Mekong River Commission
Flood Management and Mitigation Programme

Final

Seasonal Flood Situation Report for the Lower Mekong River Basin

Covering period from 1st June to 13rd November 2011

Prepared by
Regional Flood Management and Mitigation Centre

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Certification of Approval
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Seasonal Flood Situation Report for the Lower Mekong River Basin

Covering period from 1st June to 31st December 2011

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1. Flood season 2011

1.1 Rainfall situation

During the five months flood season 2011, the critical rainfall situation in the Lower Mekong Basin was concentrated in end of June to beginning of July and August, a period of Southwest Monsoon activity, low pressure troughs, storm and typhoon's appearances in the South China Sea. In terms of total seasonal rainfall, the general picture was higher than the average years (see Figure 1-1). It can be seen that the total rainfall in the flood season 2011 at stations in the upper and lower reaches of the LMB was higher than the long-term average and higher than in the previous flood season 2010.

The spatial variation of rainfall was high indicating that the intensity of heavy rain situations along the Lower Mekong Basin from upstream to downstream took place as a function of time (Annex A: 1. Graphs and Tables for monthly observed rainfall distribution during flood season):

- The wet season started in early June; the heavy rain mostly occurred in upper and middle reaches of the LMB.
- During July - August, the intensive and continued rain covered the entire LMB and appeared more frequently during this period.
- Usually, from September to October was the time of intensive rainfall in lower reach, but this year it covered the entire LMB.

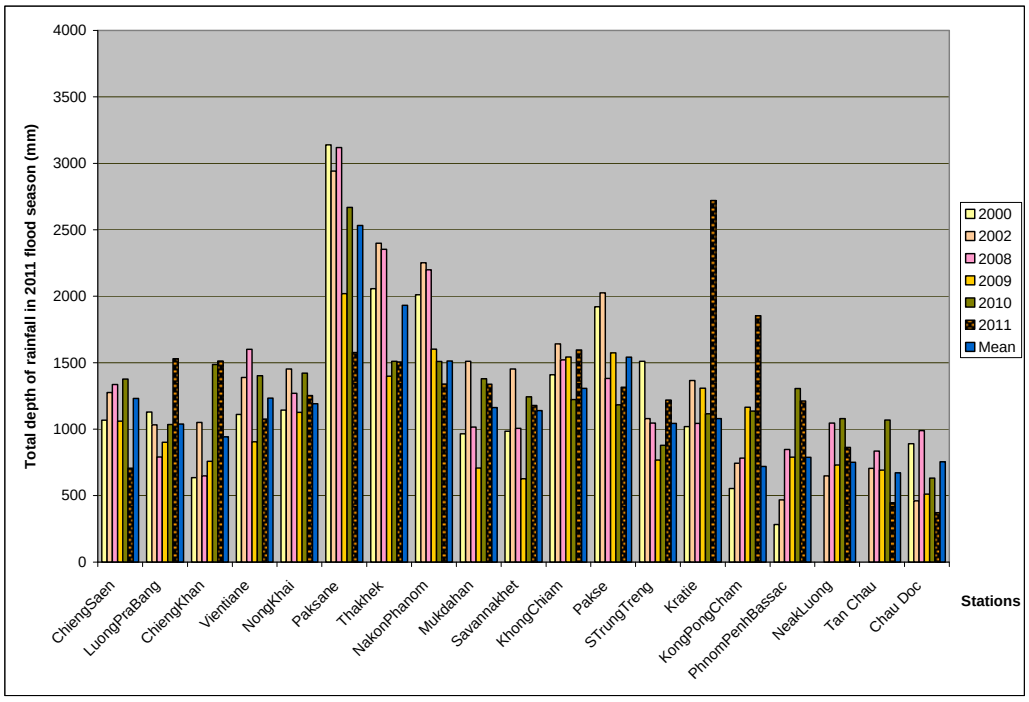


Figure 1-1 Total depth of rainfall in the flood season of the years 2000, 2002, 2008, 2009, 2010, 2011 and the long-term average flood seasonal rainfall.

In 2011, three main weather patterns caused heavy rains, which are presented below:

- Southwest monsoon: influenced the Mekong River basin from early June to mid-October; the critical activity mostly occurred in July. Typically, heavy rain event from 11th - 18th July in the upper and middle reaches of LMB, which caused rapid rise in water level. From mid-September, there was moderate to weak SW monsoon, which prevailed over Indochina Peninsula as a common phenomenon.

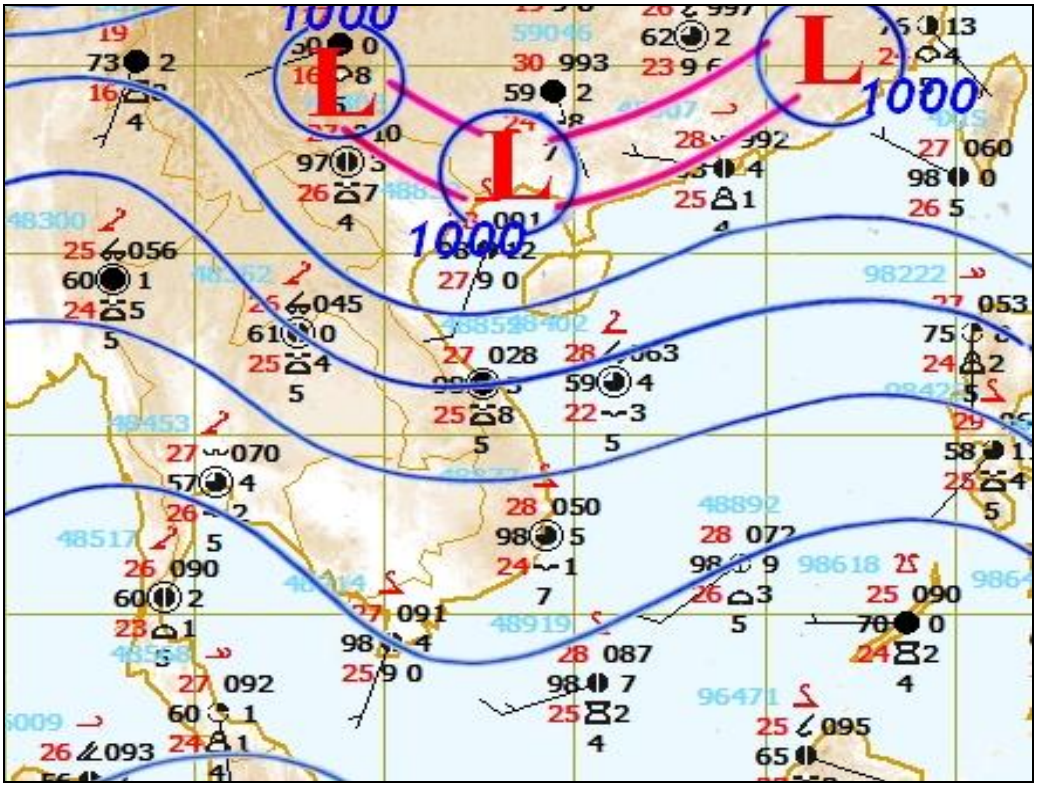


Figure 1-2 Weather map for Southwest Monsoon in the mid of July (17th July 2011).

- Tropical Low Pressure (TLP) and Inter Tropical Convergence Zone (ITCZ): these periodically appeared from early June to the mid of October with on average 3 to 7 days duration. In the flood season 2011, the frequent appearances of TLP and ITCZ during almost the entire flood season were one of the main phenomena which caused continuous heavy rain and rising water along the Mekong River. In August, TLP and ITCZ were observed and had significant influence on the upper and middle reaches of the LMB while the influence on the lower reach took place mostly in September. Figure 1-3 shows an illustration of the appearances and influences of TLP and ITCZ to the LMB in August and September.

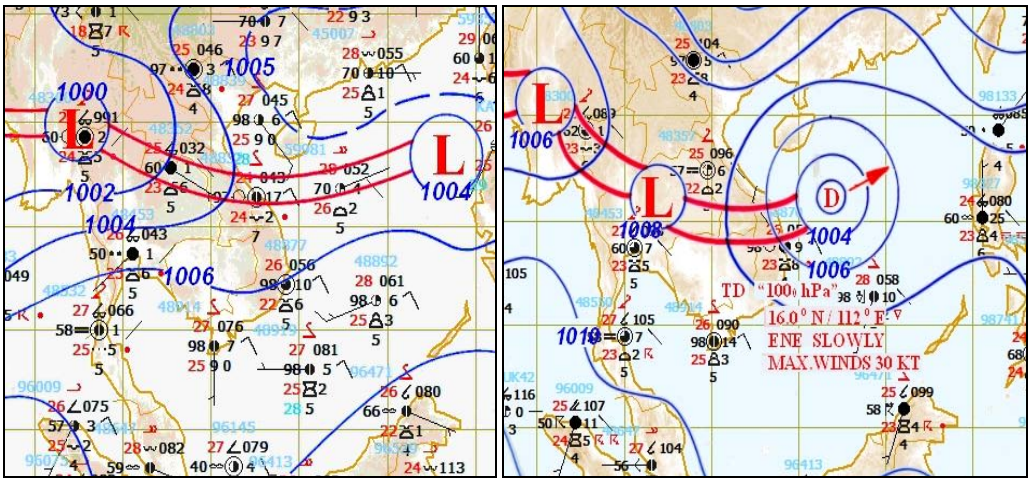


Figure 1-3 Weather maps for ITCZ in the beginning of August and in the end of September.

- Tropical depressions (TD), tropical storms (TS) or typhoons (TY): there were about 8 tropical depressions, storms and typhoons which came to South China Sea and affected the Mekong River basin with different levels. Of these, the four storms HAIMA, NOKTEN, HAITANG and NESAT were the most noticeable.

    1. HAIMA was formed as a tropical storm on the 21st June when travelling through South China Sea. After moving across Leizhou Peninsular of China on 23rd June, the TS HAIMA landed over the North of Viet Nam on 24th June and then downgraded into low pressure and disappeared when it hit to the Northern part of Lao PDR on 26th June. HAIMA Storm Track was shown in Figure 1-4. Weather maps for HAIMA before and after landing were shown in Figure 1-5 and Figure 1-6, respectively.

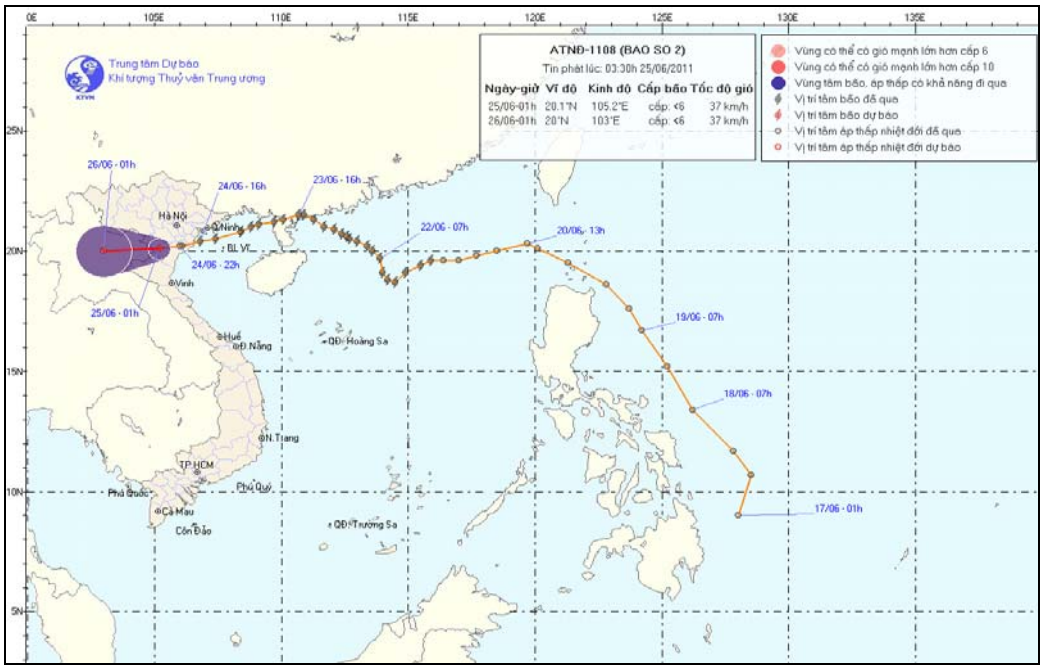


Figure 1-4 HAIMA Storm Track.

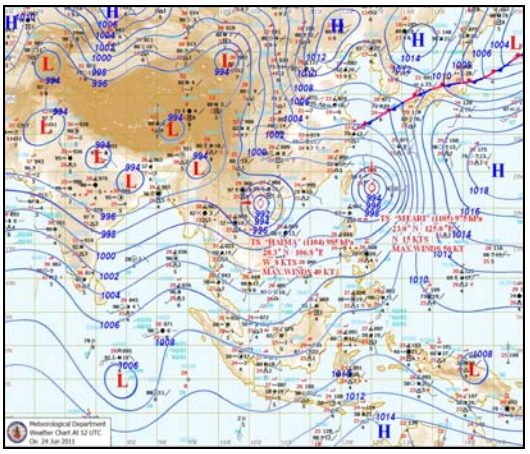


Figure 1-5 Weather map for HAIMA Tropical Storm on 24th June 2011, before landing.

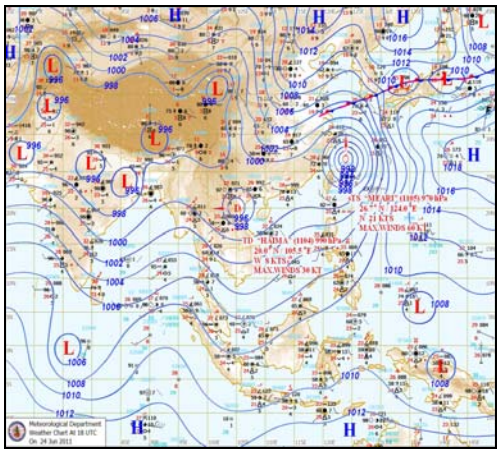


Figure 1-6 Weather map for HAIMA Tropical Storm on 25th June 2011, after landing.

2. Tropical storm NOKTEN was formed in the East Philippines on the 26th July 2011, cased intensive damages in the Luzon Island of the Philippines and moved into South China Sea on 29th July 2011. After travelling though Hainan Island of China, the TS landed over Northern part of Central of Viet Nam on the 30th July and arrived at middle part of Lao PDR. It downgraded into low pressure on the 31st July when moving into Thailand territory. NOKTEN Storm Track was shown in Figure 1-7 and its weather maps before and after landing were shown in Figure 1-8 and Figure 1-9, respectively.

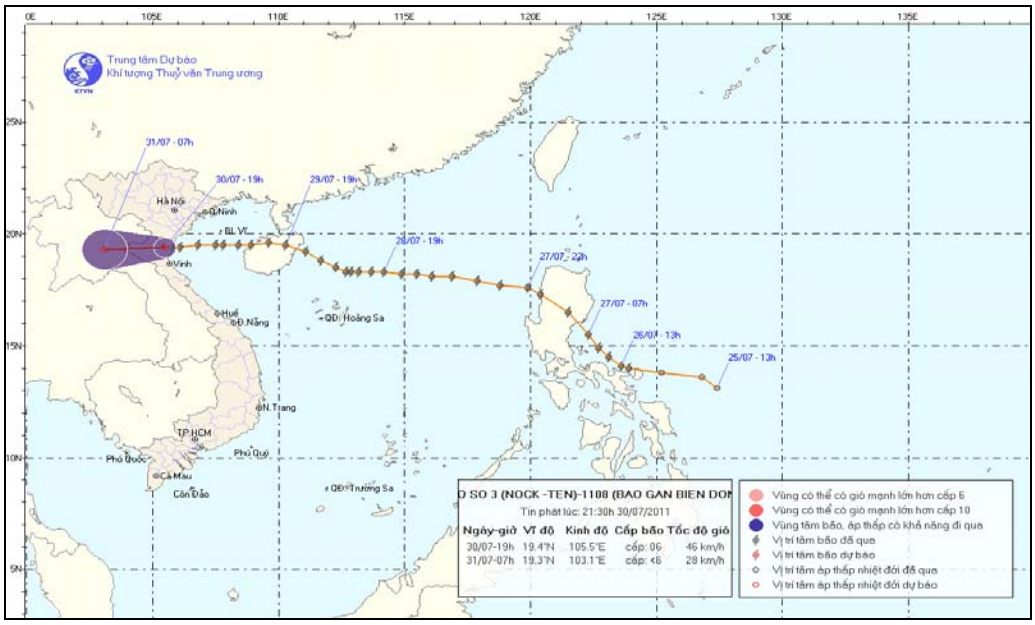


Figure 1-7 NOKTEN Storm Track.

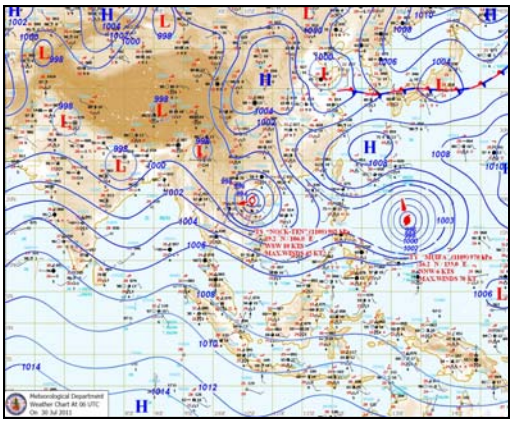


Figure 1-8 Weather map for NOKTEN Tropical Storm at 13h on 30th July 2011, before landing.

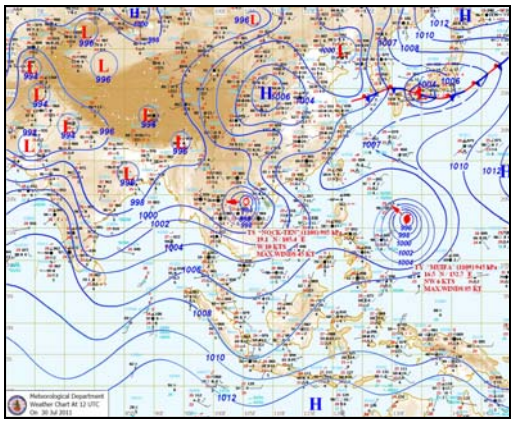


Figure 1-9 Weather map for NOKTEN Tropical Storm at 19h on 30th July 2011, after landing.

3. Tropical storm HAITANG was formed on 25th September in the East Sea of Viet Nam, landed over Quang Ngai, Da Nang provinces in the Central of Viet Nam on 26th September. On 27th September afternoon, it downgraded in to a Tropical Depression and disappeared in the Thailand territory after moving deep in to the mainland.

4. Typhoon NESAT was formed on 24th September in the East Sea of the Philippines, caused extensive damage when landing over Luzon Island of the Philippines on 27th September, 2011. After travelling through South China Sea, the TY-NESAT hit to the Hainan Island, China and kept moving West-Northwest ward and finally made landfall in the North of Viet Nam on 30th September, 2011. It downgraded in to low pressure and disappeared when moving deep into mainland. Figure 1-10 presents the track of TY NESAT when it travelled through South China Sea and Hainan Island before landing over Viet Nam coastline. NESAT's weather maps before and after landing were shown in Figure 1-11 and Figure 1-12, respectively.

