costs, is a constraint on national economic growth.

Even though this Report is addressing flood management and mitigation in the LMB, it is relevant to mention that severe flooding occurred during the 2011 monsoon season in Thailand. Beginning at the end of July triggered by the landfall of Tropical Storm NOCK-TEN, flooding soon spread through the provinces of Northern, Northeastern and Central Thailand along the Mekong and Chao Phraya river basins. In October floodwaters reached the mouth of the Chao Phraya and inundated parts of the capital city of Bangkok. Flooding persisted in some areas until mid-January 2012.

2. WHAT HAS BEEN LEARNT SINCE THE EVENTS OF 2000?

2.1 Flood damage and losses – 2000 and 2011 compared

The flood conditions that prevailed in 2000, particularly over the Cambodian floodplain and the Mekong Delta, are generally acknowledged to have caused the greatest levels of total damage and loss documented since systematic assessments began in the 1980's. The 2000 floods affected all four countries in the Mekong River Basin - Cambodia, Lao PDR, Thailand and Viet Nam. According to the Mekong River Commission, however, Cambodia suffered the most severe effects of the floods with 43% of the total number of deaths recorded and 40% of the estimated damage.

The Royal Government of Cambodia (RGC) stated that the 2000 floods were the worst in more than 70 years and caused damage to infrastructure and livestock, population displacement, food shortages and disease. A report, compiled by the National Committee for Disaster Management (NCDM) in November 2000, put the death toll at 347 (80 percent of whom were children). Of the 750 600 households affected, comprising almost 3.5 million people, equivalent to over 25% of the national population, about 85 000 families had to be temporarily evacuated from their homes to safe areas.

Other statistics released by the RGC indicated that the agricultural and infrastructure losses were:-

- Rice crop destroyed 374 100 ha
- Other crops destroyed 47 460 ha
- 988 schools affected (7 000 classrooms damaged)
- 158 health centers and hospitals damaged
- Almost 318 000 houses were damaged
- Over 7 000 houses destroyed.

Based on the NCDM report, the Council of Ministers estimated the total physical and direct damage at US$ 157-161 million.

In the Delta in Vietnam there were a reported 319 fatalities of whom almost 240 were children. Severe flash flooding across the Khorat Plateau in NE Thailand caused 25 deaths and in the Northern and Eastern Highlands of Lao PDR 15. In the Delta total economic losses were estimated to have been US$ 125.5 million.

The public health situation following the floods was precarious. The overcrowded and unsanitary conditions in safe areas raised fears of major waterborne epidemics, such as cholera or acute diarrhea. The loss of life due to water borne disease was a major factor that explains why juveniles accounted for by far the greater proportion of the flood related fatalities. In the post-emergency phase therefore the focus was to be on preventative health activities; specifically water and sanitation, the prevention of flood associated diseases and health education to affected populations.

The estimation of flood damage and losses in economic terms is difficult, as it is with other geophysical hazards such as droughts and earthquakes. Different sources can reveal substantial disparities. In the overview that follows it are the relative figures that provide the focus of interest rather than the absolute values, which are drawn from a wide spectrum of MRC and other documents and reports. A key observation is that within the Lower Mekong Region as a whole damage and loss is fundamentally a rural issue. The major towns and cities, such as Vientiane, Phnom Penh and those in the Delta are protected by engineering works, whereas rural areas are not. As a consequence they are the most exposed, with agricultural damage and losses in terms of local domestic property, schools and clinics at the forefront.

The image below confirms this perspective. It shows the flood inundation local to Phnom Penh on 15th October 2011. The city itself is largely free from flooding but to the east and along the Bassac River there is widespread inundation.

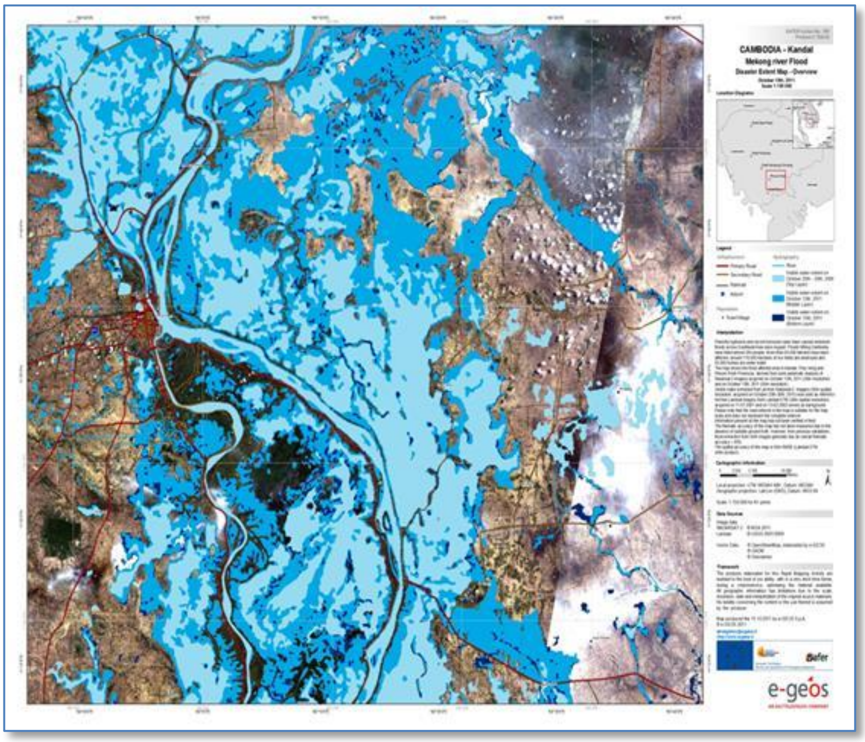


Figure 2-1 The flood situation local to Phnom Penh on 15th October 2011. The city itself is largely free from inundation, but the unprotected rural areas to the east and south reveal widespread flooding.

Table 2-1 2011 Flood – fatalities and damage within the Mekong Basin in each of the four riparian countries.

Country	Deaths	Property units affected	Property units damaged	Schools affected	Rice crop lost or damaged (ha)	Other crops lost or damaged (ha)
Cambodia	250	268 600	13 000	1 360	267 000	17 300
Lao PDR	42	-	82 500	250	77 000	-
Thailand	na	na	na	na	na	na
Viet Nam, Delta	89		176 000	1 260	250 000	-
Viet Nam, Mekong highlands	15		85 000	-	3 300	-

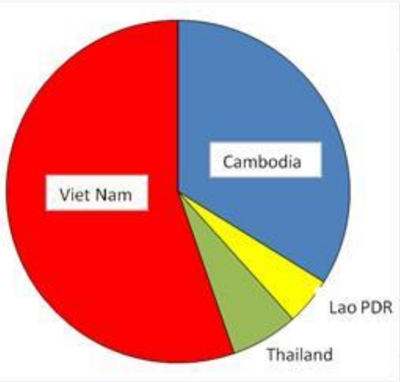
With these considerations in mind, Table 2-1 reveals the 2011 flood fatalities and damage that occurred in each of the riparian countries during 2011. The geography of the event, in that it was largely confined to areas downstream of the Se Kong, Se San and Srepok tributary system from which most of the flood water originated, means that Cambodia and the Delta suffered by far the most. Of the recorded fatalities 85% occurred here, with 63% in Cambodia alone. The damage estimates are dominated by losses in the same areas of the Basin. A comparison between the 2000 and 2011 floods (Table 2-2) shows a repeat of this pattern.

Table 2-2 Preliminary comparison of fatalities and economic damage between the 2000 and 2011 flood events in the Lower Mekong Basin.

Country	2000 Flood		2011 Flood	
	Fatalities	Economic damage (million US$)	Fatalities	Economic damage (million US$)
Cambodia	350	157 - 161	250	100 – 160
Lao PDR	15	30	42	22.6
Thailand	25	21	na	na
Viet Nam	320	125	104	260

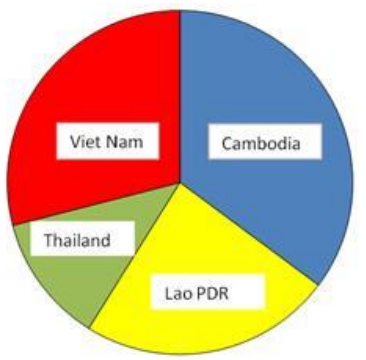
Figure 2-2 to Figure 2-4 bring together the history of flood fatalities and economic loss in the years between 2000 and 2011:

- In terms of fatalities over the 12 year period almost 90% occurred in Viet Nam and the Delta (Figure 2-3) while they also accounted for 64% of total regional economic damage and loss according to the estimates (Figure 2-4).
- Of the 2 210 regional fatalities over the same period, the floods of 2000, 2001 and 2011 accounted for 74%, with the 2000 figure the most significant. (Figure 2-5).



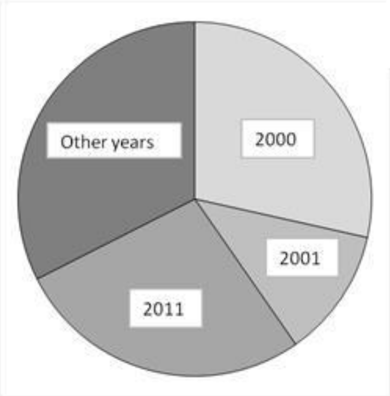
Country	Number	% total
Viet Nam	1 222	55
Cambodia	748	34
Thailand	140	6
Lao PDR	100	5
Total	2 210	100

Figure 2-2 Flood fatalities in the Lower Mekong Basin by riparian country – 2000 to 2011.



Country	Total losses Millions US$	% total
Viet Nam	513	29
Cambodia	622	35
Thailand	215	12
Lao PDR	419	24
Total	1 770	100

Figure 2-3 Flood damage (millions of US $) in the Lower Mekong Basin by riparian country – 2000 to 2011.



Year	Total losses Millions US$	% total
2000	517	29
2001	215	12
2011	493	27
2002 - 2010	589	32
Total	1 814	100

Figure 2-4 Flood damage (millions of US$) in the Lower Mekong Basin by year – 2000 to 2011.

Of damage and loss over the 12 years, 68% was accounted for in the same three years (Figure 3-1).

These results clearly reveal the vulnerability of the Cambodian floodplain and the Mekong Delta to the regional flood hazard and its impacts. The reasons are largely demographic. Here are the highest regional population densities, attracted in the main by the agricultural potential of the floodplain and deltaic soils. This is not to say that floods and flooding in NE Thailand and Lao PDR are inconsequential in comparative terms. It is simply that the scale of impacts is much less. A distinction could me made here:-

- Floods and flooding over the greater part of the Cambodian floodplain and the Mekong Delta are the result of hydrological factors in the form of critically high water levels in the Mekong mainstream.
- Over the greater part of Lao PDR and the Thai Mekong region, remote from the Mekong itself, floods and flooding are the result of meteorological conditions resulting in more local flash flooding and storm induced inundation when drainage infrastructure cannot cope.

In other words meteorological factors are either direct or indirect. Tropical depressions and typhoons cause high water levels in the Mekong resulting in flooding. Or extreme storm rainfall is the primary cause of flooding elsewhere. In effect the direct cause of floods is either hydrological or meteorological.

Upstream of the Cambodian floodplain in Lao PDR and Thailand there are areas adjacent to the mainstream that are susceptible to overbank flooding but these are nowhere near as extensive as those further downstream. One of the principal effects that exacerbates the extent of flooding in these upstream zones is that high water levels in the mainstream causes significant backwater effects in the large left bank tributaries in Lao and in the Mun-Chi Basin in Thailand, thus extending the flooding laterally.

In summary, Table 2-4 indicates the average annual flood loss by country, which confirms the vulnerability of the Cambodian floodplain and Delta, which together account for over 70% of the regional economic losses from year to year.

Table 2-3 Average annual flood loss and damage in the Lower Mekong Basin by country (Source, MRC, 2012).

Country	Average annual flood loss Millions US$
Viet Nam	25
Cambodia	18
Lao PDR	11
Thailand	7
Total	**61**

2.2 Flood Management and Mitigation Initiatives since the events of 2000 - Options

There are five principal flood risk management measures (see also FMMP 2011-2015 Programme Document, Volume 2, para. 2.2: The IFRM Process) that can be implemented, only one of which is structural in nature:

Structural Works The aim of structural works, which include flood protection dikes, flood control reservoirs, sacrificial flood basins, river improvements, etc., is to protect existing and future development from flooding, i.e. to '*keep the water away from the people*'. It is generally impossible to provide total protection against flooding, but structural works can reduce the likelihood of flooding and the associated existing and future flood risks. Flood protection embankments are commonly used in the four riparian countries, more so in the Delta than elsewhere. Large multi-purpose dams attenuate major floods, but those planned and under construction in the Lower Mekong Basin for hydropower generation are unlikely to incorporate any operational flood control policy for mitigation purposes.

Land-use Controls. Floodplain zoning is aimed at '*keeping people away from the water*', i.e. attempting to ensure that land-use is appropriate to flood hazard and that flood-sensitive land use are encouraged to relocate to less hazardous areas of the floodplain. Land-use controls can limit flood risk exposure to community infrastructure, assets and the population at risk and are the most cost-effective means of reducing exposure to future flood risk. However, land-use controls will be of limited effectiveness in the Lower Mekong because of unrelenting and increasing population pressures across flood-prone areas of the basin.

Development and Building Controls Along with regional and community flood emergency planning, development and building controls recognize that flooding cannot be eliminated and aim '*to minimize flood damage to infrastructure and assets' by 'flood proofing*', so reducing residual flood risk by enabling the ready return to use of infrastructure and assets in the aftermath of a flood. Infrastructure damage is a significant component of total flood damage in Cambodia and the Delta and to a lesser extent elsewhere in the LMB. To date, little consideration appears to have been given to reducing losses by flood proofing, although for some years now Viet Nam has had a programme of constructing flood-proof houses in the Delta.

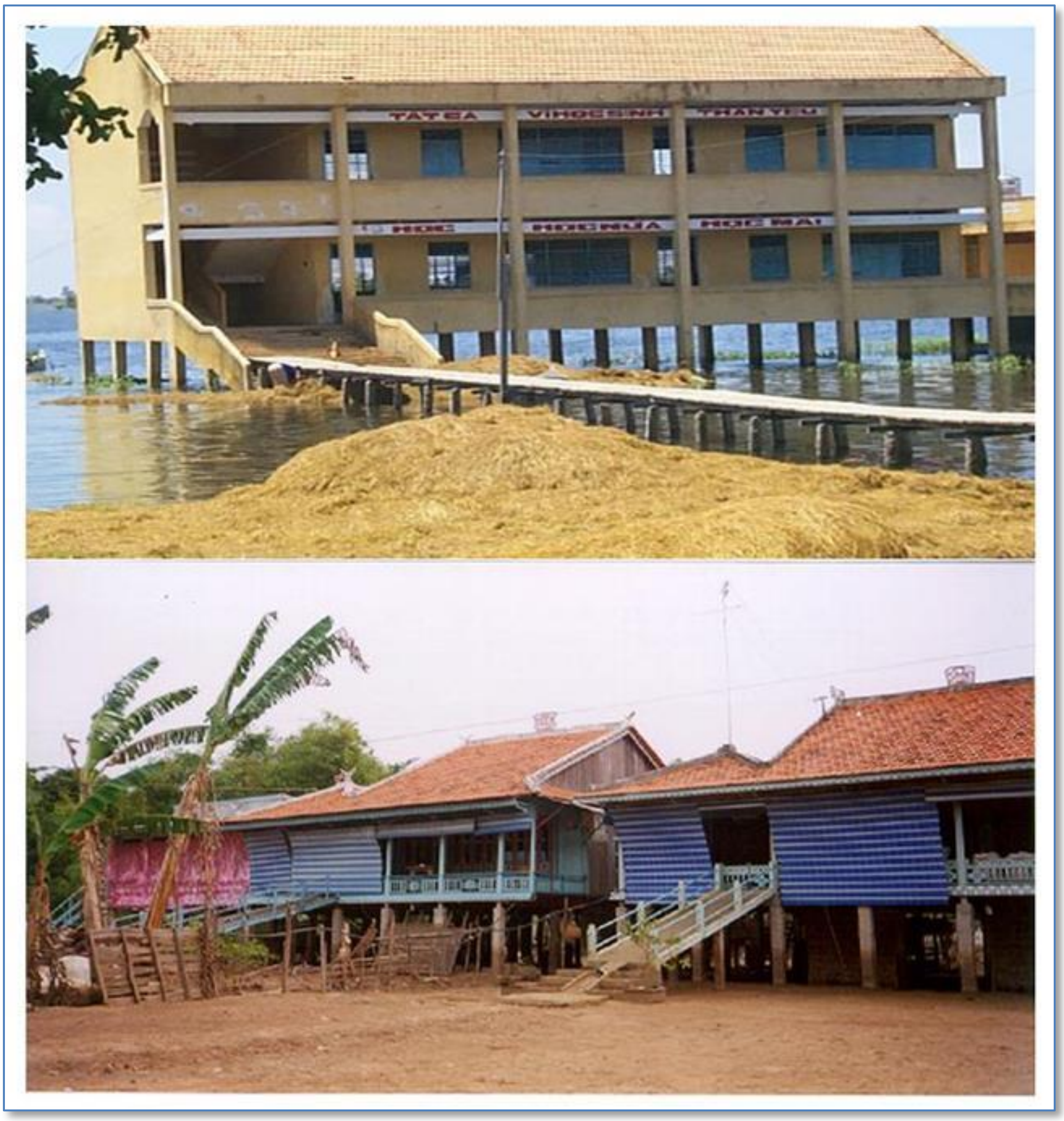


Figure 2-5 Flood "proofing' in the Viet Nam Delta – school (top) and domestic property (bottom) raised on concrete columns.

