

# Annual Mekong Flood Report 2014



## Flood Management and Mitigation Programme

Mekong River Commission

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For sustainable development



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# **Annual Mekong Flood Report 2014**

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## **LIST OF ACRONYMS**

DWR	Department of Water Resources
FFGS	Flash Flood Guidance System
GTS	Global Telecommunication System
LMB	Lower Mekong Basin
MAP	Mean Areal Precipitation
MRC	Mekong River Commission
MOWRAM	Ministry of Water Resources & Meteorology
RFMMC	Regional Flood Management & Mitigation Center
RID	Royal Irrigation Department

## **1. SYNOPSIS**

As is now the established format the Annual Flood Report is made up of three major sections:

- The annual theme, which for 2014 is the impact of flash floods
- A review of the flood season over the year, and
- A summary overview of the four National Flood Reports

Every year intense rainfall, often generated by tropical storms sweeping in over the Lower Mekong Basin (LMB) cause the sudden rise of water level in tributary catchments, resulting in what is known as flash floods. Because this often takes place in mountainous and steep areas the water flows with high speed, causing erosion, uprooting of trees, landslides and local flooding. This in turn results in damage to houses, roads, bridges and other infrastructure, and sometimes leads to loss of human life. Flash floods are the main cause of damage in Thailand's Mekong part, and in Lao PDR. In Cambodia and Viet Nam inundation of the flood plains cause the most damage, but flash floods occur every year, especially in the Central Highlands of Viet Nam.

An attempt is made to look at the performance of the Flash Flood Guidance System (FFGS) installed at Regional Flood Management and Mitigation Centre (RFFMC) of the Mekong River Commission (MRC). The FFGS has been in operation since 2010, and provided warnings for flash floods based on satellite imagery.

The year 2014 was more or less normal concerning rainfall, and did not experience any serious inundation floods along the Mekong River. Water levels stayed mostly below alarm level, and also the flash floods were less damaging than during many previous years.

The influence of the Chinese hydropower cascade on the mainstream Mekong in Yunnan had a distinct effect on the downstream flow regime. The dry season flows were highest on record, but flood season flow volume especially at Chiang Saen was very low, indicating that filling of upstream reservoirs was cutting flood peaks downstream. The ratio between dry season and wet season flows was record high at Chiang Saen, but the effect dissipates somewhat when going downstream.



## **2. IMPACT OF FLOODS**

### **2.1 Floods as a hazard**

The regular flood pulse of the Mekong River dictates the life and environment around the river, and is generally considered beneficial and a prerequisite for supporting agriculture and fishing livelihoods in the area. Caused by rainfall associated with the Southwest Monsoon it shows a remarkable regularity, the flood season normally starting in June and ending in early November. But of course this seasonal pattern may be stronger or weaker, starting and ending earlier or later and carry different water volumes, making the individual floods having their own features.

Although the Mekong flood is considered beneficial and not a hazard there can sometimes be too much water in the wrong place, causing loss of human lives and damage. But it is important to distinguish between the types of floods causing the hazards and understand the mechanism behind them, to be able to prepare for them and mitigate the impacts. An obvious example is when extreme water levels in the mainstream Mekong cause overflow of river banks and inundation of areas along the river. Such floods have been preceded by a rising water level during a period of days, and have thus given an alarm in advance. Given reliable weather and rainfall forecasts this type of flood can be predicted with a high degree of confidence to make appropriate preparations to combat it. This type of flood recedes in a few days, but can become quite prolonged in the flood plains of Cambodia and Viet Nam. On the other extreme, flash floods in the tributaries are caused by intense rainfall during a short period of time, causing high rise of water levels within a few hours. They occur in steep streams or small tributaries and the high speed of the water flow causes erosion, land and mud slides and other damage, sometimes with human casualties. They are not necessarily preceded by constant rainfall during a long time, but can occur at any time during the rainy season, and they will recede rapidly. These floods are much harder to predict, as the extreme, intense rainfall may be concentrated to a small area in the watershed. It is often the case, though, that local damage of floods often happens in connection with storms sweeping in over the Lower Mekong Basin (LMB), bringing rainfall that in some cases last several days. Soil conditions first become saturated and then an intense but not necessarily an extreme rainfall event can rapidly trigger a flood in small watersheds, as the soil cannot absorb any more of the rainfall. The prediction of such floods calls for skills and systems especially designed for this.

In previous Annual Mekong Flood Reports different aspects of the Mekong flood have been extensively discussed. The theme of the 2012 Report was flash floods, and the distinction between these floods and riverine floods was stressed. Attention was given to flash flood monitoring and remote sensing tools and the flash flood guidance system

(FFGS) at MRC, together with an overview of the regional history of flash floods. In this report emphasis is put on damage caused by floods and the extent and effectiveness of flash flood warnings issued by the MRC's Regional Flood Management and Mitigation Centre (RFMMC) in Phnom Penh.

## **2.2 Impact of flash floods in the Lower Mekong Basin**

Flash floods are potentially dangerous not only because water levels rise quickly, but also because water flow velocities are high. The force of the water can cause erosion, mudslides, uproot trees and tear away boulders, and the flow of debris can sweep away houses and destroy bridges. The collection of debris in the river bed should be cleared away as soon as possible to ensure that it does not block the water flow should there arrive a new flood event. Therefore it is important that disaster management agencies identify locations where flash floods and damages have occurred, to provide immediate relief and aid. As flash floods are local in character this information has in most cases to come from local authorities or village people themselves. Recovery works, such as repairing damaged roads, bridges and other infrastructure, usually needs broader support from national agencies.

As river valleys often are the most productive parts of the land it is natural that there is pressure to establish settlements in these areas, despite the risk of floods. Risk management, such as land use planning is the key to lessen the exposure to risks, and at least public structures, such as schools, hospitals and the like should be built in areas safe from floods.

The annual losses caused by floods in the LMB countries are indicated in Table 2-1, as reported in the Annual Mekong Flood Report 2011. The losses in Cambodia and Viet Nam are mainly caused by high water levels in the mainstream Mekong, causing long-term flooding of the Cambodian plains and the Delta. The losses here account for about 70% of the economical flood damage losses in the region.

The figures quoted in Table 2-1 cover losses from floods in general, no distinction was made by flash floods and inundation (river) floods.

Table 2-1 Average annual flood loss and damage in the Lower Mekong Basin by country  
(Source, Annual Mekong Flood Report 2011).

Country	Average annual flood loss in Millions USD
Viet Nam	25
Cambodia	18
Lao PDR	11
Thailand	7
Total	61

In Table 2-2 the damages for years 2010 to 2014 is shown and it can be seen that the amount of damage varies greatly from year to year, 2011 and 2013 being disastrous. The figures for the whole Thailand and Viet Nam are shown for comparison.

In 2013 the reported losses in Lao PDR and Thailand were 62 and 210 Million USD, respectively. They were the consequences of floods in tributaries during several tropical storms hitting the region.

Table 2-2 Average annual flash flood and river flood loss and damage in the Lower Mekong Basin 2010-2014 in Millions USD (Source: MRC National Flood Reports, MRC 2015, Desinventar.net).

	2010	2011	2012	2013	2014	Mean annual loss
Cambodia	N/A	624	N/A	356	N/A	-
Lao PDR	21	220	1.5	62	12	64
Thailand (LMB part)	47	N/A	N/A	210	6	88
Viet Nam, Delta	55	260	16	23	2.7	71
Viet Nam, C. Highlands	N/A	60	1	0.2	5.7	17
Entire Thailand	1 200	45 000	176	295	N/A	12 000
Entire Viet Nam	750	700	N/A	1 200	132	700

Inundation floods in the flood plains of Cambodia and in the Delta of Viet Nam cause a lot of damage when they happen, because these areas are densely populated and have much infrastructure. In the year 2000, another disastrous year, the estimated losses in Cambodia were 160 Million USD and in the Viet Nam Delta 25 Million USD. Also in Thailand and Lao PDR river inundation floods may cause huge damages, as in 2008, but in other years flash floods are the main cause of flood damage. However, in many cases it may be difficult in tributaries to make a strict distinction between river and flash floods.

Table 2-3 Average annual number of fatalities due to floods in the Lower Mekong Basin.

	2010	2011	2012	2013	2014	Total
Cambodia	8	250	26	168	49	501
Lao PDR	7	42	5	17	5	76
Thailand (LMB part)	N/A	N/A	N/A	17	4	
Viet Nam, Delta	78	104	38	35	12	267
Viet Nam, C. Highlands	N/A	15	0	45	17	77
Entire Thailand	79	655	5	80	4	1 200
Entire Viet Nam	238	265	N/A	285	133	230

In whole Viet Nam 250 flash floods have been recorded between 2000 and 2014, causing more than 600 fatalities and costing more than 150 Million USD (Viet Nam Annual Flood Report 2014). In the LMB part only areas in the Central Highlands experience flash floods, 77 fatalities were recorded in the period 2010-2014.

In Cambodia there are some occurrences of flash floods but losses from inundation from the mainstream Mekong cause the most economical damages and fatalities. Since 2010 more than 500 fatalities has been reported in Cambodia. In Lao PDR and Thailand (Mekong part) the losses are mainly caused by flash floods, with 76 fatalities recorded in Lao PDR and 27 in Thailand during 2010 to 2014. In Table 2-3 a summary of fatalities in the 4 countries is presented.

Flash floods have a significant impact on the lives of people affected, causing loss of lives and inflicting damage on houses and infrastructure. Preparedness on flash floods is restricted to assessment the local risk in terms of soil saturation and forecasted rainfall intensity for the catchment, and to issue warnings to at least minimize the risk to people's life.

### 2.3 The Flash Flood Guidance System (FFGS) at FMMRC

In late 2009 the computational and dissemination servers for the MRC-FFG system were installed at MRC's Regional Flood Management and Mitigation Centre (RFMMC) in Phnom Penh, which allowed the line agencies of the MRC member countries and the RFMMC to obtain access to the FFG products for training as well as for operational purposes.

The system is driven by satellite imagery, which provides:

- Mean areal precipitation (MAP) for the catchment
- Average Soil Moisture, updated every 6 hours
- Flash flood risk indicator, updated every 6 hours

The system provides a map as shown in Figure 2-1 showing the amount of rainfall needed for a certain time step to cause overbank flow, taking into account the average soil moisture saturation estimated by the system. Combined with the predicted mean areal precipitation the system evaluates the flash flood risk level. There is a flood risk if the predicted mean areal precipitation (MAP) exceeds the amount needed for overbank flow.

The information received from the system is processed and updated every 6-hour and then posted on the MRC flood forecasting webpage in parallel with the Mekong mainstream flood forecast once a day. Only high risk levels are distributed as warnings, so that recipients are not unnecessarily loaded with information.

The accuracy of the system is dependent on the level of accuracy of information used, such as elevation delineation and digitized stream network data, land cover, land use, soil texture etc., and of course the satellite imagery. Therefore the performance of the system has to be monitored to identify weaknesses and to improve predictions.

During the 2014 flood season the flood forecasting team of RFMMC continued to operate the Flash Flood Guidance System (FFGS) and to provide warnings on its website .

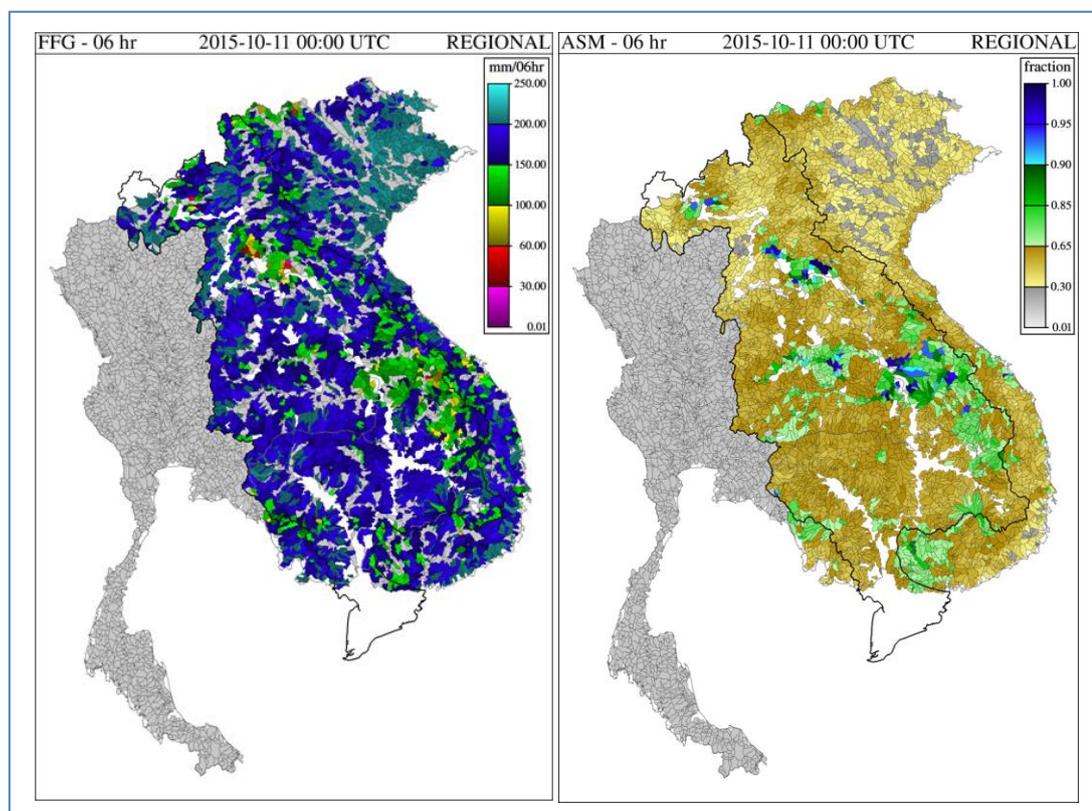


Figure 2-1 Flash Flood Guidance map. The map shows the amount of rain needed during a 6 hour period to cause flooding (left), and soil moisture saturation (right).

The warnings that the FFGS system has identified as being critical are each day collected in Excel files, and can be downloaded from the MRC website. There the areas for which there is a risk for flash floods are listed by country. The extent of the area for which warnings are issued depends on country. In Cambodia and Lao PDR the warnings are given on village level, in Thailand and Viet Nam on district level. In practice the warnings for Cambodia and Lao PDR are given on a sub-basin or sub-catchment level, and normally a warning is given to all villages listed in the database within this sub-basin if a risk has been identified. Thus the warning count is multiplied with the number of villages located in the sub-basin. The area of these sub-basins in Cambodia and Lao PDR is generally much smaller than the area of districts in Thailand and Viet Nam; a district in Lao PDR is typically divided into approximately 10 sub-basins. Thus the number of warnings given in each province or country does not in itself automatically indicate how risky the region is in terms of flash floods. It is to be noted that the MRC-FFGS gives warnings for some areas in Thailand and Viet Nam outside the LMB, in fact the entire area of Viet Nam is covered by the system. After the flood season 2014 warnings will not be issued for areas outside the LMB in Thailand.

The special character of flash floods, local character, difficulty to predict and short lead time means that the solutions developed for the management of river floods do not prove effective in dealing with flash floods, and require separate means. A flash flood guidance system is an important component of the management of flash flood risk management, but what is considered key in managing flash floods is the activity of local authorities in warning and responding to floods, with their main goal being to limit the danger to human lives. The activity of local authorities in warning and responding to floods is essential to limit the danger to human lives and property (APFM, 2007). For the warnings to be effective, the organization (in particular in form of response plans) needs to be good, and there needs to be a high degree of community awareness in the areas in danger. There is of course always a dilemma of how, on the one hand, to avoid false alarms, and on the other to encourage the warning of residents about a flood that is about to happen. Local authorities should be encouraged to follow up the behavior of their river when a warning is issued. They are the ones best suited to then make decisions. In order to be effective it is not enough that a flash flood warning system is able to forecast the potential location of a flash flood, the warning must also reach the people at risk. The countries have system in place to forecast floods and announce them, often some days ahead. But this system, designed for riverine floods may not be fully appropriate for flash floods, given the short lead time, and may have to be complemented by other systems such as internet facilities or using cellular phone systems. This requires ongoing education and information, and the training of crisis services.

## 2.4 Flash flood warnings given by RFMMC 2010-2014

During the period of flash flood guidance operation at MRC in the years 2010-2014 more than 35 000 flash flood warnings was issued by the RFMMC, see Table 2-4. Warnings are issued for the period May to November. Most of the warnings (roughly 80%) are issued for Lao PDR, and comparatively few warnings are issued for Cambodia. The high number for Lao PDR is partly due to the fact that the warnings are given on a village level, apart from warnings in Thailand and Viet Nam, as explained in the previous section. Nevertheless, the numbers clearly indicate that within the Mekong basin Lao PDR is potentially most exposed to flash floods. Only 3 of the provinces in Viet Nam which are issued flash flood warnings are located within the LMB in the Central Highlands, and they receive roughly 10% of the warnings issued for Viet Nam. Due to its flatness the Delta receives no warnings by the system.