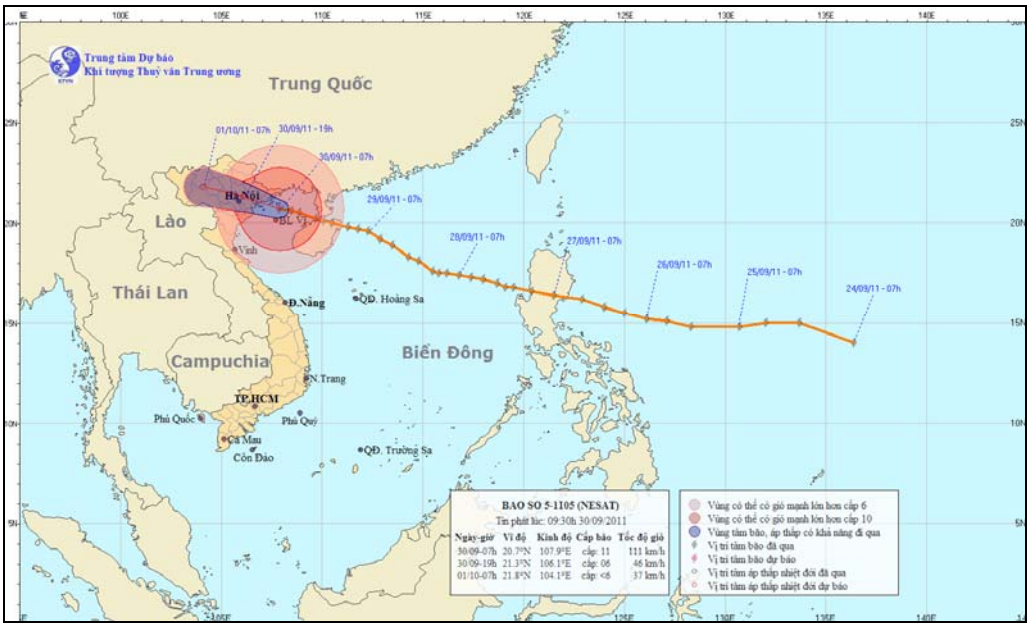


Figure 1-10 NESAT Storm Track

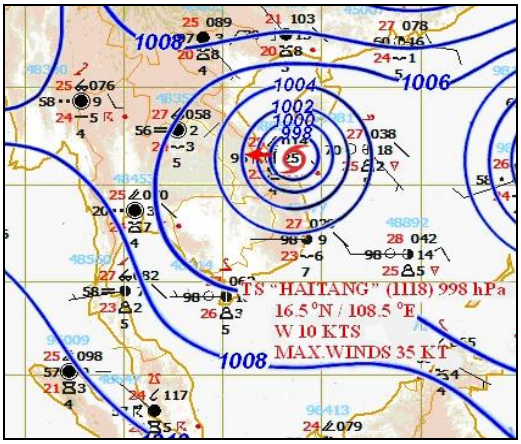


Figure 1-11 Weather map for NESAT Tropical Storm on 26th September 2011, before landing.

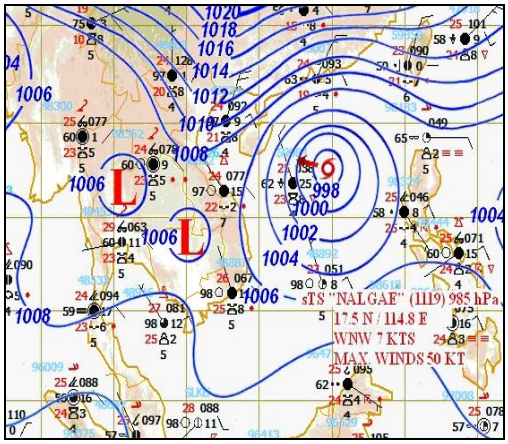


Figure 1-12 Weather map for NESAT Tropical Storm on 2nd October 2011, after landing.

1.2 General Behaviour of the Mekong River and Seasonal Flood Situation

The terms "flood" and "flooding" may world-wide have different meanings. Therefore the definitions as used in this report are basically adopted from the Mekong Annual Mekong Flood Forums:

- ***Flood:*** *natural abundance of water in response to storm, rainfall, snowmelt, etc ... ergo the flood season on the Mekong ..... however, this does not necessarily lead to flooding;*
- ***Flooding:*** *the inundation of areas, which usually are not submerged.*

The 2011 flood season started earlier than in previous flood years. The first flood event occurred at end of June and July with the appearances and influences of low pressures and two tropical storms: *HAIMA* and *NOK-TEN.*

In general terms, the water levels at most stations in LMB started about or above the long-term average (LTA) at the beginning of flood season, then rose up rapidly above the LTA in July till September in which water level at Nong Khai was twice above alarm level of 11.4m (as defined by the national agencies) on 23rd August and during 21st – 26th September, Thakhek was twice above alarm level of 13.0m (as defined by the national agencies) during 4th – 13th August and 20th – 21st September, Mukdahan was above alarm level of 12.5m on 8th August and then above flood level of 12.6m during 9th – 14th August, Pakse was twice above flood level of 12.0m during 8th – 19th August and 19th – 24th September, Stung Treng was twice above alarm level of 10.7m during 11th – 13th August and 22nd – 25th September, Kratie was above alarm level of 22.0m during 22nd – 27th September, Kompong Cham was twice above alarm level of 15.2m during 14th – 16th August and 20th September – 1st October, Phnom Penh Bassac was above alarm level of 10.5m during 24th September – 24th October, Phnom Penh Port was above alarm level of 9.5m during 23rd September – 25th October, Koh Khel was twice above alarm level of 7.4m during 15th – 19th August and 12th September – 31st October, Neak Luong was above flood level of 8.0m during 27th – 30th September, Prek Dam was above flood level of 10.0m during 2nd – 26th October, Tan Chau was above flood level of 4.2m during 21st September – 1st November, Chau Doc was above flood level of 3.5m during 19th September – 5th November (Annex C presents the hydrographs of 22 main hydrological stations along the Mekong River).

In 2011, flood season has distinct characteristics compared to previous year:

- The rapid rise of the flood peak of the year was observed in early July at many stations in the upper, middle and upper-lower reaches of LMB.
- By the tropical storm HAIMA and NOKTEN influences, a flood event with large amplitude of 3 to 6 meters occurred on the mainstream from Luang Prabang to Kompong Cham from beginning to mid of July. The situation on the tributaries was more extreme.

Table 1-1 shows the flood peaks of main locations along the Mekong mainstream during 2011 flood season.

Table 1-1 The flood peaks of main locations along the Mekong mainstream during 2011 flood season.

ID	Station	Alarm level	Flood Level	Day/Month of Peak	Hmax (m)	Comment
10501	Chiang Saen	11.5	11.8	27-Aug	6.49	Below alarm level
11201	Luang Prabang	17.5	18	22-Sep	14.06	Below alarm level
11903	Chiang Khan	17.32	17.4	23-Sep	13.14	Below alarm level
11901	Vientiane	11.5	12.5	23-Sep	10.62	Below alarm level
12001	Nong Khai	11.4	12.2	23-Sep	11.88	Above alarm level
12703	Paksane	13.5	14.5	22-Sep	13.42	Below alarm level
13101	Nakhon Phanom	12.6	12.7	05-Aug	12.25	Below alarm level
13102	Thakhek	13	14	05-Aug	13.30	Above alarm level
13402	Mukdahan	12.5	12.6	11-Aug	13.00	Above Flood level
13401	Savanakhet	12	13	12-Aug	11.89	Below alarm level
13801	Khong Chiam	16	16.2	11-Aug	15.72	Below alarm level
13901	Pakse	11	12	11-Aug	13.11	Above Flood level
14501	Stung Treng	10.7	12	23-Sep	11.25	Above alarm level
14901	Kratie	22	23	24-Sep	22.88	Above alarm level
19803	Kompong Cham	15.2	16.2	25-Sep	16.02	Above alarm level
33401	Phnom Penh Bassac	10.5	12	11-Oct	10.86	Above alarm level
20111	Phnom Penh Port	9.5	11	10-Oct	10.00	Above alarm level
33402	Koh Khel	7.4	7.9	28-Sep	7.89	Above alarm level
19806	Neak Luong	7.5	8	28-Sep	8.06	Above Flood level
20112	Prek Dam	9.5	10	20-Oct	10.19	Above Flood level
19803	Tan Chau	3	4.2	10-Oct	4.78	Above Flood level
39801	Chau Doc	2.5	3.5	08-Oct	4.24	Above Flood level

(Alarm levels and flood levels are defined by the national Line Agency)

The main hydrological situations along the Mekong River are presented in more detail below:

For stations from Chiang Saen to Vientiane/Nong Khai

During the 2011 flood season, water level of all stations started about or above the long-term average (LTA) then quickly rose up above LTA in end of June and beginning of July by influences of Tropical Storm-HAIMA and NOKTEN, then continue rising above LTA till October by influence of South west monsoons and ITCZs. Only Chiang Sean station had less effect from tropical storms, SW and ITCZ as compared to the rest. There were two flood events with amplitudes over 3 meters which occurred at those stations, except Luang Prabang with three flood events (see more detail in Annex A, Part 3, Table A2).

During June to July there were two tropical storms (HAIMA and NOKTEN), moderate to heavy rainfall occurred in this region. All recorded rainfalls in July were over 200mm, such as at Chiang Sean (244.3mm), at Luang Prabang (245.6mm), at Chiang Khan (248.3mm), at Vientiane (367.7mm) and at Nong Khai (639.7mm). Therefore, the water level rising occurred at all stations from Chiang Saen to Vientiane/ Nong Khai. It should be noted that flood amplitudes for the stations Luang Prabang, Chiang Khan, Vientiane and Nong Khai were over 3.5m (Annex A, Part 3, Table A2). Figure 1-13 shows rapidly rising of water levels at stations Luang Prabang, Chiang Khan and Pak Beng during 19th – 27th June.

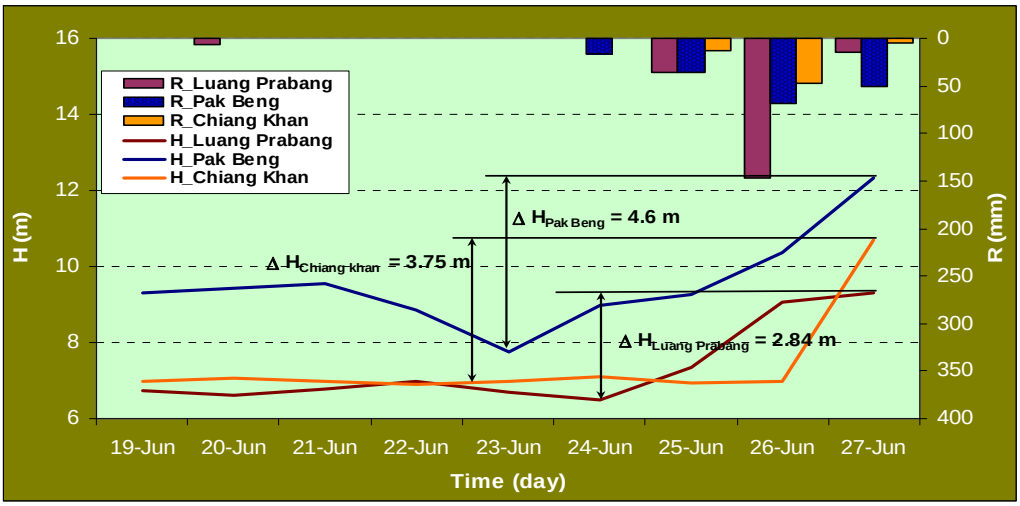


Figure 1-13 Rapidly rising of water levels at stations: Luang Prabang, Chiang Khan and Pak Beng during 19th – 27th June.

Continuous occurrences of south west monsoons as well as ITCZ across upper Lao PDR, Northern Thailand, Viet Nam and Myanmar from mid-July to September resulted in intensive rainfalls in Eastern part of Thailand, upper part of Lao PDR, middle part of Viet Nam and the middle of the LMB. The amount of rainfall in this region was recorded from the 15th to the 30th September at Chiang Saen (218mm), at Luang Prabang (161.5mm),; at Chiang Khan (105.7mm), at Vientiane (211.7mm) and at Nong Khai (311.3mm). A flood event occurred at those stations with flood amplitudes over 2 meters (Annex A, Part 3, Table A2). It was to note that from the 23rd August, 21st to 25th September, water level at Nong Khai was recorded above the respective alarm level of 11.4m.

For stations from Paksane to Pakse

During the 2011 flood season, water level of all stations started above the long-term average (LTA) then quickly rose up above LTA in end of June and beginning of July by influences of Tropical Storm-HAIMA and NOKTEN, then continue rising above LTA till October by influence of South west monsoons and ITCZs. There were two flood events with amplitudes over 4 meters which occurred at those stations (see more detail in Annex A, Part 3, Table A3).

During June to July there were two tropical storms (HAIMA and NOKTEN), moderate to heavy rainfall occurred in this region. All recorded rainfalls in July were about or over 300mm, such as at Paksane (791.9mm), at Nakhon Phnom (747.4mm), at Thakhek (772mm), at Mukdahan (445.5mm), at Savannakhet (422.6mm), at Khong Chiam (364.2mm)

and at Pakse (277.8mm). It should be noted that flood amplitudes for all stations were over 4.5m (Annex A, Part 3, Table A3). Figure 1-14 shows rapidly rising of water levels at stations Paksane, Nakon Phanon and Thakhet during 19th – 27th June.

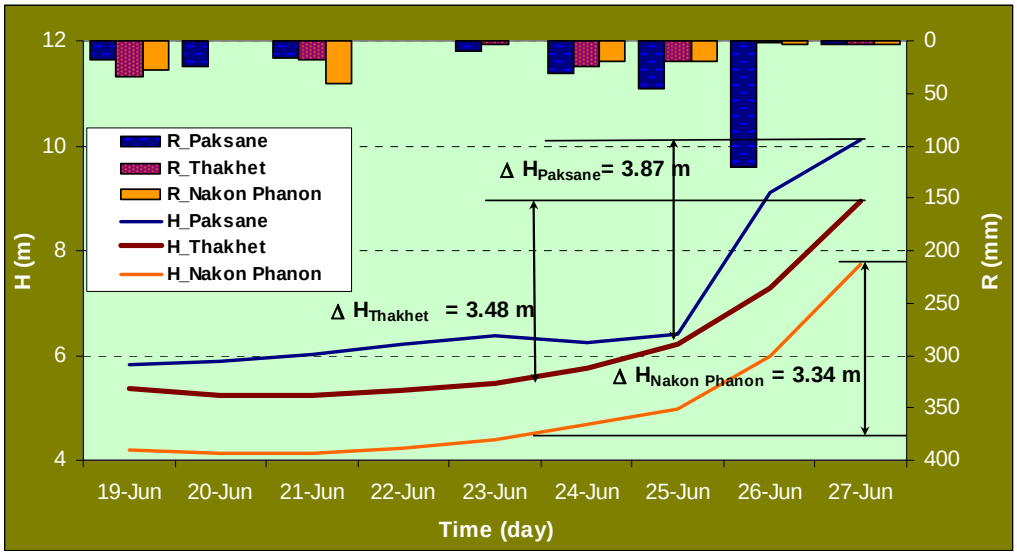


Figure 1-14 Rapidly rising of water levels at stations: Paksane, Nakon Phanon and Thakhet during 19th – 27th June.

Continuous occurrences of south west monsoons as well as ITCZ across upper Lao PDR, Northern Thailand, Viet Nam and Myanmar from mid-July to September resulted in intensive rainfalls in Eastern part of Thailand, upper part of Lao PDR, middle part of Viet Nam and the middle of the LMB. The amount of rainfall in this region was recorded from the 15th to the 30th September at Paksane (282.5mm), at Nakhon Phnom (258.1mm), at Thakhek (241.3mm), at Mukdahan (50mm), at Savannakhet (72.1mm), at Khong Chiam (281.5mm) and Pakse (288.9mm). A flood event occurred at those stations with flood amplitudes about or over 2 meters (Annex A, Part 3, Table A3).

It was to note that water levels at Thakhet was above alarm level of 13m during 4th to 7th August, 10th to 13th August and 20th to 21st September; Mukdahan was above flood level of 12.6m during 20th to 21st September and 9th to 14th August; and Pakse was above flood level of 12m during 19th to 24th September and 8th to 19th August.

For stations from Stung Treng to Kompong Cham

During the 2011 flood season, water level of all stations started above the long-term average (LTA) then quickly rose up above LTA in end of June and beginning of July by influences of Tropical Storm-HAIMA and NOKTEN, then continue rising above LTA till October by influence of South west monsoons and ITCZs. There was one flood event with amplitudes over 2 meters at Stung Treng, and over 3.5 meters at Kratie and Kompong Cham (see more detail in Annex A, Part 3, Table A4).

During June to July there were two tropical storms (HAIMA and NOKTEN), moderate to heavy rainfall occurred in this region. All recorded rainfalls in July were over 200mm, such as at Stung Treng (260.1mm), at Kratie (271.7mm) and at Kompong Cham (245.7mm). It

should be noted that flood amplitudes for all stations were over 2m (Annex A, Part 3, Table A4).

Continuous occurrences of south west monsoons as well as ITCZ across upper Lao PDR, Northern Thailand, Viet Nam and Myanmar from mid-July to September resulted in intensive rainfalls in Eastern part of Thailand, upper part of Lao PDR, middle part of Viet Nam and the middle of the LMB. The amount of rainfall in this region was recorded from the 15th to the 30th September at Stung Treng (285.5mm), at Kratie (235.4mm) and at Kompong Cham (139.6mm). A flood event occurred at Stung Treng and Kratie with flood amplitudes over 1.5 meters (Annex A, Part 3, Table A4).

It was to note that water levels at Stung Treng, Kratie and Kompong Cham were above alarm level during 22nd to 25th September, 22nd to 27th September and 20th September to 1st October, respectively (see Table 1-1 for more details on Day/Month of Peak).

For stations from Phnom Penh to Koh Khel/Neak Luong

During the 2011 flood season, water level of all stations started above the long-term average (LTA) then quickly rose up above LTA in end of June and beginning of July by influences of Tropical Storm-HAIMA and NOKTEN, then continue rising above LTA till October by influence of South west monsoons and ITCZs. There was one flood event with amplitudes over 2 meters at Bassac Chaktomuk, Phnom Penh Port and Prek Kdam (see more detail in Annex A, Part 3, Table A5).

During June to July there were two tropical storms (HAIMA and NOKTEN) that had less affected in this region. All recorded rainfalls in July were less than 200mm, such as at Bassac Chaktomuk (152mm), at Koh Khel (160.5mm), at Neak Luong (107.5mm) and at Prek Kdam (152.6mm). As a result of flood water from the upper and middle reaches of the LMB, water levels of stations at downstream rose steadily with average intensity of 0.10 - 0.20m/day except at Bassac Chaktomuk, Phnom Penh Port and Prek Kdam where flood amplitudes for were over 2 meter had occurred (Annex A, Part 3, Table A5).