Regional Flood Emergency Planning The provision of regional flood emergency services, typically by State agencies, is aimed at assisting flood-prone communities better prepare for, respond to, endure, and recover from floods, i.e. reducing residual flood risk. To this end, Regional Preparedness, Response, Relief and Recovery Plans (PRRR Plans) are developed. These activities are aimed at reducing community vulnerability by assisting flood-prone communities to better '*live with floods*'. Post 2000, there has been a change of focus in regional flood emergency planning activities from response and relief activities to supporting community-based activities aimed at flood preparedness and vulnerability reduction.

Community Flood Emergency Planning In this case, flood-prone communities are encouraged to accept responsibility for their own community flood risk and to develop Community Flood Preparedness, Response, Relief and Recovery Plans to reduce flood impacts. Again, these activities are aimed, in the most direct sense, at reducing residual flood risk and community vulnerability. Today's community-based flood risk management activities place increasing emphasis on flood preparedness and vulnerability reduction.

2.3 Supplementary Flood Risk Management Measures

The four supplementary flood risk management measures are described below. All of these measures are 'non-structural' in nature; forecasting and warning are commonly regarded as principal flood risk management measures in their own right, although they are better regarded as part of a regional and community-based flood emergency response.

Integrated Land-Use Planning is necessary to define land-use controls for flood-prone areas. Along with flood risk, the integrated land-use planning process needs to embrace other factors affecting land-use, such as the socio-economic needs of the community, together with ecologically sustainable development and natural resource management considerations.

Flood Simulation Modeling via mathematical models provides an understanding of flood processes across the area of interest, e.g. the extent, depth and velocity of floodwaters across the floodplain, the rates of rise and fall of floodwaters and duration of flooding, and so enables flood risk and hazard to be assessed quantitatively. Flood simulation models can be quite complex. The MRC has developed hydrologic and hydraulic computer models to simulate flood flows along the mainstream river reaches of Lao PDR and Thailand and across the Cambodian Lowlands and the Delta.

Flood Forecasting allows the future behaviour of an actual flood event to be simulated (predicted) analysed and used for warning purposes. Typically, mathematical models are used to generate flood forecasts. In recent years, MRC's Flood management and Mitigation Programme (FMMP) has developed a mainstream forecasting model for the river reaches and Lower floodplains and a 'Flash Flood Guidance System' to assist in the provision of 'flash flood alerts' along tributaries (See Section 6.1b)

Flood Warning is an essential component of regional and community-based flood emergency response plans. Ideally, flood warnings should be accurate and delivered in a timely fashion to those at risk, who should know how to respond appropriately and reduce their vulnerability.

2.4 The need for Integrated Flood Risk Management (IFRM) Measures

There is a widely perceived need for all nine flood risk management measures to be integrated to provide a coherent overall regional policy to be implemented by all of the relevant agencies that have a role to play. Land-use planning and social policy play key roles in IFRM. Not only does flood risk have to be taken into account in determining appropriate land-use across flood-prone areas, but also community needs, environmentally sustainable development considerations, natural resource management considerations and river basin management consideration need to be assimilated.

Integrated flood risk management aims to reduce the human and socio-economic losses caused by flooding while taking into account the social, economic and ecological benefits from floods and the use of floodplains. In regions such as the Lower Mekong Basin IFRM should be considered to be a fundamental element of regional planning and governance.

Flood risk management policy is based on considerations of flood risk management measures, roles and responsibilities of government agencies and departments. As particularly flash floods affect the local communities in rural and remote areas, the resilience of local communities against the negative effects of flash floods is a relevant issue to deal with. One flood risk management measure is to enhance the resilience level of local communities through a cycle of systematic actions:

- Preparedness,
- Response,
- Relief,
- Recovery, and
- Reassessment of the management system and policy strategies

Informal technical cooperation provides various benefits and is, in most cases, ahead of more formal institutional and political cooperation. This is certainly the case in the Lower Mekong. In the long run, however, both technical and institutional/political cooperation are required, particularly in multinational river basins. Political support is needed to make technical cooperation sustainable, long-term and effective in the field of trans-boundary water management. In many cases, it is not the technical capacity that is missing – i.e. for flood forecasting, early warning and the identification of effective mitigation measures – but rather the institutionalization of trans-boundary flood risk management through bilateral and multilateral agreements and continued cooperation. Such a holistic approach therefore needs to integrate both land and water resources management. Cooperation usually starts as a first step at the more technical level: through joint flood forecasting, flood warning and exchange of data. The MRC through the Flood Management and Mitigation Programme has been, since 2004, the primary regional instrument aspiring to bring about this holistic approach to regional flood mitigation through the development of technical advances, pilot projects and institutional strengthening.

2.5 Roles and Responsibilities

The management of flood risk in the Lower Mekong Basin is the statutory responsibility of the four riparian governments, each of which has different priorities and differing capabilities regarding the provision of flood risk management services. A number of different agencies and programmes provide resources and assistance to the flood risk management activities of the countries.

- **Lao PDR.** The National Disaster Management Office (NDMO) is the main government agency to implement disaster management programmes. This is supported the National Disaster Management Committee (NDMC) established in 1999. The NDMC consists of representatives from 13 key ministries.
- **Thailand.** At the center of the roles and responsibilities in Thailand is the National Water Resources Committee. It is a national-level organization established under the Office of Prime Minister. The committee is chaired by the Prime Minister and consists of members who are appointed by the Prime Minister. River Basin Committee s comprises members selected from government officials, state enterprise representatives, representatives of local organizations and water uses organizations, stakeholders who work or live in the concerned river basin, and qualified person who have knowledge and experience relating to water resources management. From the flood events, there are aids from many institutes such as The Rajaprajanugroh Foundation under Royal Patronage, The Thai Red Cross Society, Department of Disaster Prevention and Mitigation, Thailand Local Administration Network, Royal Irrigation Department, Royal Thai Army, and Department of Water Resources.
- **Cambodia:** The National Committee for Disaster Management (NCDM) which was establishes in 1995 is responsible for providing timely and effective emergency relief to the victims of all kind of disasters and also required to develop preventive measures to protect or reduce the effect of the disasters. The NCDM currently has evolved from top down at the national level to commune level and from early 2007 this network even has taken the role of the Cambodian Red Cross in terms of warning and dissemination of flood information at the provincial level.
- **Viet Nam:** The Government of Vietnam has implemented a National Strategy for Natural Disaster Prevention, Response and Mitigation for the whole

country, which has paid particular attention to the Mekong Delta through a Flood Management and Mitigation Programme. This reflects the key importance of the Delta’s resources and agricultural productivity to the national economy. A wide spectrum of ministries, line agencies and centers of academic expertise are co-opted to provide a hierarchical.

Many international donors finance flood risk management programmes and projects (e.g. ADB, WB, UNISDR, GWP and ASEAN); numerous NGOs also provide flood preparation, response, relief and recovery assistance along with capacity building, typically at the community level. The Mekong River Commission (MRC) has a basin-wide role in flood management though its Flood Mitigation and Management Programme (FMMP 2004-2010), which is described below. Improved coordination and integration of the various flood risk management initiatives would lift the overall effectiveness of individual efforts to reduce flood risk.

2.6 The evolution of flood management and mitigation policies in the Lower Mekong Basin since the events of 2000

The flood of 2000 was considered to be the most devastating in more than 70 years, given the scale of the fatalities and the magnitude of the damage and economic losses. It was followed by severe flooding again in 2001. These events prompted a review of flood management and mitigation measures and the technical and operational improvements that would need to be put in place if vulnerability were to be reduced and resilience increased. As far as is known, however, no formal reviews were published by any of the riparian countries but at the political level it was recognized that the emphasis of national policies needed to change from relief response to protection and mitigation.

It could be argued that the 2000 flood occurred within a hydrological knowledge vacuum in so far as the necessary quantitative knowledge of the potential incidence and severity of flooding was inadequate. In other words the necessary formal evaluations of risk, a key element within the overall framework necessary for policy development, had not been undertaken to the required level.

It was also acknowledged that the various components required for integrated flood management and mitigation had not been drawn together in any systematic regional policy formulation. These elements including possible structural measures, flood proofing, trans-boundary cooperation, flood emergency management strategies and land management needed to be assimilated into an overall regional strategy. This was also a perceived need for training and institutional strengthening.

The instrument required to realize these objectives was recognized early on by the international donor community. This was to be formulated as the Food Management and Mitigation Programme within the MRC and began in 2004, with Phase 1 lasting until 2010.

2.7 The formulation of the Flood Management and Mitigation Programme (FMMP) within the Mekong River Commission (MRC) in 2004

The formulation of the FMMP in 2004 was a key response to the events of 2000. The MRC was recognized as having a fundamental role to play in flood risk management in the Lower Mekong. According to Article 1 of the 1995 Mekong Agreement, 'Areas of Cooperation', 'flood control' is listed as one of the activities to be managed for the '*mutual benefits of all riparian and to minimize the harmful effects that might result from natural occurrences and man-made activities*' (MRC, 1995). Thus, 'natural' flood risk and any 'man-made' activities that affect flood risk fall within the MRC's ambit of cooperation. However, MRC's role is limited to (MRC, 2001):

(i) The provision of technical products and services to the four countries;
(ii) Facilitating the resolution of trans-boundary flood issues; and
(iii) Capacity building and technology transfer.

The MRC *has no mandate to physically manage flood risk* in the LMB; it can only assist the riparian countries to do so. Capacity building was deemed to be an important and common element of all components, of which there are five, as detailed in Table 2-4.

To date, the FMM Programme has spent some USD 27 Million on the better management of flood risk in the Lower Mekong. The key achievements of Phase 1 to 2010 include:

- The establishment of a purpose-built regional flood management and mitigation center (RFMMC) at Phnom Penh in Cambodia (Component C1). This center will become the 'Office of the Secretariat, Phnom Penh' (OSP) and can continue serve as a regional focus for future basin-wide flood risk (and possibly drought risk) management initiatives.
- The development of improved mainstream flood forecasting procedures of world-class standard (Component C1), of which the .constituents are :-

    1) The new mainstream flood forecasting system uses the 'Flood Early Warning System' computer platform to manage hydro-meteorological data, flood simulation models and flood forecasts (Delft-FEWS, 2009).

2) A hydrologic rainfall-runoff model (URBS) is used to forecast tributary discharges and mainstream flood behaviour along the mainstream river reaches of Lao PDR and Thailand (URBS, 2009).
3) Currently (early 2011), a multi-channel one-dimensional hydraulic model (ISIS) is being tested for use in forecasting flood discharges, water levels and velocities over the Cambodian Lowlands and Cuu Long Delta (Wallingford, 2009). This model runs from Kratie to the East Sea and includes the Great Lake and all tributaries draining this portion of the basin.
4) One-day and 7-day basin-wide forecast rainfalls generated by a climate model on a 40 km x 40 km spatial grid are used to make flood forecasts (NWS, 2009d).
5) During the flood season, RFMMC provides 1-day and 5-day water level forecasts at 22 locations along the mainstream of the Mekong and Bassac Rivers, and 1-day and 7-day estimates during the dry season.
6) A ‘Flash Flood Guidance System’ that assesses the likelihood of flash flooding in tributaries has been installed at the RFMMC for testing (HRC, 2009) and is now operational. This system (MRC-FFG) uses satellite estimates of soil moisture and 6-hour forecast rainfalls (NWS, 2009b; NWS, 2009d) to estimate the likely depth and rate of surface runoff, and hence the likelihood of flash flooding.

Table 2-4 Details of MRC's Flood Management and Mitigation Programmeme 2004-2010.

Programme Component	Key Activities
C1. Establishment of a Regional Flood Management and Mitigation Centre	Establish a regional center in Phnom Penh. Improve mainstream and tributary flood forecasts, including flood forecasting models, and the collection and handling of hydro-meteorological data.
C2. Structural Measures and Flood proofing.	Develop and demonstrate a comprehensive set of best practice guidelines for the design, construction, maintenance and impact assessment of structural flood mitigation measures, and for the flood proofing of infrastructure and buildings.
C3. Enhancing Cooperation in Addressing Trans-boundary Flood Issues.	Demonstrate the use of flood simulation models to assist in the understanding and resolution of trans-boundary flood issues
C4. Strengthening Flood Emergency Management.	Improve flood emergency planning at the community and local government levels. Foster inter-provincial and inter-country assistance in flood emergencies.
C5. Land Management	Assess local flood characteristics and incorporate the associated flood hazard into land-use decision making by communities and local government.

- Components C2, C3, C4 and C5 have all delivered a number of successful pilot projects that demonstrate the principles and application of individual flood risk management measures.
- All five components have managed to engage with counterpart agencies in the four countries and have delivered intensive capacity building.

Four supplementary flood risk management measures have also been developed. All of these measures are 'non-structural' in nature; forecasting and warning are commonly regarded as principal flood risk management measures in their own right, although they are better regarded as part of regional and community-based flood emergency response.

Integrated Land-Use Planning is necessary to define land-use controls for flood-prone areas. Along with flood risk, the integrated land-use planning process needs to embrace other factors affecting land-use, such as the socio-economic needs of the community, together with ecologically sustainable development and natural resource management considerations.

Flood Simulation Modeling via mathematical models provides an understanding of flood behaviour across the area of interest, e.g. the extent, depth and velocity of floodwaters across the floodplain, the rates of rise and fall of floodwaters and duration of flooding, and so enables flood risk and hazard to be assessed quantitatively. Flood simulation models can be quite complex. The MRC has developed hydrologic and hydraulic computer models to simulate flood flows along the mainstream river reaches of Lao PDR and Thailand and across the Cambodian Lowlands and the Cuu Long Delta.

Flood Forecasting allows the future behaviour of an actual flood event to be simulated (predicted) analysed and used for warning purposes. Typically, mathematical models are used to generate flood forecasts. In recent years the FMMP has developed a mainstream forecasting model for the river reaches and Lower floodplains and a 'Flash Flood Guidance System' to assist in the provision of 'flash flood alerts' along tributaries.

Flood Warning is an essential component of regional and community-based flood emergency response plans. Ideally, flood warnings should be accurate and delivered in a timely fashion to those at risk, who should know how to respond appropriately and reduce their vulnerability.

All components of FMMP 2004-2011 are complete. The programme itself has been reviewed and its extension into a second phase has been recommended along the following lines:-

1) Consolidation and improvement of key functions at the RFMMC (the provision of flood forecasts and warning information for mainstream and flash floods) and possible expansion of these functions to include tributary forecasting, drought assessment and possibly drought forecasting, and an assessment of the impact of climate change on flood and drought behaviour;

2) Continuing to assist member countries resolve trans-boundary flood risk issues through the provision of technical, socio-economic and administrative tools and analyses;

3) Provision of capacity building and training;

4) Assisting member countries through the development, dissemination and support of flood risk management products; and

5) Assisting member countries understand and implement Integrated Flood Risk Management (IFRM) principles in their land use and other planning processes.

2.8 Outstanding issues to be addressed by the FMMP

Although the FMMP provides the regional focus for flood management, the development of policy and technical expertise, the donor review at the end of Phase 1 raised some important issues:

- The review found that many of the flood risk management 'products' produced and demonstrated by the five components had not been taken up with full effectiveness by the four member countries. To some extent, this reflects the reactive nature of the design of FMMP.
- The reactive nature of the Programme (in response to the Year 2000 Floods), coupled with the need for donors to fund individual components that met their development goals, meant that the integration of the various components into a comprehensive flood risk management framework (see Section 6.1b) was not as strong as it could have been.

FMMP 2011-2015

The follow-on Flood Management and Mitigation Programme 2011-2015 is based on the experiences of the period 2004-2010 and complemented with re-assessed needs expressed by the MRC member countries. The programme is no longer structured in Components, but along Outcomes; the FMMP 2011-2015 has 5 Outcomes and 15 Outputs.

Outcome 1: Member Countries strengthen their Basin Planning and Strategy, their national policies, (long-term) strategies and planning processes by incorporating IFRM principles.

Outcome 2: Operational basin-wide flood forecasting, impact assessment, modeling, monitoring and knowledge management (and drought monitoring and forecasting1).

Outcome 3: Efficient dialogue and coordination among Member Countries and Dialogue Partners in addressing transboundary (TB) flood issues.

Outcome 4: Awareness raised, capacities and skills developed at level of relevant National Line Agencies and NMCs to apply IFRM knowledge

Outcome 5: Transition to a financially sustainable and professionally capable RFMMC initiated.