Table 2-4 The number of warnings issued by the MRC Flash Flood Guidance System in 2010-2014. Warnings for Thailand and Viet Nam include areas outside the LMB. Data provided by RFMMC.

	2010	2011	2012	2013	2014	Total
Cambodia	29	47	24	8	29	137
Lao PDR	6 852	1 468	10 379	2 919	6 435	28 053
Thailand	165	16	133	107	269	690
Viet Nam, total	199	1 042	1 856	956	1 123	6 274
Viet Nam, LMB	15	84	133	160	200	757

It can also be seen that the number of warnings fluctuates greatly from year to year, but it is surprising that the number of warnings does not seem to correlate with the accumulated rainfall amount. The year 2011, with the least number of flash flood warnings, was normal or wetter than an average year in the LMB.

On the other hand, the in the year 2012, which was a meteorologically dry year with flood volumes much below average, a record number of flash flood warnings were issued in Lao PDR. The geographically uneven distribution of rainfall most likely accounts for this. For example, in 2011 the river flow volume during the flood season was much below normal at Chiang Saen, normal at Vientiane and much higher than normal at Kratie.

If there are differences in the geographical distribution of warnings, there are also differences in the temporal distribution of warnings, as shown in Figure 2-2. The majority of warnings are issued during the period July to September, which generally are the wettest months. In Cambodia October seems to be the most critical month, as nearly half of the warnings for Cambodia occur then.

The provinces receiving most of the warnings are listed in Figure 2-3. In Thailand the majority of warnings are issued in the Northern Highlands, in the provinces of Chiang Rai and Chiang Mai. In the Mekong Basin the Kok and Ing River watersheds seem potentially vulnerable to flash floods, while in the Mun-Chi basin warnings are geographically less concentrated and less frequent.

In Lao PDR the provinces of Luang Prabang and Xienkuang receive by far the most warnings, then followed by Phongsaly and Xaysomboun.

In Viet Nam the most warnings are given for provinces in the northernmost parts of the country. The three provinces within the LMB in the Srepok and Se Kong River watershed, Dak Lak, Kon Tum and Gia Lai receive 11% of all warnings given for Viet Nam.

Cambodia is issued very few warnings compared to the other LMB countries, only 137 for the 5-year period 2010-2014, half of which for the provinces of Ratana Kiri and Pursat.

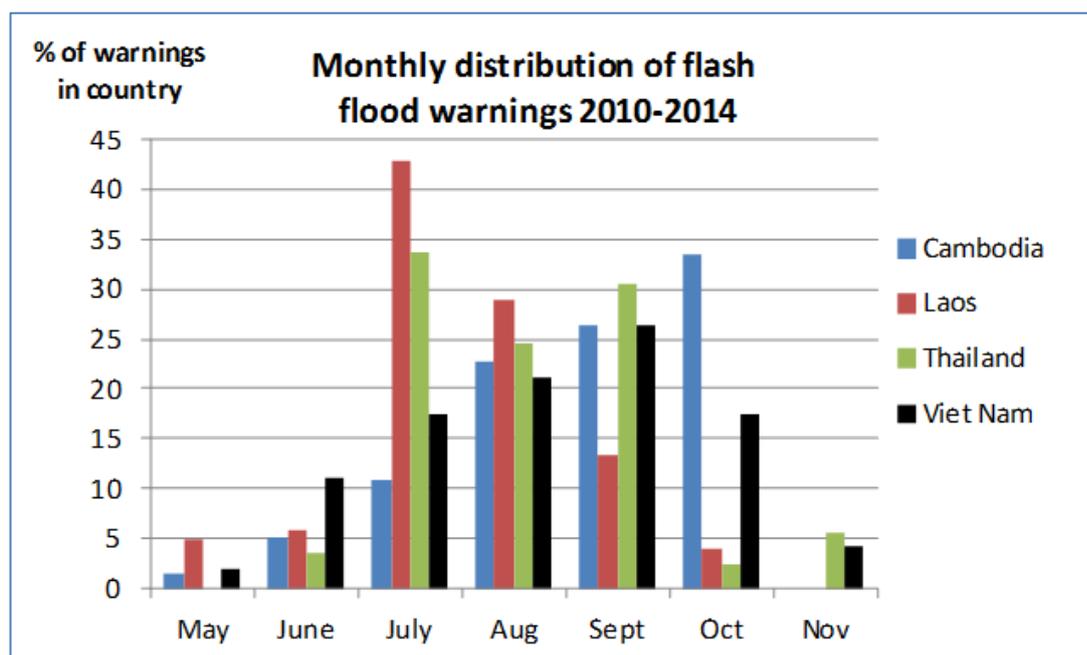


Figure 2-2 The monthly distribution of flash flood warnings in LMB countries.

The sub-basins and districts receiving most of the flash flood warnings are depicted in Figure 2-6. The warnings in different countries have been adjusted in this figure to be comparable with each other. In Thailand and Viet Nam the warnings are depicted on district level, in Cambodia and Lao PDR only the village with most warnings within one sub-basin has been included. In this way only the warnings per unit area is shown and there is no artificial “multiplication” of warnings when several villages are located within the area for which a warning is issued.

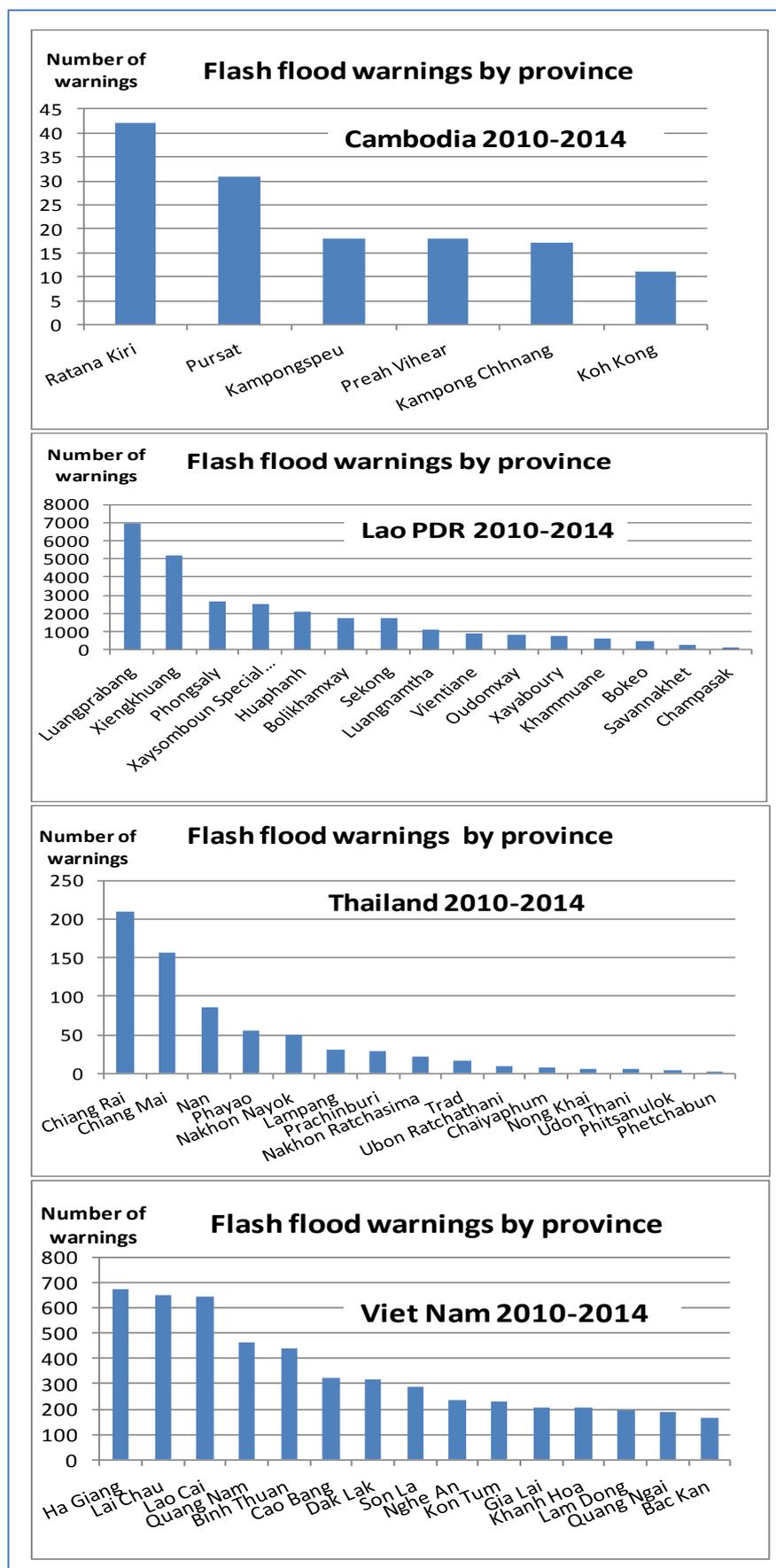


Figure 2-3 The top provinces where flash flood warnings were issued by the MRC Flash Flood Guidance System in the period 2010-2014

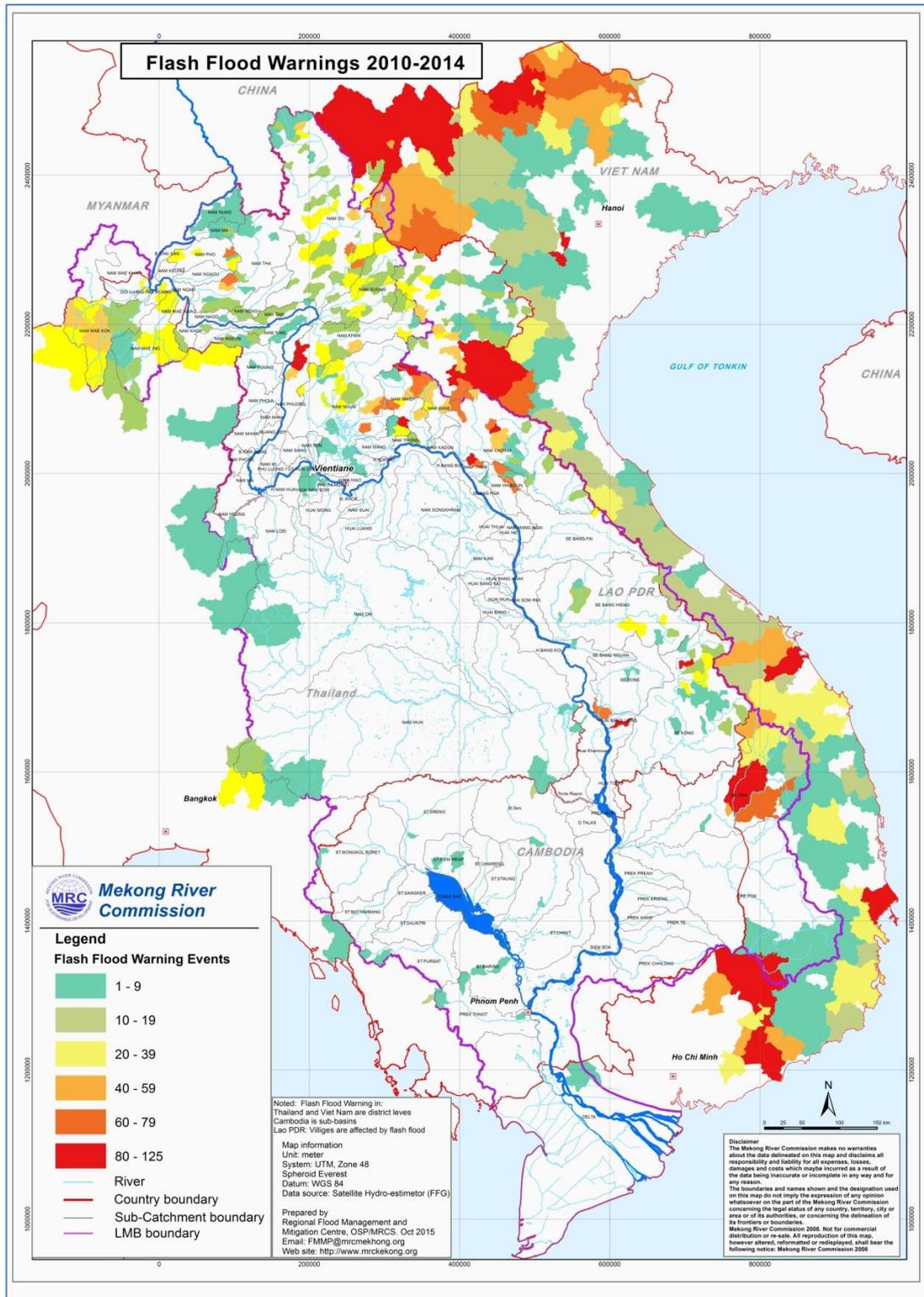


Figure 2-4 Sub-basins (catchment areas) in Cambodia and Lao PDR and districts in Thailand and Viet Nam receiving flash flood warnings.

The flash flood warnings are concentrated to specific, generally mountainous areas, where the meteorological conditions for exceptional convective rains prevail, and the pattern is very patchy. In Cambodia and Lao PDR the sub-basins receiving most of the warnings are usually located in the upper reaches of the tributaries. In Cambodia the

upper catchments of Se San, Stung Pursat, Tonle Sap and Stung Duan Tri receive the most warnings, and in Lao PDR the most warnings are given for the Nam Nhiep catchment, but also Nam Thon, Sekong, Nam Khan, Nam Hin Boun, Houei Bang Lieng, Nam Ngum and Nam Ou catchments are frequently issued flash flood warnings.

In Thailand a large part of districts the Nam Mae Kok and Nam Mae Ing catchments have received warnings, but warnings are also given to the moderately steep regions of Mun-Chi basin, where flash floods have been reported on several occasions.

In Viet Nam in the Mekong part the most warnings are issued in the upper catchments of Srepok River, and the warnings are quite frequent. This is an area which experiences flash floods annually.

The geographical distribution of flash flood warnings coincides as might be expected to a high degree with areas with high rainfall (see Figure 2-5).

As flash floods are of local character, very intense potentially causing extensive damage and of comparatively short duration, warnings on local level are very useful, so that sufficient preparations can be made. In Cambodia only 32 villages are included on the warning list, in Lao PDR the number is more than 10 000.

In Thailand 392 districts are on the list for which flash flood warnings can be issued. The size of the districts varies from a few hundred km<sup>2</sup> to more than 1 000 km<sup>2</sup>. In Viet Nam 588 districts are included in the potential warning list. In the LMB part of Viet Nam 18 districts are situated in the province of Dak Lak, 12 in Gia Lai and 7 in Kon Tum. The size of the districts is similar to those of Thailand.

A warning on district or especially sub-basin (or village) level is thus quite precise from a geographical point of view. It is therefore instructive to look at the number of warnings in each district or sub-basin during the period 2010-2014. In Figure 2-6 the number of warnings on village or district level in the four countries is shown.

Several villages in Lao PDR have received more than 100 warnings during a five-year period, and 2 villages received 21 warnings during one month. This may indicate an over-cautious warning system with too many unfounded alerts. A system check should be made for these cases to see if necessary parameters have the correct value when evaluating the flood risk.

It is interesting to note that in the Lao district Nan, which receives the most warnings of all districts in Lao PDR, more than half of the 74 villages in the district have not received a single warning during the 5-year period of FFG operation. This shows how locally concentrated the conditions for flash floods are, as the area of the Nan district is only about 1 000 km<sup>2</sup>. Therefore a warning on a district level may be too coarse to

pinpoint areas where there is a genuine risk of devastating flash floods. On the other hand it may well be that within the district there is local knowledge at hand to identify areas or even villages at risk.