Continuous occurrences of south west monsoons as well as ITCZ across upper Lao PDR, Northern Thailand, Viet Nam and Myanmar from mid-July to September resulted in small rainfall in this region which were recorded from the 15th to the 30th September at Bassac Chaktomuk (94.2mm), at Koh Khel (104.4mm), at Neak Luong (126mm) and at Prek Kdam (179.1mm). A flood event occurred at Neak Luong and at Prek Kdam stations with flood amplitudes over 1 meter (Annex A, Part 3, Table A5).

It was to note that water levels at Bassac Chaktomuk, Phnom Penh Port and Koh Khel were above alarm level during 24th September to 24th October, 23rd September to 25th October and 12th September to 30th October, respectively; while water levels at Neak Luong and Prek Kdam were above flood level during 27th to 30th September and 2nd to 26th October, respectively (see Table 1-1 for more details on Day/Month of the flood peak).

Tan Chau and Chau Doc

During the flood season 2011, the two stations recorded water levels that remained about the LTA, even though water levels at these stations are affected by tidal regime. This was one of the main reasons why during the beginning of June to the end of July water levels at these two stations showed rising and falling trends with high fluctuation amplitudes. From

August to September, as a result of flood water from the upper and middle reaches of the LMB, water levels of these stations rose steadily with average intensity of 0.10 - 0.15m/day levels (see more detail in Annex A, Part 3, Table A6).

It was to note that from the 21st September to 1st November 2011 and 19th September to 1st November 2011 water levels at Tan Chau and Chau Doc were recorded above the flood levels of 4.2 and 3.5 meters, respectively.

2 Flood Forecast in 2011

2.1 Data collection for models and flood forecast bulletin dissemination

Daily data collection consisted of hydrological and meteorological data (observed water level and rainfall) by HydMet from Line Agencies, Satellite Rainfall Estimate (SRE) and Numerical Weather Prediction (NWP) obtained from NOAA which served as inputs for the Mekong Flood Forecasting System (FFS). The performance indicators are shown in the Tables and graphs of the forecast achievement, Annex B (Table B3, Figure B2 to Figure B4).

The results of the evaluation show that the data from most of LAs normally arrived before 9 AM (Annex B, Table B3 and Figure B2). The manual data collected by HydMet was checked by LAs; hence, the quality of data is in general terms fairly good. However, there are a number of unavoidable problems in data transmission such as the late transfer of data, errors and especially missing data during five months of this flood season (see more detail in Table B3 and graphs in Performance, Annex B).

Satellite Rainfall Estimation and Numerical Weather Prediction inputs for the URBS/FEWS, were the most important factors to determine forecast results. Following the investigations and comments of the forecaster-in-charge in the weekly reports throughout the 2011 flood season, it is found that the high variability in both SRE and NWP was one of the main reasons which lead to large errors of forecast results, especially when the weather patterns caused heavy rain as tropical storms, south west monsoon and ITCZ.

Performance indicators of bulletin delivery (Annex B, Table B3 and Figure B4) shows that the flood bulletins containing flood situation information were disseminated timely to the registered national Line Agencies, MRC website, and other interested users around 10h30 AM, which is a prescribed time in the Operational Manual. It can be seen that the time of flood forecasting bulletin delivery in July to October of the flood season was a bit later than 10h30. This was due to two main factors:

- The late transfer and incomplete of data from LA's usually occurred during flood season.
- The low water level together with significant tidal effect in the downstream of the LMB, which resulted in difficulties for forecaster-in-charge in analysing and adjusting forecast results and which consequently lead to the late bulletin dissemination.

During the 2011 flood season, the data of several stations was sometimes not updated by national Line Agency for 2 to 3 continuing days, and in case data were missing over 2-3 days it was not possible to provide a forecast at those stations. Figure B5 in Annex B shows that during the 2011 flood season (in June) there was one station without forecasts.

2.2 Accuracy and limitations in forecasting

During the 2011 flood season, the degree of accuracy varies from station to station. The shorter the lead time, the more accurate of the forecast (see Annex B, Figure B1). The evaluation of forecast achievement is presented in Figure B1 by indicating the % of days

"successful" against a respective benchmark presented in Figure B2 (which were narrower than those of the year 2010). In general, the forecast errors for all lead time at all stations along the Mekong River did not show large differences, except for Luang Prabang, Paksane to Pakse and Kratie which were strongly affected by tropical storms (HAIMA and NOKTEN) where accuracies for 3-5 day forecast lead times were less than expect, if following the benchmarks of success. Based on the weekly flood situation reports, the large errors on 3-5 day forecasts at these stations mainly occur during mid-June to mid-July when flood amplitudes of mentioned stations were greater than 4.0 meters (see Annex A, Table A2 to A4).

Forecast errors for 3-5 day lead time were less than 0.90 meter for all stations in LMB, although the worse was at Luang Prabang times (Figure B1: Average flood forecast accuracy along the Mekong mainstream, Annex B). T

For the lower reach of Mekong River, it can be seen that the use of a regression model is quite promising. Stations downstream from Phnom Penh Bassac, show average errors for 1-day and 2-day forecasts smaller than 0.05m and 0.10m respectively, while average errors for 4-day to 5-day forecasts were smaller than 0.25m.

Based on investigations and forecasting experiences of the RFMMC, the main factors that influenced forecast accuracy can be summarized as below:

1. *Internal model functionality in forecasting at tidal affected stations in downstream:* The limitations in developing URBS models were mentioned and analysed by Terry Malone in the report "Sensitivity Analysis and Evaluation of the MRC Mekong Flood Forecasting Systems", April 2009, in which the main factors, which influenced the results of model calibration can be found as rating curves, inventory of dams, reservoirs and operational regulations, future development of dams. At the same time the sparse gauge network was another reason leading to poor results for forecast at stations in the upstream of LMB. The forecast results at Luang Prabang were a specific illustration of this. The forecast performances by mean absolute error in using original forecast results from both regression and ISIS models were presented in Figure 2-1 and Figure 2-2 respectively. It was easily realized that the average error for 3-day to 5-day forecasts at Koh Khel, Neak Luong, Prek Kdam and Tan Chau were under 0.1 meter for Regression model as compared to ISIS model.
2. *The high variability of satellite rainfall estimate (SRE) and Numerical Weather Prediction (MWP):* SRE rainfall was used instead of observed rainfall, and the NWP model provided a 7-day GFS rainfall forecast. Throughout the 2011 flood season, the output for the URBS model, as could be seen from the results of daily forecast, was really sensitive to both SRE and NWP. SRE could be either under- or overestimated if compared with the observed rainfall. NWP could provide high variable rainfall forecast leading to high variation of forecast results, especially at stations in the upper and middle reaches when critical weather patterns such as tropical storms occurred. Based on weekly investigation of the forecasting team, the original forecast results calculated from the model caused relatively large errors as compared to observations. This was a practical difficulty for forecaster-in-charge in forecast adjustment.

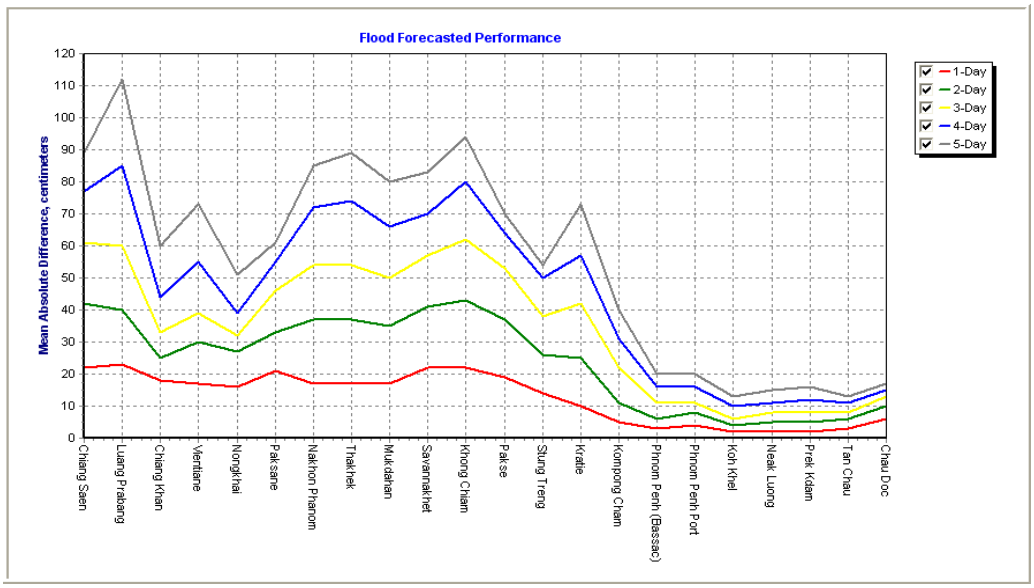


Figure 2-1 Forecast performance based on original results by URBS and Regression.

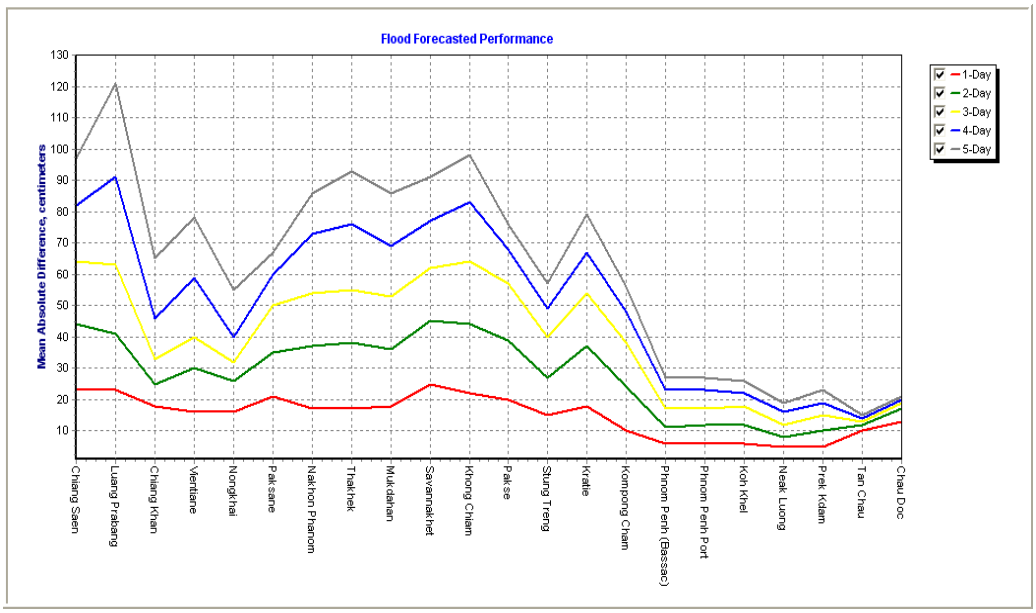


Figure 2-2 Forecast performance based on original results by URBS and ISIS.

3. *The quality and accuracy of forecast is also determined by the quality of forecast adjustment, which was usually performed by forecaster-in-charge so their knowledge, expertise and experiences were also the prominent determinant of the final forecast result*.

2.3 Lesson learned and actions to be taken

The following lessons have been drawn from the 2011 flood season, which can serve as the main factors that need to be taken into account by the flood forecasting team of the RFMMC in improving the forecast results:

1. The availability and quality of both hydrological and meteorological (rainfall) data as inputs for models are always the highest priority because these are the deciding factors for forecast results and accuracy. A Senior International Satellite Precipitation Expert was engaged by the RFMMC in 2010 to develop a tool of bias correction of SRE to produce corrected SRE-rainfall. The product depends very much on observed rainfalls provided from LAs which contained lot of missing data (see Annex B, Table B3 and Figure B3). Correct SRE can provide better results if less missing data.
2. The data from stations in the upstream of the Mekong River system in China is very important for analysing and forecasting in the LMB, not only during the flood season but also during the dry season. Hydrological and meteorological data from stations belonging to China need as much and as often as possible to be shared during dry season of 2011-2012.
3. Strengthening the relationship and cooperation with Line Agencies in exchanging and collecting observed water level and rainfall data at stations on the Mekong mainstream in order to collect daily data on time and to minimize the missing and incorrect data.
4. Improving model calibration by updating the rating curves and other parameters at stations in the MRC's member countries to be supported by LAs.
5. The forecaster-in-charge needs to have more understanding of sub-basin characteristics, flow regime of left bank tributaries in the middle part of the LMB where frequently intensive rainfall and flooding occurs as well as more understanding of influences of tidal regime to the downstream of the LMB.

Aside from above-mentioned lessons in order to improve the accuracy of flood forecasting for next flood season 2012, a number of additional actions need to be undertaken as follows:

6. Performance of the ISIS model in the Cambodian Floodplain and the Mekong Delta should be compared with that of the Regression Model during the 2011 flood season. It is found that the discharges generated in ISIS are not consistent with the observed water levels. It is recommended to replace the old version in the MRC Mekong Flood Forecast System with the latest version of ISIS.
7. Continue to efficiently use water level and rainfall of the existing two stations: Jinhong and Manan of China. Analyse the impact of water release from dams to the water levels at Jinhong and to water level changes at stations in the upper part, such as at Chiang Saen and Luang Prabang, especially during transitional period between dry and wet season.
8. Watch closely situations of the sudden increasing water levels of left bank tributaries in the middle part of the LMB, such as Ban Mixay and Muong Ngoy, Moung Mai, Moung Kao, Ban Phone Si, Se Kong River at Vuen Khen, Se Bang Fai River at Mahaxai, when the weather patterns would inflict intensive rainfall such as Typhoon or Tropical Depression occurrences in South China Sea, the creations of low pressure trough line and Inter Tropical Convergence Zone (ITCZ) and sometimes the critical activity of South West monsoon.
9. Through the 2011 flood season, forecast results of water levels at stations in downstream of the LMB by using Regression model were evaluated as fairly good, however the error for 3-day and 4-day forecasts at hydrological stations affected by tidal at Tan Chau and Chau Doc were high although forecaster had referred to the

reference of tidal regime forecast documentation in 2011 provided by National Centre for Hydro-meteorology of Viet Nam. Therefore, availability of such a document in 2012 will be useful in improving the accuracy at those stations.

10. Learn more about the weather products of rainfall forecast published on the websites of the World Meteorological Organization and their practical applications.
11. Study the possibility of having 2nd run of daily flood forecast and medium-term forecast (6-10 days) – data availability and other requirements of the system by having further evaluation of the system's performance by using historically similar rainfall patterns.

For more details see the following Annex:

Annex A;

- Graphs and Tables for monthly observed rainfall distribution during flood season 2011
- Graphs for monthly rainfall in flood season from 2000 to 2011 and long-term average along the Mekong River
- Tables of flood event characteristics along the Mekong River during flood season 2011

Annex B:

- Graph for flood forecast accuracy along the Mekong mainstream
- Table of forecast achievement
- Tables and graphs for performance

Annex C:

- Seasonal Water Level Graphs

Annex A Graphics and Tables

1. Graphs and Tables for monthly observed rainfall distribution during flood season 2011

Table A1 Monthly observed rainfall in flood season 2011.

Unit in mm

2011	Jinghong	Chiang Saen	Luang Prabang	Chiang Khan	Vientiane	Nong Khai	Paksane	Thakhek	Nakhon Phanom	Mukdahan	Savannakhet	Khong Chiam	Pakse	Stung Treng	Kratie	Kompong Cham	Phnom Penh Port	Bassac Chaktomuk	Neak Luong	Tan Chau	Chau Doc
June	46.0	111.5	215.3	223.7	123.5	151.3	203.8	173.8	139.2	135.2	92.9	139.8	110.7	135.6	335.7	185.5	No Data	106.4	68.8	21.8	18.4
July	158.7	148.8	320.8	313.8	218.9	255.7	326.7	313.8	280.6	276.4	251.2	301.5	246.9	228.4	515.7	337.6		199.8	134.9	55.3	41.0
August	220.9	168.4	362.7	352.0	271.8	313.8	388.9	388.5	355.9	365.6	329.9	427.9	355.5	299.4	636.6	445.0		278.5	198.9	101.4	78.3
Septebe	187.0	160.9	363.8	351.3	275.5	314.8	372.5	351.1	321.1	318.9	284.8	399.9	333.4	296.4	634.3	447.5		299.3	218.8	122.8	104.8
October	0.0	117.1	267.1	272.1	185.7	217.7	285.0	277.8	243.2	242.5	220.1	326.5	268.6	259.0	597.5	438.0		328.3	240.9	144.6	129.5
Season	612.6	706.7	1,529.6	1,513.0	1,075.4	1,253.2	1,576.9	1,504.9	1,339.9	1,338.5	1,178.9	1,595.5	1,315.0	1,218.8	2,719.8	1,853.6		1,212.3	862.3	446.0	372.0

(*) Observed data for Jinhong from 15th June to 15th October

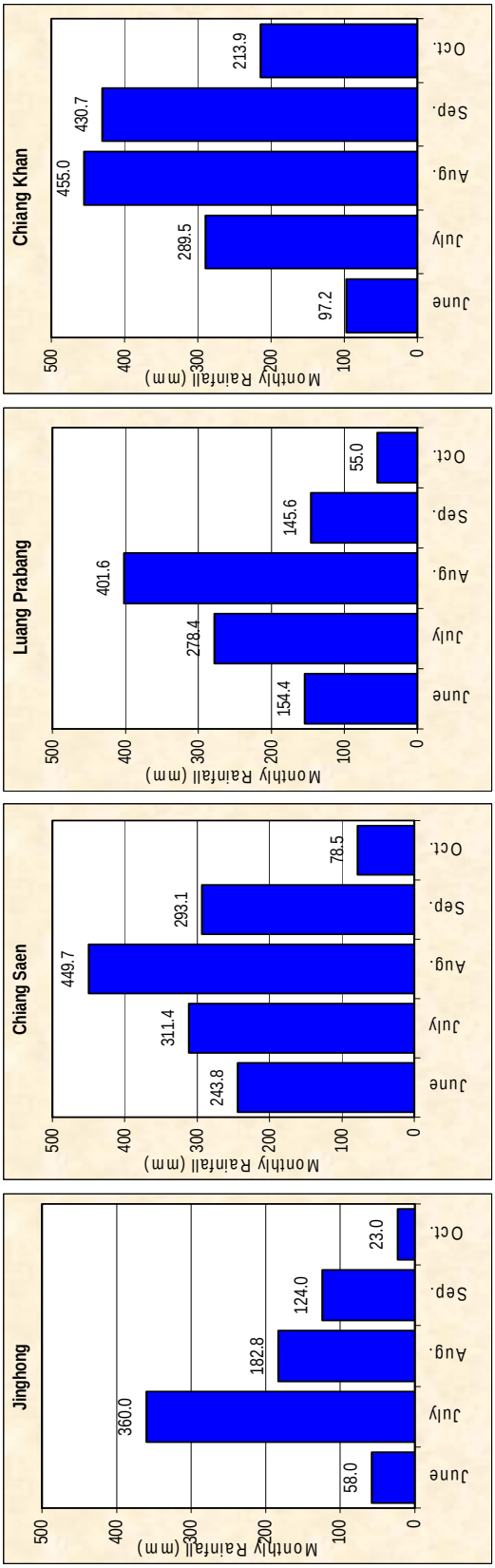


Figure A1 Monthly rainfall distribution for Jinghong, Chiang Saen, Luang Prabang and Chiang Khan.