[1] services offered by FMMP to DMP

Apart from the further development of the MRC “key” river basin functions of flood forecasting and early warning, the FMMP is presently systemizing climate change into short term flood forecasting and medium and long term flood simulation modeling. The latter has generated a structure of tied cooperation with especially the Climate Change and Adaptation Initiative (CCAI) and the Information Knowledge Management Programme (IKMP), but also with the Drought Management Programme (DMP), the Basin Development Planning Programme and the Mekong Integrated Water Resources Management Project.

2.9 Towards community based flood risk management

A major lesson learnt post 2000 is that flood-prone communities should be encouraged to accept responsibility for their own community flood risk and to develop Community Flood Preparedness, Response, Relief and Recovery Plans to reduce flood impacts. These activities are aimed, in the most direct sense, at reducing residual flood risk and community vulnerability. Current community-based flood risk management activities place increasing emphasis on flood preparedness and vulnerability reduction. This programme involves the resettlement of communities most exposed to flood and landslide risks. Flood-proofing is achieved by the protection of new settlements with flood embankments or by constructing new settlements on flood-free raised earth platforms. The new settlements are supplied with water and electric power. Over the period 2001-2008, the Government of Viet Nam constructed nearly 100 000 new flood-proof houses, and the programme has been extended to construct another 55 000 houses. This effort will largely eliminate the hazard and social impact of flooding in the new settlements, but not the risk to agricultural crops.

2.10 Flood embankments and “hard” engineering solutions

One of the lessons realized in 2000 is that large scale “hard’ engineering solutions to reduce the risk of flood inundation is not really a practical option, bearing in mind that at the time the peak and volume of flow entering the Cambodian floodplain and delta as recorded at Kratie were 56 000 cumecs and 480 km^3 respectively, which are huge figures linked to the vast investments required.

The use of flood protection embankments is a common means of managing flood risk around the world. However, the construction of embankments may lead to a progressive loss in natural floodplain storage, the redirection of flood flows, and an increase in flood levels at other locations. The redirection of flood flows can alter the flooding and drainage behaviour of wetlands and interfere with fish spawning cycles and habitat. Thus, the impact of proposed flood protection embankments on flood behaviour and the environment need to be assessed carefully.

The effects of constructing a 150-km long flood protection embankment to reduce flooding in the Eastern area of the Cambodian Lowlands was investigated by the MRC in 2007. The proposed embankment ran along the Eastern bank of the Mekong River from Kampong Cham (about midway between Phnom Penh and Kratie) to Neak Luong (to the North of Tan Chau). It terms of its impact on Year 2000 Flood behaviour, modeling studies revealed that in the protected area, flood levels were reduced by 2 m or more and the duration of flooding was reduced by 2 months. However, these benefits were offset by increased flood levels elsewhere (an increase of 1 m at Kampong Cham and 0.5 m in the Great Lake). Thus, the proposed embankment would have both positive and negative impacts and cause significant changes to flooding behaviour, especially to the Great Lake, with associated environmental, fishery and social consequences. All these aspects need to be assessed in detail and considered before deciding on whether to construct such a project.

Further upstream flood protection works do become a viable option as the new infrastructure for the protection of Vientiane illustrates. Other solutions, such as flood retention ponds are not really an option, except perhaps locally, since the volumes of flood flow are huge.

2.11 National flood management and disaster risk mitigation policies, strategies and plans

The Mekong region and the Mekong water issues are very complex. Each of the four LMB countries is currently dependent on the resource in different ways and to different degrees. Each country perceives its future water-related opportunities and risks in a very different way. Arguably, Cambodia and the Delta are potentially the most at risk in the case of unsustainable management of the river elsewhere.

The four countries are all engaged in flood management and flood mitigation through their line agencies and disaster management organizations at the different levels of government. Each one has its legal frameworks, has dedicated national policies and strategies on disaster management and mitigation. However, they are clearly at different levels of development; have different realities in data collection and processing systems and different capacities to deal with floods; hydrological and meteorological services are at different stages of development, flood forecasting tools are different, there are different procedures and capabilities for flood warning, in flood preparedness and emergency management.

Awareness of flood risk assessment and management is different and the embedding of flood risk management principles in the various planning processes varies greatly. Communication between the different sectors at different levels of government varies in structure and effectiveness.

Cambodia

In 2002: Royal Cambodian Government issued Decree No 2 02/040 on the establishment of the National Council for Disaster Management (NCDM). In 2009 the Government launched the strategic National Action Plan for Disaster Risk Reduction. The current Disaster Management Law has been drafted and is under review by the Ministry of the Interior. In general, the principles of IFRM have been adopted as the main concept for flood risk management. However the main constraints for implementing IFRM are still: (i) inadequate human resources and capacity (ii) lack of coordination among the concerned institutions, and (iii) the lack of financial resources to actually implement the various interventions that are required.

Lao PDR

The current Country Programme Action Plan (CPAP) includes the development of national and local capacities to better prepare for and respond to disasters and ultimately strengthen capacities for disaster risk management as a priority activity. The existing mechanisms for disaster management in the country are the National Disaster Management Committee (NDMC) and its secretariat, the National Disaster Management Office (NDMO), which have the responsibility to develop national and local capacities for disaster risk management.

Thailand

In 2002, Thailand established the Department of Disaster Prevention and Mitigation under the Ministry of the Interior. To minimize impacts by natural disasters, with special emphasis on floods, the Department of Water Resources initiated the Water Crisis Management Centre to provide flood information in river basins during periods of flood preparedness and crisis. The Center also acts as the coordinating mechanism among the various agencies concerned. Whilst quite advanced in the water sector, as compared to other Member Countries, Thailand's existing policies and strategies still lack the principles of IFRM in its policies.

Viet Nam

The National Strategy for Natural Disaster Prevention, Response and Mitigation to 2020 was promulgated in 2007. For the Mekong River Delta, a 'living with flood' approach has been adopted for natural disaster prevention, response and mitigation, ensuring safety for sustainable development; and taking initiatives to prevent storm, thunderstorm, whirlwind, salinity intrusion and drought at the same time. The water sector has no overall integrated strategy or action plan at the national and regional basin level while IFRM is not explicitly included in the national strategy.

A common thread here is that the National Disaster Agencies are generally under resourced both financially and technically and that formal cooperation between the various relevant ministries such as water resources, agriculture, environment and urban and rural planning is not as strongly developed as it should be.

If flood risk planning is to be effective, it is necessary for national riparian governments to formulate and implement such plans on an integrated and cross-sectoral basis. It is only in this way that an effective mix of flood risk management measures can be defined and the flood risk altering actions of different government and private sector agencies be assessed and coordinated. Similarly for the MRC, flood risk considerations need to be incorporated in and addressed across all the Commission's Programmes.

2.12 Lessons learnt by NGO's during 2000

Some interesting perspectives in respect of carrying out flood relief during 2000 were reported by the Cambodian Red Cross (CRC).

1. There were some Ministries who should have been included in the National Committee for Disaster Management (NCDM). They were the Ministry of Health and Ministry of Environment. The role of the Ministry of Health in preventing impacts to the health of the population and their important responsibility over emergency health was also stated as an important concern.
2. The draft National Disaster Management Policy was first written in 1997 and had undergone two additional revisions. However, the Policy had yet to be approved by the Government.
3. Because the Policy was not officially approved and not disseminated, the NCDM Secretariat was severely constrained to perform its mandate to take actions especially directed towards improved preparedness, response, relief and recovery.

The actions required as identified by the CRC included:

i. Provide recommendations to the (NCDM) regarding the declaration on an emergency in devastated areas at the national level as well as the declaration of an emergency by Governors at provincial/Municipal levels;

ii. ii. Develop guidelines on emergency preparedness, emergency operations, prevention and mitigation measures, and proposals for rehabilitation projects to be submitted to the NCDM for approval and implementation;

iii. iii. Co-ordinate efforts with institutions and organisations and the Cambodian Red Cross in order to enhance assistance in terms of evacuation, provision of a safe haven, security, establishing a public awareness programme with regard to disaster preparedness, and preparing other programmes;

The capacity of NCDM was emphasized at the time because this issue had significant impact to the perceived and actual role of the Cambodian Red Cross (CRC) in disaster management in the country. CRC, had thus worked in a situation where no government response plan existed and had in fact assumed the traditional leadership role in disaster management in Cambodia.

The obvious lesson here is that National Disaster Agencies need to be carefully prescribed, the legislation in place and clear and the roles and responsibilities stipulated.

3. THE 2011 FLOOD SEASON

3.1 Overview

The 2011 flood season is widely regarded as historically "extreme", largely as a consequence of the areal extent and depth of seasonal inundation across the Cambodian floodplain and the Delta in Viet Nam and the associated damage and loss incurred. Comparisons have been made with the most severe event since records began at Kratie in 1924 and which occurred in 2000. In fact the 2000 flood was far more extreme if the events are compared on the basis of their annual flood volumes. In both years the peak discharges were not much above average. The annual flood volume emerges as the variable that best describes the relative severity of conditions towards the floodplain and delta rather than the peak as observed at Kratie. On this basis the flood of 2011 ranks as the 7^{th} largest since 1960, considerably less than the magnitude of those observed during 2000, 2001 and 2002, both in terms of volume and peak.

Further upstream the peak discharge could be argued to assume increased importance. Overbank inundation of areas which would not usually be defined as natural floodplain occurs when critical flow thresholds are exceeded. Such conditions also result in increased backwater effects in the tributary channels thereby extending the flood impact upstream in these lateral channels. Floods on large river systems such as the Mekong should therefore be seen as multivariate events. That is they should be assessed in terms not only of the peak discharge (or water level), but also with regard to the volume of flow during the event and the duration of the event itself. This is the approach adopted here.

Flood conditions during 2011 once again served to reveal the systematic geographical variability of the annual flood regime observed along the Mekong mainstream between Chiang Saen in the north and Kratie in the south. It was only downstream of Vientiane that daily flows during the flood season were significantly above the average. At Chiang Sean for example the peak discharge during the year was just 56% of the mean annual maximum flow. The history of extreme flood conditions in the Mekong reveals they do not extend throughout the Lower Basin. This is a scale effect. The Basin is so large that the synoptic conditions that result in extreme rainfall and therefore severe flood conditions are confined either to that part of the system upstream or downstream of Vientiane. (See the 2006 Annual Flood Report for a detailed discussion). That is the flood conditions are generated either by outflows from China and the northern tributaries in Thailand and Laos or (principally) by the large left bank tributaries further downstream. During 2011 the latter situation prevailed.

Regionally, rainfall during the year was above average, but not to any significant or widespread degree, except perhaps during September. Or at least this is what the available data indicate. Even mapping the monthly rainfall totals between June and October based upon 125 gauge sites does not definitively describe the major areas of precipitation that caused the downstream flood conditions during the year. Defining a quantitative relationship between rainfall and runoff that could, for example, be used for the confident forecasting of the onset and magnitude of flood conditions has proved to be difficult.

The temporal aspects of the rainfall climate during the year are considered in terms of the onset and end of the SW Monsoon. Both dates were consistent with the long term average such that the duration of the monsoon was typical, extending from early May to October.

3.2 The onset of the SW Monsoon across East and South East Asia

It would be a reasonable assumption that the onset of the SW Monsoon across East and South East Asia proceeds from that direction towards the north east, where the average onset date would be somewhat later. In fact, this is not the case. As Figure 3-1 reveals the onset date spreads outwards from Burma and Indochina towards the Indian sub-continent in the west and towards southern China in the east. Average Monsoonal start dates vary from the first half of May in the center of the region to mid and late June in North West India / Pakistan and south China.

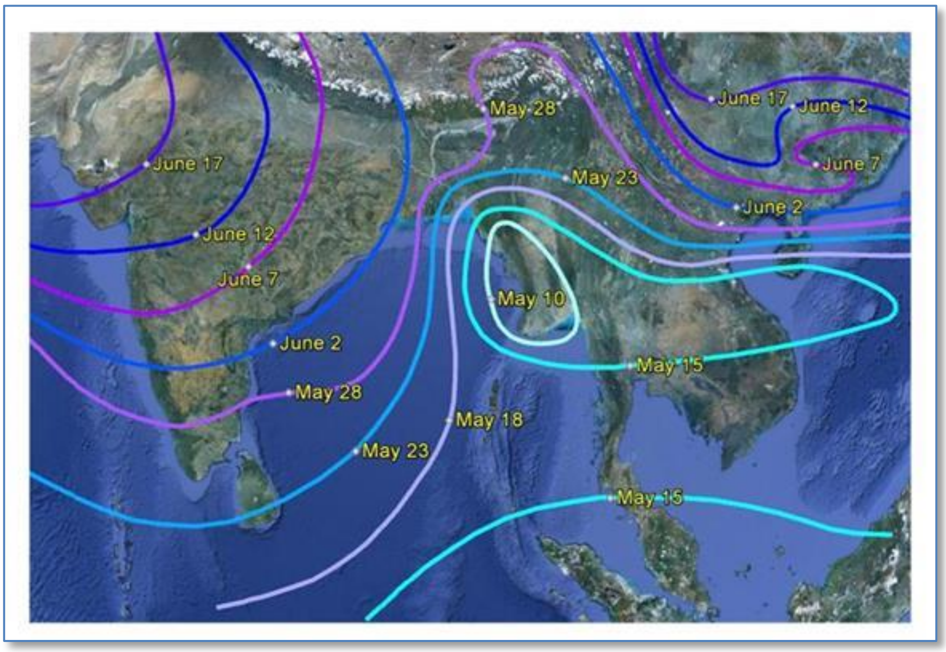


Figure 3-1 Average onset dates of the SW Monsoon across East and South East Asia. (Based on Clift and Plumb, 2008).

3.3 The temporal aspects of the SW Monsoon over the Lower Mekong Basin during 2011

The regional onset and end dates of the SW Monsoon are based upon definitions given in Khademul et al (2006). Details are provided in the 2007 Annual Flood Report. Within the Lower Mekong Basin there is almost no geographical variability in the two dates, with the exception of the far south where the withdrawal date is a month later than elsewhere, in mid November, probably a result of the early onset of the NE Monsoon, from which the rest of the Basin is protected by the Central Highlands.

The definitive feature on the monsoonal onset and end dates is their very low standard deviation. The dates typically lie within a very narrow "window", such that any significant deviation can have a considerable impact. For example, the monsoon of 2004 over the basin started several weeks later than usual and ended a month early. Other than having a major impact on agriculture, the flood season lasted for just 84 days, just 60% of its average duration. This resulted in much reduced rice yields and extensive saline intrusion in the Delta.

During 2011 the onset and end of the SW Monsoon coincided almost exactly with the long term average dates, as indicated for selected locations in Table 3-1.

Table 3-1 The onset and end of the 2011 SW Monsoon at selected sites in the Lower Mekong Basin.

Site	Monsoon onset				Monsoon end		
	Average Date	Standard Deviation	2011	Delay (days)	Average Date	Standard Deviation	2011
Chiang Saen	7th May	9 days	1st May	none	7th Nov	25 days	8th Nov
Luang Prabang	7th May	9 days	27th Apr	none	24th Oct	33 days	29th Oct
Vientiane	4th May	8 days	3rd May	none	10th Oct	16 days	2nd Oct
Mukdahan	6th May	8 days	18th May	12	8th Oct	16 days	14th Oct
Pakse	5th May	11 days	27th Apr	none	15th Oct	17 days	15th Oct
Tan Chau	18th May	12 days	8th May	none	18th Nov	13 days	27th Nov

3.4 The 2011 regional rainfall climate

Regional rainfall during the year showed the usual spatial variability, generally being either average or locally, considerably above average (Table 3-2). During the early months of the monsoon (May to July) rainfall amounts were average or below average. Later in the season (August and September) conditions were much wetter (Figure 3-2).

Table 3-2 Lower Mekong Basin – 2011 rainfall compared to the long term annual mean at selected sites.