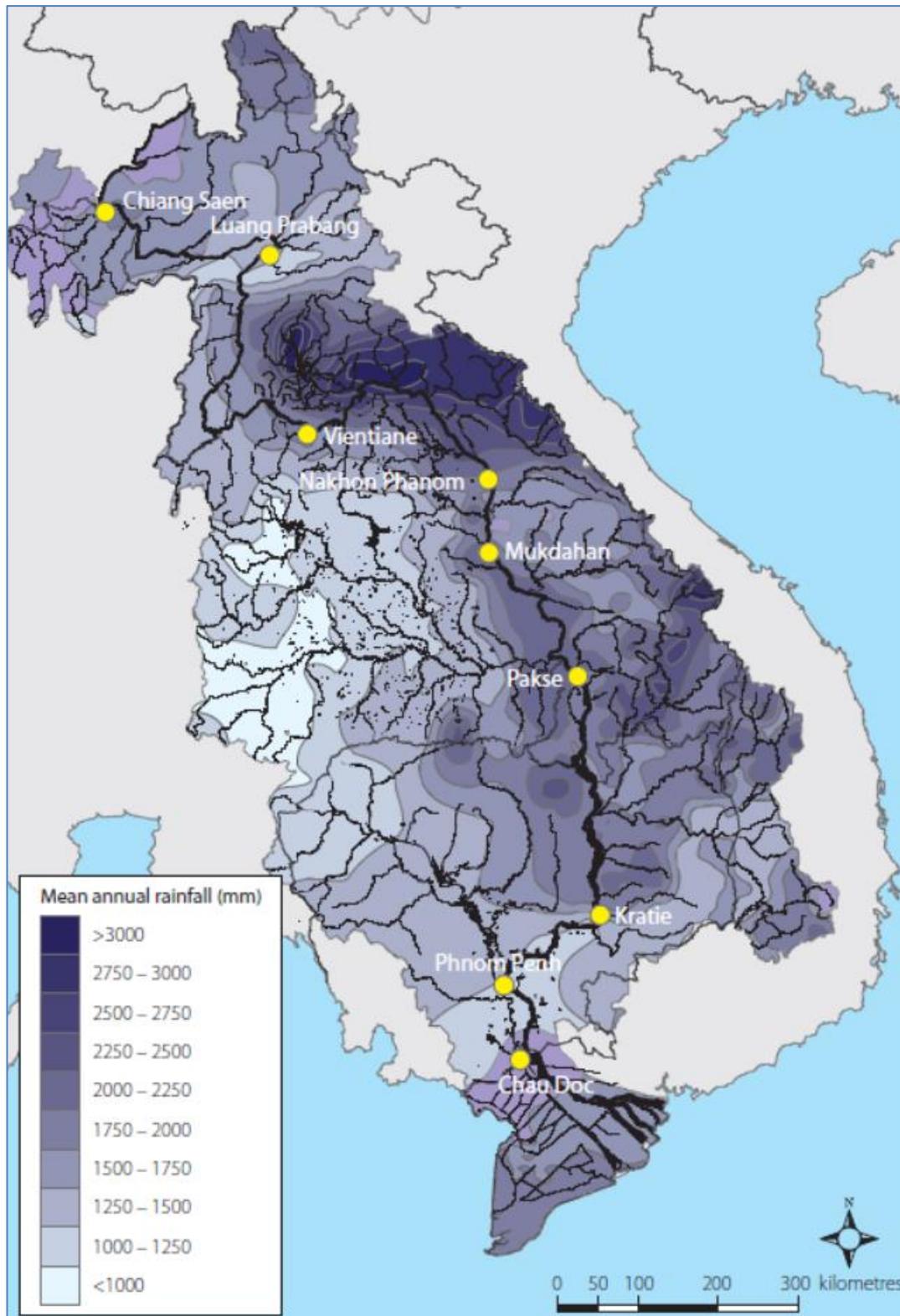


Figure 2-5 Annual mean rainfall in the LMB.



## **2.5 Reported flash floods in the LMB 2010-2014**

The occurrences of floods in countries are summarized in the national flood reports each year. They are often reported on a provincial level, and the reports clearly indicate that flash floods causing different degrees of damage occur every year in each country.

In Cambodia flash floods have been reported most often from the provinces of Pursat, Bantaey Meanchey and Siem Reap. Of these provinces only Pursat has received flash flood warnings during the same period, while the province of Ratana Kiri which has received most warnings has only one reported flash flood.

In Lao PDR most floods are reported from Luang Prabang, Khammuane and Vientiane provinces. Luang Prabang receives the most warnings of all provinces, so one would expect the number of reported floods to be high. On the other hand, Vientiane province receives relatively few flash flood warnings, yet many floods causing damage are reported to take place here. Observed floods causing some sort of damage in 2010-2012 as collected from the Desinventar database ([www.Desinventar.net](http://www.Desinventar.net))<sup>1</sup>, are shown for provinces in Figure 2-7. Comparing with Figure 2-3, where the warnings per province is shown, it can be seen that the most warnings are not always issued for provinces with most reported floods. For example, the provinces of Khammouane, Champasack and Xayabury have experienced flood damages, but comparatively few warnings were issued for these provinces. On the other hand Luang Prabang and Boulikhamxay have received many warnings, and many floods have happened here. It must be remembered that the flood observation data, like damage data, is not consequent, and data varies among the authorities collecting them.

In Thailand many flash flood warnings are issued for the Kok and Ing river catchments, and many floods are also reported from here. But many floods are also reported from the less steep Mun-Chi region, where flash flood warnings are quite uncommon.

In Viet Nam flash floods are a hazard in the Central Highland provinces of Dak Lak, Kon Tum and Gia Lai, causing damage and loss of life. They have also received a fair share of flash flood warnings, more than 700 during the operation of the FFGS. However, more extensive damage and greater hazard are caused by floods in the Mekong Delta, but here the causes are high water levels in the mainstream often combined with high tides, not flash floods.

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<sup>1</sup> “Desinventar.net” is an open source official site, sponsored by the United Nations. It is a conceptual and methodological tool for the construction of loss, damage or effects caused by emergencies or disasters.

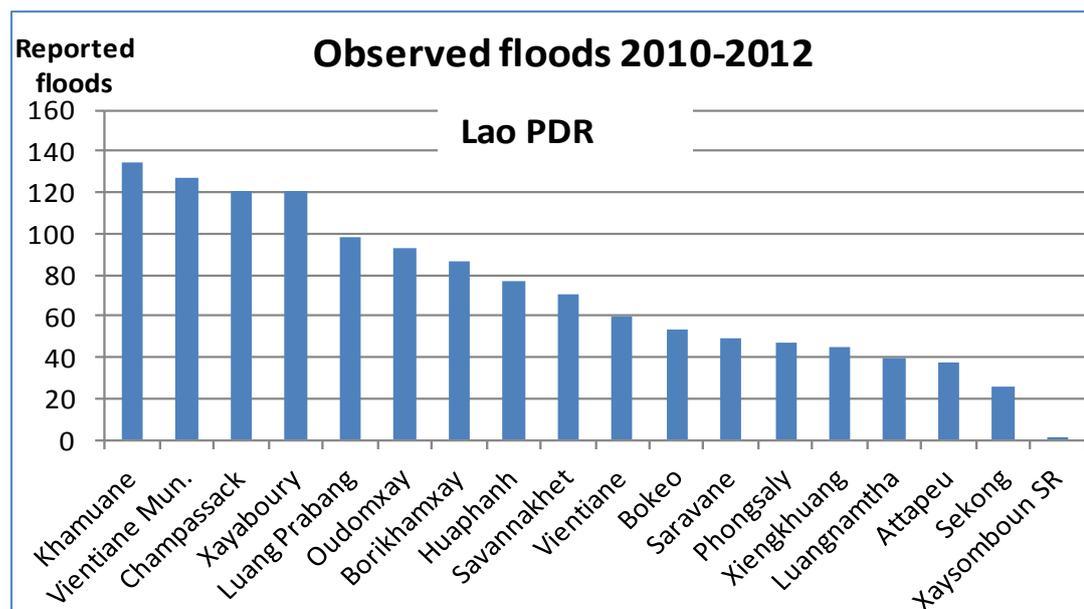


Figure 2-7 The number of observed floods in provinces of Lao PDR 2010-2012. (Source: www.desinventar.net).

## 2.6 Evaluation of the performance of the Flash Flood Guidance System at MRC

To evaluate the effectiveness of the FFGS feedback is needed from areas hit by flash floods. Such events are difficult to monitor because the observational network on water level and rainfall is sparse, and in practice it is simply not possible to have such an observational network of the necessary scale to catch even a major part of occurring flash floods. Therefore flash floods have to be evaluated based on the traces they leave in form of visible physical impact, such as erosion and damages on housing, roads, bridges, etc.

As the areas prone to flash floods are highly local and likely situated in remote places difficult to reach it is not easy to have complete coverage of incidents. Consequentially there are no national registers keeping track of flash floods, and even though flood damages are estimated annually in the countries, often no strict distinction of damages caused by riverine (inundation) floods and flash floods is done. Furthermore, flood damages reported to MRC are sometimes covering the whole country, and not specifically for the LMB region.

Despite these difficulties RFMMC has evaluated the annual performance of the FFGS since 2011.

The methodology for evaluation is based on two concepts. The first concept evaluates the feed-back of the FFGS from the users or from other sources of information such as the media or the press. As the link between the regional flood center and the local

people (through the focal person at national line agencies) is not yet fully established, the feed-back information on flash flood areas was mainly collected from the national media, such as newspapers. These constitute an important source of information on flash floods.

The second concept evaluates the FFGS through the recorded water levels that are available in the operational database of RFMMC. If a flash flood happens upstream in a sub-area where a water level stations are available, the FFG product can be evaluated by studying the changing (rising) water level records of stations located in the downstream part of the sub-catchment. Sometimes also the observed rainfall at a station can be used to verify an issued warning. Given the sparse observation network these cases are of course rare compared to the number of warnings to be evaluated.

Both concepts come with a difficulty. In newspapers covering the damage of floods the damages are often reported quite accurately (sometimes accompanied by photos), but geographically typically reported on a general level, such as a district or region (province). Only occasionally are villages named so that the affected area can be pinpointed. As flash flood warnings are given on village level in Lao PDR and Cambodia a fully secured check on the accuracy of the FFG cannot be made in most cases. However, experience has shown that the FFG system very often had successfully indicated a flash flood risk in the flooded areas, but lacking an accurate and complete database of flash flood events makes it difficult to put a number on the success rate. As has been stated above it is not therefore possible to evaluate the effectiveness of the FFGS in a fully objective manner. That a flash flood event has occurred and that a flash flood warning has been given prior to this shows that the FFGS was successful that time, but does not prove that it is always successful. But also the cases where flash floods have been observed and documented, but no warning given by the FFGS, should be thoroughly analyzed, and the reason identified. Only this way can the system be improved.

Using water level readings can only reveal a small part of the occurring flash floods. Normally the watershed above the water level observation point covers a large area, often several thousand km<sup>2</sup>, while flash floods occur on a much smaller geographical scale. A sharp rise in water level at an observation station may indicate flash floods above the point of measurement, and it can then be checked whether any flash flood warnings were issued in the upstream sub-basins. An example of this is given in Figure 2-8 from rivers Nam Khan and Nam Sane. The water level at these stations rose 3.5-5.5 m in 12-24 hours. Flash flood warnings were given in several sub-basins especially within the Nam Khan catchment, and flooding of villages and other areas was confirmed in the Vientiane Times.

This method has proven quite successful in several instances, but is not watertight. Very local and short-lived flash floods may go unnoticed as water level readings in the

operational database of RFFMC are recorded mostly only once a day, or the flood be considerably attenuated before it reaches the station.

Another way to check the accuracy of the FFGS is to turn to rainfall data. At RFFMC the evaluation of the detailed performance of the FFGS during tropical storms hitting the LMB by comparing the predicted MAP, the satellite estimated rainfall and the observed rainfall at selected stations is a work in progress.

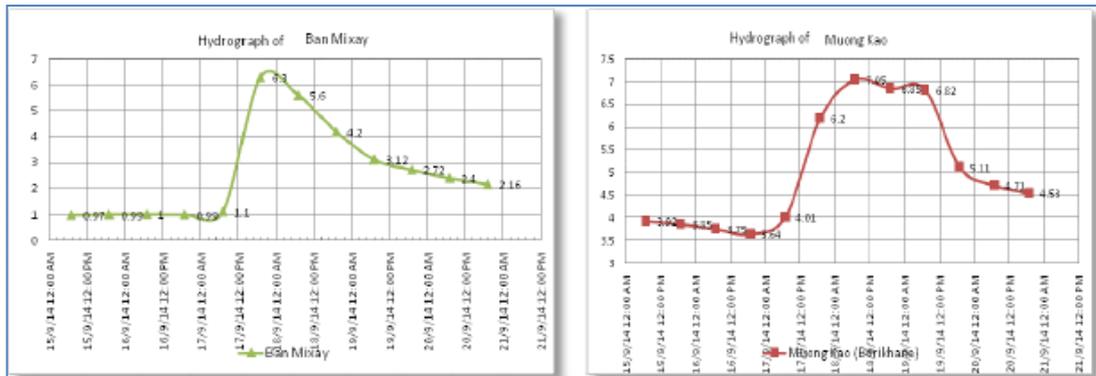


Figure 2-8 Water level records from Ban Mixay at Nam Khan and Muuang Keo at Nam Sane during tropical storm KALMAEGI.

An example of results is shown in Figure 2-9 during the tropical storm RAMMASUN in July 2014 (MRC 2014). The quality of results in the shown example ranges from excellent to acceptable. It is hoped that a thorough analysis will help to improve the flash flood predictions by improving the link between satellite predictions and observed rainfall during storms. The results are expected to be available in the near future.

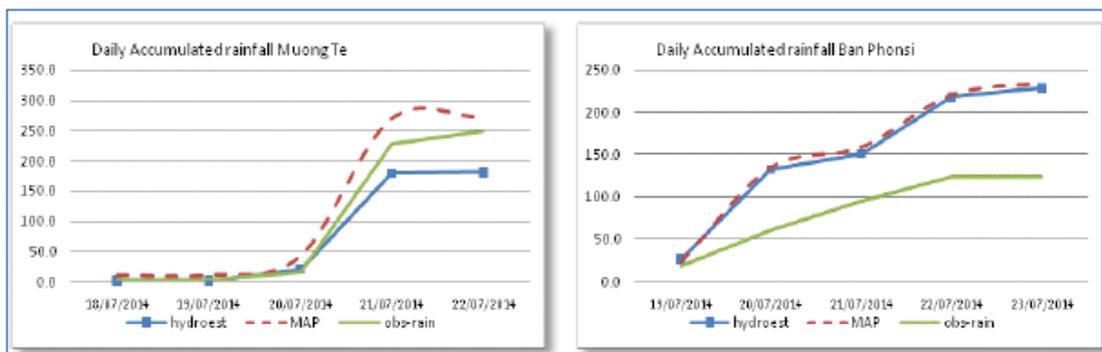


Figure 2-9 Daily accumulated rainfall (in mm) at Muong Te station and at Ban Phonsi station of Nam Kading catchment. Observed rainfall (green), mean estimated areal rainfall MAP (dotted) and satellite estimated rain (blue).

For the year 2013 a table where the observed rainfall, the predicted mean areal precipitation (MAP) and the satellite rainfall estimate for each day is listed for 113 stations with recorded daily rainfall data was collected by RFFMC. Some stations located outside the LMB were also included in this list. In Figure 2-10 the rainfall

station network is shown. Based on this data the satellite estimated mean areal precipitation (MAP) and observed rainfall from the 6 stations with the highest predicted annual rainfall are plotted (all stations located within the LMB boundaries). The result is shown in Figure 2-11. The fitted trend lines and correlation coefficients ( $R^2$ ) are shown for comparison. There is quite a large scatter of results, and high predicted values do not always correspond to high observed rainfall, and vice versa. The latter condition indicates that flash floods may potentially occur without an adequate warning from the FFGS. Such situations with flash floods with no foregoing warning have occurred and have been acknowledged by the RFMMC. Thus the FFG sometimes fails to issue warnings when it should.