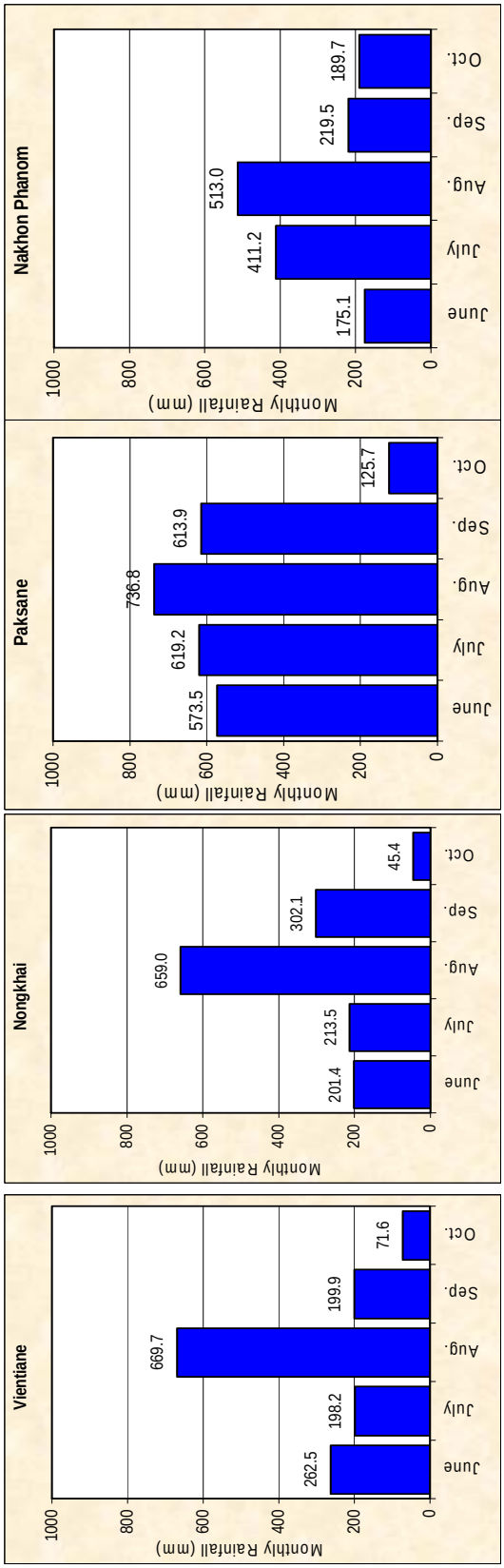


Figure A2 Monthly rainfall distribution for Chiang Khan, Vientiane, Nongkhai, Paksane and Nakon Phanom.

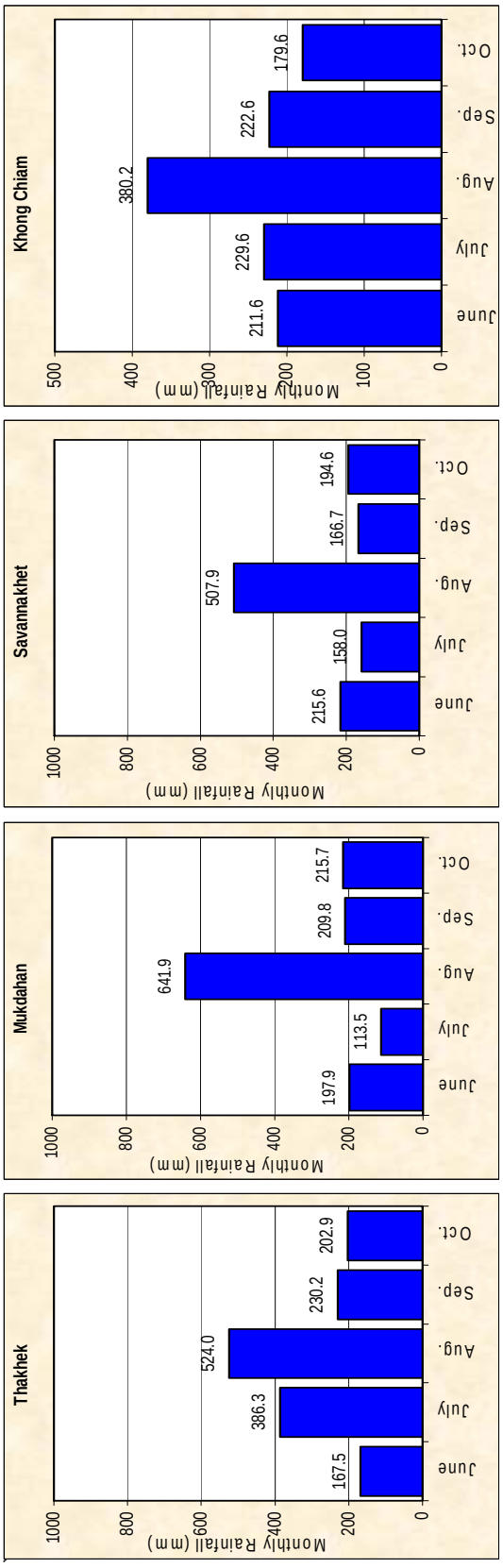


Figure A3 Monthly rainfall distribution for Thakhek, Mukdahan, Savannakhet and Khong Chiam.

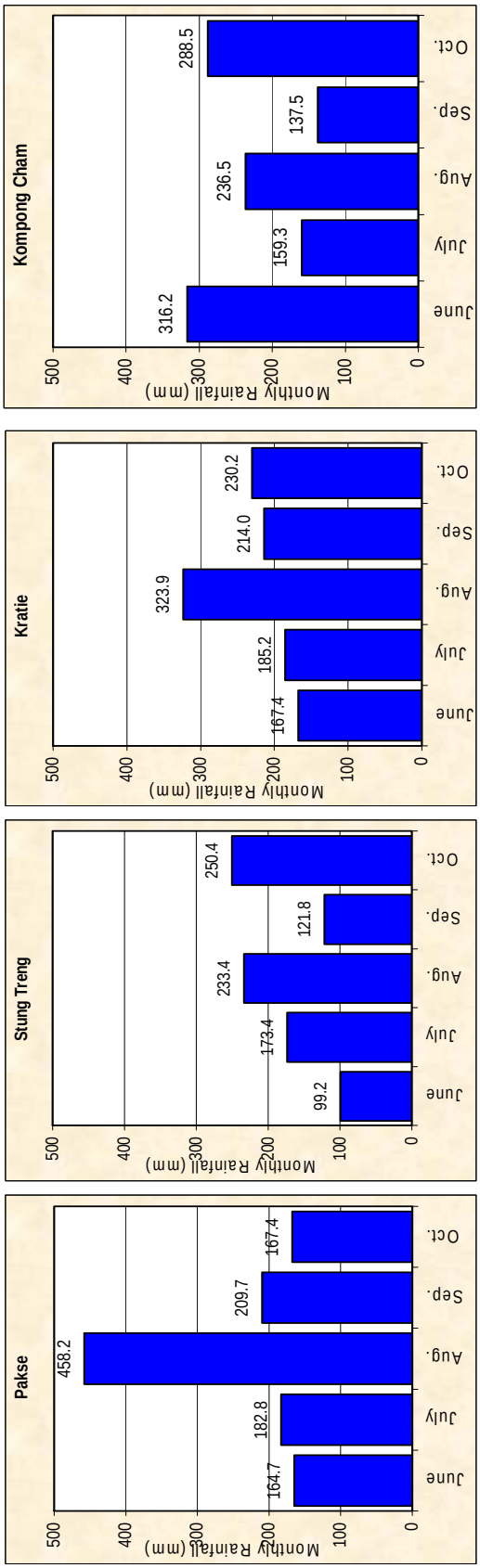


Figure A4 Monthly rainfall distribution for, Pakse, Stung Treng , Kratie and Kompong Chiam.

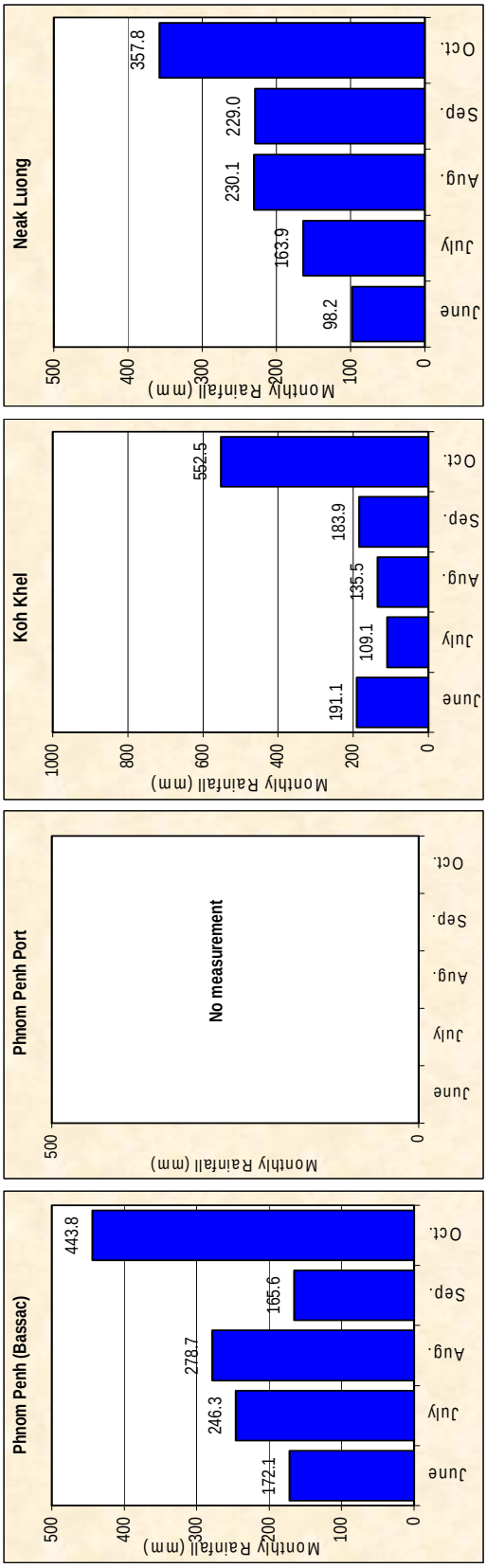


Figure A5 Monthly rainfall distribution for Phnom Penh (Bassac and Port), Koh Khel and Neak Luong.

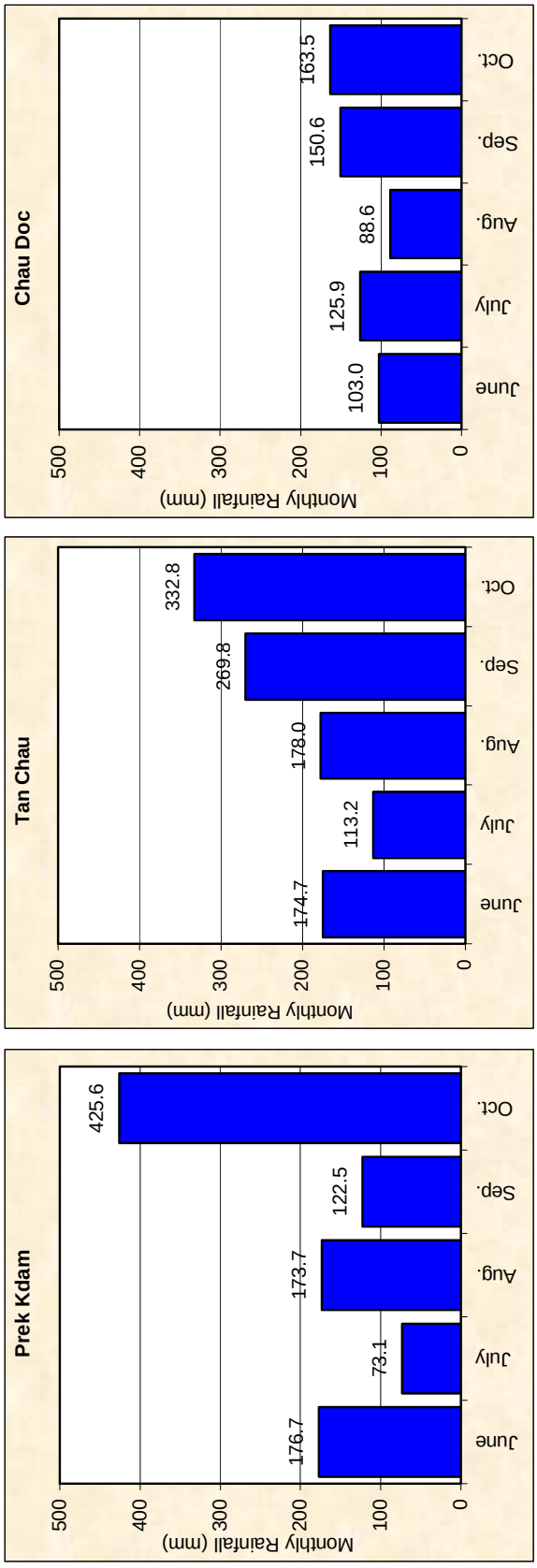


Figure A6 Monthly rainfall distribution for Prek Kdam, Tan Chau and Chau Doc.

2. Graphs for monthly rainfall in flood season from 2000 to 2011 and long-term average along the Mekong River

Figure A7 Monthly rainfall in June for main stations along the Mekong River.

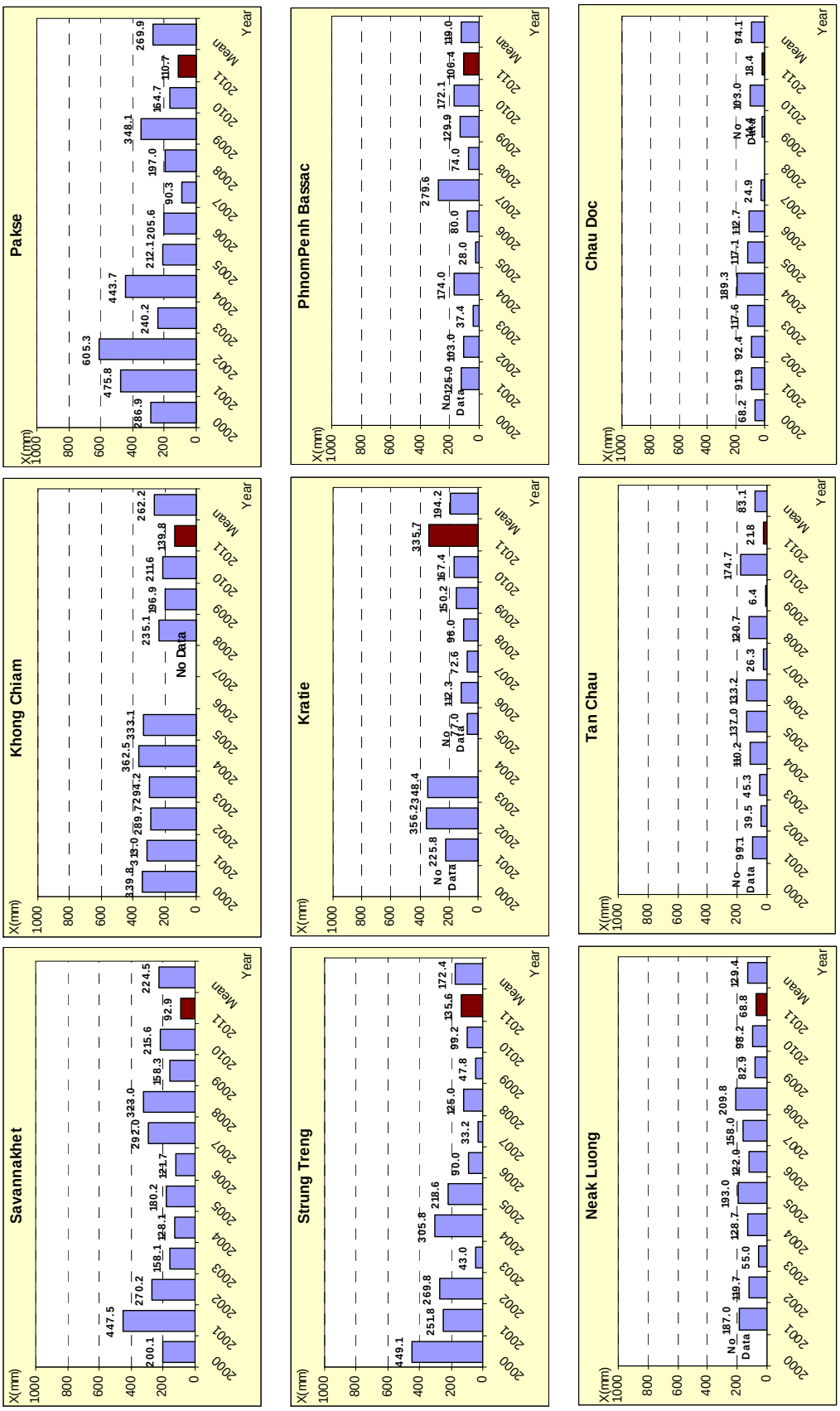


Figure A7 (cont.)

Figure A8 Monthly rainfall in July for main stations along the Mekong River.