Raingauge	Mean annual rainfall (mm)	2011 (mm)	2011 / average
Chiang Saen	1 730	1 780	103%
Luang Prabang	1 250	2 233	179%
Vientiane	1 650	2 202	133%
Mukdahan	1 500	1 820	121%
Pakse	2 040	2 182	106%
Tan Chau	1 220	1 130	93%

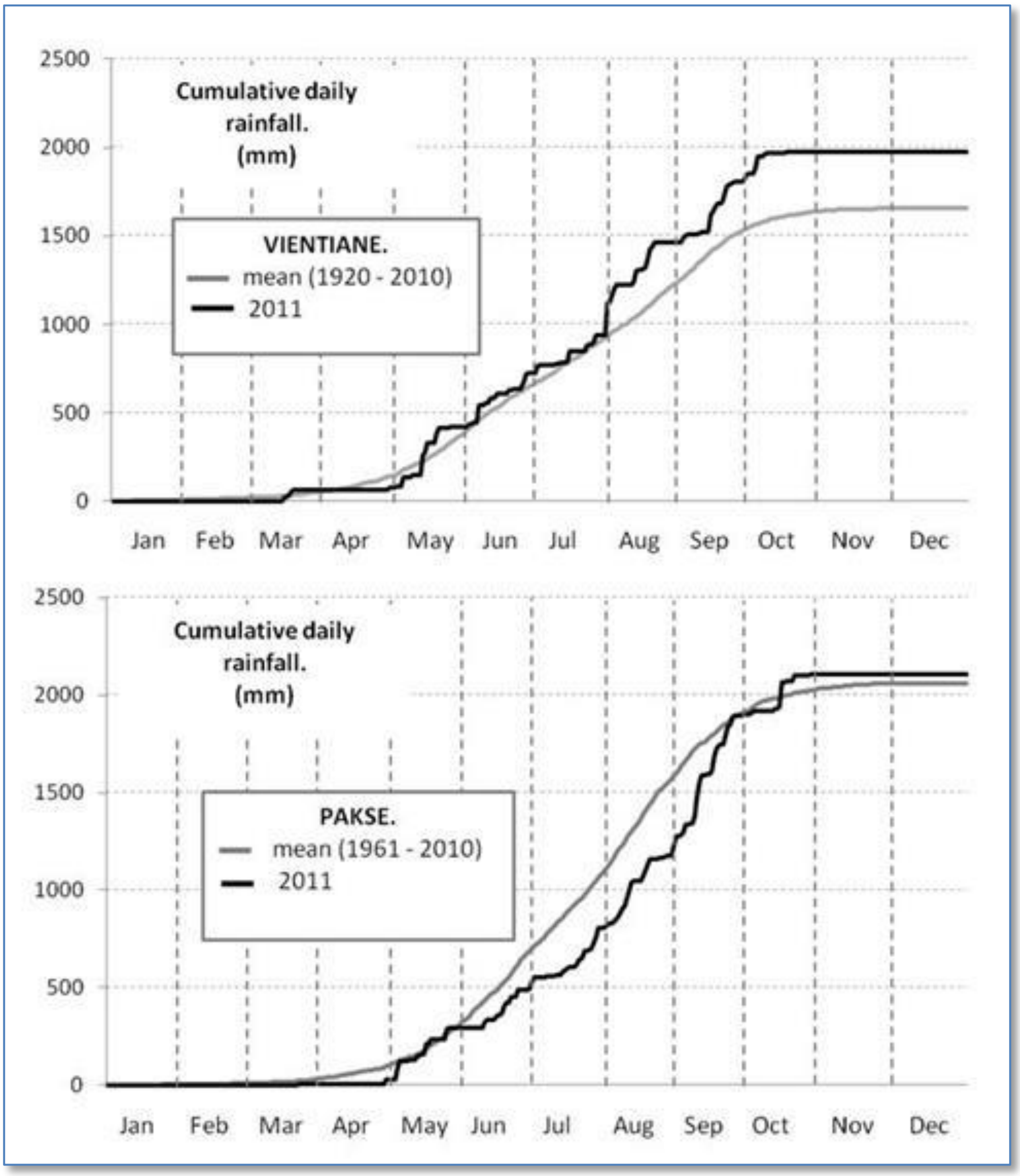


Figure 3-2 Cumulative daily rainfall at Vientiane and at Pakse during 2011 compared to the long term pattern. At Vientiane the 2011 SW Monsoon began at the beginning of May. Rainfall until late July was average. However, during June and July rainfall accumulated at a much higher rate, such that the final total for the year as a whole was significantly above average. At Pakse the accumulated rainfall from the monsoonal onset in early May was below average until July when much wetter conditions brought the overall seasonal total to a marginally above average figure.

The geography of the regional rainfall climate during each of the five months of the monsoon season is shown in Figure 3-3 to Figure 3-7.

- Rainfall amounts during June were unexceptional, though there were local areas of quite high rainfall, due no doubt to isolated tropical storms.

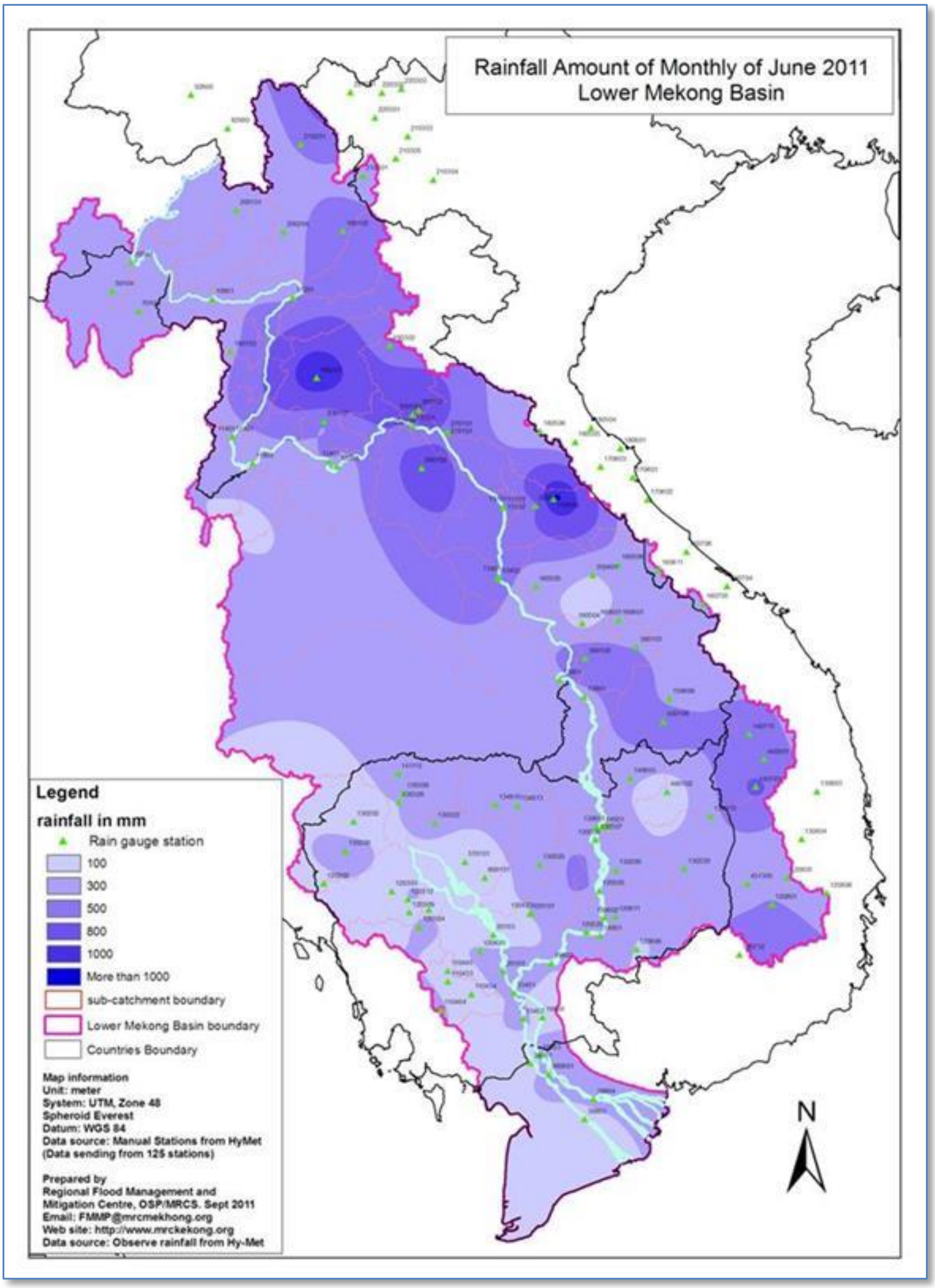


Figure 3-3 Rainfall over the Lower Mekong Basin – June 2011.

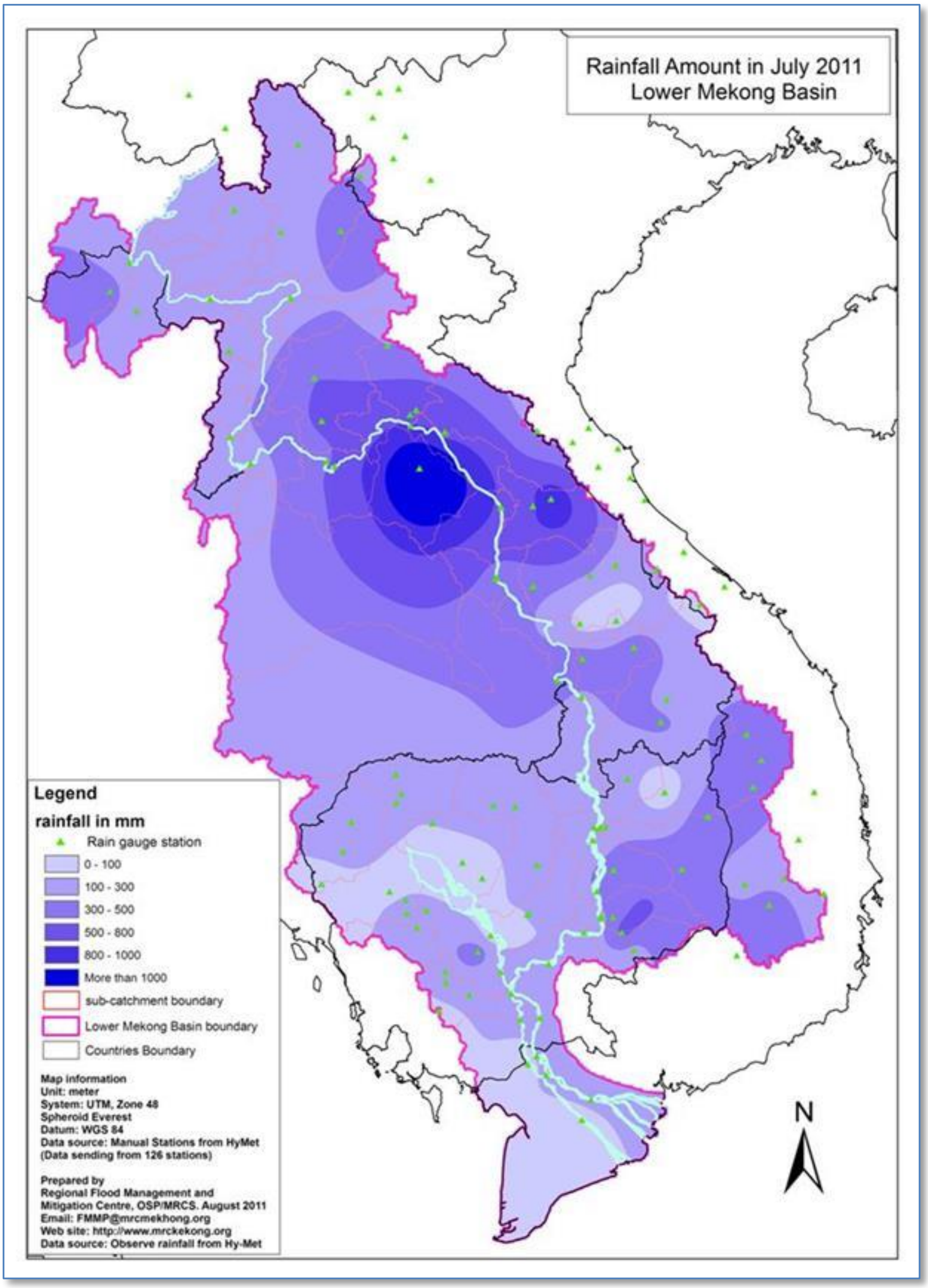


Figure 3-4 Rainfall over the Lower Mekong Basin – July 2011.

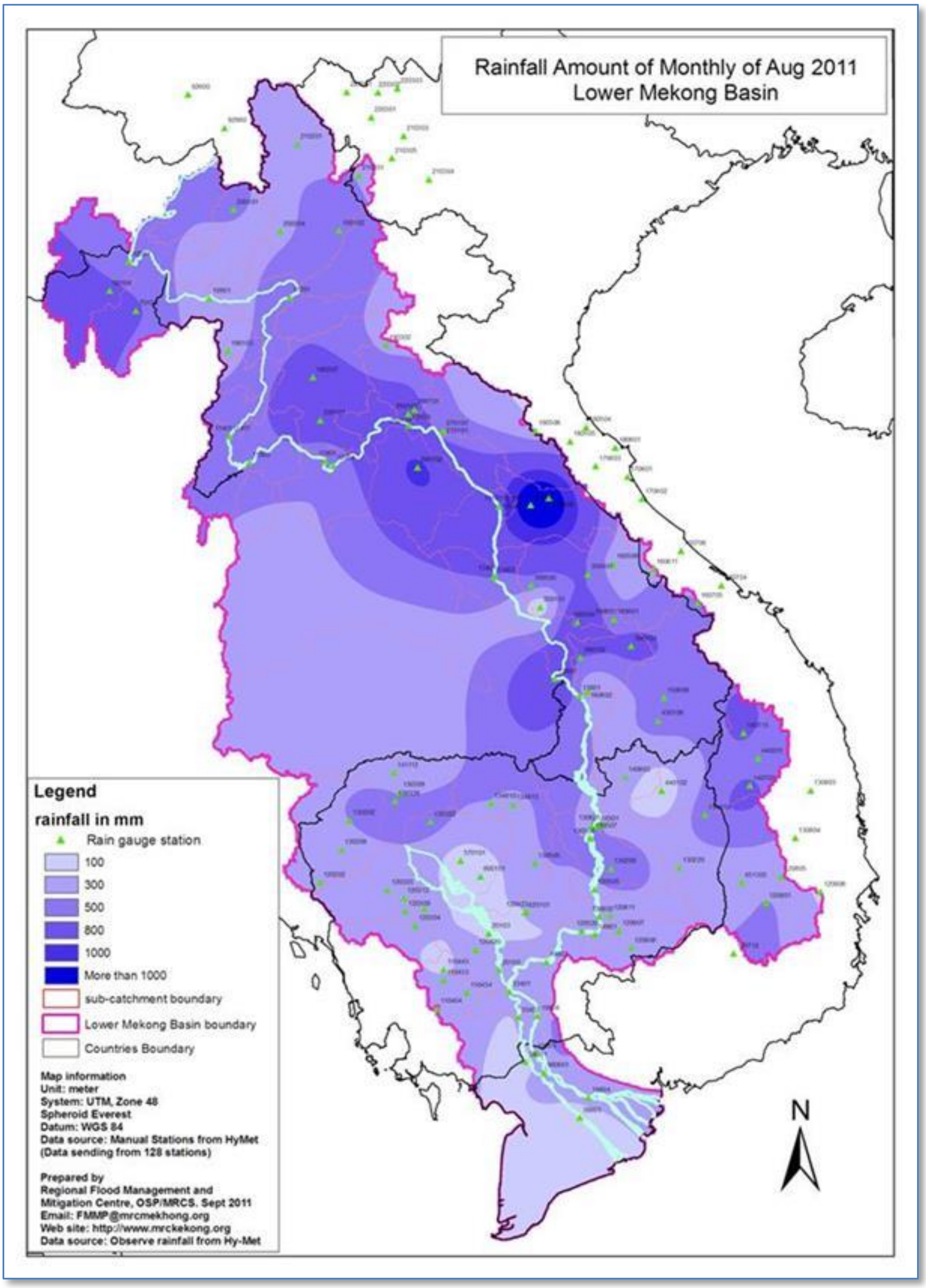


Figure 3-5 Rainfall over the Lower Mekong Basin – August 2011.