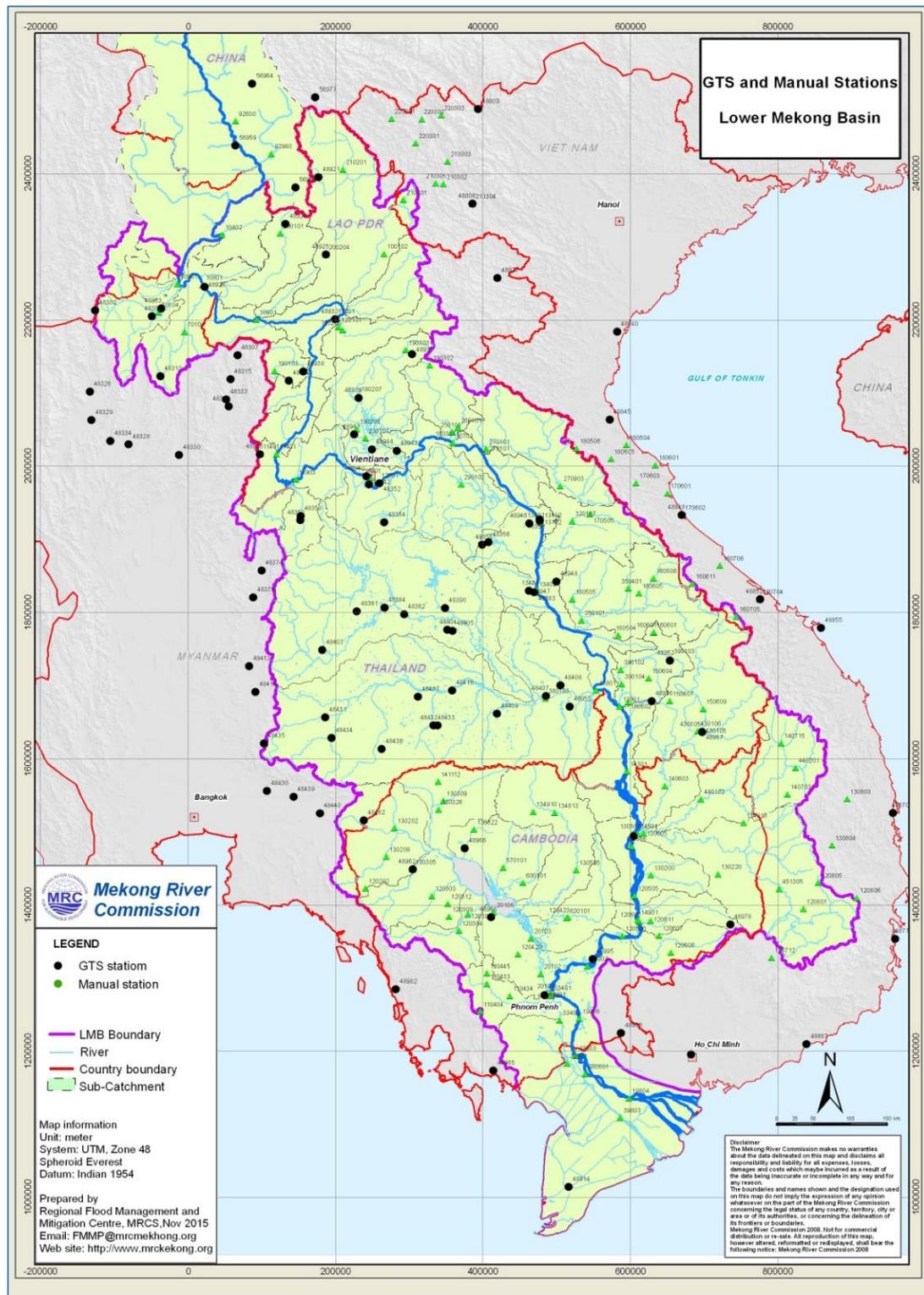


Figure 2-10 Rain gauges in the Lower Mekong Basin.

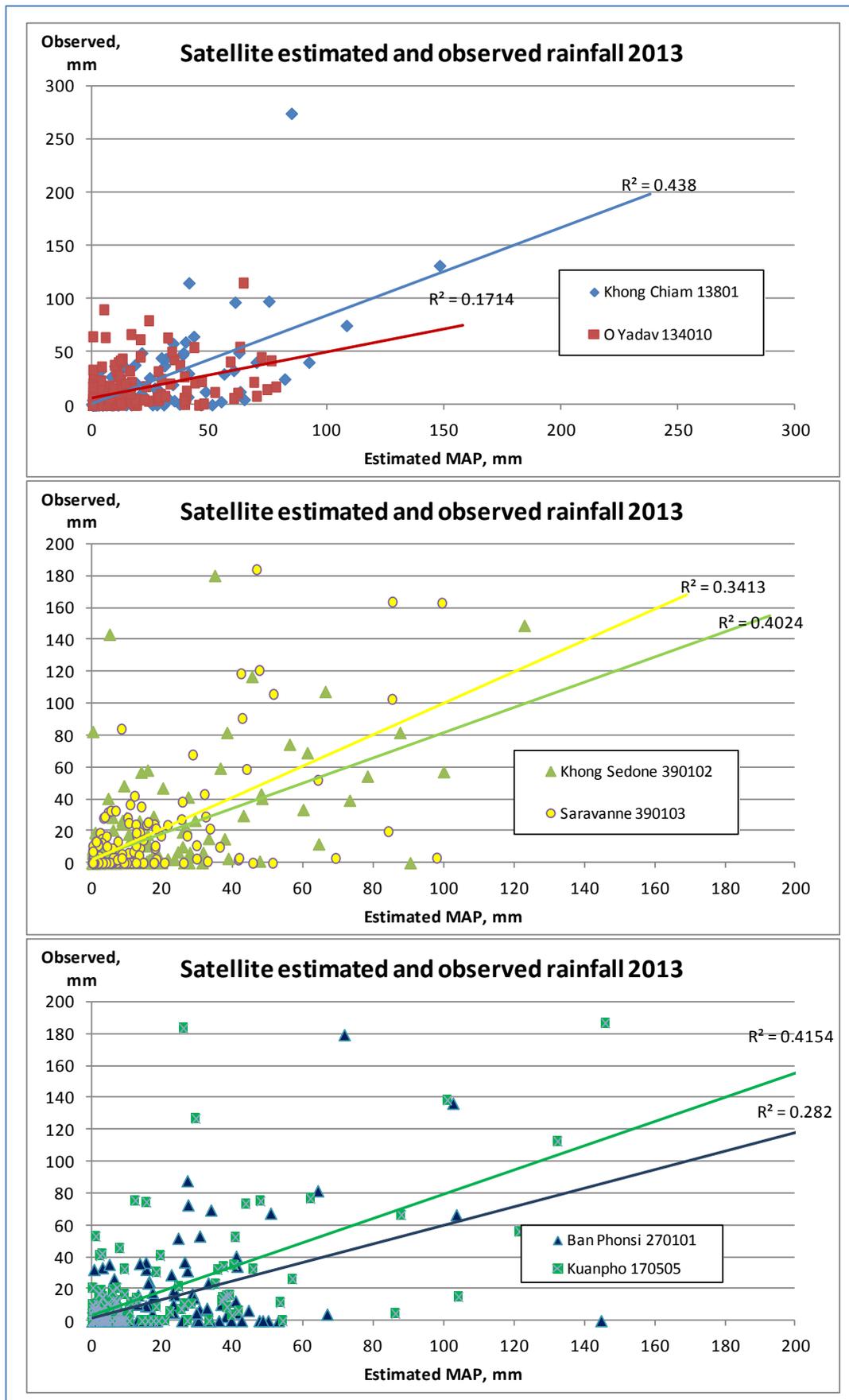


Figure 2-11 Satellite estimated daily mean areal rainfall (MAP) by the FFGS and observed daily rainfall at 6 rainfall stations during 2013.

Using this data set it was possible to compare FFGS estimated and observed rainfall amounts in an objective way for all stations, and the general accuracy of the estimated mean areal rainfall (MAP) could be evaluated. Although the study of rainfall station data alone will not identify flash flood risks or reveal areas where predicted flash floods have taken place it will at least show the level of accuracy that can be expected from the MAP component of the FFGS.

The average ratio of observed rainfall to estimated MAP for all 113 stations is 1.26, meaning that in general the mean areal precipitation is underestimated. However, the scatter is large, and the aforementioned ratio ranges from 0.53 to 3.58 among stations. Thus the situation varies from one observation site to another. But it is possible to evaluate a success rate for the rainfall prediction of the system by comparing predicted rainfall with the observed rainfall in areas with a rainfall station. In Figure 2-12 the success rate of rainfall predictions is evaluated for the 113 stations available for comparison. A prediction is considered successful if the observed rainfall exceeds a certain percentage of the predicted rainfall for a station. The total number of successful predictions is counted and compared with the number of rainfall events. The success rate for a 60% and 80% threshold are shown in the figure. It can be seen that the success rate is about 50% for daily rainfalls exceeding 60 mm. The extreme rainfalls (>140 mm) are less successfully predicted, but this can be attributed to the fact that they are quite rare and very local, meaning that they are easily missed by the rain gauge. Small rains seem also to be less accurately estimated, but from a flooding point of view this is of no importance as floods require much rainfall.

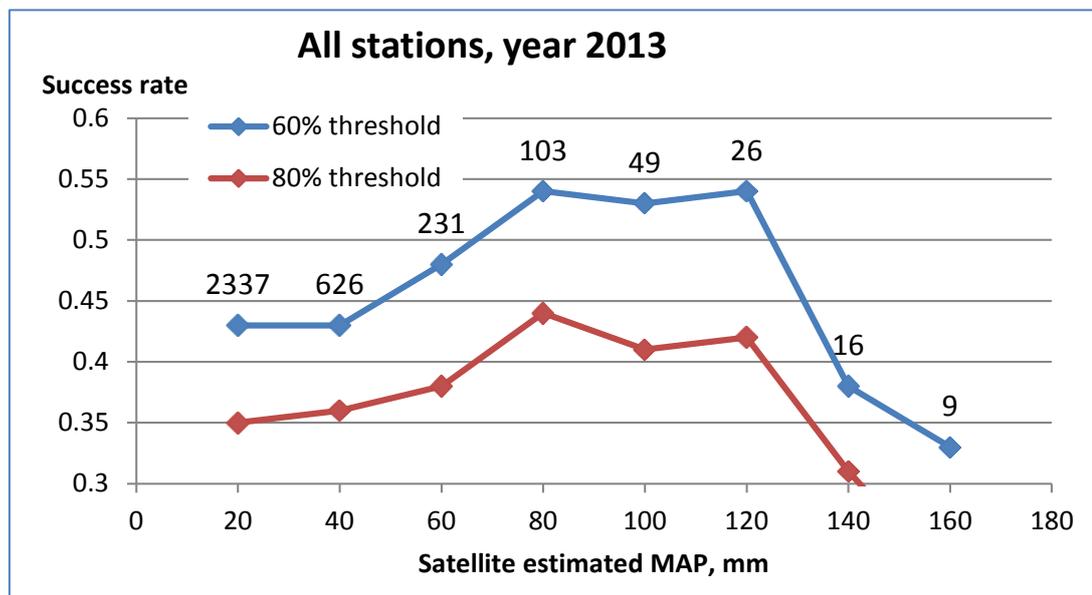


Figure 2-12 The success rate of the FFG satellite estimated daily rainfall amount (MAP). If the observed rainfall at a station is at least 60 or 80% of the estimated rainfall the estimate is considered successful. Numbers above points indicate total number of rainfall events analyzed.

The success rate for an 80% threshold is about 40%. While the success rates are not perfect they nevertheless show that heavy rains predicted by the system have a good chance of coming true. This is quite remarkable considering that the esti rainfall is based only on satellite observations of atmospheric conditions. It should also be remembered that rainfall intensity may be a more important flash flood trigger than the accumulated rainfall during one day.

Predicting rainfall correctly is only part of the FFGS. Physical characters of the sub-basin, drainage network, soil moisture and land cover also influence the risk of flash floods occurring, and must also be studied as part of the evaluation. Especially the areas receiving the most warnings should be carefully evaluated on the circumstances leading to warnings. As seen from Figure 2-4 and Figure 2-6 there are many sub-basins and villages which have received more than 100 warnings during 5 years' time. If it cannot be proven that the issued warnings had a solid base the confidence in the system will decrease.

The level of utilization of and knowledge about the FFGS at MRC seems to differ in the countries.

Viet Nam regularly follows the system output, but would like to see more training on flash flood warnings, and also flood warnings not only for mainstream Mekong but also tributaries. The FFGS of MRC should be improved.

The DMH of Lao PDR uses the output from the FFGS for their own flood forecasting and flood watch.

At Ministry of Water Resources and Meteorology (MOWRAM) in Cambodia the capacity to utilize the FFGS at MRC is still limited and the interpretation of warnings provided takes a long time before the information is released further.

Thailand has developed its own flood forecasting system, and does not seem to rely upon the MRC system when issuing flash flood warnings.

In general it seems that national agencies are not fully informed of the possibilities to use the FFGS system at MRC. There is a need to for MRC to increase the awareness of the system, complemented by training of forecasters in the use of the system.

As a conclusion of the analysis of given flash flood warnings it can be said that the FFGS clearly has the potential to be the tool for a very effective warning system. However, there is room for improvement of the performance of the system at MRC, which include:

1. Improve the Mean Aerial Precipitation (MAP) product by updating the bias correction factor for satellite rainfall (Hydroestimator) processing.
2. Strengthen the connection between the RFMMC and the National FFG operations for the region in order to receive additional information about areas where flash floods have occurred. For example, pinpointing the exact location of the flash flood would help to evaluate the effectiveness and accuracy of the system.
3. Investigate the areas receiving many flash flood warnings to see if the warnings are all warranted and the flash flood risk is correctly evaluated by the system. Too many warnings without floods may weaken the confidence in the system.
4. Look at instances where flash floods have occurred but have not been identified by the FFGS.



### 3. THE 2014 FLOOD SITUATION

#### 3.1 The regional rainfall climate during 2014

Based on the rainfall information from selected sites along the Mekong the cumulative rainfall amount for 2014 was more or less normal at the selected sites, as can be seen from Table 3-1. The onset of the monsoon season was more or less normal, with the exception of the southern areas where it was delayed by 4-5 weeks. The end of the monsoon season was mostly within the normal variation October-November (Table 3-2).

In Figure 3-1 the estimated accumulated rainfall for 2014 based on satellite data is shown. The distribution of rainfall over the region looks more or less normal, although the region around the Nam Ngum basin northeast of Vientiane had less rain than normal compared to the long-term average shown in Figure 2-5.

Table 3-1 Annual rainfall during 2014 compared to the long term average at selected sites in the Lower Mekong region.

Location	Annual rainfall (mm)		
	Average (mm)	2014 (mm)	2013 as % long term average
Chiang Saen	1 723	1 722	100
Luang Prabang	1 277	1 267	99
Vientiane	1 658	1 973	119
Mukdahan	1 496	1 290	86
Pakse	1973	1 950	99
Tan Chau	1 230	1 020	83

Table 3-2 Onset and end dates of the SW Monsoon during 2014 compared to the long term average at selected sites in the Lower Mekong region.

Site	Monsoon onset				Monsoon end		
	Average Date	Standard Deviation	2014	Delay (days)	Average Date	Standard Deviation	2014
Chiang Saen	7 May	9 days	29 April	none	7 Nov	25 days	5 Nov
Luang Prabang	7 May	9 days	29 April	none	24 Oct	33 days	4 Nov
Vientiane	4 May	8 days	29 April	none	10 Oct	16 days	6 Nov
Mukdahan	13 May	8 days	1 May	none	8 Oct	16 days	24 Sept
Pakse	5 May	11 days	9 June	35	15 Oct	17 days	1 Oct
Tan Chau	18 May	12 days	13 June	26 days	18 Nov	13 days	7 Dec

The accumulated rainfall at selected stations (Figure 3-2 and Figure 3-3) shows that there was a relatively dry spell in the region in May and early June. Especially the area near Pakse received its first rains in the beginning of June. A second dry spell

lasting about 3 weeks with no or very few rains occurred in August-September in the southern parts of the basin. On the other hand, Pakse received 390 mm of rain in 3 days and 532 mm in one week starting 31 July, raising water level in Mekong to above critical level here.