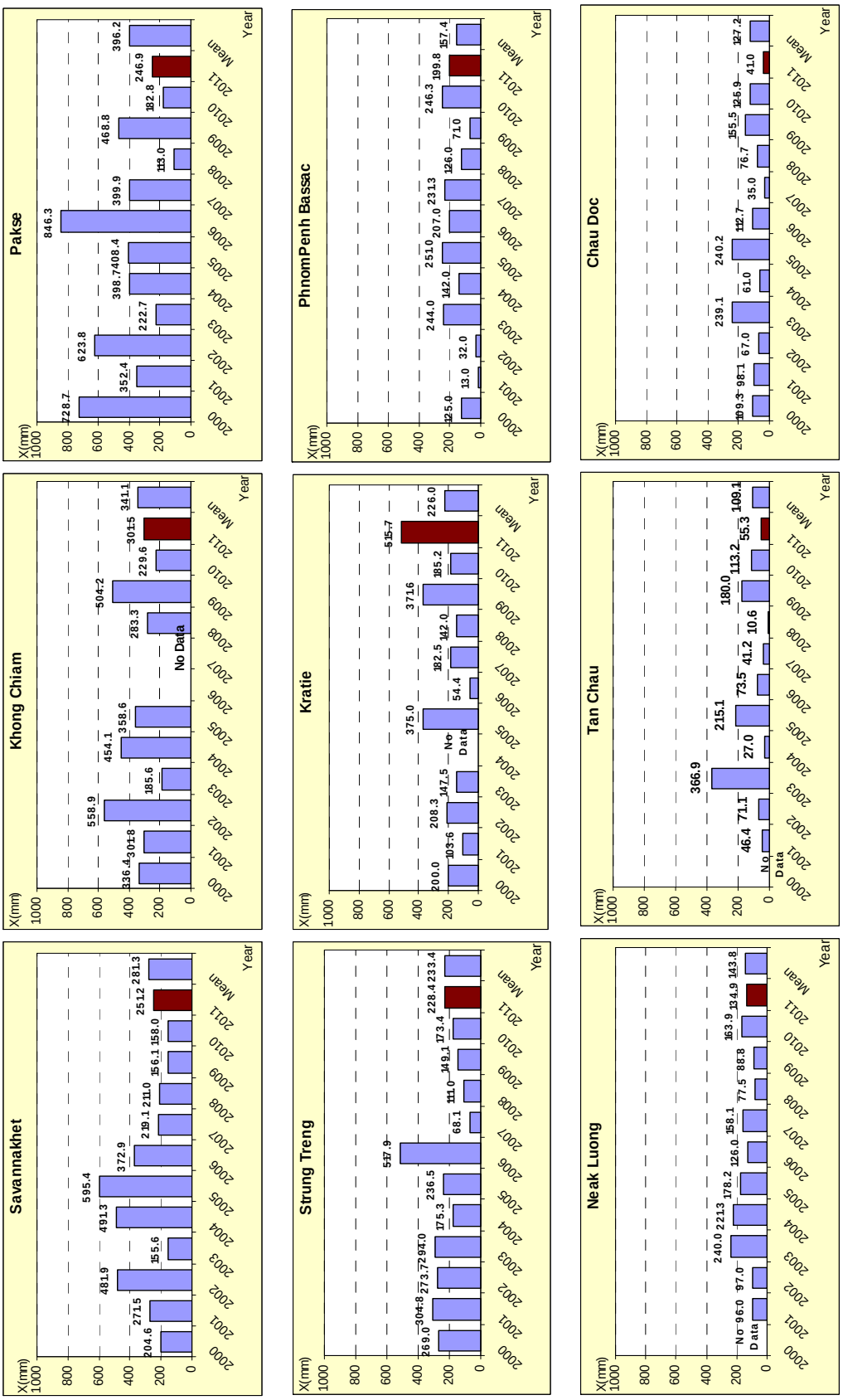


Figure A8 (cont.)

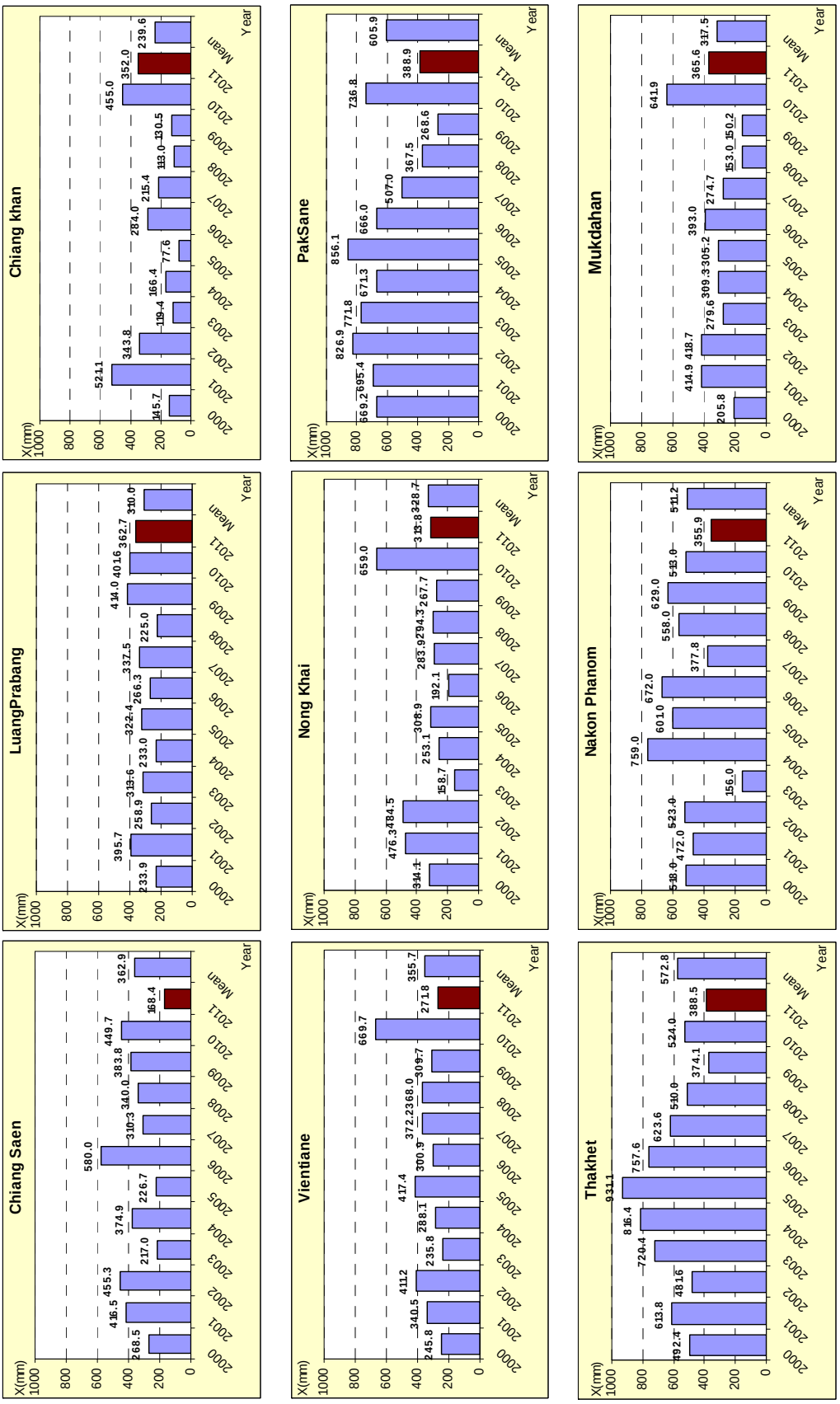


Figure A9 Monthly rainfall in August for main stations along the Mekong River.

Figure A9 (cont.)

Figure A10 Monthly rainfall in September for main stations along the Mekong River.

Figure A10 (cont.)

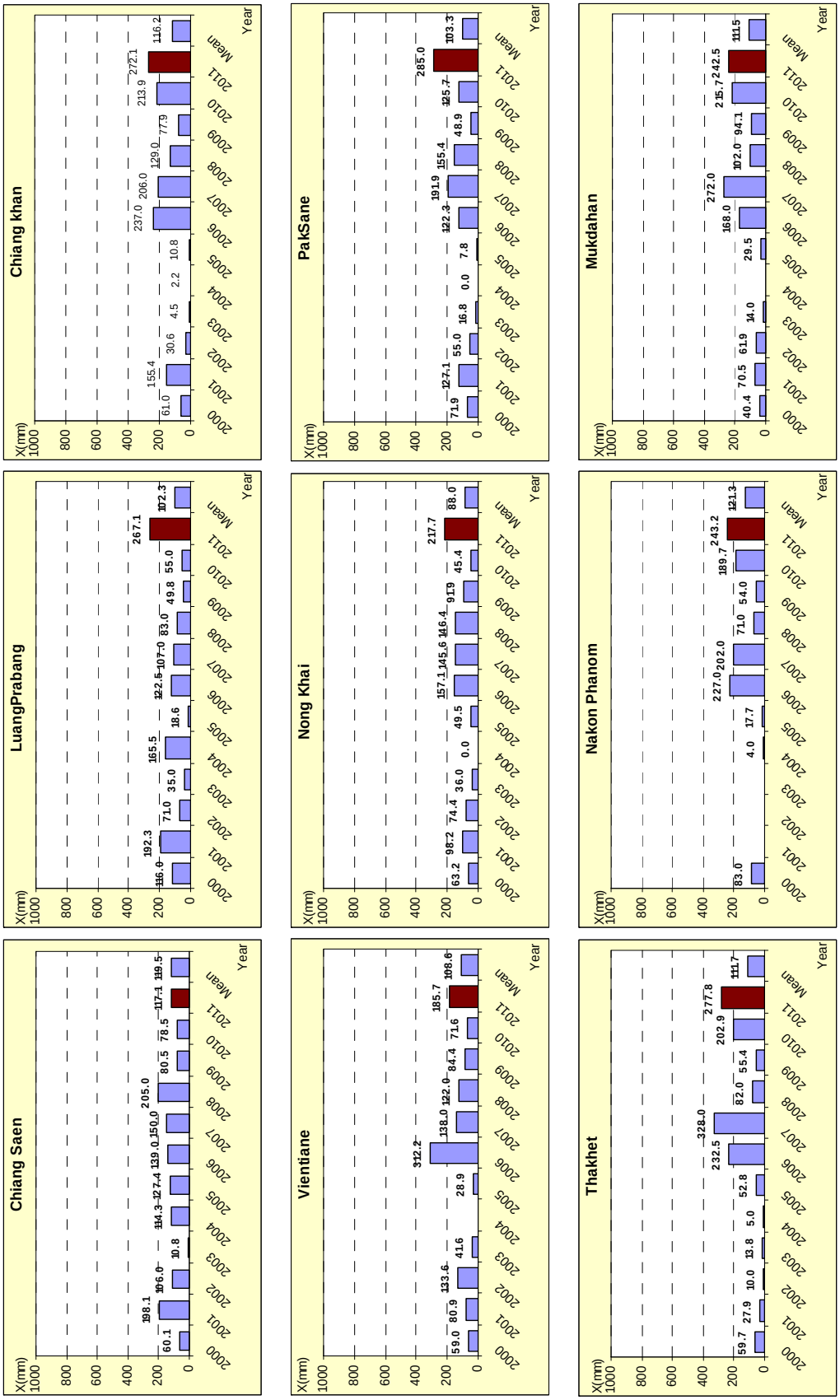


Figure A11 Monthly rainfall in October for main stations along the Mekong River.

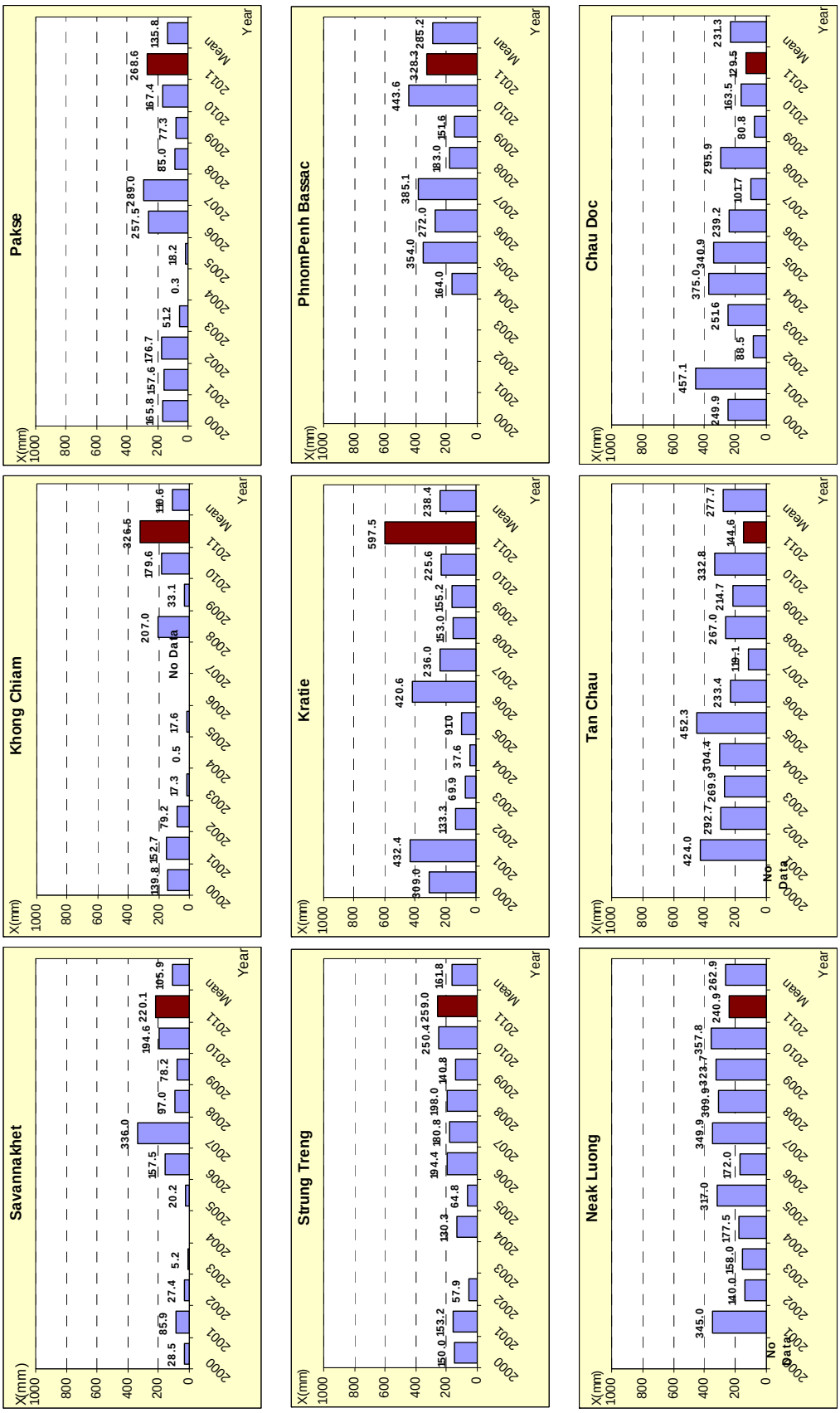


Figure A11 (cont.)

3. Tables of flood event characteristics along the Mekong River during flood season 2011

Table A2 The characteristics of flood events for station from Chiang Saen to Vientiane/Nong Khai.

ID	Station	Beginning of Flood Even		Peak of flood event		Rising Time	Flood Amplitude	Intensity of Flood Rising			Comment
		Date	Hb (m)	Date	Hp (m)	Tp (day)	(m)	Interval of Imax (Date)	Imax (m/day)	Iaverage (m/day)	
010501	Chiang Saen	25-Jun	3.45	29-Jun	4.56	4	1.11	22-Jun - 23-Jun	0.57	0.28	TS-HAIMA
		15-Jul	4.06	22-Jul	5.83	7	1.77	17-Jul - 18-Jul	0.52	0.25	SW
011201	Luang Prabang	24-Jun	6.48	03-Jul	11.28	9	4.80	25-Jun - 26-Jun	1.72	0.53	TS-HAIMA
		15-Jul	8.72	25-Jul	13.62	10	4.90	24-Jul - 25-Jul	0.76	0.49	SW
		15-Sep	10.66	22-Sep	15.25	7	4.59	16-Sep - 17-Sep	1.26	0.66	SW, ITCZ
011903	Chiang Khan	26-Jun	6.99	28-Jun	10.76	2	3.77	26-Jun - 27-Jun	3.70	1.89	TS-HAIMA
		15-Jul	8.82	26-Jul	12.14	11	3.32	25-Jul - 26-Jul	0.57	0.30	SW
		17-Sep	11.04	23-Sep	13.14	6	2.10	18-Sep - 19-Sep	0.65	0.35	SW, ITCZ
011901	Vientiane	26-Jun	3.85	28-Jun	7.59	2	3.74	27-Jun - 28-Jun	3.27	1.87	TS-HAIMA
		15-Jul	5.63	26-Jul	9.14	11	3.51	25-Jul - 26-Jul	0.74	0.32	SW
		17-Sep	8.72	23-Sep	10.62	6	1.90	18-Sep - 19-Sep	0.54	0.32	SW, ITCZ
012001	Nong Khai	24-Jun	4.47	29-Jun	8.88	5	4.41	27-Jun - 28-Jun	3.40	0.88	TS-HAIMA
		15-Jul	6.84	27-Jul	10.30	12	3.46	25-Jul - 26-Jul	0.54	0.29	SW
		18-Sep	10.25	23-Sep	11.88	5	1.63	19-Sep - 20-Sep	0.53	0.33	SW, ITCZ

Table A3 The characteristics of flood events for stations from Paksane to Pakse.

ID	Station	Beginning of Flood Even		Peak of flood event		Rising Time	Flood Amplitude	Intensity of Flood Rising			Comment
		Date	Hb (m)	Date	Hp (m)	Tp (day)	(m)	Interval of Imax (Date)	Imax (m/day)	Iaverage (m/day)	
012703	Paksane	24-Jun	6.26	03-Jul	12.00	9	5.74	25-Jun - 26-Jun	2.67	0.64	TS-HAIMA
		15-Jul	9.14	27-Jul	11.44	12	2.30	16-Jul - 17-Jul	0.72	0.19	SW
		30-Jul	10.81	04-Aug	13.24	5	2.43	31-Jul - 01-Aug	1.24	0.49	TS-NOKTEN
		12-Sep	11.52	22-Sep	13.42	10	1.90	12-Sep - 13-Sep	0.54	0.19	SW, ITCZ
013101	Nakhon Phanom	20-Jun	4.12	04-Jul	10.06	14	5.94	26-Jun - 27-Jun	1.76	0.42	TS-HAIMA
		13-Jul	7.29	18-Jul	9.23	5	1.94	16-Jul - 17-Jul	0.81	0.39	SW
		30-Jul	9.32	04-Aug	12.24	5	2.92	31-Jul - 01-Aug	1.05	0.58	TS-NOKTEN
		12-Sep	9.78	20-Sep	11.95	8	2.17	13-Sep - 14-Sep	0.47	0.27	SW, ITCZ
013102	Thakhek	20-Jun	5.23	04-Jul	11.13	14	5.90	26-Jun - 27-Jun	1.68	0.42	TS-HAIMA
		13-Jul	8.43	18-Jul	10.33	5	1.90	16-Jul - 17-Jul	0.84	0.38	SW
		30-Jul	10.39	04-Aug	13.29	5	2.90	31-Jul - 01-Aug	1.11	0.58	TS-NOKTEN
		13-Sep	10.70	20-Sep	13.00	7	2.30	13-Sep - 14-Sep	0.68	0.33	SW, ITCZ
013402	Mukdahan	21-Jun	4.07	04-Jul	10.03	13	5.96	26-Jun - 27-Jun	1.66	0.46	TS-HAIMA
		14-Jul	7.06	18-Jul	9.20	4	2.14	16-Jul - 17-Jul	0.73	0.54	SW
		30-Jul	9.15	05-Aug	12.37	6	3.22	31-Jul - 01-Aug	1.08	0.54	TS-NOKTEN
		12-Sep	9.78	20-Sep	11.95	8	2.17	15-Sep - 16-Sep	0.49	0.27	SW, ITCZ
013401	Savannakhet	21-Jun	2.40	04-Jul	8.80	13	6.40	26-Jun - 27-Jun	1.80	0.49	TS-HAIMA
		14-Jul	6.24	18-Jul	8.41	4	2.17	16-Jul - 17-Jul	0.72	0.54	SW
		30-Jul	8.38	05-Aug	11.21	6	2.83	01-Aug - 02-Aug	0.72	0.47	TS-NOKTEN
		11-Sep	8.66	21-Sep	11.05	10	2.39	15-Sep - 16-Sep	0.61	0.24	SW, ITCZ
013801	Khong Chiam	21-Jun	4.57	04-Jul	10.72	13	6.15	29-Jun - 30-Jun	1.54	0.47	TS-HAIMA
		14-Jul	7.55	20-Jul	10.04	6	2.49	17-Jul - 18-Jul	0.76	0.42	SW
		31-Jul	10.41	11-Aug	15.72	11	5.31	01-Aug - 02-Aug	0.96	0.48	TS-NOKTEN
		13-Sep	12.31	21-Sep	15.34	8	3.03	15-Sep - 16-Sep	0.90	0.38	SW, ITCZ
013901	Pakse	24-Jun	3.91	04-Jul	8.75	10	4.84	28-Jun - 29-Jun	1.70	0.48	TS-HAIMA
		15-Jul	6.13	19-Jul	8.16	4	2.03	17-Jul - 18-Jul	0.60	0.51	SW
		31-Jul	8.74	11-Aug	13.11	11	4.37	07-Aug - 08-Aug	0.77	0.40	TS-NOKTEN
		14-Sep	10.22	22-Sep	12.72	8	2.50	15-Sep - 16-Sep	0.71	0.31	SW, ITCZ

Table A4 The characteristics of flood events for stations from Strung Treng to Kompong Cham.