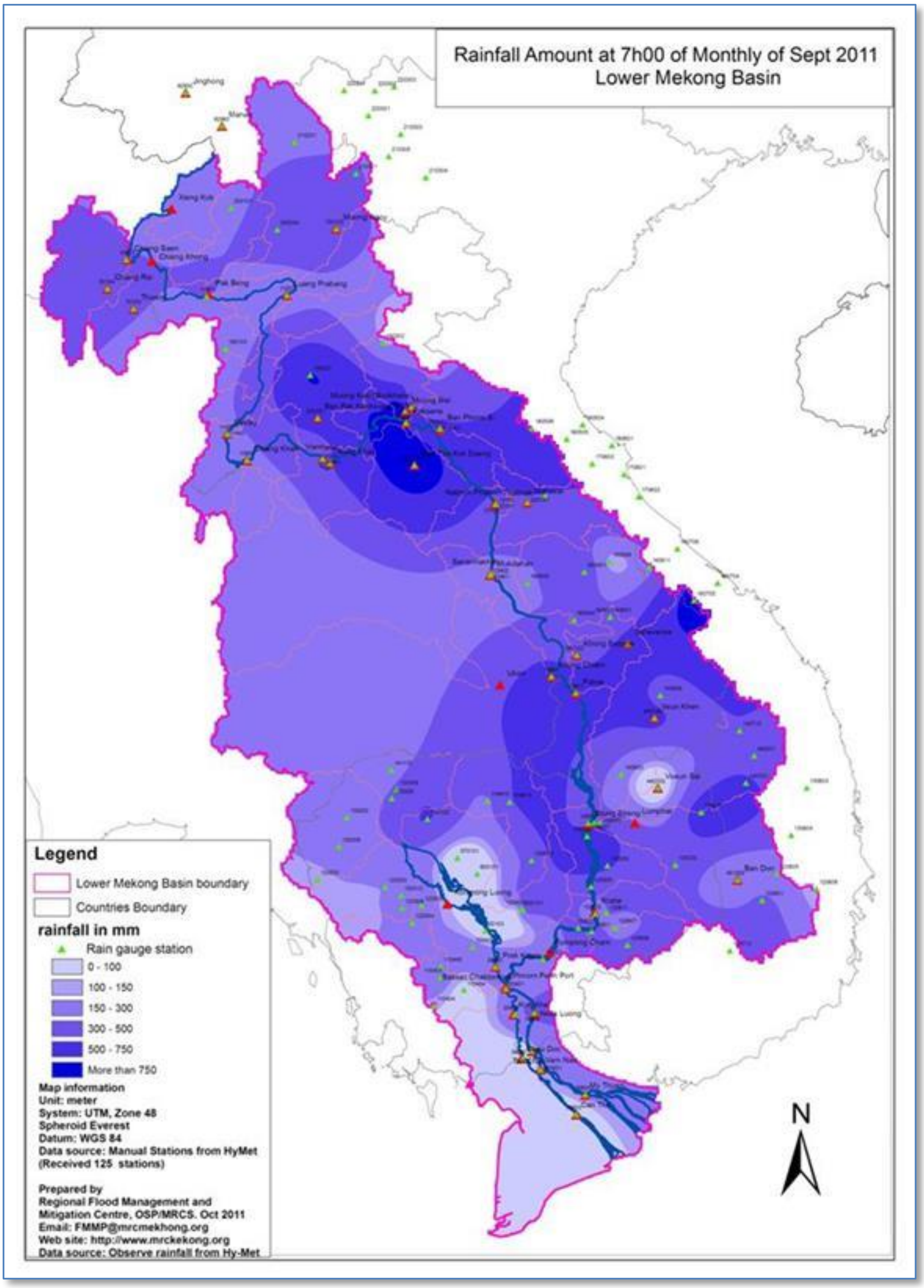


Figure 3-6 Rainfall over the Lower Mekong Basin – September 2011.

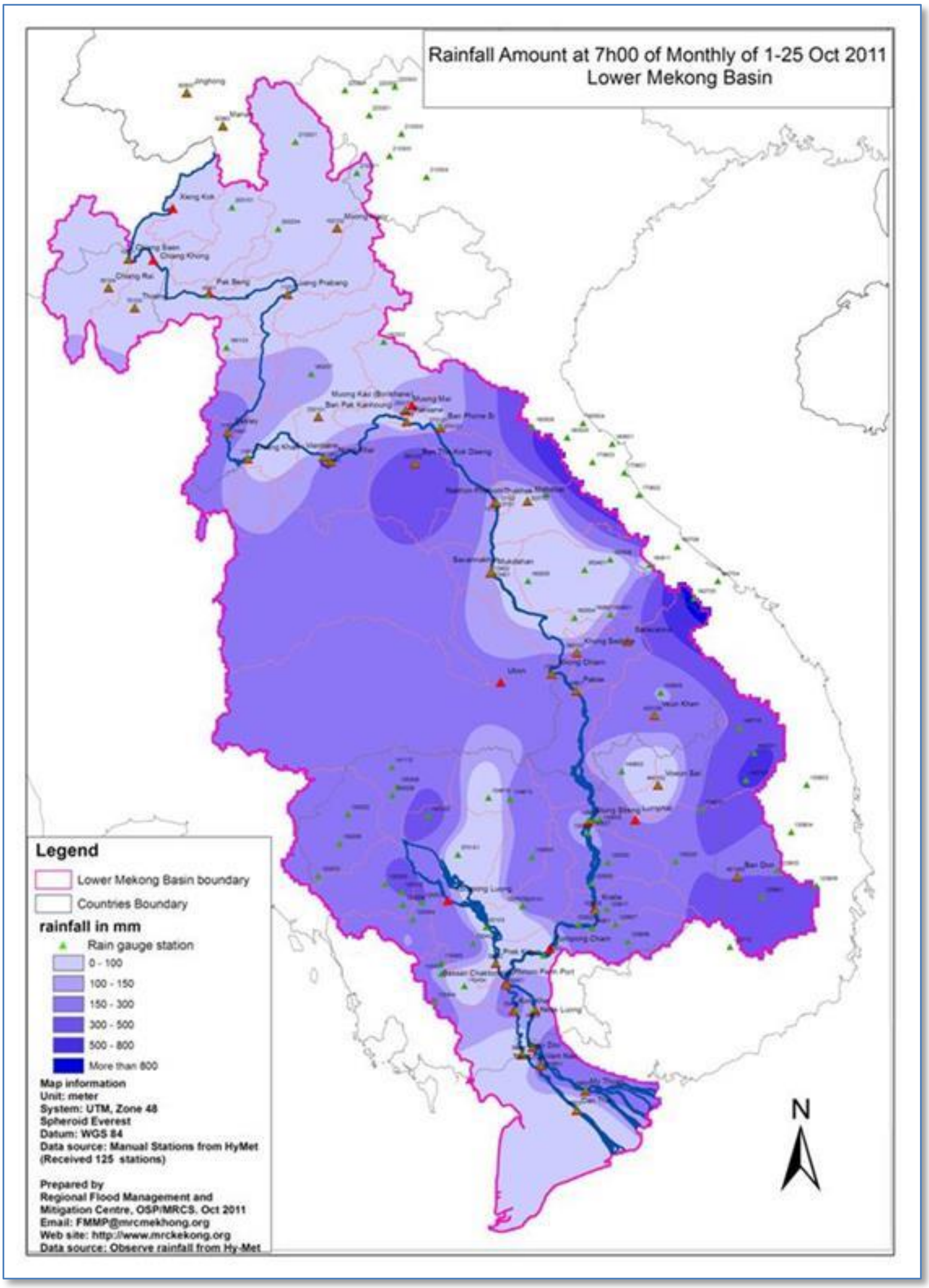


Figure 3-7 Rainfall over the Lower Mekong Basin – October 2011.

- During July the highest rainfall occurred over the central areas of the Basin, centered in the main across NE Thailand.
- A similar pattern prevailed during August, while as in the previous months rainfall within the Delta was low.
- It was during September that the monsoon strengthened leading to widespread monthly total precipitation in excess of 500 mm.
- By October the monsoon was waning with significant rainfall confined to the Central Highlands in the East.

3.5 The hydrology of the 2011 flood season

Rainfall conditions during August and September across the central and southern areas of the Basin largely dictated the geography of the hydrological response. The seasonal flood, both in terms of volume and peak, was much below average in the northern parts of the Basin but well above towards the south.

The onset and end of the flood season, defined as the period of the year when discharge exceeds the annual daily average (see the 2006 and 2007 Annual Flood Reports for the explicit definition) is again a reflection of the seasonal rainfall climate:-

- At Chiang Saen, due to deficient rainfall upstream during the early and late months of the monsoon, the flood season lasted for just 100 days, almost two months less than the average duration. The peak flood discharge and the annual flood volume were just 56 % and 60% of the long term average respectively.

Table 3-3 The Mekong at Chiang Saen. Peak and volume of the 2011 flood season and the onset and end dates, compared to the long term average figures.

Mean annual discharge cumecs	2011 flood season				
	Peak discharge cumecs	Flood volume km^3	Start date	End date	Duration days
2 600	5 750	33.9	28th June	5th Oct	100
	Long term average (1913 – 2012)				
-	10 300	57.4	12th June	13th Nov	155

- At Vientiane a similar situation prevailed. The duration of the flood season was about a month shorter than normal, though the deficit in the peak flood discharge and volume was proportionally less than that upstream at Chiang Saen.

Table 3-4 The Mekong at Vientiane. Peak and volume of the 2011 flood season and the onset and end dates, compared to the long term average figures.

Mean annual discharge cumecs	2011 flood season				
	Peak discharge cumecs	Flood volume km^3	Start date	End date	Duration days
4 500	14 950	97.1	27th June	23rd Oct	119
	Long term average (1913 – 2012)				
	16 600	101.1	23rd June	10th Nov	142

- Much further downstream at Kratie the picture changes. Here, though the peak flood discharge was close to average, the flood volume was 25% higher than normal, which is a significant excess.

Table 3-5 The Mekong at Kratie. Peak and volume of the 2011 flood season and the onset and end dates, compared to the long term average figures.

Mean annual discharge cumecs	2011 flood season				
	Peak discharge cumecs	Flood volume km^3	Start date	End date	Duration days
13 500	51 960	411.4	22nd June	17th Nov	149
	Long term average (1913 – 2012)				
-	50 900	330.0	24th June	7th Nov	137

This excessive flood volume during the 2011 season inevitably led to comparisons with the flood of 2000 at Kratie when the volume and duration of the annual flood played the key role in generating the damage and losses. On both occasions the flood peak was not a significant factor. In fact the 2011 flood at Kratie ranks just the 7th largest in terms of flood volume since 1960, as Table 3-6 indicates. The trio of floods between 2000 and 2002 dominate the recent history of flood extremes over the Cambodian floodplain and the Delta, while the peak discharge of 1978 was by far the largest observed since records began at Kratie in 1924.

Table 3-6 The Mekong at Kratie. Rank ordered annual floods since 1960 with volumes of flow exceeding 400 km^3.

Rank	1	2	3	4	5	6	7
Year	2000	1961	1978	2001	2002	1981	2011
Flood volume (km^3)	478.6	471.6	454.9	448.7	439.7	419.0	411.4
Peak discharge (cumecs)	56 200	62 400	**76 100**	58 000	54 500	63 700	51 950

The 2011 daily discharge hydrographs at Chiang Saen, Vientiane, Pakse and Kratie are illustrated in Figure 3-8 and Figure 3-9 and compared to the long term average.

- The impact of the upstream operation of the dams on the mainstream in Yunnan is noticed at Chiang Saen. Frequency increases and decreases in discharge are marked during the low flow season and are not natural.
- The frequent short term fluctuations in discharge are no longer evident further downstream at Vientiane, where they are effectively “smoothed out” by tributary inflows to the mainstream, such as those contributed by the Nam Tha and Nam Ou. The rapid decrease in discharge during early October is, however, still evident. Otherwise, flows during the flood season fluctuated above and below the long term average, though not by much, with the exception of late September / early October when there was a significant flood “spate”.
- Further downstream at Pakse, once some of the large left bank tributaries in Lao have entered the Mekong along with the contribution from the Mun / Chi system, the situation becomes quite different. Here the discharges remain above average for the whole of the flood season, characterized by two large flow “spikes” during August and September.
- This pattern is repeated at Kratie, though here the discharge deviations above the long term average are not as marked as at Pakse.

This significant downstream increase in the flood season flows relative to the average is summarized in Figure 3-10. The 2011 flood peak and volume were just 60% of the average at Chang Saen but had risen to 120 and 150% respectively at Nakhon Phanom and Mukdahan. At Kratie the peak discharge was average while the flood volume was a little more than 20% above the mean. The implication would seem to be that the major contributions to the 2011 mainstream flood came from the middle reaches of the Mekong between Nakhon Phanom and Mukdahan.

Figure 3-11 places the annual flood hydrology at three locations on the mainstream within its historical context in terms of a bivariate scatter plot of the joint distribution of flood volume and peak. Exceptional events are defined in terms of their deviation above and below the joint means specified in terms of the standard deviations.

- During the year the 2011 flood at Chiang Saen was amongst the lowest on record in terms of both variables and rivaled only by conditions in 1992.
- At Vientiane both the volume and peak were average.
- At Kratie the flood volume was one standard deviation above the average, which is defined here as a “significant” deviation from the mean. In 2000, however, the flood volume was two standard deviations above the mean, which is considered to be “extreme”. Historically the flood of 1978 stands apart both in terms of peak and volume. This event is quoted in the World

Catalogue of Large floods as one of the most extreme events observed globally.

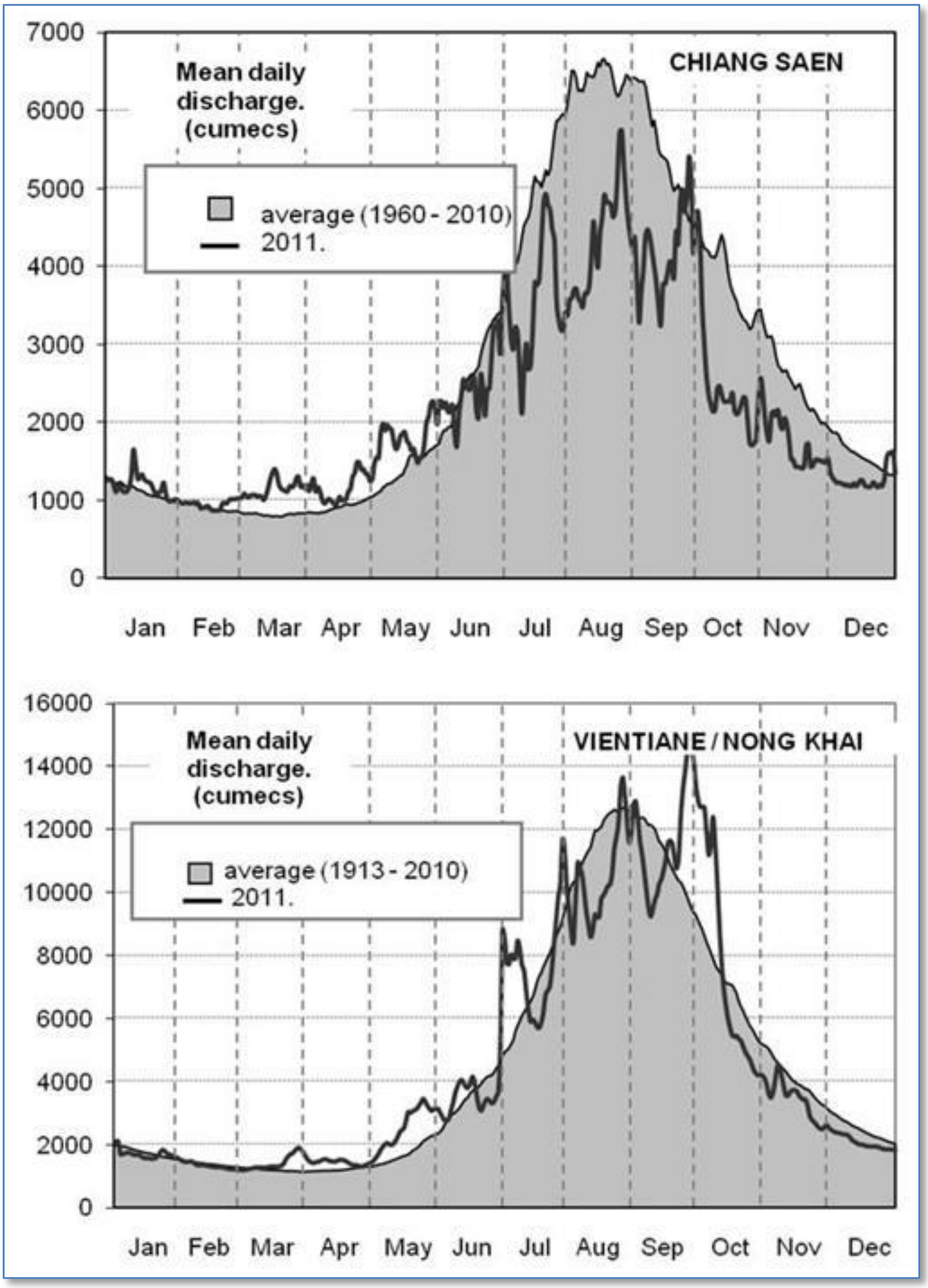


Figure 3-8 The 2011 annual hydrographs at Chiang Saen and at Vientiane / Nong Khai, compared to their long term average.