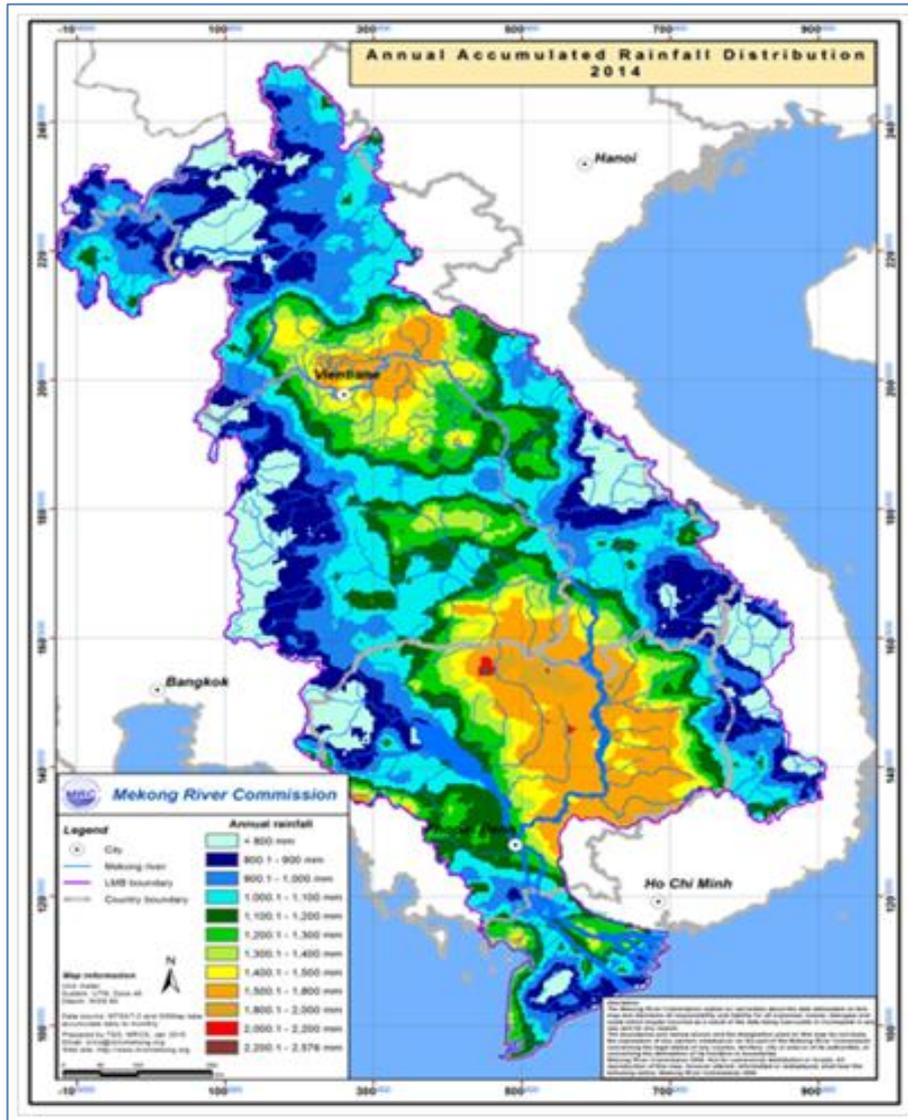


Figure 3-1 Accumulated rainfall across the Lower Mekong Basin during 2014, based on daily rainfall from MTSAT satellite data.

Several storms affected the LMB region during 2014:

- Tropical storm RAMMASUN between 7-20 July
- A tropical depression the first week in August
- A tropical depression in the middle of August, causing heavy rains in the northern parts
- A tropical depression the last week in August
- A tropical depression the first week in September
- Tropical storm KALMAEGI in middle of September

They left a trace on discharges at observation sites along the Mekong, causing spikes in the recorded discharges.

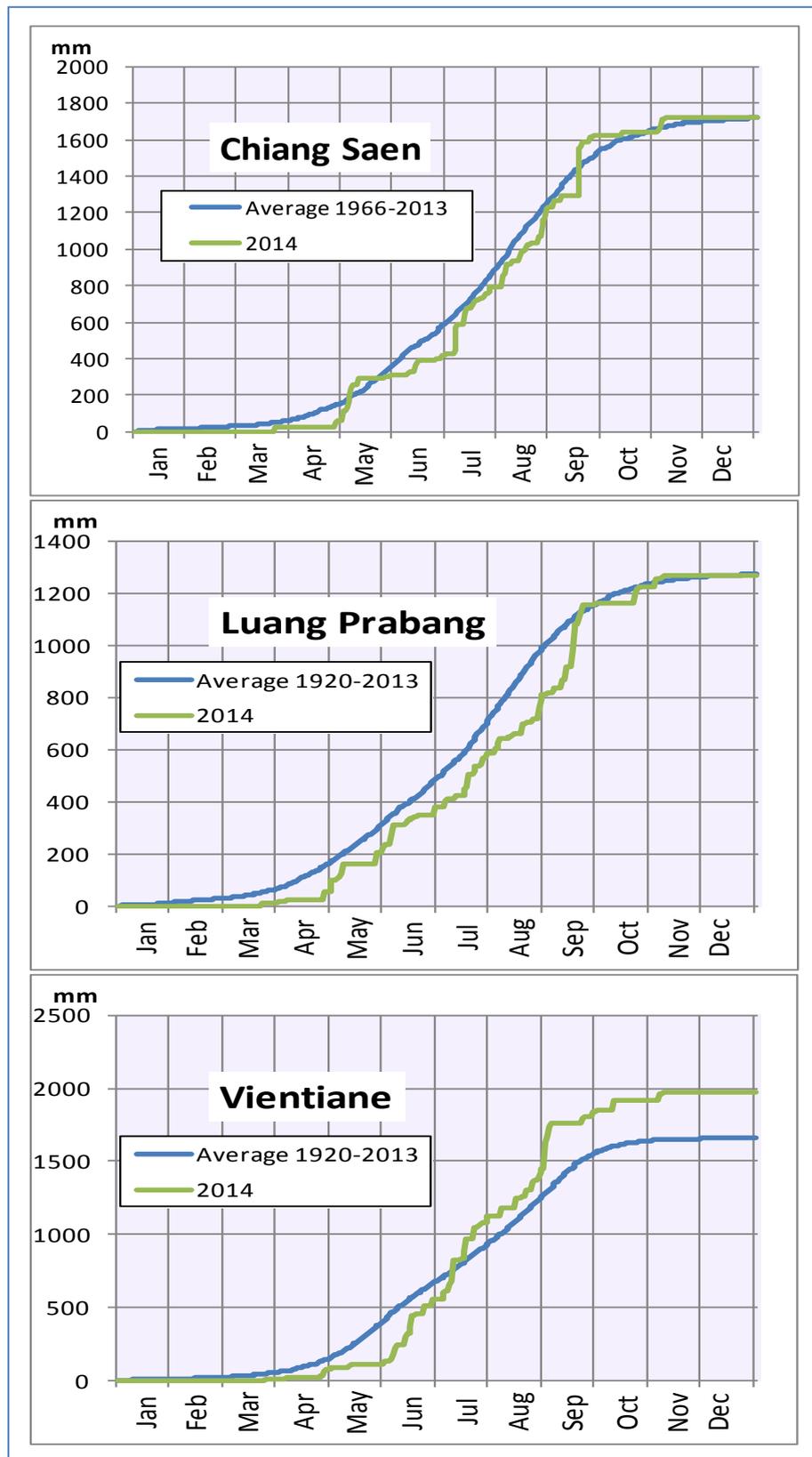


Figure 3-2 Chiang Saen, Vientiane and Pakse – cumulative daily rainfall pattern during 2014.

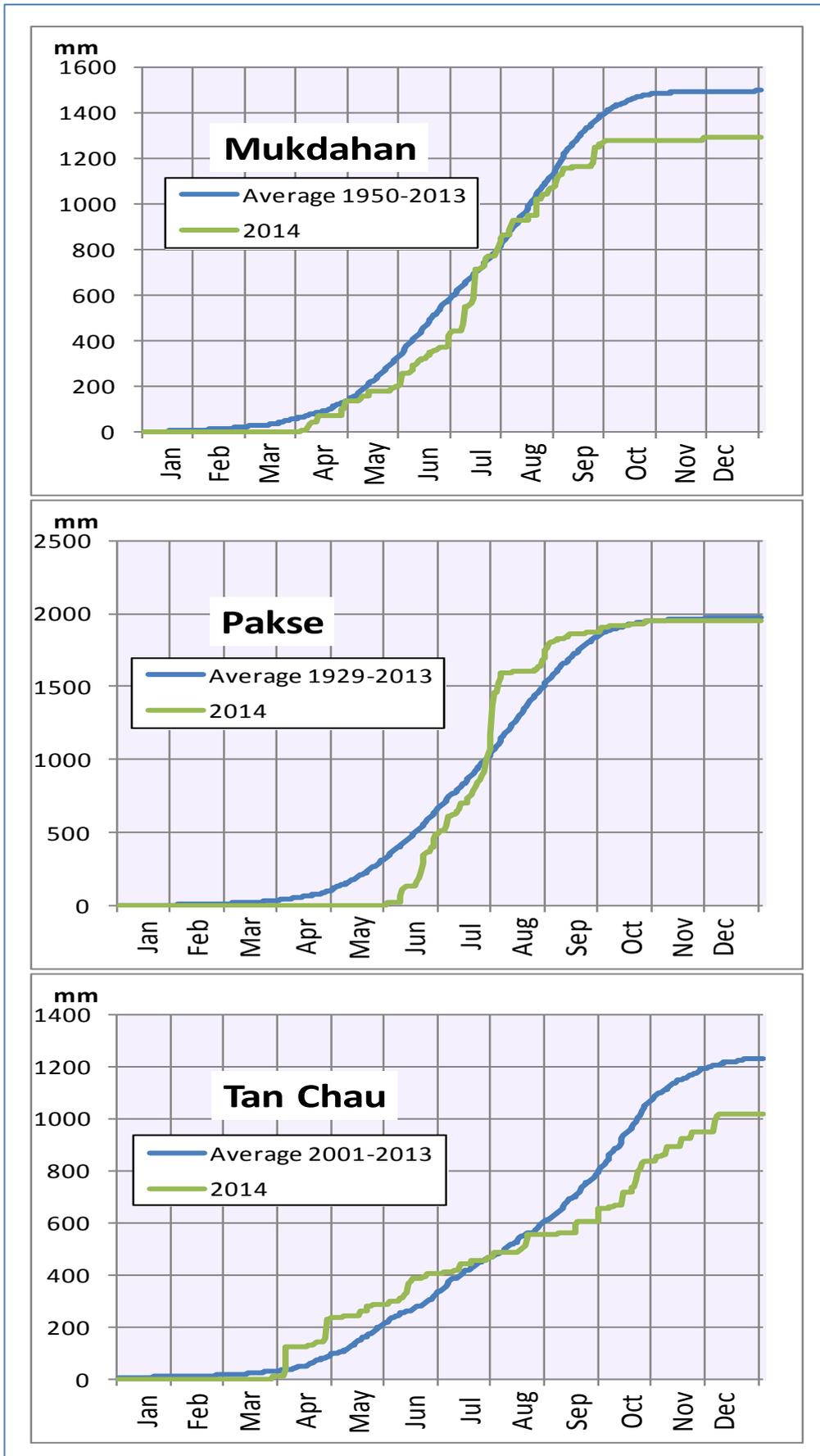


Figure 3-3 Mukdahan, Pakse and Tan Chau – cumulative daily rainfall pattern during 2014.

### 3.2 Water flow in mainstream Mekong

The discharge at the different locations along mainstream Mekong was characterized by a late onset of the rising limb at the river stretch from Chiang Saen to Vientiane. Further south the discharge started to increase quite normally, reaching peak flows in the very beginning of August and then decreasing rapidly towards the end of the month. In the northern parts the flood had several distinct peaks, but in general flows at Chiang Saen and Luang Prabang were lower than normal throughout the flood season apart from a sudden peak at the end of September. The discharges for 2014 are depicted in Figure 3-4 and Figure 3-5. The effect of the tropical depression in the first week of August can clearly be distinguished from Mukdahan and downstream, whereas the tropical storm KALMAEGI caused a steep rise in discharge in the northern parts of the LMB, leading to the annual peak flow at the northern stations.

The onset of the flood season at Mekong mainstream sites can be defined in as the date when the rising discharge of the river exceeds the long-term average annual discharge. The end of the flood season is defined in a similar way as the date when the falling discharge crosses the long-term average discharge. In typical years only one such crossing occurs during the rising and falling stage. The flood volume can be defined as the total flow volume for the days with more than the long-term average flow between the start and end dates. Using these criteria one arrives at the values presented in Table 3-3 and Table 3-4.

Table 3-3 Onset and end of flood season at selected sites along the mainstream Mekong.

Site	Onset of flood season		End of flood season	
	Historical average	2014	Historical average	2014
Chiang Saen	12 June	16 July	13 November	25 October
Vientiane	23 June	16 July	10 November	29 October
Kratie	24 June	24 June	7 November	16 October

Table 3-4 The Mekong River at selected sites. Flood volume and peak discharge of the 2014 flood season, compared to the long term average values.

2014	Chiang Saen	Vientiane	Kratie
Flood volume km <sup>3</sup>	30.5	70.7	278.8
Peak discharge m <sup>3</sup> /s	5 498	13 135	49 475
Annual discharge m <sup>3</sup> /s	2 507	4 101	12 617
Long-term average			
Flood volume km <sup>3</sup>	57	101	330
Mean peak discharge m <sup>3</sup> /s	10 500	16 500	50 900
Mean annual discharge m <sup>3</sup> /s	2 700	4500	13 200

That the LMB flood season in 2014 was shorter and mostly drier than an average year can be seen by studying the hydrographs at stations along Mekong, once again

referring to Figure 3-4 and Figure 3-5. At Chiang Saen and Luang Prabang the flow is much below average during the flood season, but going further downstream flows becomes more or less normal. The increased regulation of flows in the China part of Mekong undoubtedly affected the flow pattern downstream both during the dry season and the wet season. The effect is of course most clearly felt at the most upstream stations of the Mekong, as the flow from the Chinese part of the Mekong, the “Yunnan component”, makes up a significant part of the flow here. This will be discussed further in the next chapter.

The flood volume at Chiang Saen was the third smallest in recorded history, and was only 54% of the long-term average. Only in 1992 and 2013 has it been smaller. At Vientiane and Kratie the flood volume was similar to that in 2013, being 70 and 85% of the long-term average. However, the annual mean discharge was close to normal at each station, underscoring the fact that the actual flood season in Chiang Saen and Vientiane was less pronounced than usually. The peak discharge at Chiang Saen was extremely low, only very slightly higher than the historical minimum of 1992.

Figure 3-6 and Figure 3-7 place the flood conditions of 2014 within their full historical context. Those at Chiang Saen are identified as being historically extreme according to the proposed criteria. Meanwhile, those at Vientiane would be defined as significantly deficient. At Kratie, the flood both in terms of peak and volume was close to average overall.

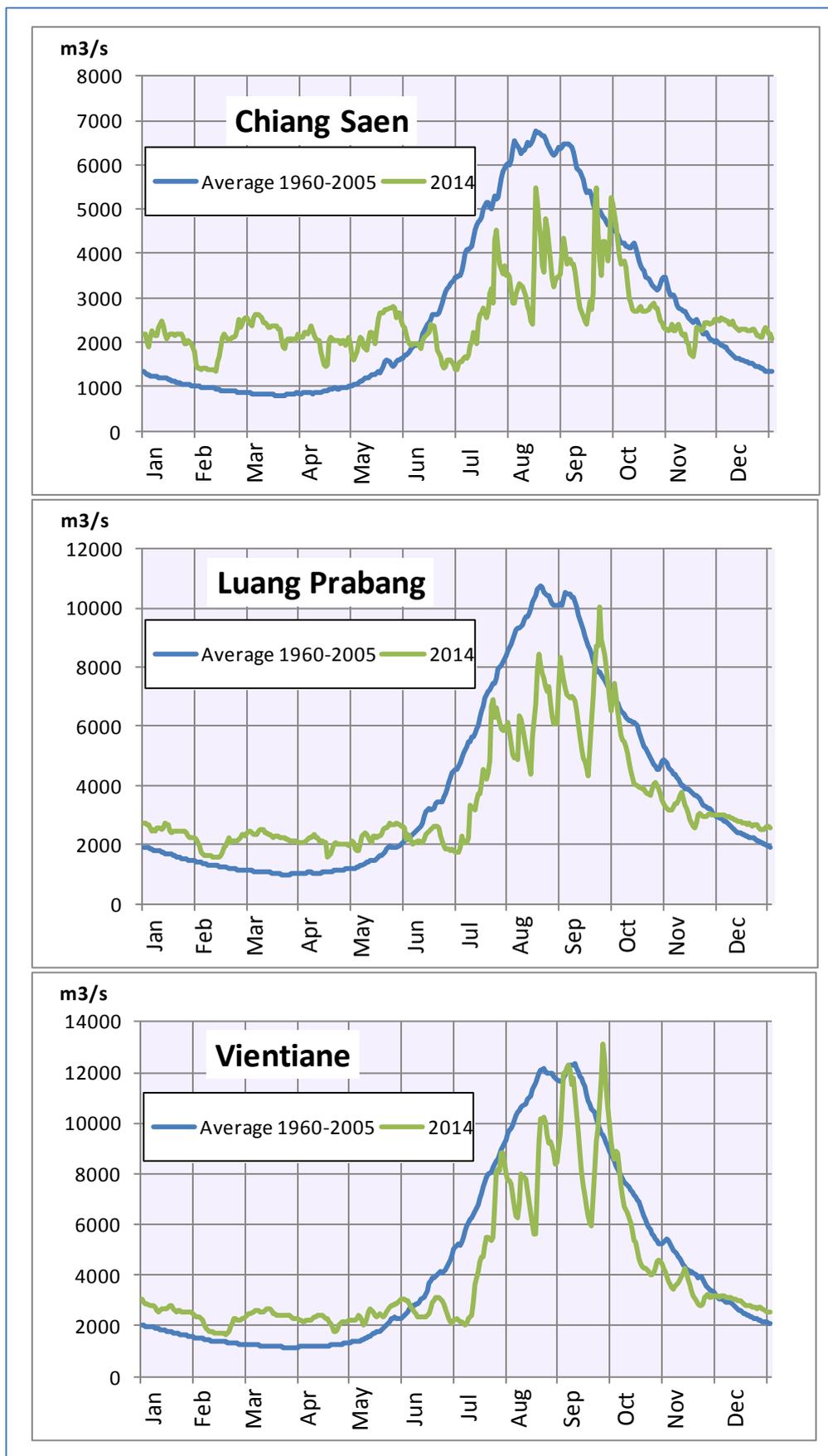


Figure 3-4 The 2014 annual hydrographs at Chiang Saen, Luang Prabang and at Vientiane / Nong Khai, compared to their long term average.