ID	Station	Beginning of Flood Even		Peak of flood event		Rising Time	Flood Amplitude	Intensity of Flood Rising			Comment
		Date	Hb (m)	Date	Hp (m)	Tp (day)	(m)	Interval of Imax (Date)	Imax (m/day)	Iaverage (m/day)	
014501	Stung Treng	18-Jun	4.30	22-Jun	5.67	4	1.37	19-Jun - 20-Jun	0.55	0.34	TS-HAIMA
		29-Jun	5.30	03-Jul	7.40	4	2.10	30-Jun - 01-Jul	0.88	0.53	SW
		07-Aug	9.36	12-Aug	10.87	5	1.51	07-Aug - 08-Aug	0.64	0.30	TS-NOKTEN
		07-Sep	8.61	11-Sep	10.55	4	1.94	09-Sep - 10-Sep	0.52	0.49	SW, ITCZ
014901	Kratie	19-Jun	11.10	23-Jun	13.64	4	2.54	19-Jun - 20-Jun	0.85	0.64	TS-HAIMA
		29-Jun	12.40	07-Jul	17.00	8	4.60	30-Jun - 01-Jul	1.42	0.58	SW
		07-Aug	19.66	13-Aug	21.79	6	2.13	08-Aug - 09-Aug	0.63	0.36	TS-NOKTEN
		08-Sep	19.63	12-Sep	21.80	4	2.17	10-Sep - 11-Sep	0.65	0.54	SW, ITCZ
019802	Kompong Cham	19-Jun	6.00	24-Jun	8.32	5	2.32	20-Jun - 21-Jun	0.80	0.46	TS-HAIMA
		30-Jun	7.46	07-Jul	11.26	7	3.80	01-Jul - 02-Jul	1.28	0.54	SW
		08-Sep	13.84	13-Sep	15.19	5	1.35	10-Sep - 11-Sep	0.37	0.27	SW, ITCZ

Table A5 The characteristics of flood events for stations from Phnom Penh Bassac/Phnom Penh Port, Koh Khel/Neak Luong to Prek Kdam.

ID	Station	Beginning of Flood Even		Peak of flood event		Rising Time	Flood Amplitude	Intensity of Flood Rising			Comment
		Date	Hb (m)	Date	Hp (m)	Tp (day)	(m)	Interval of Imax (Date)	Imax (m/day)	Iaverage (m/day)	
033401	Bassac Chaktomuk	20-Jun	3.57	24-Jun	4.69	4	1.12	21-Jun - 22-Jun	0.34	0.28	TS-HAIMA
		30-Jun	4.27	08-Jul	6.59	8	2.32	02-Jul - 03-Jul	0.67	0.29	SW
		08-Sep	9.37	15-Sep	9.95	7	0.58	12-Sep - 13-Sep	0.12	0.08	SW, ITCZ
020101	Phnom Penh Port	19-Jun	2.63	24-Jun	3.81	5	1.18	22-Jun - 23-Jun	0.44	0.24	TS-HAIMA
		30-Jun	3.30	08-Jul	5.71	8	2.41	02-Jul - 03-Jul	0.68	0.30	SW
		09-Sep	8.59	16-Sep	9.14	7	0.55	13-Sep - 14-Sep	0.11	0.08	SW, ITCZ
033402	Koh Khel	20-Jun	3.29	24-Jun	4.22	4	0.93	21-Jun - 22-Jun	0.30	0.23	TS-HAIMA
		30-Jun	3.88	08-Jul	5.80	8	1.92	02-Jul - 03-Jul	0.58	0.24	SW
		09-Sep	7.25	17-Sep	7.56	8	0.31	10-Sep - 11-Sep	0.05	0.04	SW, ITCZ
019806	Neak Luong	20-Jun	2.26	24-Jun	3.02	4	0.76	21-Jun - 22-Jun	0.24	0.19	TS-HAIMA
		30-Jun	2.66	08-Jul	4.48	8	1.82	02-Jul - 03-Jul	0.53	0.23	SW
		09-Sep	6.79	28-Sep	8.06	19	1.27	25-Sep - 26-Sep	0.13	0.07	TS-HAITANG, TS-NALGAE
020102	Prek Kdam	19-Jun	2.55	24-Jun	3.67	5	1.12	21-Jun - 22-Jun	0.31	0.22	TS-HAIMA
		30-Jun	3.33	08-Jul	5.38	8	2.05	02-Jul - 03-Jul	0.58	0.26	SW
		09-Sep	8.51	29-Sep	9.98	20	1.47	13-Sep - 14-Sep	0.13	0.07	SW, ITCZ

Table A6 The characteristics of flood events for stations from Tan Chau and Chau Doc (**).

ID	Station	Beginning of Flood Even		Peak of flood event		Rising Time	Flood Amplitude	Intensity of Flood Rising			Comment
		Date	Hb (m)	Date	Hp (m)	Tp (day)	(m)	Interval of Imax (Date)	Imax (m/day)	Iaverage (m/day)	
019803	Tan Chau	08-Jun	0.38	14-Jun	1.08	6	0.70	12-Jun - 13-Jun	0.24	0.12	Tidal Influence
		01-Jul	1.08	08-Jul	1.82	7	0.74	02-Jul - 03-Jul	0.20	0.11	SW
		10-Sep	3.75	28-Sep	4.75	18	1.00	24-Sep - 25-Sep	0.11	0.06	TS-HAITANG, TS-NALGAE
039801	Chau Doc	08-Jun	0.21	14-Jun	1.10	6	0.89	12-Jun - 13-Jun	0.34	0.15	Tidal Influence
		02-Jul	0.90	08-Jul	1.30	6	0.40	04-Jul - 05-Jul	0.20	0.07	SW
		10-Jul	3.22	29-Sep	4.13	812	0.91	24-Sep - 25-Sep	0.11	0.00	TS-HAITANG, TS-NALGAE

(**) Water levels at Tan Chau and Chau Doc are influenced by tidal effect; the WL in the Table A6 were recorded at 7AM during 2011 flood season.

Annex B Accuracy and performance

Accuracy

"Accuracy" describes the accuracy of the adjusted and published forecast, based on the results of the MRC Mekong Flood Forecasting System, which are then adjusted by the Flood Forecaster in Charge taking into consideration known biases in input data and his/her knowledge of the response of the model system and the hydrology of the Mekong River Basin.

The information is presented as a graph below, showing the average flood forecasting accuracy along the Mekong mainstream.

The graph of average difference between forecast and actual water levels for the whole flood season from the 1st June to the 31st October shows the normal pattern.

In general terms, the accuracy is good for all forecasts lead time at most stations along Mekong River, however the accuracy for 3-day forecast at Vientiane, Nakhon Phanom, Mukdahan to Kratie. The detail analysis is presented in paragraph 2.2.

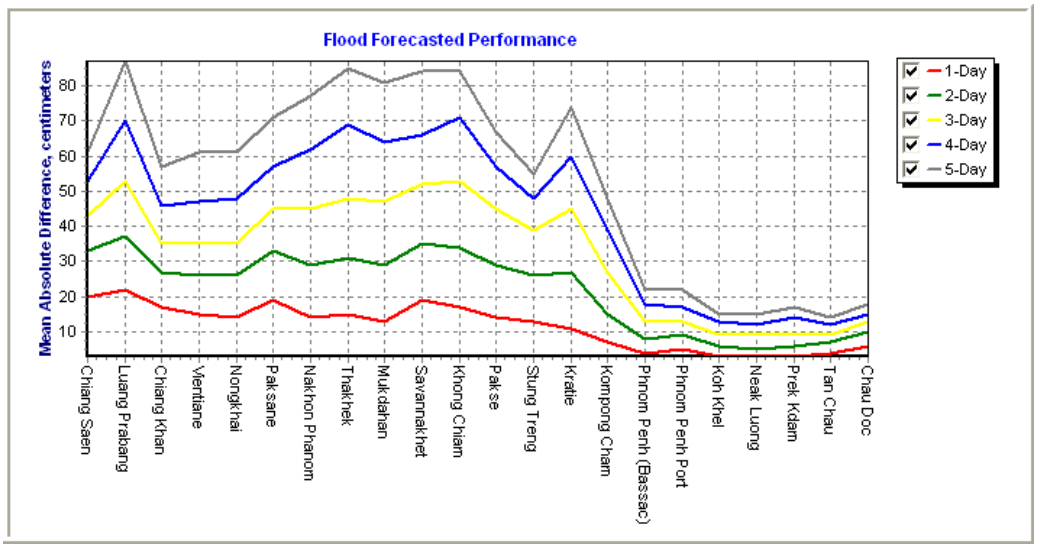


Figure B1 Average flood forecast accuracy along the Mekong mainstream.

Forecast Achievement

The forecast achievement indicates the % of days that the forecast at a particular station for a lead-time is successful against a respective benchmark (Table B2).

Table B1 Achievement of daily forecast against benchmarks.

unit in %

	Chiang Saen	Luang Prabang	Chiang Khan	Vientiane	Nongkhai	Paksane	Nakhon Phanom	Thakhek	Mukdahan	Savannakhet	Khong Chiam	Pakse	Stung Treng	Kratie	Kompong Cham	Phnom Penh (Bassac)	Phnom Penh Port	Koh Khel	Neak Luong	Prek Kdam	Tan Chau	Chau Doc	*Average*
1-day	70.1	73.1	80.8	54.5	59.9	50.9	53.9	56.3	54.5	53.9	50.3	54.5	55.1	62.9	82.6	94.6	86.8	97.0	95.2	95.2	90.4	83.8	70.7
2-day	76.5	76.5	84.9	59.6	65.1	59.6	60.2	62.0	57.2	56.6	55.4	61.4	57.8	57.8	81.9	77.7	69.3	88.6	89.8	88.6	81.9	75.3	70.2
3-day	66.7	58.2	77.0	48.5	57.6	52.1	42.4	50.9	38.8	41.8	38.8	46.7	44.2	37.0	60.0	61.2	62.4	76.4	71.5	72.7	74.5	69.1	56.7
4-day	77.4	61.0	64.0	64.6	69.5	68.9	56.1	60.4	56.7	61.0	50.6	60.4	62.8	53.7	75.0	47.0	79.9	67.1	88.4	84.8	65.2	57.9	65.1
5-day	68.7	52.1	57.7	52.1	59.5	60.1	42.9	46.0	44.2	52.8	39.9	57.1	56.4	44.8	62.6	68.7	68.7	82.2	83.4	80.4	85.9	76.7	61.0

Table B2 Benchmarks of success (Indicator of accuracy in mean absolute error).

Unit in cm

	Chiang Saen	Luang Prabang	Chiang Khan	Vientiane	Nongkhai	Paksane	Nakhon Phanom	Thakhek	Mukdahan	Savannakhet	Khong Chiam	Pakse	Stung Treng	Kratie	Kompong Cham	Phnom Penh (Bassac)	Phnom Penh Port	Koh Khel	Neak Luong	Prek Kdam	Tan Chau	Chau Doc
1-day	25	25	25	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
2-day	50	50	50	25	25	25	25	25	25	25	25	25	25	25	25	10	10	10	10	10	10	10
3-day	50	50	50	25	25	25	25	25	25	25	25	25	25	25	25	10	10	10	10	10	10	10
4-day	75	75	50	50	50	50	50	50	50	50	50	50	50	50	50	10	25	10	25	25	10	10
5-day	75	75	50	50	50	50	50	50	50	50	50	50	50	50	50	25	25	25	25	25	25	25

Note: *An indication of the accuracy given in the Table B2 is based on the performance of the forecast made in 2008 from the new flood forecasting system and the configuration for the 2009 flood season and is published on the website of MRC (http://ffw.mrcmekong.org/accuracy.htm).*

A new set of performance indicators that is established by combining international standards and the specific circumstances in the Mekong River Basin, is applied officially for the flood season of 2011 onward.

Performance

Performance is assessed by evaluating a number of performance indicators, see Table and graphs below:

Table B3 Overview of performance indicators for flood season 2011 from June to October.

	Flood Forecast: time sent				Arrival time of input data (average)									Missing data (number)							
2011	FF completed and sent (time)	stations without forecast	FF2 completed and sent (time)	Weather information available (number)	NOAA data	China	Cambodia - DHRW	Cambodia - DOM	Lao PDR - DMH	Thailand - DWR	Viet Nam - NCHMF	NOAA data	China	Cambodia - DHRW	Cambodia - DOM	Lao PDR - DMH	Thailand - DWR	Viet Nam - NCHMF
June	*10:12*	*1*	-	*27*	*08:12*	*09:51*	*07:31*	*05:53*	*09:06*	*08:00*	*07:14*	*0*	*4*	*32*	*398*	*621*	*12*	*189*
July	*10:36*	*0*	-	*13*	*08:12*	*07:38*	*07:31*	*06:24*	*09:02*	*07:41*	*07:13*	*1*	*12*	*3*	*278*	*515*	*5*	*162*
August	*10:36*	*0*	-	*14*	*08:11*	*08:14*	*07:36*	*05:52*	*09:01*	*07:42*	*07:06*	*0*	*0*	*2*	*159*	*481*	*4*	*176*
September	*10:34*	*0*	-	*19*	*08:06*	*08:14*	*07:23*	*06:27*	*09:14*	*07:39*	*06:59*	*0*	*0*	*28*	*311*	*532*	*10*	*131*
October	*10:34*	*0*	-	*20*	*08:11*	*08:09*	*07:28*	*05:57*	*09:10*	*07:36*	*07:17*	*1*	*0*	*60*	*712*	*490*	*13*	*314*
season	*10:31*	*1*	-	*93*	*08:10*	*08:18*	*07:30*	*06:07*	*09:06*	*07:43*	*07:10*	*2*	*16*	*125*	*1858*	*2639*	*44*	*972*

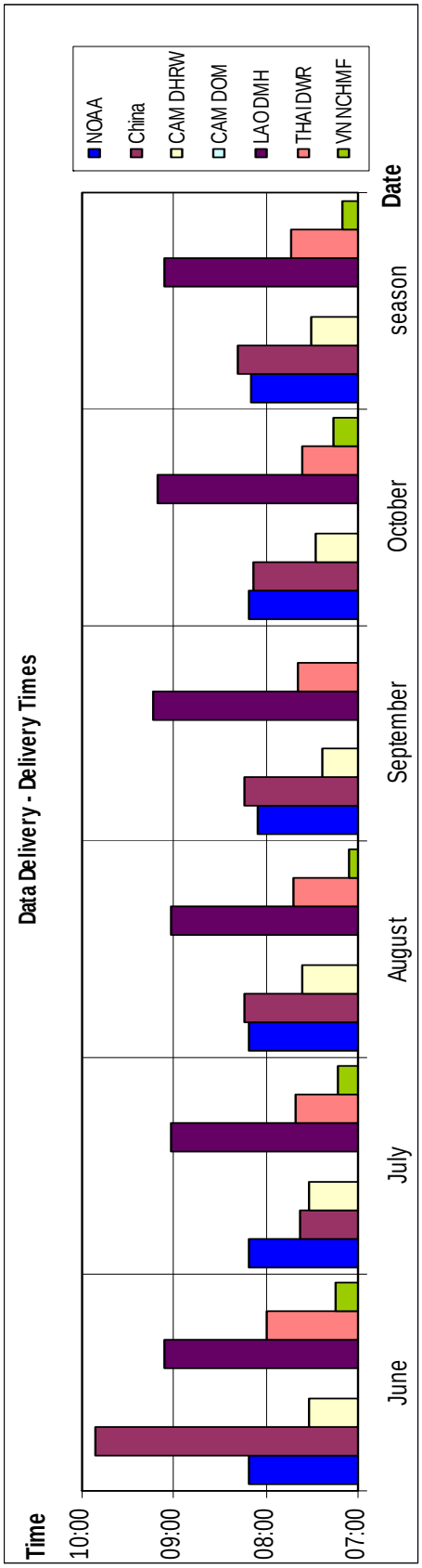


Figure B2 Data delivery times for flood season 2011 from June to October.

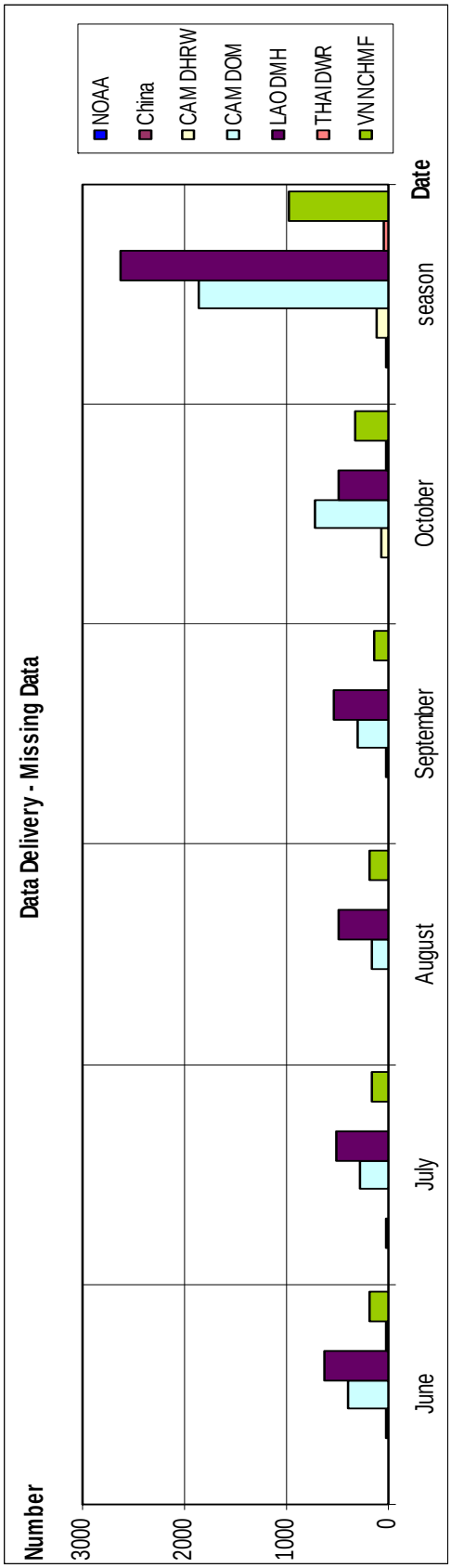


Figure B3 Missing data for flood season 2011 from June to October.