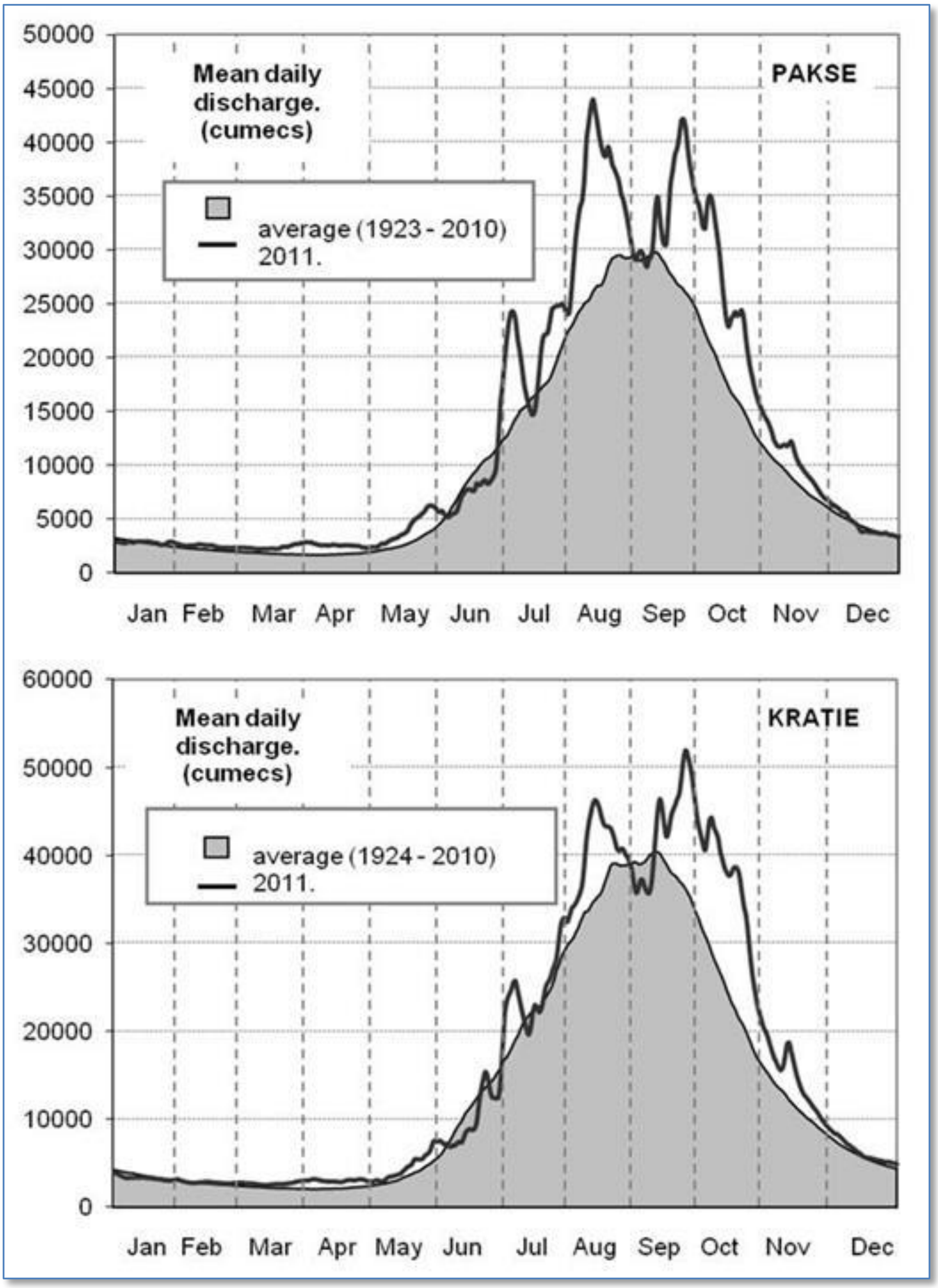


Figure 3-9 The 2011 annual hydrograph at Pakse and at Kratie, compared to the long term average.

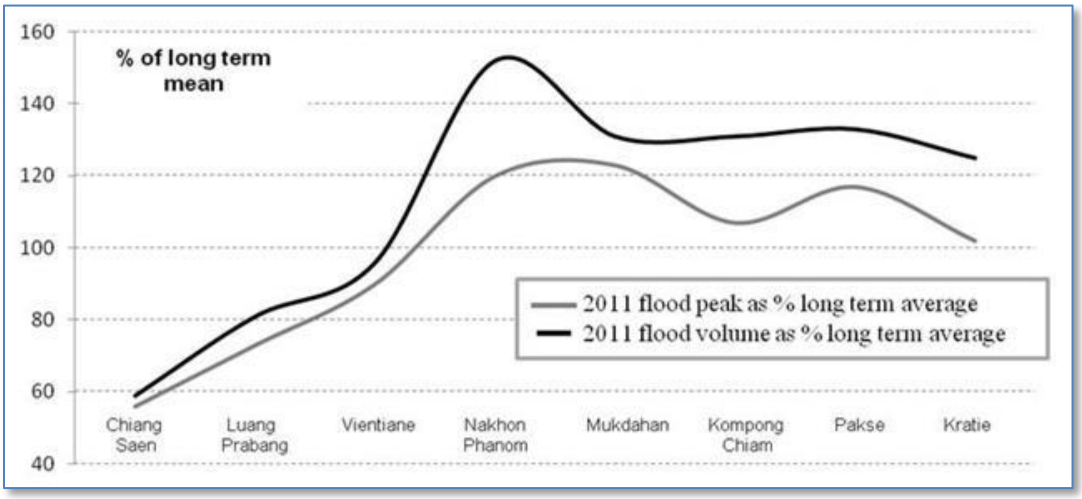


Figure 3-10 Annual flood peaks and volumes as a proportion of the long term average on the Mekong mainstream between Chiang Saen and Kratie during 2011.

The 2000 and 2011 daily discharge hydrographs at Kratie are compared in Figure 3-12.

- In a number of respects the hydrographs are comparable, particularly with regard to the peak discharge achieved in each of the two years. Also the overall duration of flows above 30 000 cumecs is similar, for example.
- The major distinction is the very high flows that occurred during July 2000. This caused the un-seasonally early inundation of the Cambodian floodplain and expansion of the Great Lake area such that the duration of flooding was much longer than normal. It was this, as much as anything, which contributed to the significant loss of life, mostly due to water borne disease and to major agricultural losses.
- In large river systems the duration of critical flows, which is related to the flood volume, is just as important as the peak discharge. Primary economic damage is the result of the fact of inundation. Secondary economic damage is the result of the duration of flows above critical thresholds and the length of time that economic activities are suspended. As catchment area increases indirect or secondary damage tends to become an increasing proportion of total damage.

The joint distribution of flood peak and volume can be set within a probabilistic framework on the basis of their bi-variate distribution, as illustrated in Figure 3-13. At Kratie the statistical result indicates that the 2011 flood conditions have a mean recurrence interval of 1 : 10 years and those of 2000 1 : 20 years. The very extreme flood of 1978 is estimated to have a mean recurrence interval in excess of 1 : 50 years.

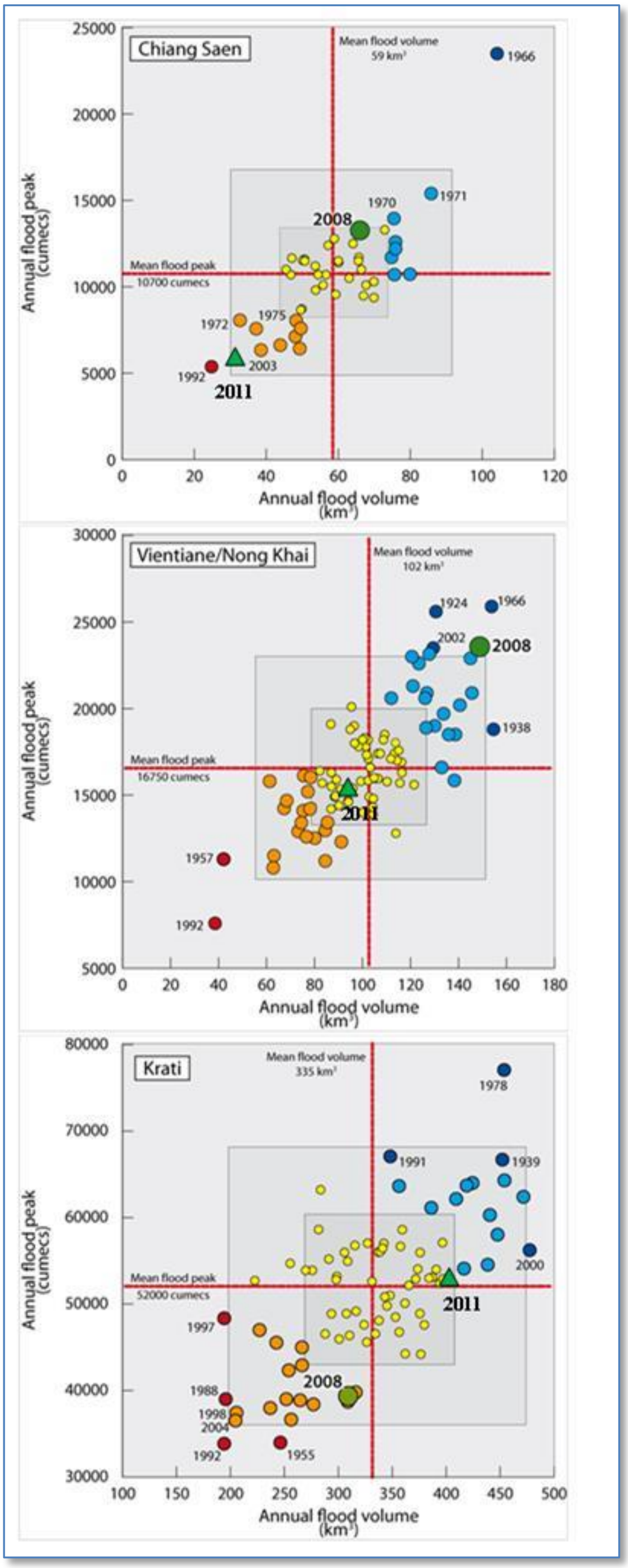


Figure 3-11 Scatterplots of the joint distribution of the annual maximum flood discharge (cumecs) and the volume of the annual flood hydrograph (km^3) at selected sites on the Mekong mainstream. The 'boxes' indicate one (1δ) and two (2δ) standard deviations for each variable above and below their respective means. Events outside of the 1δ box might be defined as 'significant' flood years and those outside of the 2δ box as historically 'extreme' flood years.

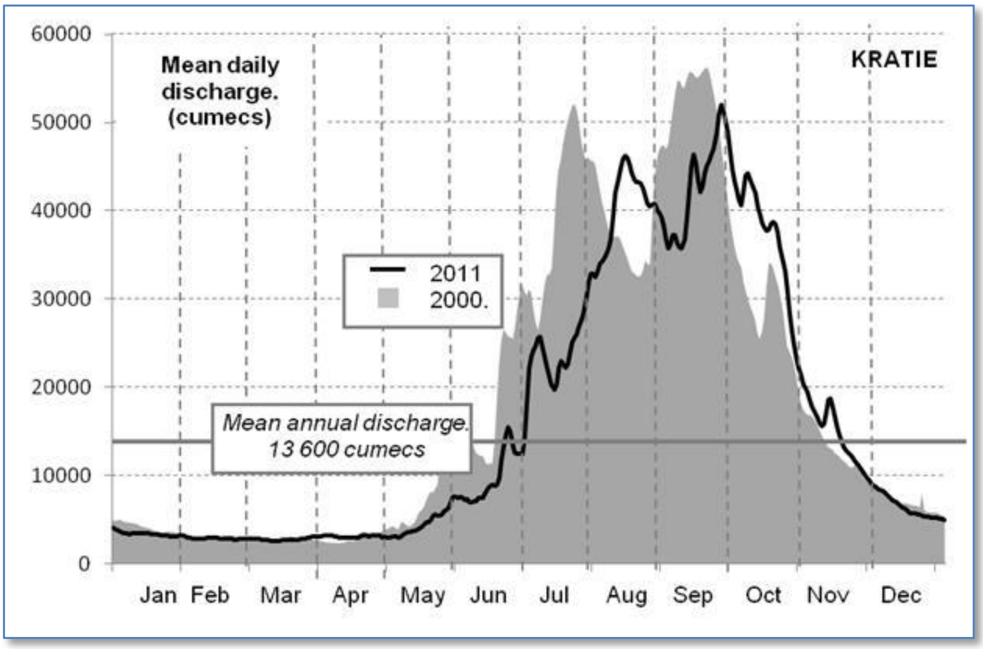


Figure 3-12 The Mekong at Kratie – the daily discharge hydrographs of 2000 and 2011 compared.

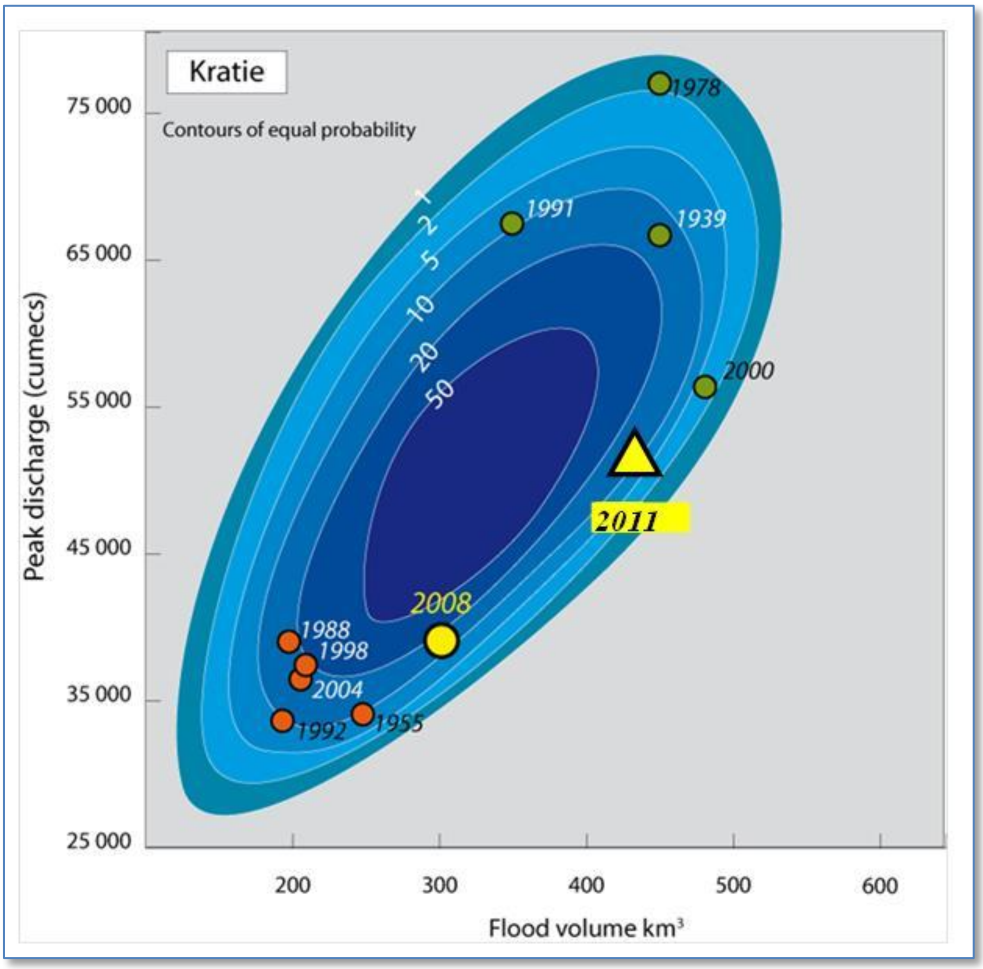


Figure 3-13 Mekong at Kratie - the bi-variate distribution of annual flood peak and volume, 1924 to 2011. The estimated recurrence interval of the 2011 event in terms of the joint distribution of the two variables is just 1 : 10 years. That of 2000 1 : 20 years.

3.6 Water levels across the Cambodian floodplain and the Delta in Viet Nam during 2011

With Kratie as the upstream hydrological boundary, water levels across the Cambodian floodplain and the Mekong Delta obviously reflected the upstream conditions. Natural overbank storage on the floodplain attenuates and smoothes out the hydrograph as is evident from those illustrated in Figure 3-14. The release of flood water from over bank storage and the Great Lake as mainstream water levels fall towards the end of the flood season effectively delays the timing of the peak water levels to October, compared to their occurring in September further upstream.

The three hydrographs indicate that water levels were above average throughout the major part of the flood season with the maximum exceedance occurring during October. The Tonle Sap water levels continued to be significantly greater than average into December (and in fact during January and February, 2012) as flood water flowed out of the Great Lake and back into the Mekong. The maximum water levels achieved during the year were 13% or so above the historical annual average (Table 3-7), which might be considered to be significant.

Revealingly, the maximum water level observed on the Tonle Sap at Prek Dam of 10.26 masl was the second highest on record, exceeded only by that which occurred during the flood of 2000 (Table 3-8). This would in turn imply that the mean depth and areal extent of the Great Lake during 2011 was amongst the highest recorded.

Table 3-7 Maximum water levels reached during 2011 in Cambodia and the Mekong Delta compared to their long term average.

Site	Period of Record	Annual maximum water level. (masl)		
		Historical average	2011 (m)	2011 as % long term average
Phnom Penh Port	1960 - 2010	9.00	10.08	112
Prek Kdam	1960 – 2010	9.08	10.26	113
Tan Chau	1980 – 2010	4.30	4.85	113
Chao Doc	1980 - 2010	3.82	4.32	113

Table 3-8 Tonle Sap at Prek Dam. Rank ordered annual maximum water levels since 1960.