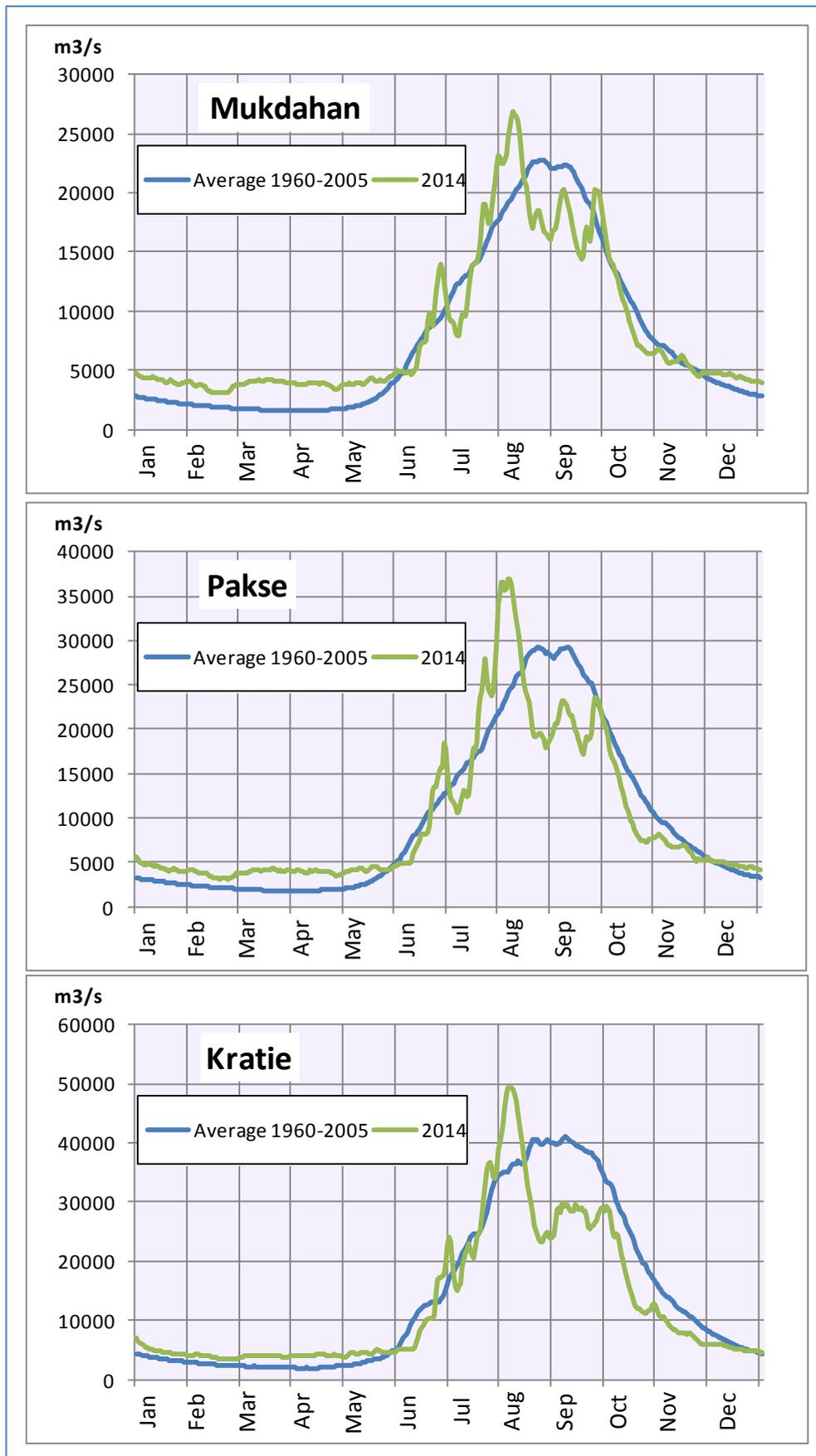


Figure 3-5 The 2014 annual hydrographs at Pakse and at Kratie compared to their long term average.

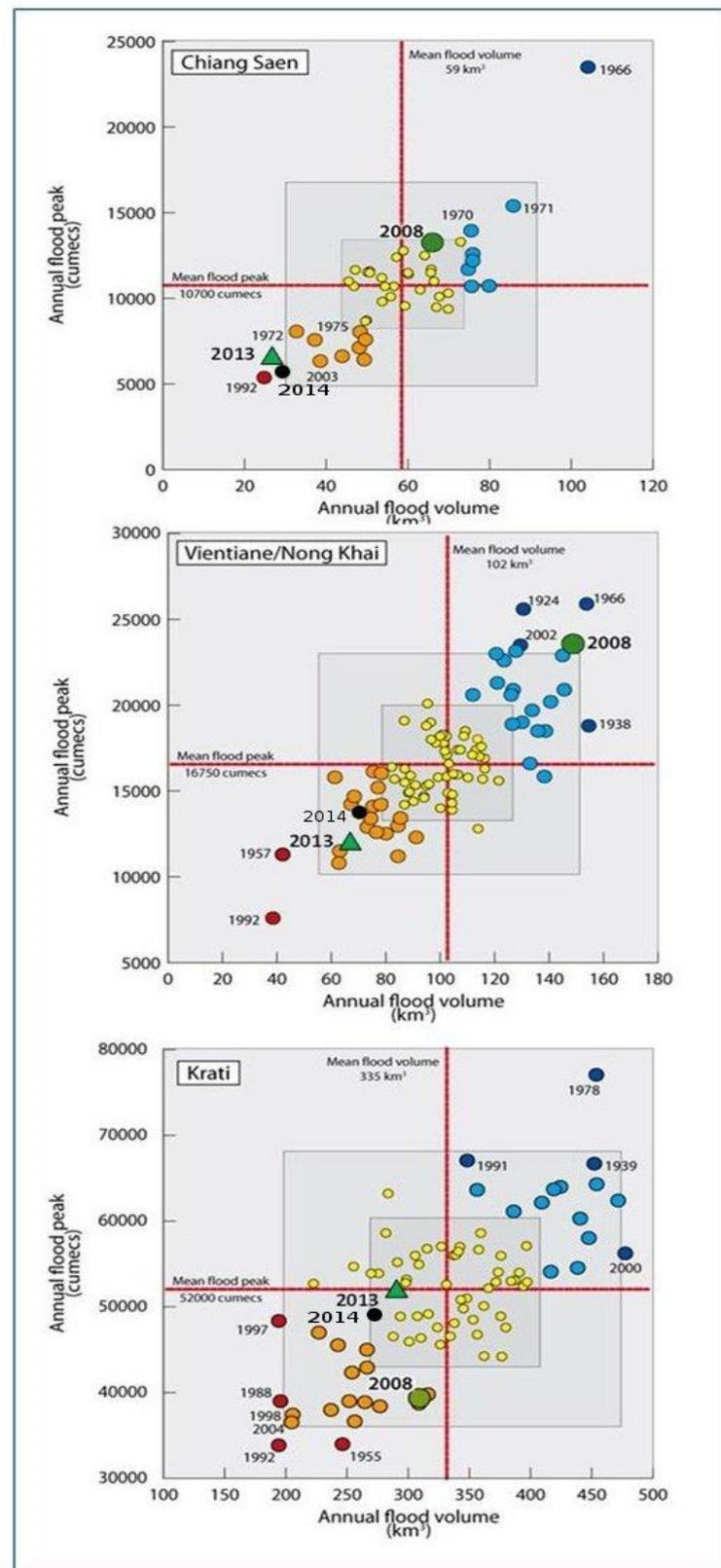


Figure 3-6 Scatter plots of the joint distribution of the annual maximum flood discharge (cumecs) and the volume of the annual flood hydrograph (km<sup>3</sup>) at selected sites on the Mekong mainstream. The ‘boxes’ indicate one ( $1\delta$ ) and two ( $2\delta$ ) standard deviations for each variable above and below their respective means. Events outside of the  $1\delta$  box might be defined as ‘significant’ flood years and those outside of the  $2\delta$  box as historically ‘extreme’ flood years.

Figure 3-7 places this bivariate relationship between flood peak and volume into a probabilistic framework. Selecting the Mekong at Kratie as indicative of hydrological conditions within the Lower Mekong Basin as a whole, then those of 2013 and 2014 were fundamentally average, with a recurrence interval of about once in two years or a 50% exceedance probability.

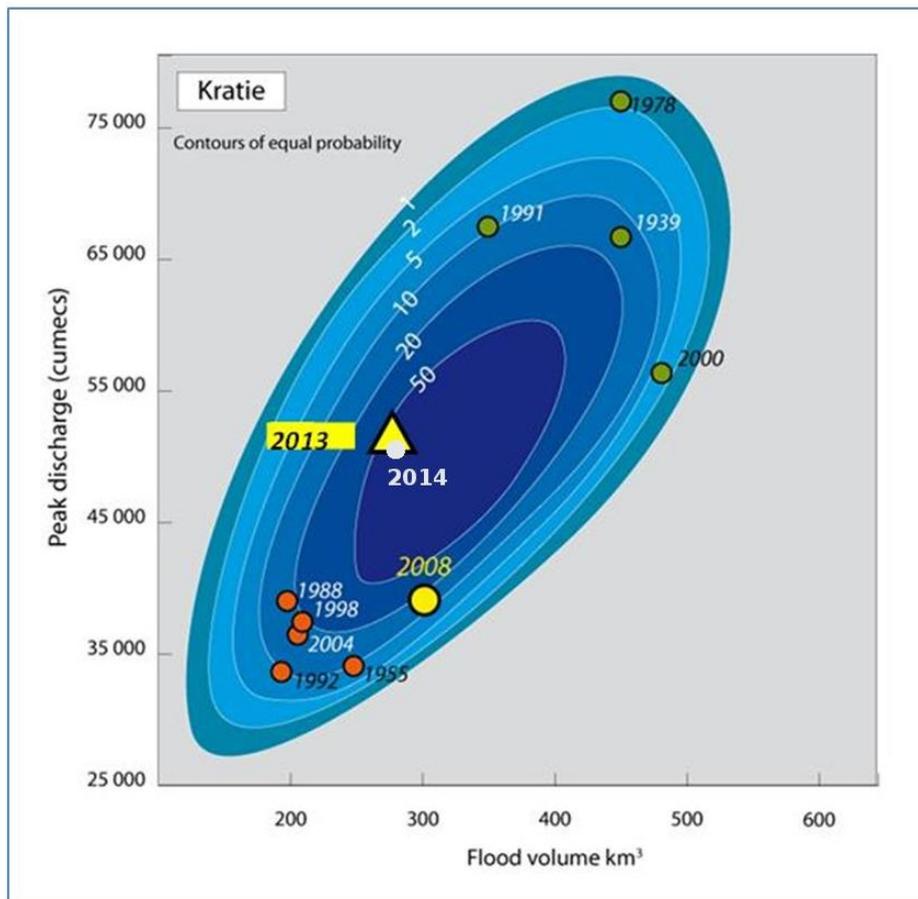


Figure 3-7 Mekong River at Kratie - the bi-variate distribution of annual flood peak and volume, 1924 to 2013. The estimated recurrence interval of the 2013 event in terms of the joint distribution of the two variables is 1 : 2 years.

### 3.3 Water levels across the Cambodian floodplain and the Delta in Viet Nam during 2014

The start of rising water levels in the flood plains of Cambodia and Viet Nam was approximately 3 weeks late due to scarce rainfall in May to mid-June, but then water levels rose rapidly, to reach their maximum levels in the second week of August, which is quite exceptional. The annual maxima thus occurred about 5-6 weeks earlier than usual, indicating a very steep rise of the water level compared to an average year. The water levels then fell quickly to 1-2 m below normal levels, and remained lower than average for the rest of the year, see Figure 3-8. This is a reflection of the discharge situation at Kratie, as was shown in Figure 3-5

The maximum water levels on the Cambodian plains were around normal, but the peak was of short duration. In Viet Nam at Tan Chau the maximum water level was slightly lower than normal. In Table 3-5 the water level and duration of the flood is given for selected stations.

As a consequence of the low water levels later in August and throughout the remaining flood season the water volume of Tonle Sap Lake at peak level was much smaller than usual, only 80% of the average volume as shown in Figure 3-9.

Table 3-5 Annual maximum water levels and duration of flood season at three sites in the Cambodian floodplain and Viet Nam. The water level gauge readings have here been converted to meters-above sea-level.

Site	Annual maximum water level (masl)		Duration of flood season (days)	
	Average	2014	Average	2014
Phnom Penh (Bassac)	8.85	8.80	167	142
Prek Kdam	9.02	8.52	162	163
Tan Chau	4.18	3.95	151	131

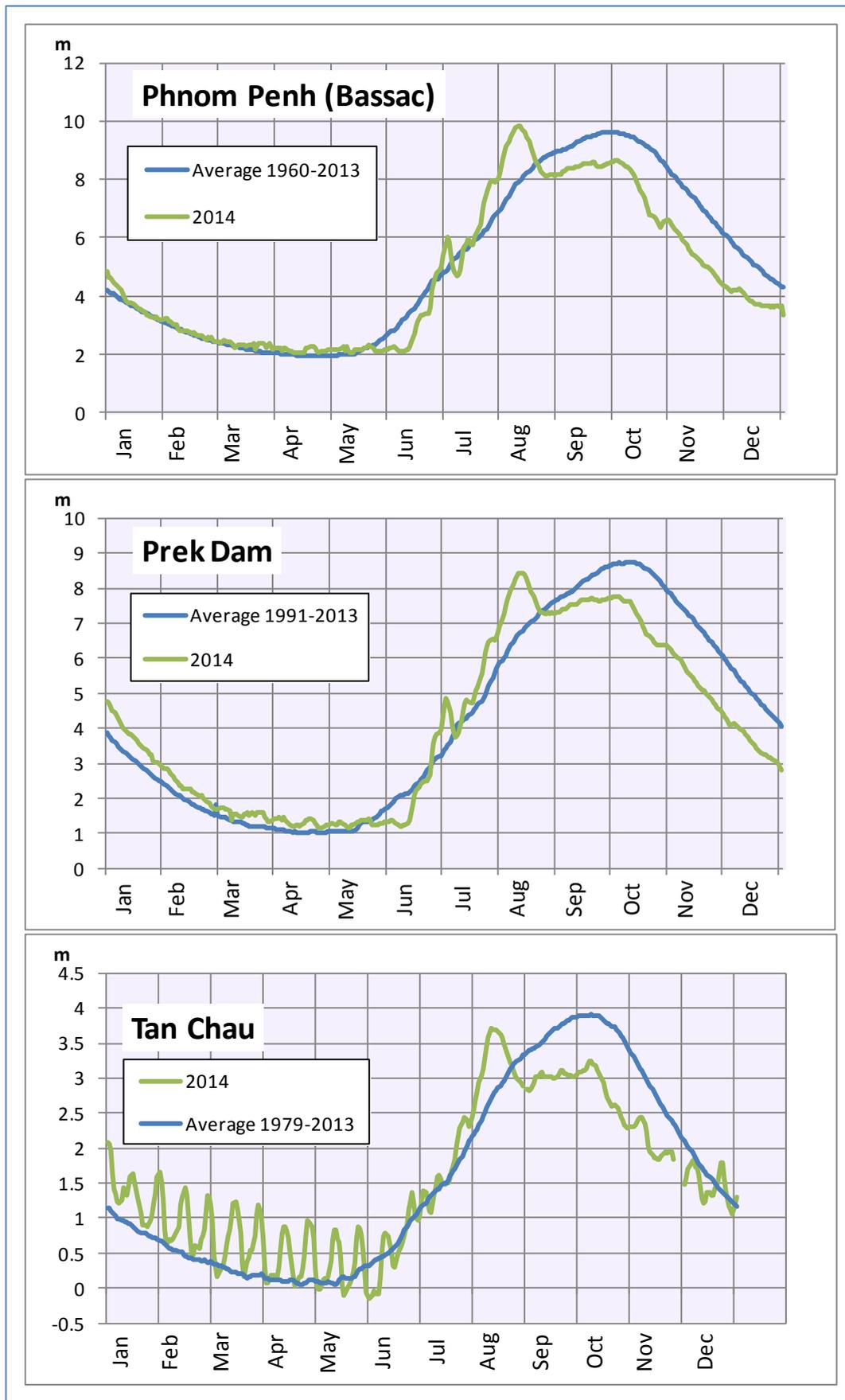


Figure 3-8 The 2014 annual hydrograph at Phnom Penh and on the Tonle Sap at Prek Kdam, compared to the long term average.