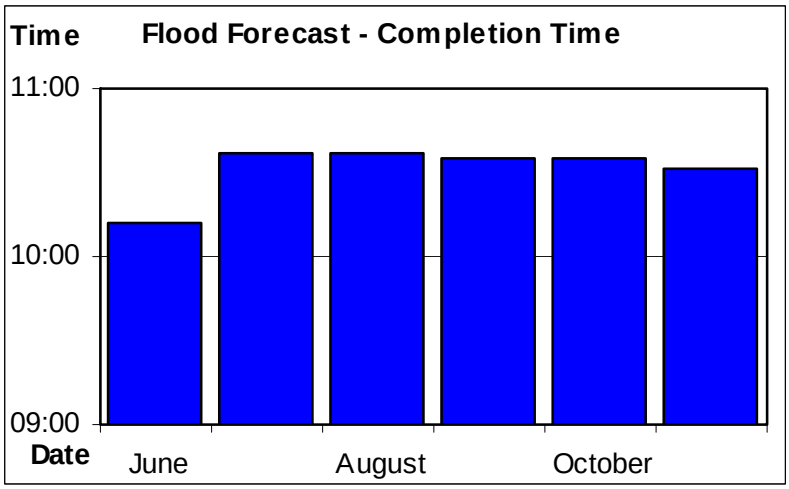


Figure B4 Flood forecast completion time.

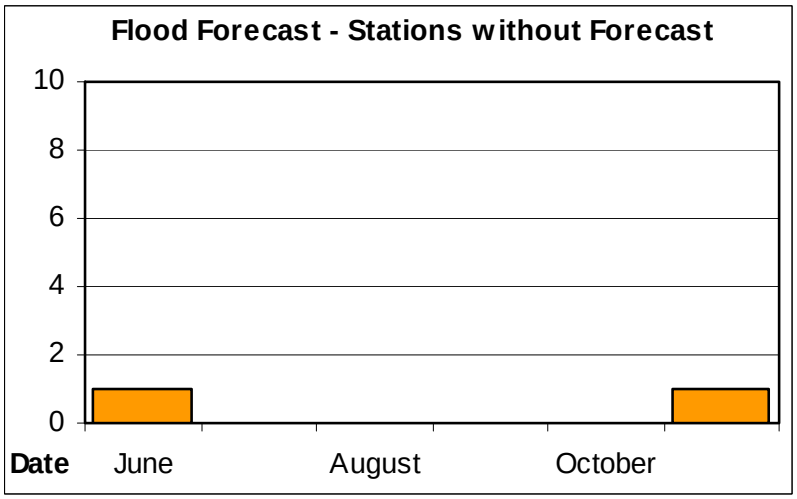


Figure B5 Flood forecast stations without forecast.

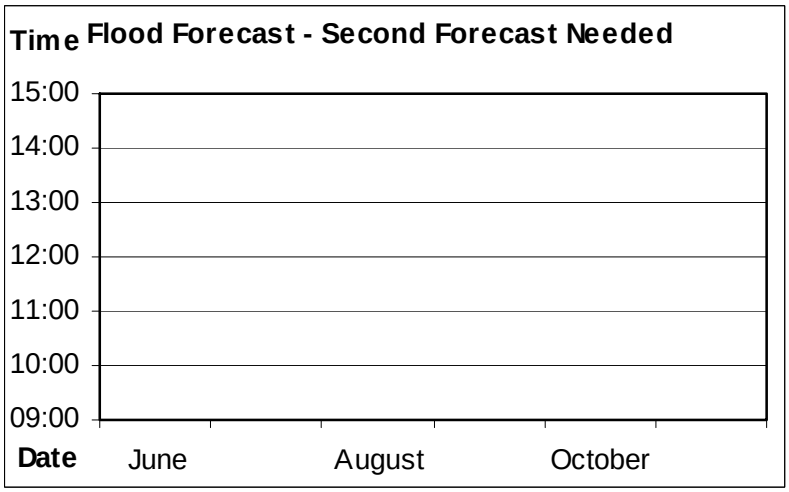


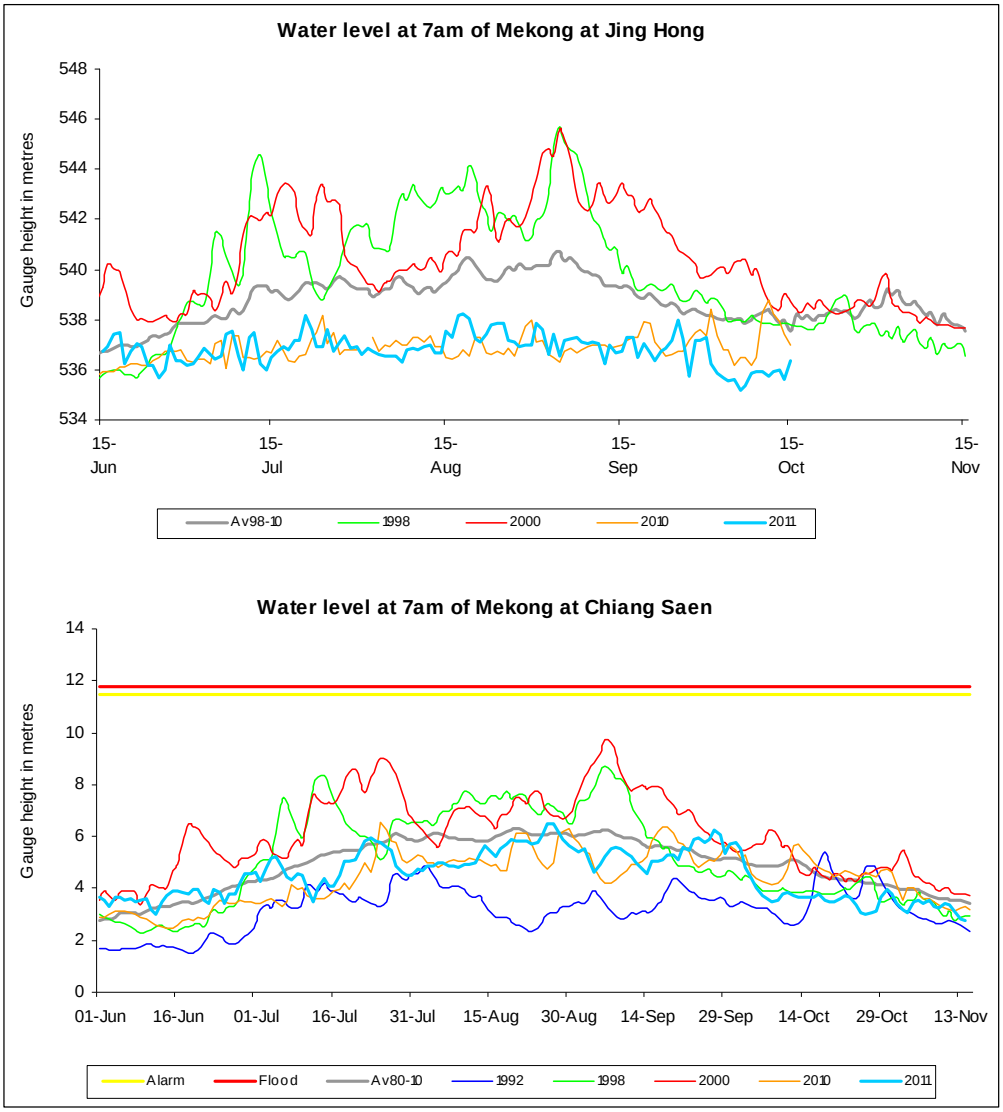
Figure B6 Second forecast needed.

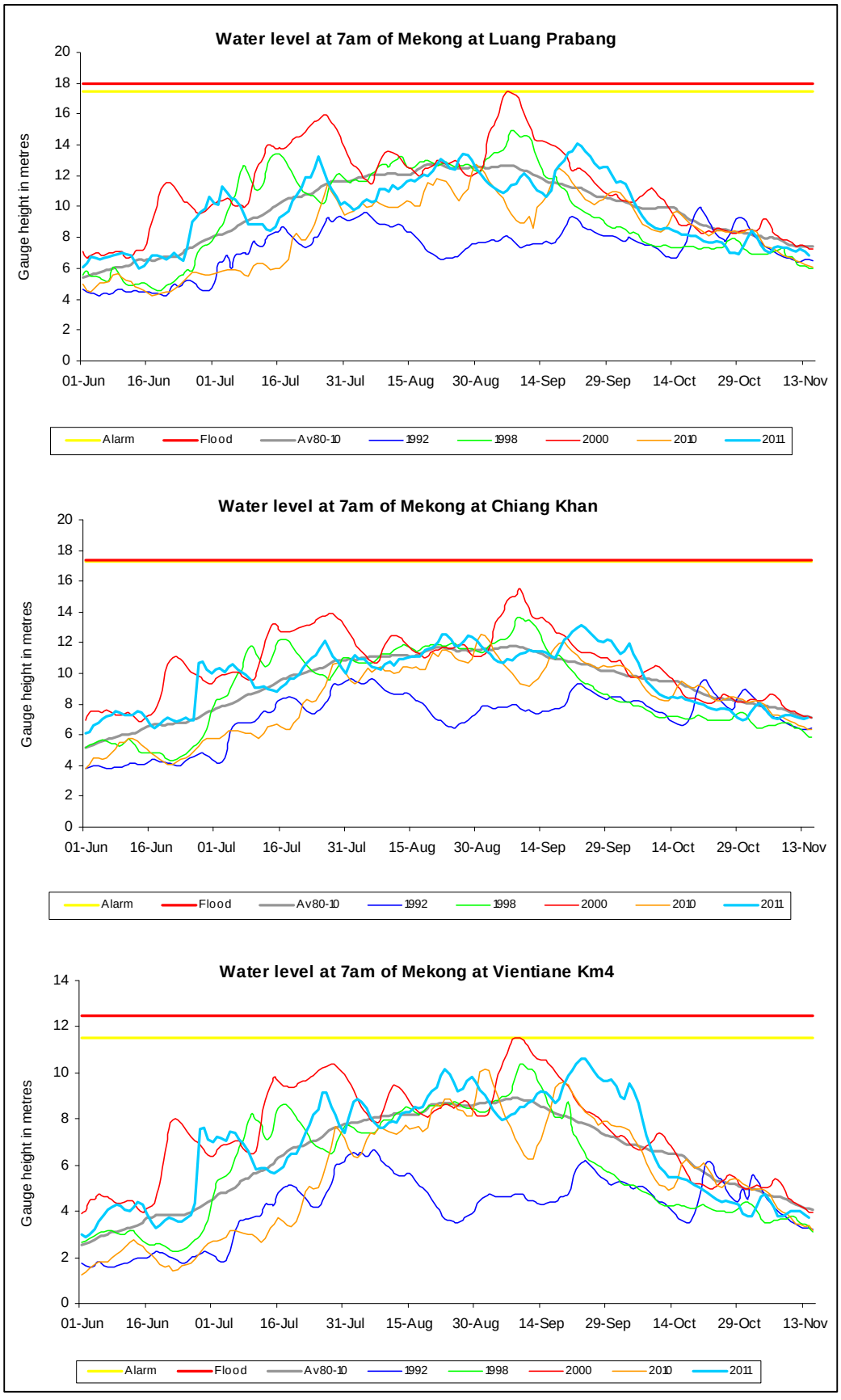
Annex C Season Water Level Graphs

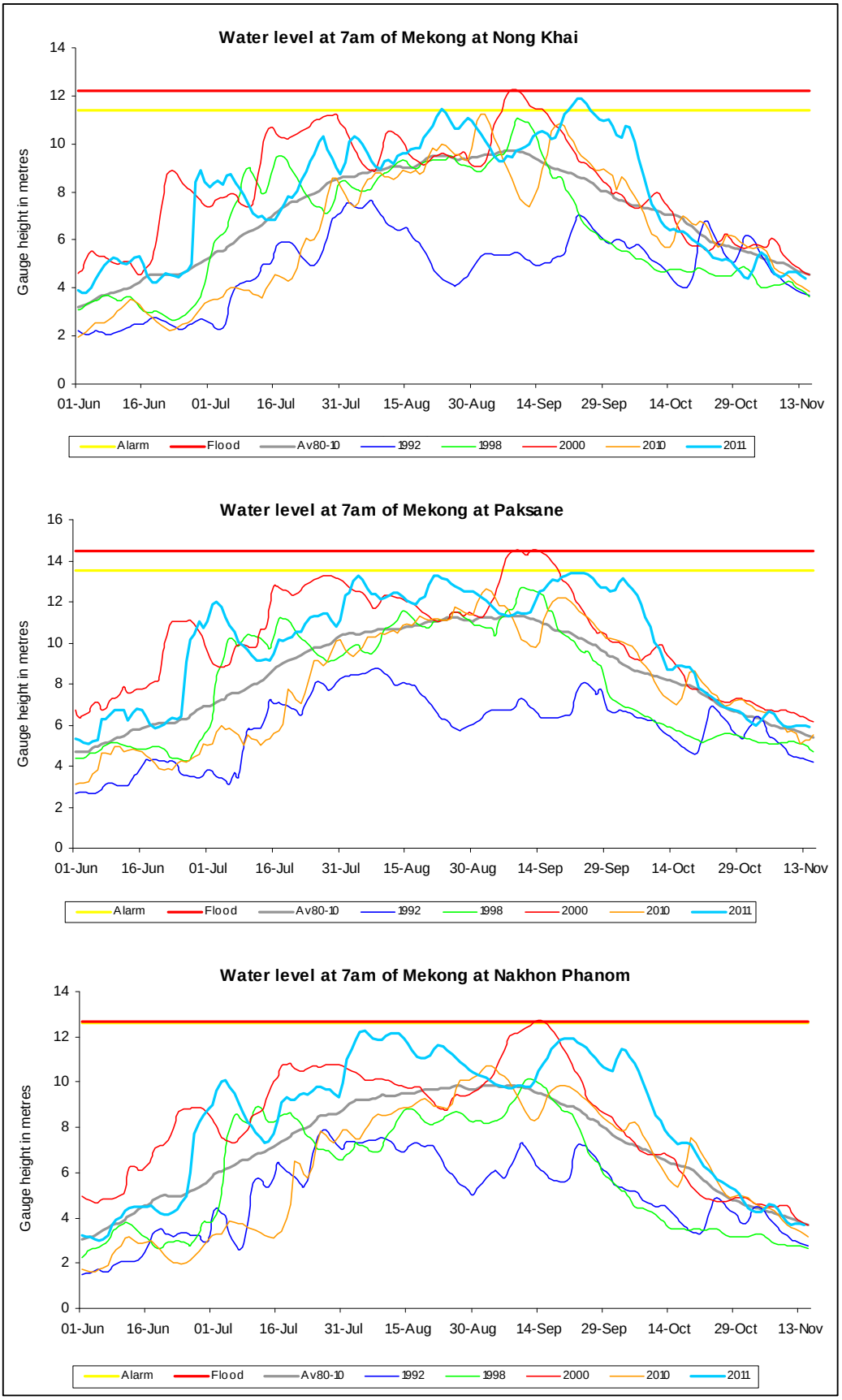
This Annex has the water level and rainfall graphs of the report date. These graphs are distributed daily by email together with the Flood Bulletins.