Year	Annual maximum water level (masl)
2000	10.42
2011	10.26
1961	10.22
1991	10.21
1966	10.10
2002	10.08

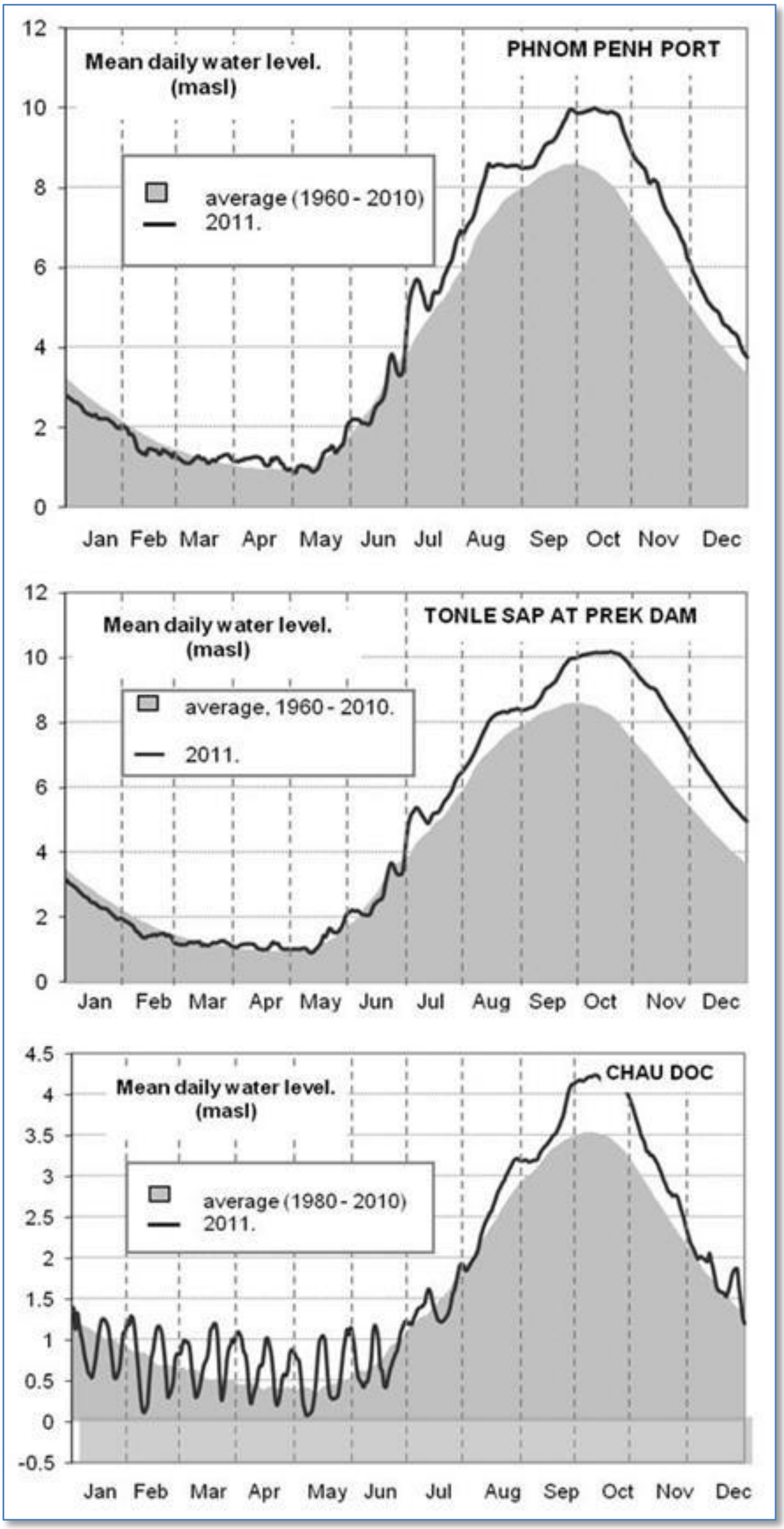


Figure 3-14 The 2011 annual hydrograph at Prek Dam, Phnom Penh Port and at Chao Doc, compared to the long term average.

Figure 3.15 shows the comparative geography of the extent of flood inundation across the Cambodian floodplain and within the Mekong Delta for 2000 and 2011.

- In Cambodia there appears to be little difference between the two years in terms of inundated area. This is not surprising given the marginal difference in regional annual maximum water levels for 2000 and 2011 indicated by the Prek Dam figures in Table 3-8.
- Further downstream in the Delta the flooding during 2000 was significantly more extensive than in 2011, particularly in the south eastern areas (Figure 3-15). This is largely explained by the fact that the annual maximum water level attained at Chau Doc during 2000 was more than half a meter higher than in 2011 (Table 3-9).

Table 3-9 A comparison of the annual maximum water levels achieved at Tan Chau and Chau Doc during 2000 and 2011. The figures illustrate quite clearly that even modest comparative maximum water levels in the Delta lead to the much more extensive inundation, as illustrated for 2000 in Figure 3-15.

Station	Maximum water level (masl)	
	2000	2011
Chau Doc	4.89	4.24
Tan Chau	5.04	4.74

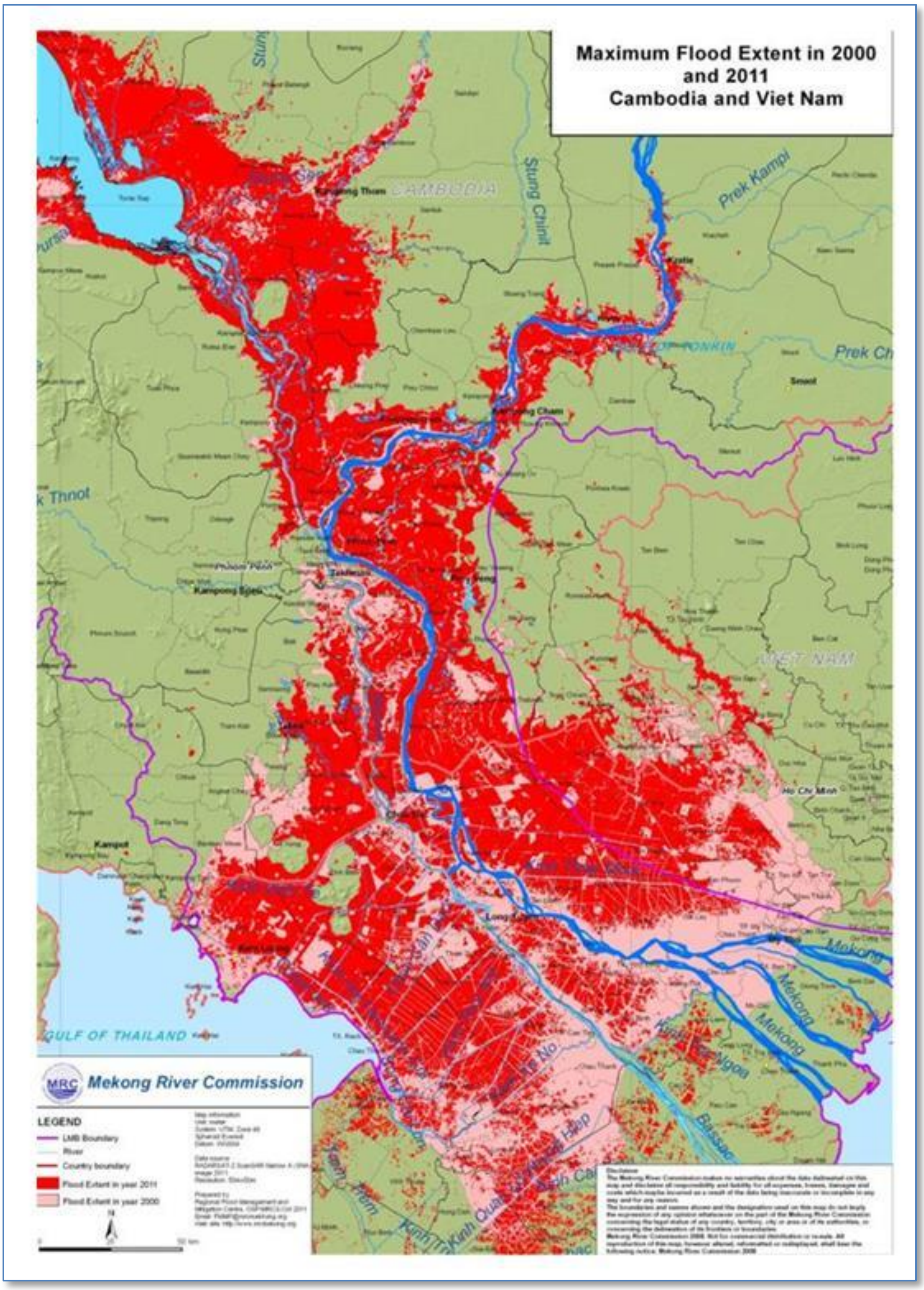


Figure 3-15 The comparative geography of flooding across the Cambodian floodplain and within the Mekong Delta during 2000 (pink) and 2011 (red). Source MRC, 2011.

4. COUNTRY REPORTS

4.1 Cambodia

The flood of 2011 exceeded warning levels on the Mekong mainstream at Kratie and at Chaktomuk but only exceeded the flood level at Prek Kdam on the Tonle Sap (Table 4-1). The figures suggest that at Kratie the 2011 peak water level slightly exceeded that of 2000, though this is not borne out by other figures (see for example, Figure 3-12). Elsewhere, the 2011 maximum water levels were slightly less than, but very close to, those of 2000.

Table 4-1 Comparison of maximum water levels reached in 2000 and 2011 with flood and flood warning levels (masl) at Kratie, Chaktomuk and Prek Kdam.

Station	Flood level	Warning level	2000	2011
Kratie	23.0	22.0	22.6	22.9
Chaktomuk	12.0	10.5	11.2	10.9
Prek Kdam	10.0	9.5	10.3	10.2

During the year the peak water level in the Great Lake of 9.89 m was reached during the third week of October. This figure is comparable to that achieved during 2000.

In 2011 some localities were affected by flash flooding between October and November 2010 due to heavy rain, especially during second week of October, which caused severe damage to infrastructure and crops, particularly in Takeo, Kandal, Pursat, Battambang, Banteay Meanchey, Siem Reap, Kampong Speu and Phnom Penh. Locally daily rainfalls exceeded 150mm per day over three days. On 11th October the figures recorded in Siem Reap, Takeo and Kampong Cham were 140 105 and 76 mm respectively.

Flood conditions during the year were considered to be “extreme”, particularly along the Mekong mainstream and were comparable to those that occurred during 2000. According to the National Committee for Disaster Management (NCDM) 18 provinces were affected by mainstream and flash flooding, namely Preah Vihear, Kampong Thom, Battambang, Banteay Meanchey, Siem Reap, Oudormeanchey, Kampong Cham, Kratie, Stung Treng, Prey Veng, Kandal, Kampong Chhnang, Pursat, Takeo, Phnom Penh, Svay Rieng, Kampot and Pailin. Provincial damage and losses for the year are indicated in Table 4-2. The number of flood related deaths reported was considerable at 250.

The NCDM has developed downwards from the national level to commune level and from early 2007 this network has taken over (in large part) the role of the Cambodian

Red Cross in term of warning and dissemination of flood information. However, the role of the Red Cross in relief, the provision water and medical supplies largely remains. At the provincial level the Committee for Disaster Management organizes annual seminars to prepare the provincial preparedness plan before each flood season. Under the Flood Management and Mitigation Programme 2004-2010 Component 4 “Flood Preparedness Management Strengthening” the provincial and district Committees for Disaster Management of each province along the Mekong were facilitated to implement provincial and district Flood Preparedness Plans; these plans are annually revisited in the context of the recurrent updates of the socio-economic development plans.

Table 4-2 Cambodia, 2011 flood damage and losses.

Province	2011 flood damage and losses							
	House		People		School	Rice (ha)	Other crops (ha)	Road (km)
	Affected	Damaged	Killed	Injured	Affected	Damaged	Damaged	Affected
Preah Vihear	1 320	6	4		24	2 018	110	152
Kampong Thom	7 629	23	41	3	189	69 396	1 793	620
Battambang	13 921	13	8	3	85	35 000	10	540
Banteay Meanchey	11 268	419	14	1	95	18 894	6195	594
Siem Reap	17 787	23	24	1		15 120	1 616	648
Oudormeanchey					2	650	1 128	149
Kampong Cham	33 053	119	47	1	230	20 049		421
Kratie	9 891	75	19	5	102	5 191	615	275
Stung Treng	465					1 410		180
Prey Veng	59 797	423	52	5	248	47 268	1 752	751
Kandal	66 740		4		207	5 770	2 717	432
Kampong Chhnang	11 534		18		53	11 166		64
Pursat	4 000	22	6		30	17 940	519	225
Takeo	7 869	85	8		46	5 566	8	175
Phnom Penh	14 570	2	2	2	22	681		79
Svay Rieng	6 140	51	3	2	17	7 761	444	208
Kampot	2 369				10	3 254		63
Pailin	258	36				50	357	10
Total	**268 631**	**1 297**	**250**	**23**	**1 360**	**267 184**	**17 264**	**5 586**

However, a lack of data and capacity to produce longer lead-time flood forecasts limits the efficiency of the response to and the management and mitigation of flood impacts during extreme events.

With the exception of Phnom Penh, almost all urban areas have no structural flood protection works beyond earth bunds. These often have multiple uses including bank protection and ensuring that as far as possible road communications remain open.

However, very few of them are gated and properly operated and they are vulnerable to erosion. Under component 2 of the FMMP and the ADB flood and drought project, a number of structural measure have been proposed as part of the integrated flood risk management process but little progress has been made.

Figure 4-1 Two views of the flooding in Cambodia during 2011.

The major lessons learnt during the events of 2011 remain much the same as in previous years. There is a need to clarify the roles and promote greater coordination amongst the various national agencies concerned in order to increase the effectiveness of flood mitigation and emergency relief. The whole process needs a much higher level of funding.

4.2 Lao PDR

In 2011, Lao PDR was badly affected by two major tropical storms, namely HAIMA and NOCK-TEN. On 24th – 26th June, HAIMA passed over the northern and central provinces and between 30th July and 1st August the NOCK-TEN affected the central and southern provinces. The associated heavy rains resulted in high water levels in many tributaries. In addition, the country was also affected by tropical storm HAITANG during September and typhoon NESAT and typhoon NALGAE during October. As a result, many provinces suffered floods and landslides. Twelve provinces across the country were affected to various degrees - Phongsaly, Oudomxay, Luang Prabang, Oudomxay, Xayaburi, Xiangkhouang, Vientiane, Borikhamxay, Khammouanne, Savannakhet, Champasak and Vientiane Capital, as indicated in Figure 4.2. The floods caused agricultural and infrastructure damage and losses and there were a reported 42 fatalities. Total costs are estimated to have been in the region of US$ 220 million.

- Tropical Storm HAIMA swept through the northern and central provinces, causing widespread flooding in four provinces, namely Borikhamxay, Xayaburi, Vientiane, and Xiengkhouang. The floods caused extensive damage to livelihoods, property and to social and physical infrastructure. On 26th June 180 mm rainfall was recorded at Xayaburi, 140 mm at Xiangkhouang, 82 mm at Pakkangung, and 120 mm at Paksane. The National Disaster Management Office (NDMO) reported that more than 80 000 people from 362 villages in 36 districts were directly affected. At least 18 people were killed.
- Tropical Storm NOCK-TEN caused widespread flooding. On 31st July 206 mm rainfall was recorded at Ban Phonesy, 203 mm at Mahaxay and 98 mm at Paksane. Rainfall at Thakhek over the three days between 30th July and 1st August summed to almost 250 mm.