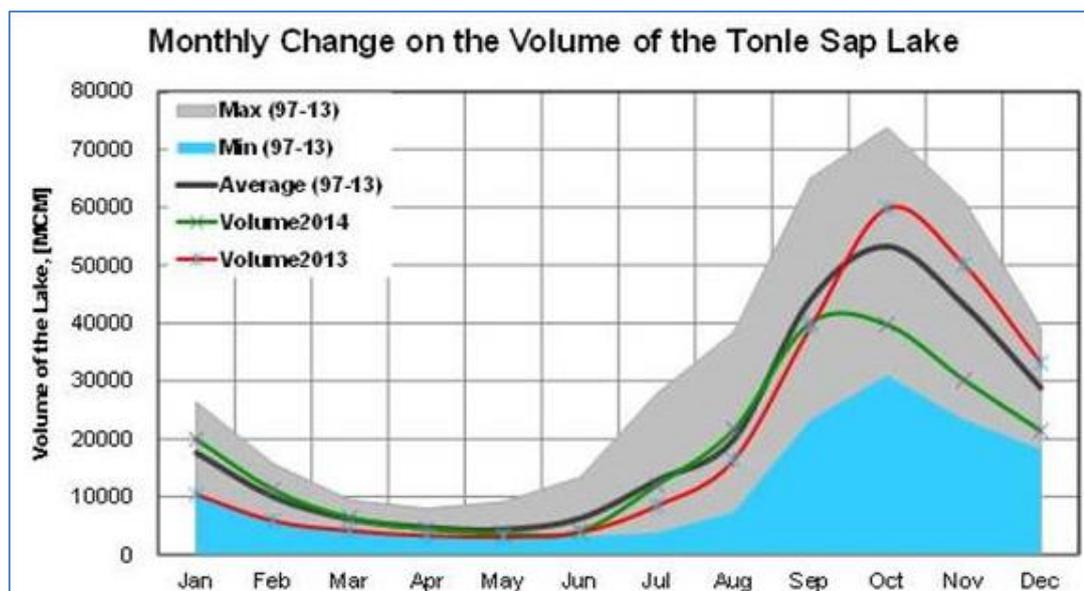


Figure 3-9 Water volume development of Tonle Sap Lake during the year..

### 3.4 The effect of Chinese Dams

After that the last of the 9 turbines was installed at the Nuozhadu dam in June 2014 there are now 6 operational dams in China in the upstream part of Mekong, namely Manwan, Daochaoshan, Jinghong, Xiaowan, Gongguoqiao and Nuozhadu, listed in order of completion (from X.X. Lu et al., 2014). Of these Xiaowan (completed in 2010) and Nuozhadu are the biggest, with an active storage capacity of 9.9 and 12.5 km<sup>3</sup>, respectively. These two dams are sufficiently big to be operated inter-annually, which means shifting water from one year to another. The other dams are smaller and used for seasonal storage only, with a total regulating capacity of 1 km<sup>3</sup>. This means that there is now a 23.4 km<sup>3</sup> regulation capacity upstream of Chiang Saen. If this regulation capacity is used to its maximum extent for release during 6 months in the dry season it would theoretically mean an added 1 500 m<sup>3</sup>/s discharge to the natural flow. Of course it is not possible in practice to operate at this extreme level, but it shows that the regulation capacity is now significant compared to the natural flow entering the LMB from China.

Existing and planned dams in the mainstream Mekong is shown in Figure 3-10 (current dam situation).

In Figure 3-11 the average flow for the period January-April since 1960 is shown for Chiang Saen, to give an impression of the potential effects of the dams upstream. The effect of regulation was clearly seen already in the dry season of 2013, and the effect is very much stronger in 2014. The mean flow in January-April 2014 at Chiang Saen, 2073 m<sup>3</sup>/s, was more than double the long-term 1960-2009 average (before completion of Xiaowan and Nuozhadu dams) of 964 m<sup>3</sup>/s and the effect can be seen as far down

as Kratie. A 1 000 m<sup>3</sup>/s increase in dry season flows translates to a 25% increase in dry season flows at Kratie, on average, and this must be considered significant.

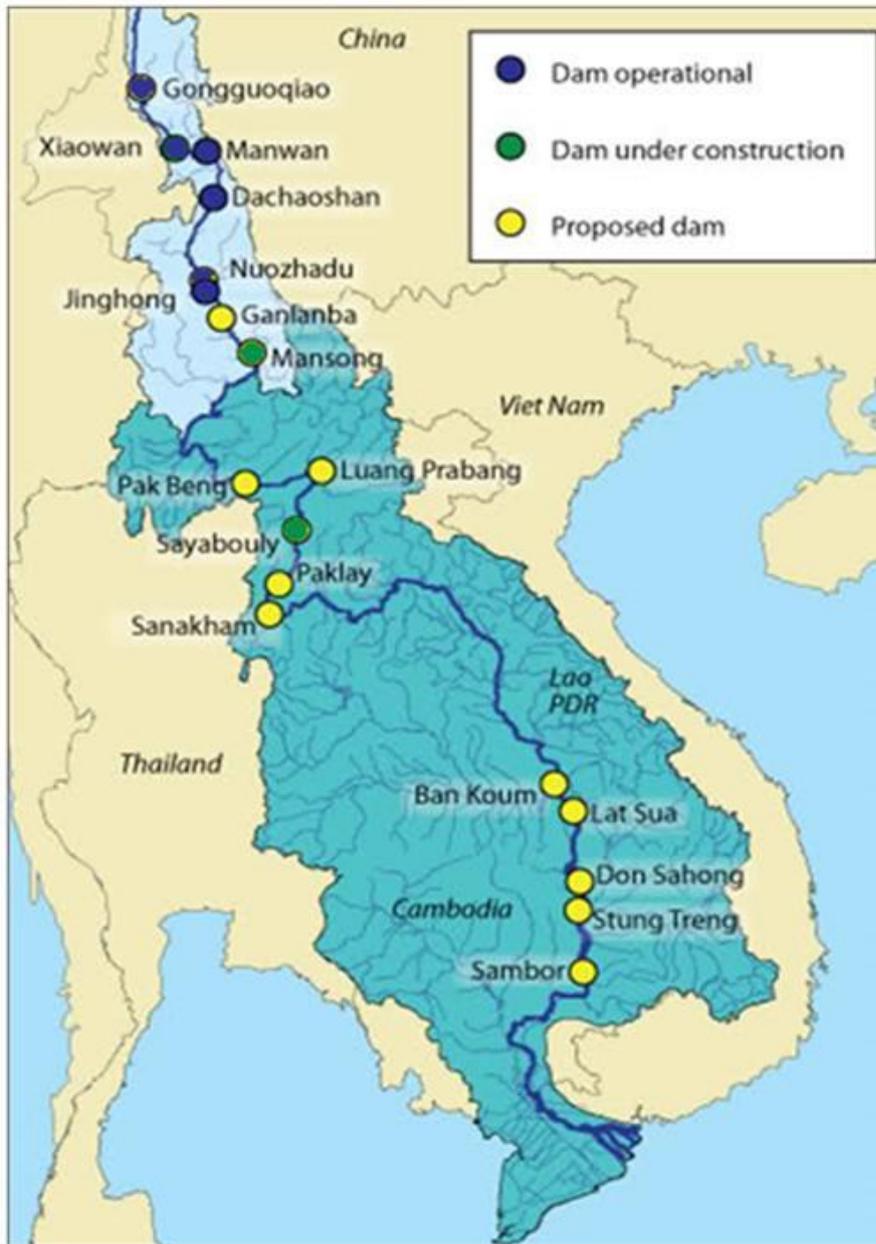


Figure 3-10 Existing and planned dams in the mainstream Mekong.

There is no information at hand on how the dams in the upper Mekong have operated in 2014, but it is reasonable to assume that they were refilled again during the wet season. Thus the natural flood season flow downstream the dams will decrease with the corresponding amount that the dry season increases. How the daily discharges will be affected downstream depends on the period for refilling, and this will certainly vary from year to year according to the hydrological situation. Again, the effect will be felt most clearly at Chiang Saen and become weaker in Vientiane and the stations further

downstream due to inflow from tributaries. The effect is not as dramatic as during the dry season, because the Yunnan component is much smaller during the flood season

The shifting of water from the flood season to the dry season certainly affected the river hydrology in 2014 by reducing the flood season flow, most notably at Chiang Saen, Luang Prabang and Vientiane. Even though the annual average flow during 2014 was close to normal throughout the mainstream Mekong stations the flood volumes were smaller than average, especially in the north where they were much smaller.

One way to measure this shift from wet season to dry season is to look at the mean daily flow of the driest period of the year (January-April) and the wettest (July-October). At Chiang Saen the ratio of dry season to wet season flow has been 0.20 (range 0.12-0.42) for the period 1960-2009, and in 2014 the ratio was 0.64 (Figure 3-12). It can be seen that this ratio has been higher than average after 2010 when the Xiaowan dam was completed.

The ratio decreases when going downstream from Chiang Saen as the inflow from the tributaries increase the flow in the mainstream. At Vientiane the corresponding dry season / wet season average ratio is 0.16 and for 2014 it was 0.33. At Pakse it was 0.11 and 0.21, respectively.

There is reason to believe that the experienced situation in 2014, with increased dry season flows and smaller differences between dry season and wet season flows, will be the standard from now on.

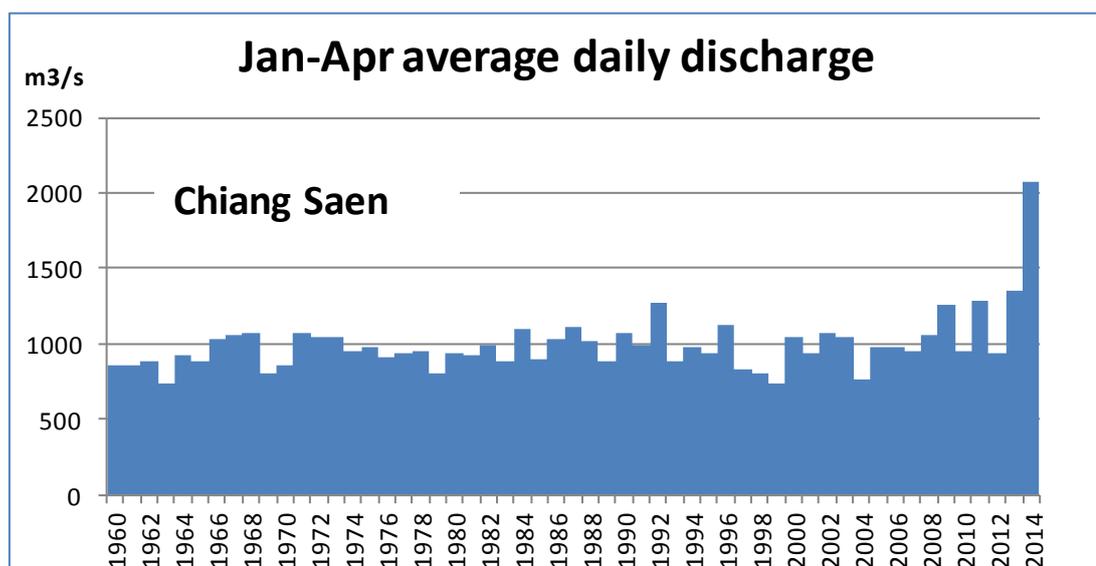


Figure 3-11 Average daily flow at Chiang Saen during the dry season months January to April.

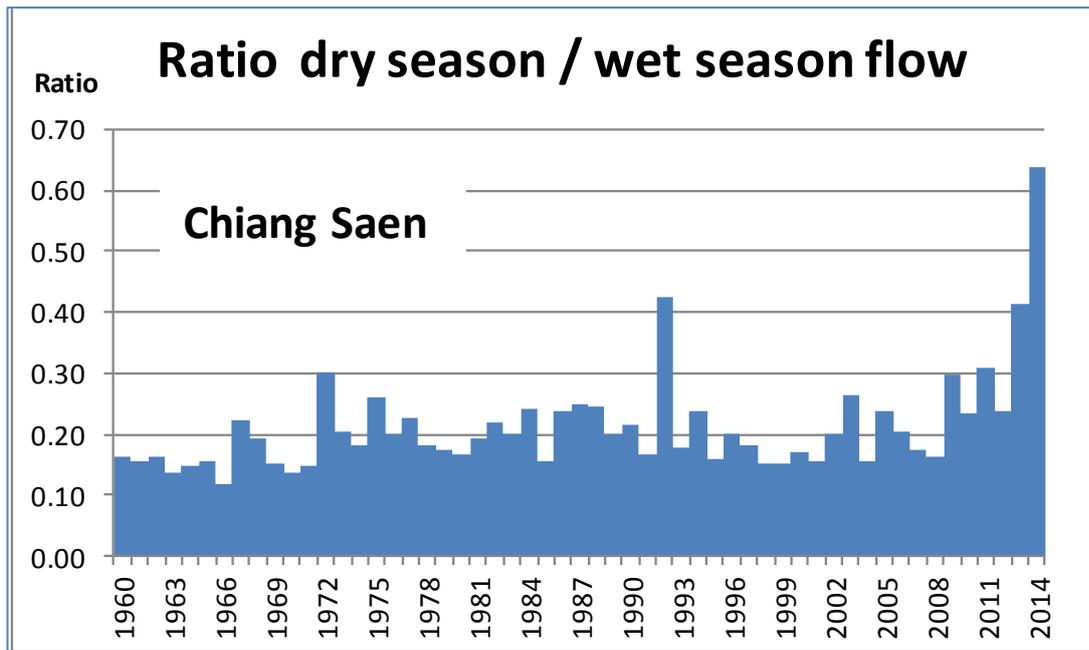


Figure 3-12 Flow ratio of mean daily flows in January-April (dry season) and July-October (wet season) at Chiang Saen.

## 4. COUNTRY REPORTS

### 4.1 Cambodia

The tropical storm RAMMASUN had a significant impact on the Mekong flow in the beginning of August. Following heavy rains the water level at Kratie rose rapidly to 22.79 m, close to the flood level of 23.00 m. The water level at Kratie in 2014 is exceeded approximately only once in ten years, so it was higher than the long-term average. Also at Stung Treng and Kampong Cham the Mekong rose to levels 2-3 m above the average annual maximum, but stayed below the flood level. Further downstream on the Cambodian flood plain the water levels rose to slightly higher than normal. Despite the high water level at Kratie the maximum discharge 49 500 m<sup>3</sup>/s was very close to the long-term average 50 900 m<sup>3</sup>/s.

Table 4-1 Rainfall at different stations during 2009-2014 in Cambodia.

No.	Station Name	2009	2010	2011	2012	2013	2014
1	Battambang	1365	1284	1707	1339	1394	881
2	Bantey Meanchey	1043	1084	1476	1319	1471	619
3	KompongCham	1815	1322	1382	1694	1467	1322
4	KompongChhnang	1680	1298	1929	1831	1583	1436
5	KompongThom	1505	1412	1669	1395	1644	1174
6	KompongSpeu	1408	1171	1378	1444	1465	993
7	KohKong	4609	3777	4304	4914	5253	5830
8	Kompot	2150	1301	1949	1819	1999	1784
9	Kandal	1020	1664	1248	1465	1318	1194
10	Kratie	1844	1369	1986	2221	1984	1697
11	PreyVeng	1230	1837	1370	1789	1371	1674
12	Pochentong	1512	1470	1495	1336	1420	1462
13	Pailin	1161	1917	1076	1105	1464	844
14	PrehVihear	1944	1439	1955	1282	2051	1647
15	Pursat	1104	1400	1488	1640	1584	1285
16	Ratanakiri	1406		1947	2502	2630	1919
17	Stung Treng	1544	1159	2318	1783	2241	2359
18	SvayRieng	1425	1968	1488	1731	1467	1430
19	SiemReap	1442	1526	1686	1466	1861	1490
20	SihanoukVille	2229	2138	2347	2758	2682	2726
21	Takeo	980	1388	1487	1358	1258	1383
22	OdorMeanchey			1190	1231	1696	1360
	<b>Minimum</b>	<b>980</b>	<b>1084</b>	<b>1076</b>	<b>1105</b>	<b>1258</b>	<b>619</b>
	<b>Average</b>	<b>1638</b>	<b>1596</b>	<b>1767</b>	<b>1791</b>	<b>1877</b>	<b>1659</b>
	<b>Maximum</b>	<b>4609</b>	<b>3777</b>	<b>4304</b>	<b>4914</b>	<b>5253</b>	<b>5830</b>

The inflow into the Tonle Sap Lake was high in early July 2014, but drastically decreased from Aug 2014 onward. The maximum volume of Tonle Sap was only 80% of the normal maximum, leading to a reduced outflow from the lake later on.