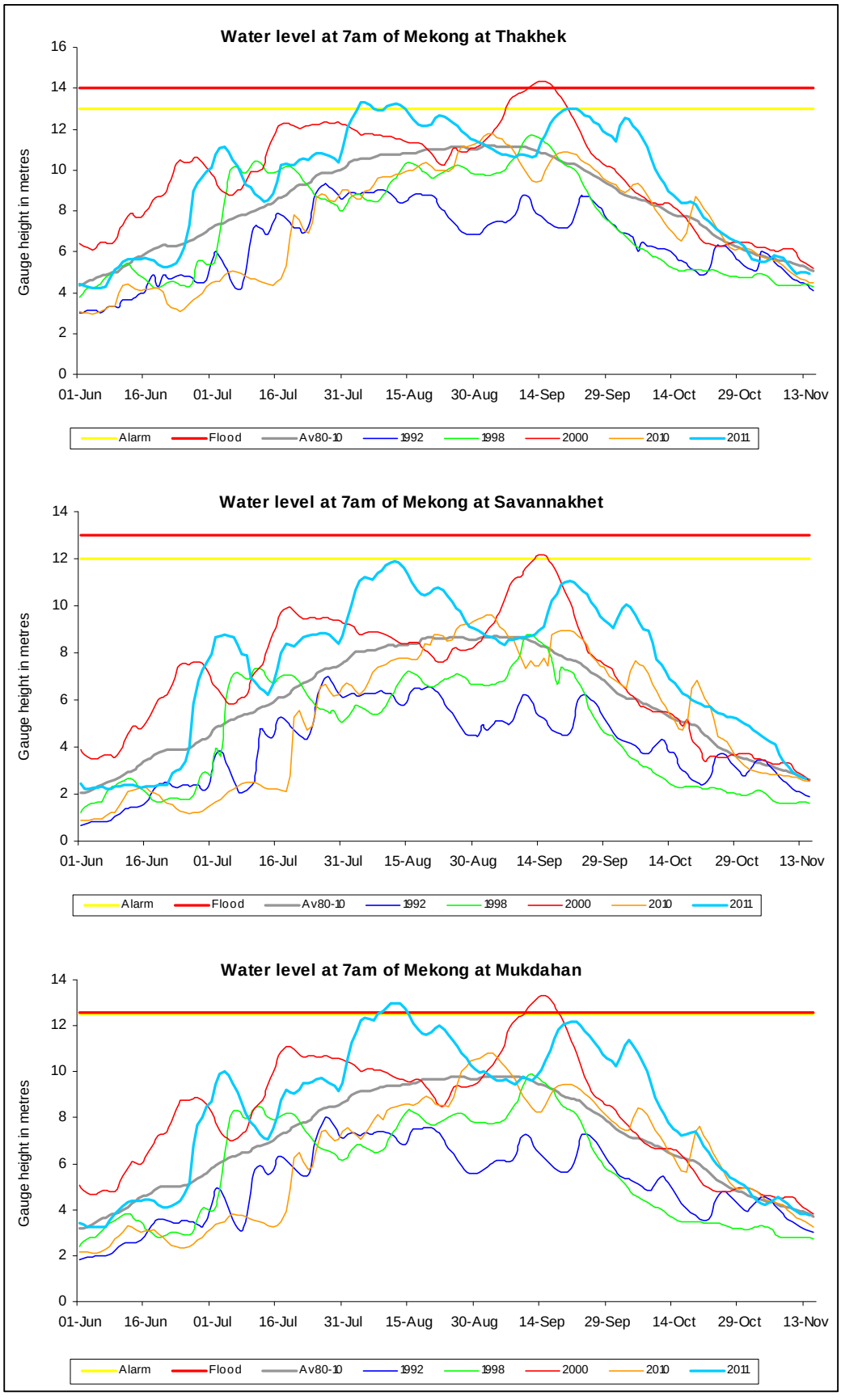
HYDROGRAPHS OF THE MEKONG AT MAINSTREAM STATIONS

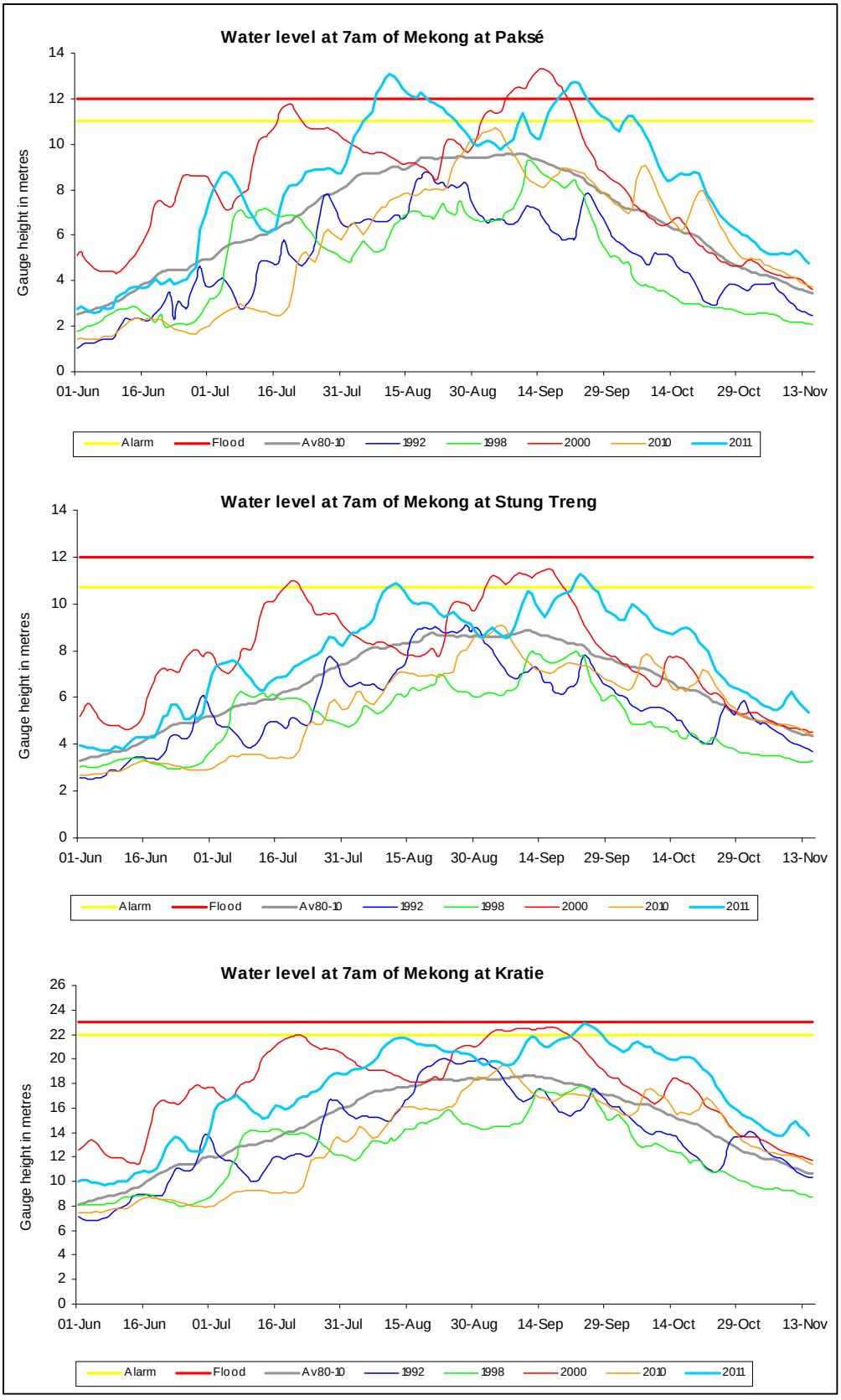
IN FLOOD SEASON FROM 1 JUNE TO 3 OCTOBER

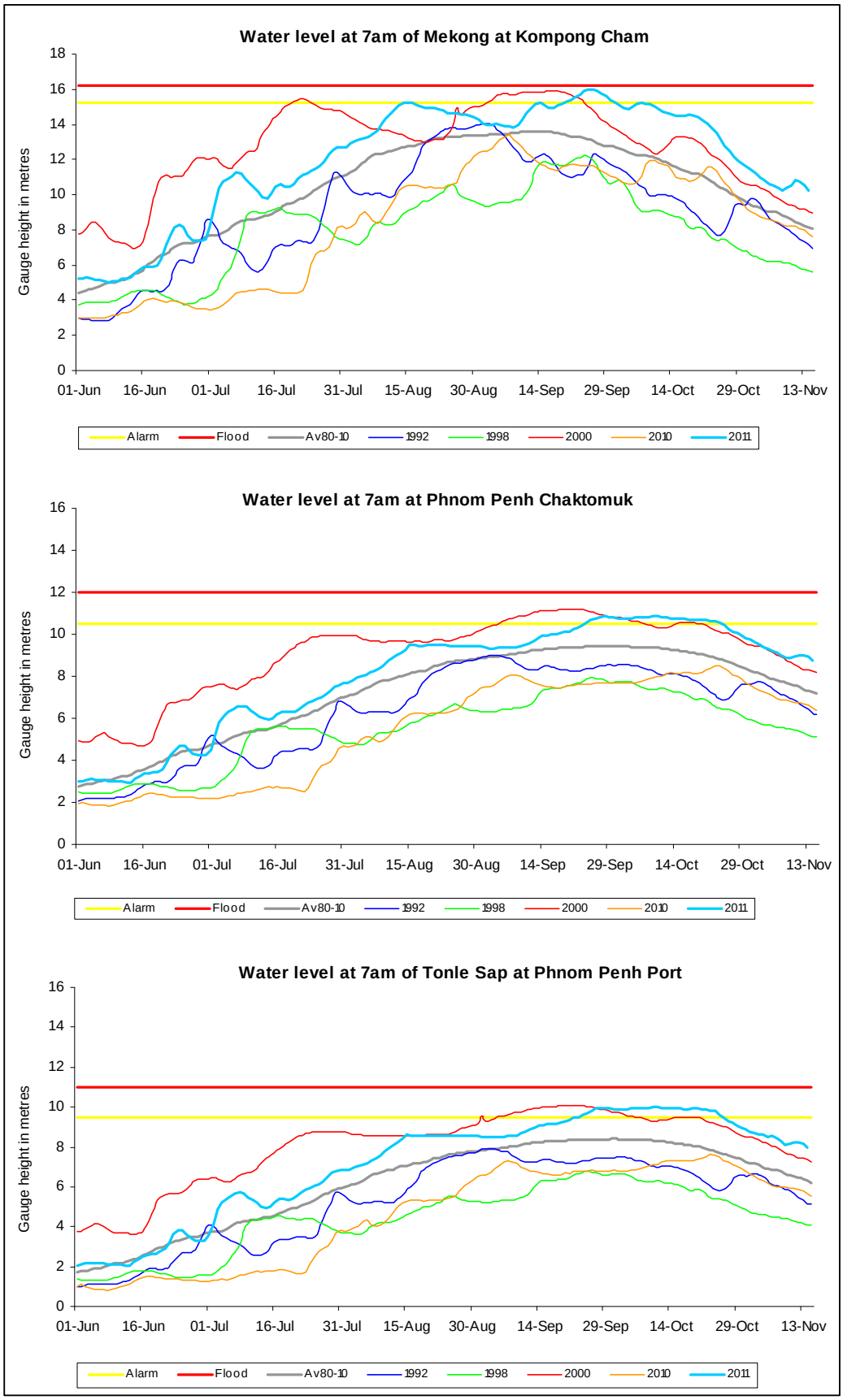


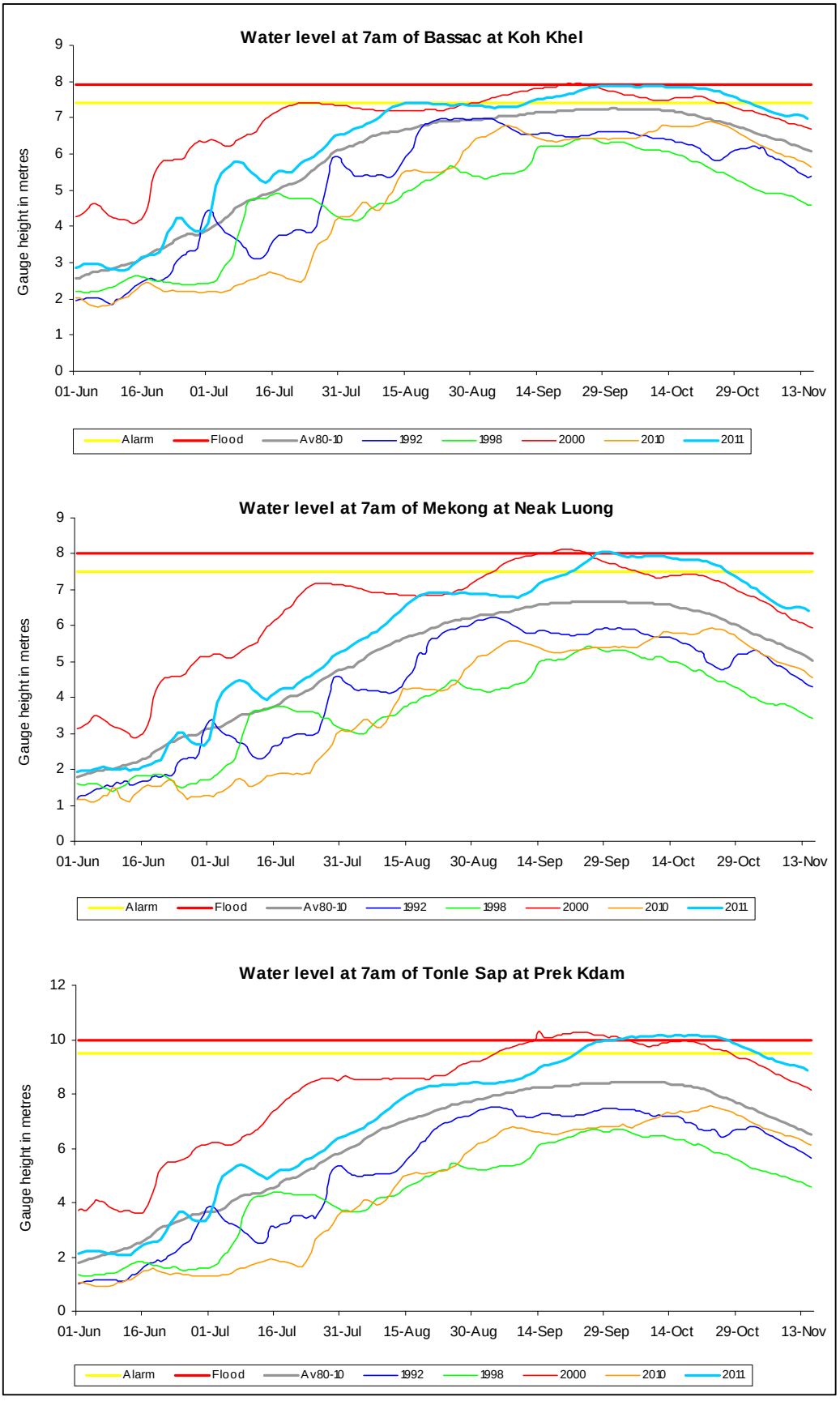

Water level at 7am of Mekong at Luang Prabang
Gauge height in metres
20
18
16
14
12
10
8
6
4
2
0
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Alarm
Flood
Av80-10
1992
1998
2000
2010
2011
Water level at 7am of Mekong at Chiang Khan
Gauge height in metres
20
18
16
14
12
10
8
6
4
2
0
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Alarm
Flood
Av80-10
1992
1998
2000
2010
2011
Water level at 7am of Mekong at Vientiane Km4
Gauge height in metres
14
12
10
8
6
4
2
0
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Alarm
Flood
Av80-10
1992
1998
2000
2010
2011

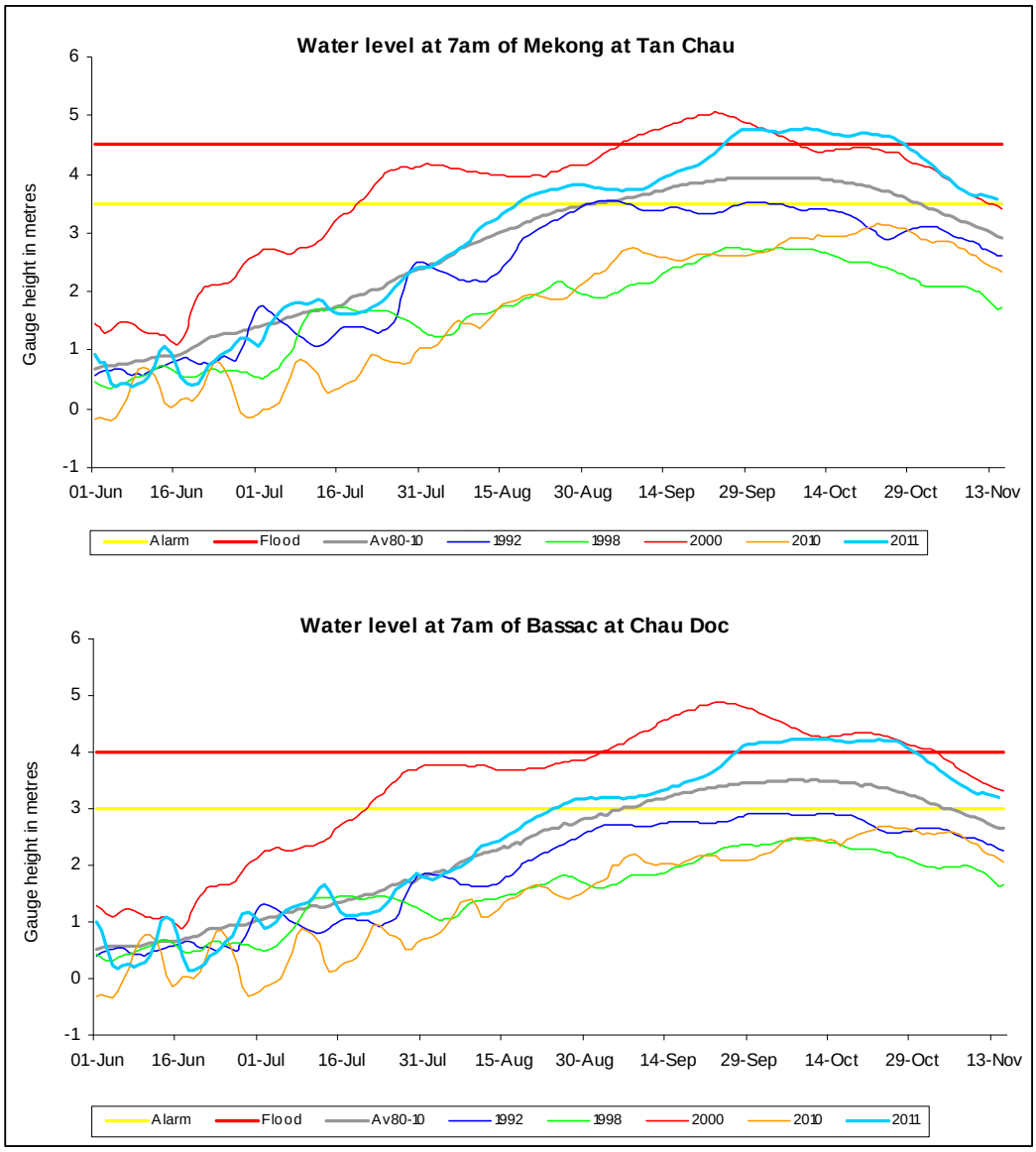

Water level at 7am of Mekong at Nong Khai
Gauge height in metres
0
2
4
6
8
10
12
14
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Alarm
Flood
Av80-10
1992
1998
2000
2010
2011
Water level at 7am of Mekong at Paksane
Gauge height in metres
0
2
4
6
8
10
12
14
16
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Alarm
Flood
Av80-10
1992
1998
2000
2010
2011
Water level at 7am of Mekong at Nakhon Phanom
Gauge height in metres
0
2
4
6
8
10
12
14
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Alarm
Flood
Av80-10
1992
1998
2000
2010
2011


Water level at 7am of Mekong at Thakhek
Gauge height in metres
0
2
4
6
8
10
12
14
16
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Alarm
Flood
Av80-10
1992
1998
2000
2010
2011
Water level at 7am of Mekong at Savannakhet
Gauge height in metres
0
2
4
6
8
10
12
14
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Alarm
Flood
Av80-10
1992
1998
2000
2010
2011
Water level at 7am of Mekong at Mukdahan
Gauge height in metres
0
2
4
6
8
10
12
14
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Alarm
Flood
Av80-10
1992
1998
2000
2010
2011


Water level at 7am of Mekong at Paksé
Gauge height in metres
0
2
4
6
8
10
12
14
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Alarm
Flood
Av80-10
1992
1998
2000
2010
2011
Water level at 7am of Mekong at Stung Treng
Gauge height in metres
0
2
4
6
8
10
12
14
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Alarm
Flood
Av80-10
1992
1998
2000
2010
2011
Water level at 7am of Mekong at Kratie
Gauge height in metres
0
2
4
6
8
10
12
14
16
18
20
22
24
26
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Alarm
Flood
Av80-10
1992
1998
2000
2010
2011


Water level at 7am of Mekong at Kompong Cham
Gauge height in metres
0
2
4
6
8
10
12
14
16
18
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Alarm
Flood
Av80-10
1992
1998
2000
2010
2011
Water level at 7am at Phnom Penh Chaktomuk
Gauge height in metres
0
2
4
6
8
10
12
14
16
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Alarm
Flood
Av80-10
1992
1998
2000
2010
2011
Water level at 7am of Tonle Sap at Phnom Penh Port
Gauge height in metres
0
2
4
6
8
10
12
14
16
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Alarm
Flood
Av80-10
1992
1998
2000
2010
2011


Water level at 7am of Bassac at Koh Khel
Gauge height in metres
0
1
2
3
4
5
6
7
8
9
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Alarm
Flood
Av80-10
1992
1998
2000
2010
2011
Water level at 7am of Mekong at Neak Luong
Gauge height in metres
0
1
2
3
4
5
6
7
8
9
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Alarm
Flood
Av80-10
1992
1998
2000
2010
2011
Water level at 7am of Tonle Sap at Prek Kdam
Gauge height in metres
0
2
4
6
8
10
12
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Alarm
Flood
Av80-10
1992
1998
2000
2010
2011


Water level at 7am of Mekong at Tan Chau
Gauge height in metres
6
5
4
3
2
1
0
-1
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Alarm
Flood
Av80-10
1992
1998
2000
2010
2011
Water level at 7am of Bassac at Chau Doc
Gauge height in metres
6
5
4
3
2
1
0
-1
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Alarm
Flood
Av80-10
1992
1998
2000
2010
2011