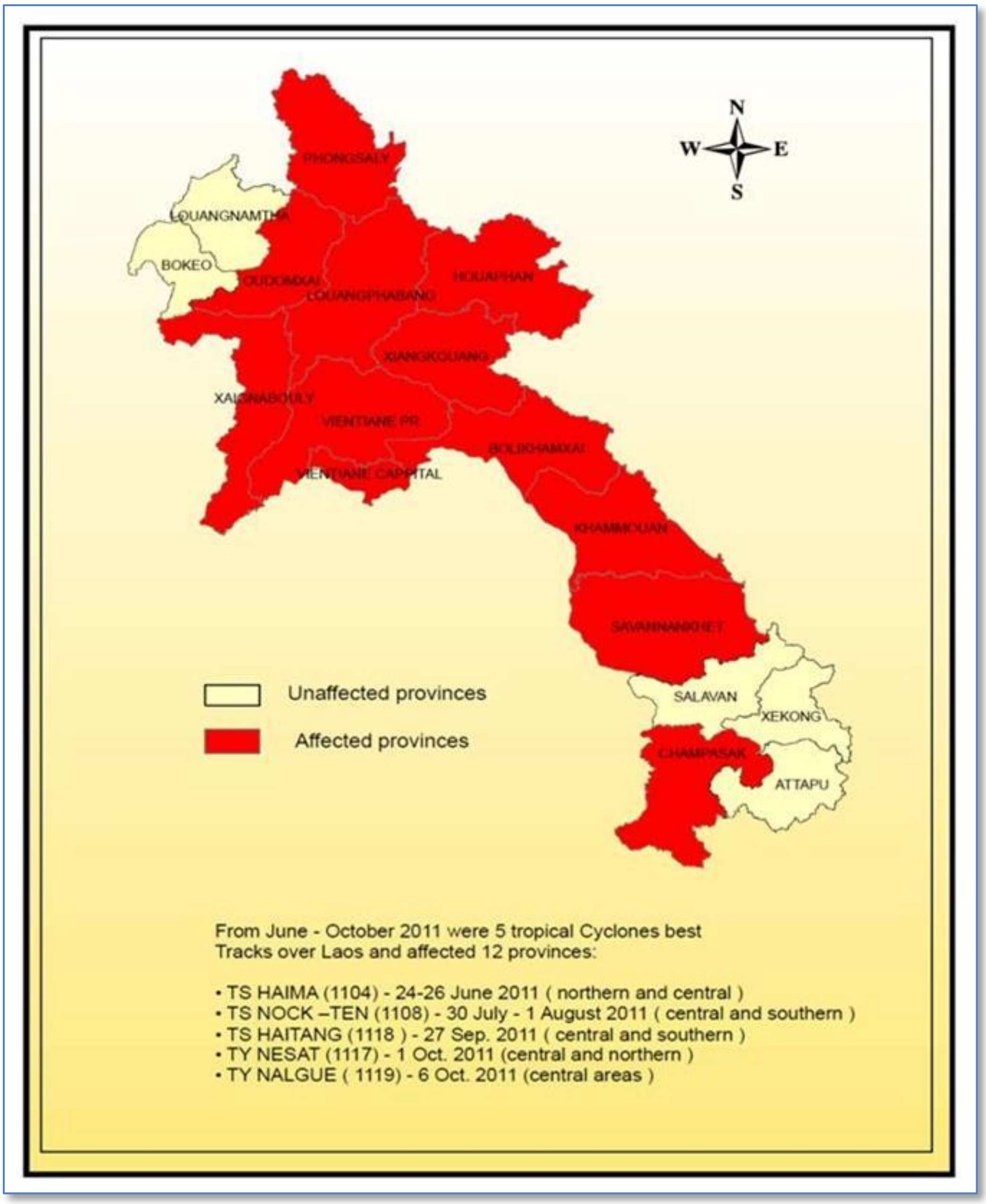


Figure 4-2 Lao PDR – provinces affected by floods and landslides during 2011.

Water levels along the Mekong mainstream in Lao PDR only exceeded critical and danger levels in the south of the country at Pakse. Towards the north they were well below any level of concern (See Table 4.3).

Table 4-3 Maximum water levels achieved on the Mekong mainstream in Lao PDR at Vientiane and Pakse during 2011 (with date), compared to the critical and danger levels. Only in the south at Pakse was the danger level exceeded (by more than 1 m). Elsewhere the maximum water levels were not a concern.

Mekong at:-	Water level (m above gauge datum)		
	Critical	Danger	2011
Vientiane	11.5	12.5	10.7 (23/9)
Pakse	11.0	12.0	13.1 (10/8)

The national losses and damage incurred during 2011 are summarized in Table 4-4, below:

Table 4-4 Lao PDR – Summary of 2011 flood damage and loss.

Lao PDR : 2011 flood damages	
The most affected provinces	Xiengkhouang, Khammouanne, Champasak, Vientiane, Xayabuli, and Borikhamxay
Districts affected	96
Villages affected	1 790
Household affected	82 490
People affected	429 950
People injured	N/A
People killed	42
Agriculture	
Hectares of Rice paddy fields affected	76 940 ha
Hectares of upland rice and crop damaged	Upland rice field 106 ha; Other crops: 8 245 ha
Domestic rice storage affected	54 sites
Livestock	
Cattle	2 500 head lost
Total damage and losses	**US$ 220 million**

As will always be the case, there were lessons to be learnt from the serious flooding during 2011:

1. The timely forecasting and warning dissemination provided by Department of Meteorology and Hydrology (DMH) was very helpful for making arrangements and preparing measures at each level of Government , both National and Provincial. A major challenge is the dissemination of warnings to the remoter areas and particularly those prone to flash flooding.
2. Improvements to data coverage are still required for comprehensive flood forecasting, warning and dissemination.
3. Public education and capacity building, particularly at the local level, remains

a focal area and ongoing priority.

4. Internal and external coordination mechanisms amongst the various agencies require ongoing attention.

4.3 Thailand

In 2011, Thailand experienced unprecedented flooding throughout the year. The worst affected areas were the north and central regions. Moreover, the Bangkok area endured its worst flooding in seventy years damaging agriculture, industry, economic, social and other sectors. The area was declared a flood crisis disaster area from late July 2011 until November, such that 65 of Thailand's 77 provinces suffered extreme flood impacts. Damage was widespread and severe in many locations. More than 657 people were killed and 4 million residents were either left homeless or displaced. More than 1.80 million hectares of farmland, 13 961 roads, 982 weirs and 724 bridges were damaged or destroyed completely. Economic losses were estimated by the World Bank to be US$ 45.7 billion, making the flood impacts of 2011 the fifth costliest natural disaster in the modern history of the country.

Thailand was influenced both directly and indirectly by five storm systems moving from the East Sea, namely tropical storms HAIMA, NOCK-TEN, HAITANG, NESAT and NALGAE. At the end of June the northern and northeast areas of Thailand were hit hard by the tropical storm HAIMA. The water level increased significantly in the Yom River as a result. Then, in the late July, runoff in the northern areas reached extreme flood conditions. The storm NOCK-TEN quickly followed adding to the disaster situation. Tropical storm HAITANG then affected the northeast area of the Mekong River Basin between 27th and 29th September. This almost unprecedented sequence of storm systems was completed with the NESAT, HAITANG and NALGAE during September and early October.

Locally, the total rainfall from January to November in 2011 peaked at over 1 780 mm compared to an average of 410 mm. Generally, seasonal rainfall was between 20 and 60% above average. The maximum daily rainfall in upper Thailand was 190 at Ban Phaeng in Nakhon Phanom province on 2nd August. In Loei, Mukdaharn, Chaiyaphume and Ubon Ratchathani provinces daily rainfalls in excess of 140 mm were recorded during August.

The Mun and Chi rivers rose to the overbank condition in the middle of September casing riparian inundation until late October. In the north east upland flash floods were extensive, while over flooding occurred in the lower river reaches. The provinces affected by the flooding during August and September included Kalasin, Nakornphanom, Bungkarn, Mukdaharn, Yasothon, Roi Et, Amnat Charoen, Sakonnakorn, Nongkhai, Udonthani and Ubonratchathani.

The principal lessons learnt were that:

- To increase flood management, there must be an agency that takes direct responsibility to plan and coordinate and act in concert with the related organizations at the community, basin and national level. In order to encourage stakeholders to participate in many procedures to support, develop tools, and act as key mechanism to manage, i.e. water operation center, development of surveillance, monitoring, forecasting and early warning systems to support the decisions support system etc.
- This lack of a centralized water resource management agency is a concern within many sectors. The process of managing and mitigating flood disasters when performed by many overlapping agencies leads to duplication and potential legal issues.

Figure 4-3 Flooding in Nong Khai Province during August.

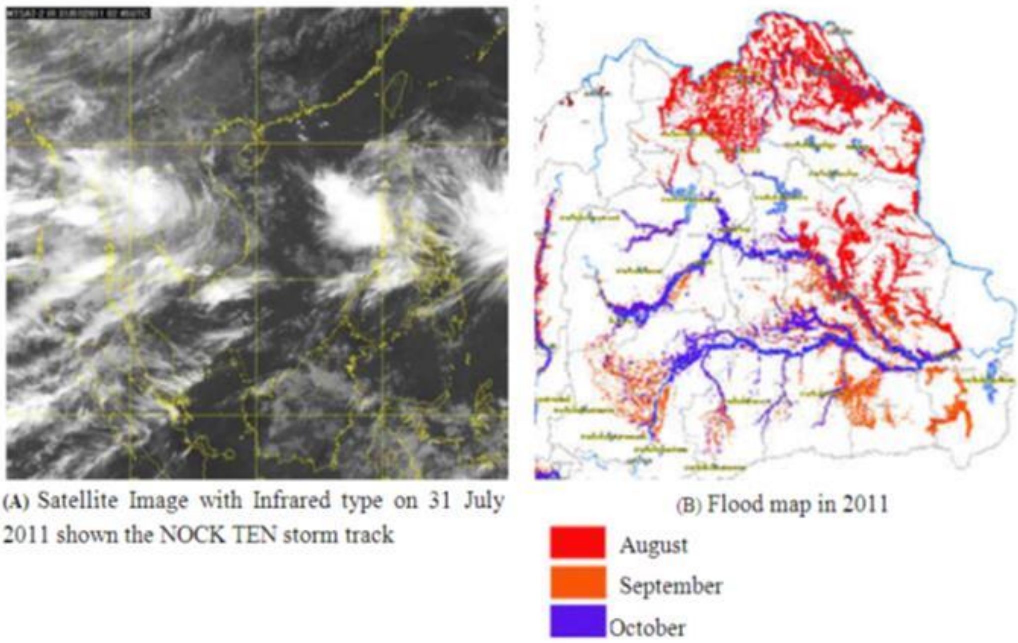


Figure 4-4 Flooding in the North East of Thailand during 2011.

4.4 Viet Nam

In the Delta the 2011 flood peak at Tan Chau station reached 4.86 m on 29th September (higher than alarm level III of 0.36 m) which was lower than 2000 flood peak but higher than those of 2001 and 2002. Meanwhile, the flood peak at Chau Doc reached 4.27 m on 12th October (higher than alarm level III 0.27 m), lower than the peak levels reached during 1999, 2000, 2001 and 2002. These levels were maintained for a considerable duration of 25 to 26 days, comparable to the figure in 2000.

Rainfall over the Delta was not particularly excessive and all of the tropical storms which severely affected Lao PDR and Thailand passed to the north. The flood waters mostly came from the Mekong mainstream further upstream.

Table 4-5 indicates flood damage and loss during the year over Viet Nam as a whole. In Mekong Delta, floods in 2011 killed 89 people, included 75 children, destroyed 906 houses; damaged 176 588 houses, 1 268 schools, 29 hospitals, 620 official buildings, public infrastructures and agricultural production. (Sources were from the Central Committee for Flood and Storm Control):

Transportation:	34 bridges and sluices destroyed; 923 bridges and sluices damaged; 37 transporting ships sank; 870 km roads damaged.
Aquaculture:	7 305 ha ponds flooded; 5 216 fish cages washed ways; and 5 606 tan fish lose.
Powers:	19 high voltage towers, 33 low voltage towers collapsed; and 15 transformers and substations damaged.
Irrigation:	About 3 370 km dyke river slipped; 69 pumping stations flooded.
Hospital:	29 hospital stations damaged.

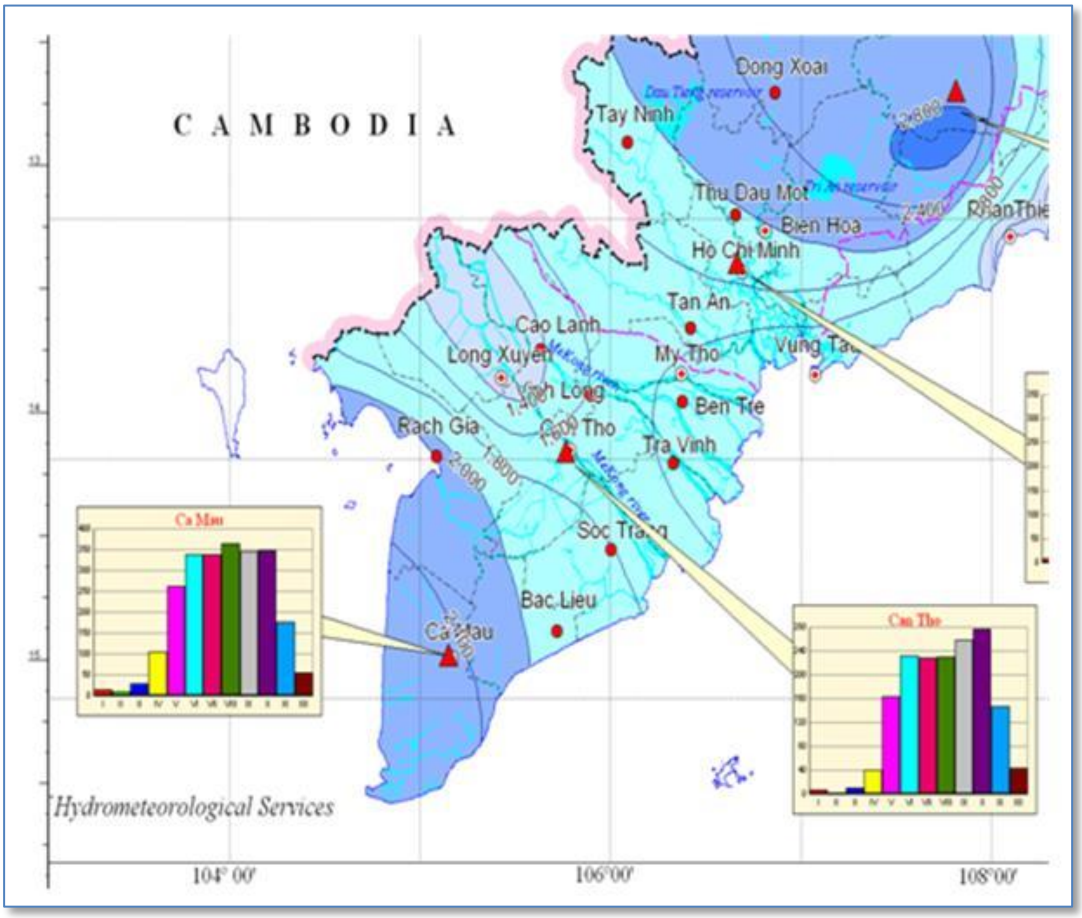


Figure 4-5 Isohyets of the distribution of rainfall over the Mekong Delta during 2011.

Education:	1 268 schools flooded and damaged; 743 tables/chairs damaged.
Agriculture:	27 418 ha paddy fields damaged; 70 244 ha fruit trees damaged.
Economics:	About 4 393 896 x 10^6 VND losses.

In the Central Highlands the 2011 damage and losses were as below:

Person:	15 killed and 26 injured.
Houses:	9 collapsed, drifted; 84 799 damaged.
Agriculture:	3 332 ha paddy submerged; 14 520 ha farms submerged and damaged;
Aquaculture:	1 034 ha fishing area damaged.
Irrigation:	597 932 m^3 soil and rock drifted.
Transportation:	598 053 m^3 soil and rock eroded; 110 bridges and sluices damaged.

Table 4-5 Flood damage and loss in Viet Nam as a whole during 2011.

Category	Item damaged	Unit	Total
People	Killed	Person	265
	Injured	Person	274
	Missing	Person	30
Housing	Houses collapsed, drifted	No	2 170
	Houses submerged and damaged	No	447 694
School	School collapsed	Room	86
	School submerged and damaged	Room	1 945
Hospital, clinics	Clinics collapsed	No	0
	Clinics submerged and damaged	No	107
Agriculture	Rice fields submerged	Ha	248 768
	Farms submerged, damaged	Ha	101 599
	Food damaged by water	Ton	
Irrigation	Land washed away	m3	6 865 401
	Small hydraulic structures collapsed	Unit	565
Transportation	Land drifted	m3	2 362 077
	Bridge, sewer collapsed	Unit	1 274
	Roads damaged	Km	47 628
Aquatic product	Shrimp, fish poll broken	Ha	14 700
	Ships sunk, lost	Unit	163
	Ships sunk, damaged	Unit	49
	Total damage	**US$**	**600 million**

5. CONCLUSIONS

The events in 2011 with regard to flood conditions in the Lower Mekong Basin reflect those of 2000, though they were not quite as extreme. Water levels were not as high and although flood damages and losses were comparable this reflects, more than anything, the ongoing development of the Basin and the ever increasing pressure on land resources in riparian zones exposed to flood inundation. The historical statistics indicate that although such extreme flood conditions are not a perennial event, they are frequent enough to warrant the development of more effective flood management and mitigation policy strategies. A major concern is that there are too many agencies in each country involved in flood relief and mitigation and the lack of a centralized body to coordinate mitigation and relief. Without this centralized management, relief in particular can become non-optimal.

The major focus, though, since 2000, has been the delegation of flood preparedness and relief policy from the national to the local level. This, however, requires levels of autonomy, education, training and investment which are as yet to be forthcoming for effective implementation. The positive, is that these short comings are appreciated and such organizational challenges need to be addressed.

The flood events of 2011 illustrated quite clearly that flood management and mitigation in the Lower Mekong Basin requires considerable levels of investment in data management, effective forecasting and the systematic improvement of public awareness to the risks. It is not known how many people or what proportion of the regional population are exposed directly to the dangers linked both to the annual flood on the Mekong mainstream and to flash floods in the tributary uplands. The numbers, though are significant and probably increasing.

The magnitude of damage and loss reported here, during what was a relatively common situation, is far beyond a local or regional issue. The damage to the national riparian economies, not only in terms of economic loss, but probably more significantly in terms of replacement costs, is a constraint on national economic growth.

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