The rainfall amount as a whole in the area was slightly drier than previous years, see Table 4-1. However, the heavy rainfall connected with the RAMMASUN storm caused flash floods in Preah Vihear and Kampong Thom provinces in early August. Torrential rains of 86 and 73 mm on July 4 and September 28 in the Phnom Penh area flooded homes and businesses. The impact and damages of flood 2014 was not as big and serious compared to the extreme flood in 2000, 2011 and 2013. Continued migration from rural to urban areas and major cities such as Phnom Penh and Siem Reap has happened without adequate land use planning and has impacted flooding in the cities during high rainfall intensity. Improvements of drainage systems and pumping stations have been initiated to reduce the urban flooding.



Figure 4-1 Flood in Phnom Penh on 04 Jul 2014 (rainfall 86 mm/day).

## **4.2 Lao PDR**

In 2014, Lao PDR was directly affected by local storms and indirectly affected by two typhoon storms, namely RAMMASUN and KALMEAGI. These storms brought heavy rains, which had caused the rise of water levels in many rivers including Mekong

River. However, this year did not see any reports of serious damaged caused by Mekong floods. Most of the flash floods and inundation floods were caused by the high intensity of rainfall and overflow of small rivers and tributaries of Mekong.

Heavy rains between 7-19 July were found in every part of the country. In Oudomxai 194 mm of rainfall was measured on 27 July. Heavy rainfall continued in the beginning of August, with flash floods in the southern provinces of Sekong, Salavan, Khammouane, Savannakhet and Champasack.

In mid-September, in the aftermath of typhoon KALMAEGI, flash floods and landslides occurred in the northern provinces of Luangnamtha, Luang Prabang, Houaphan, and Xiangkouang.

Water levels along the Mekong were not at critical level except for Pakse, where the water level rose to 11.78 m, 0.12 m from the danger level, and causing flooding in Champasack province for a period of 10 days. On the other hand severe flooding exceeding the danger level occurred in some tributaries, notably Xe Bang Fai in August and Nam Ngiep in September.

As a result of heavy rainfall many provinces were significantly affected by flash floods and landslides. Such damage was reported to affect 58 districts, 696 villages, 27,311 households and 92,165 people, agricultural areas, infrastructure. 5 people were reported killed. The total damage cost was estimated to about 12 Million USD.

The following observations and conclusions regarding the flash floods and inundation floods in 2014 were made:

- In Lao PDR, the radio and internet (Facebook) are the most powerful for public awareness on weather, flood forecast and warning.
- The timely forecasting and warning dissemination provided by DMH was very helpful.
- The system of recording information on yearly floods and flood damage data collection techniques at local organization level should be improved.



Figure 4-2 Flash flood in Long village in Xieng Ngeun District in Luang Prabang Province, 17 September 2014.

### 4.3 Thailand

Thailand experienced abundant rainfall and flash floods in late July, mid-September and late November caused by the indirect impact of typhoon “RAMMASUN” typhoon “KALMAEGI” and tropical storm “SINLAKU”, respectively. The rainfall in July, caused by RAMMASUN, brought higher than normal rains, about 80-115 mm on 15-18 July, to the upper north and north-eastern parts of the country (Figure 4-4). This caused floods in 10 provinces including Chiang Rai, Phayao, Nan, Nakhon Phanom, Udon Thani, Sakon Nakhon, Ubon Ratchathani, Sisaket, Yasothon, Amnat Charoen, affecting 1,916 villages and 207 000 people.

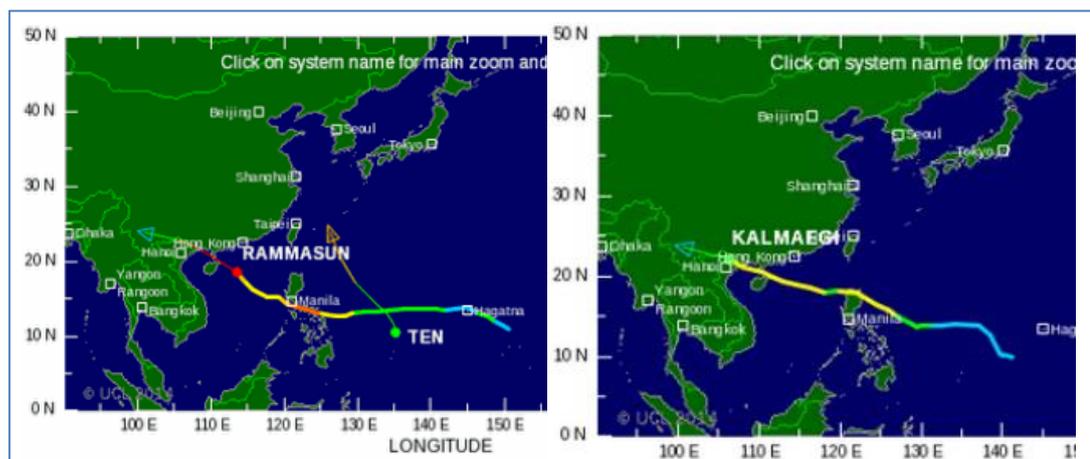


Figure 4-3 Tracking the storms RAMMASUN and KALMAEGI.

In mid-September 550 villages in the north, north-east and eastern parts were affected by the typhoon KALMAEGI, principally in the provinces Chiang Rai, Phayao and Nakhon Ratchasima.

In 2014, the flood affected and displaced an estimated 400 000 people. There is also a report that it has caused the deaths of four people. More than 2 000 houses as well as 34 000 hectares of agricultural land was damaged. The total compensated damage was estimated to 6 Million USD.

In Thailand a center that performs both forecasting and warning at national level does not exist, but national hydrological monitoring, forecasting and a system with warnings has been developed by many national agencies, and many of them publish these on websites.

In addition to the hydrological forecasts, there are also flood preparation plans and mitigation measures in the basins. The above-mentioned agencies including the Department of Disaster Prevention and Mitigation (DDPM), the Department of Mineral Resources (DMR), the Land Development Department (LDD), Department of

Water Resources (DWR), and Royal Irrigation Department (RID) are involved in hydrological investigations for flood preparation mitigation purposes.

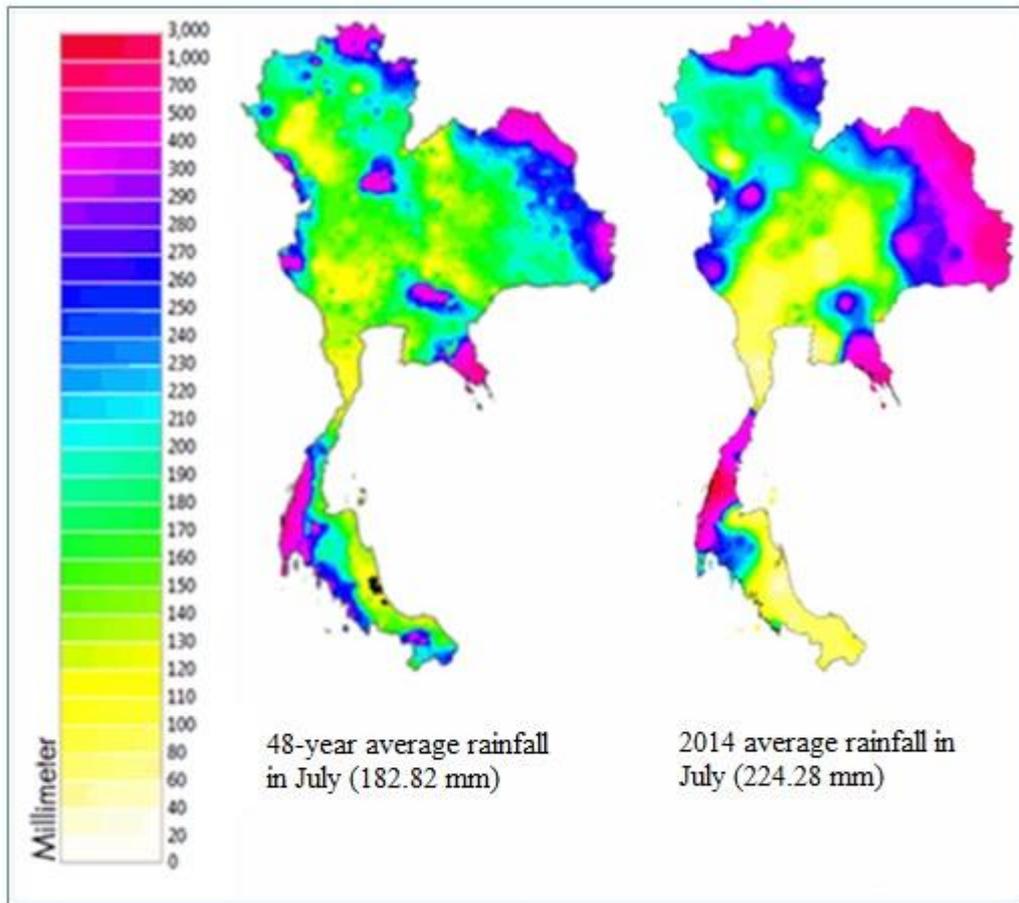


Figure 4-4 Average rainfall distribution in July (1951-2012, left) and rainfall distribution in July 2014 (right)



Figure 4-5 Flood in Mae Sai District in Chiang Rai Province in September 2014.

## 4.4 Viet Nam

Viet Nam experienced 5 tropical storms and 3 tropical depressions in 2014, which was less than in a typical year, which sees more storms. No serious flash floods were reported from the LMB part of Viet Nam, although floods, landslides and fatalities caused by them occurred elsewhere. An example of fast rising tributaries to Srepok is shown in Table 4-2 and Figure 4-6.

Flood peak levels at Tan Chau and Chau Doc were lower than average. Despite this floods and tidal surges caused damage, estimated to 3 Million USD, in the Delta, as listed in Table 4-3.

Table 4-2 Characteristics of some floods in Srepok tributaries 13 to 17 September 2014

River	Station	Flood foot		Flood peak		$\Delta H$ (cm)	Time up (h)	$I_{up-aver.}$ (cm/h)	$I_{max}$ (cm/h)
		Time hour/date	$H_f$ (cm)	Time hour/date	$H_p$ (cm)				
Pô Kô	Đăk Mod	22h/14/9	58331	5h/15/9	58487	156	7	22.3	59
ĐăkBl a	KonPlong	19h/14/9	59155	3h/15/9	59278	123	8	15.4	25
	KonTum	1h/15/9	51605	8h/15/9	51767	162	7	23.1	86

(Sources: National Center of Hydrology and Meteorology Forecasting)

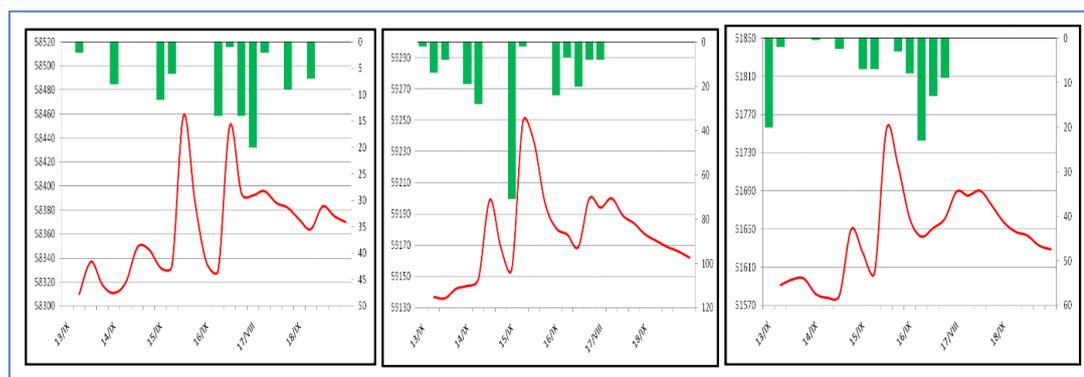


Figure 4-6. Rising water levels due to heavy rainfall at Dak Mod, Kon Plong and Kon Tum stations. (Sources: National Center of Hydrology and Meteorology Forecasting).

Table 4-3. Summary report on main damage in Mekong Delta part of Viet Nam caused by disasters in 2014.

Category	Item damaged	Unit	Total	By flood, storm, tide
People	Killed	Person	34	12
	Injured	Person	35	
	Missing	Person	2	
	Affected	households	155	155
Housing	Houses collapsed, drifted	No	1.057	1
	Houses submerged and damaged	No	3.983	1.374
School	School collapsed	Room	12	5
	School submerged and damaged	Room		
Hospital, clinics	Clinics collapsed	No		
	Clinics submerged and damaged	No		
Agriculture	Rice fields submerged	Ha	15.342	2.246
	Farms submerged, damaged	Ha	664	643
	Fruit tree area	Ha	209	209
	Food (salt) damaged by water	Ton		
Irrigation	Dyke damage	m		
	Small channel damaged	m	4.792	1.209
Transportation	Land drifted	m <sup>3</sup>		
	Bridge, sewer collapsed	Unit	1	
	Roads damaged submerged	m	119.117	114.117
Aquatic product	Shrimp, fish poll broken	Ha	147	142
	Ships sunk, lost	Unit	12	
	Ships sunk, damaged	Unit	1	
	Total damage	10 <sup>6</sup> USD	9,0	2,73

Source: Centers for Flood Control on Southern (2015)

The damage caused by the flash floods to Viet Nam's mountainous provinces are not recorded or documented very well, but damages are usually not extensive, at least compared to riverine flood damage in the Delta. One reason is that they usually occur in mountainous poor regions with low density of people. Flash floods and landslides have occurred in the mountainous provinces (Ha Giang, Lai Chau, Cao Bang, Son La, Ha Tinh, Thanh Hoa, Binh Phuoc....) causing 19 people dead or missing, including two families in the town and district of Tam Duong Hoang Su Phi.

It is recommended that:

- Flash floods carry a very high potential risk to people, so the MRC-FFGS should be improved to prevent or reduce damages.
- More attention should be paid on flash floods happening in the Central Highlands and training on flash flood forecasting is necessary.

- Between 2002 and 2010, and in 2014 there was no big flood in the Mekong Delta, but if it happens it could have significant impact. Therefore a flood preparedness plan needs to be carried out for the region.
- The MRC flood forecast should be extended to cover tributaries, and should be widely distribute to the public.



Figure 4-7 After a flash flood in Ha Giang Province.



## **5. CONCLUSIONS**

Flash floods occur in the Mekong region every year, and cause serious damage in the region. Several hundred people have been killed in the last few years, and flash floods are the main cause of flood damage in Lao PDR and Thailand Mekong area, but cause local damage regularly also in Cambodia and Viet Nam.

The LMB countries have become increasingly more concerned with flash floods during recent years, and are looking for ways to improve flood preparedness to limit the extent of damage. Here the RFMMC's Flash Flood Guidance System could contribute to the preparedness by offering training courses in the use of the system, and by urging the countries to use the outputs. Normal weather forecasts and flood forecasts for major river bodies cannot cope with the rapid development of flash floods. Special software and fast response is required to forecast flash floods when tropical storms sweep over the LMB.

It can be shown that the Flash Flood Guidance System is capable of predicting expected rainfall amount with reasonable accuracy, and that it is a potentially very effective tool to forecast flash floods. To improve the accuracy of the FFGS and to build confidence in the system a more systematic way to collect information about flash floods is needed. National flood relief authorities should build up a data base on the exact location of flash floods and the damage that has happened, and communicate this to the RFMMC. Then the effectiveness of the system can be properly evaluated, and weaknesses of the system identified and rectified. The FFGS is capable to evaluate the flash flood risk on a very small sub-catchment scale (currently a few hundred km<sup>2</sup>), so the evaluation has to be done on a similar scale. At the moment the effectiveness is evaluated based on a few selected cases and not covering the whole spectrum of events.

There is increased awareness in the countries that tools are needed to deal with the flash floods, which cause so much damage and hardship for the often very poor and vulnerable people affected.



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