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 31st October 2010

Prepared by
Regional Flood Management and Mitigation Centre

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Certification of Approval
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Table of Contents

List of Figures

List of Tables

1. Flood season 2010

1.1 Rainfall situation

During the five months flood season 2010, the critical rainfall situation in the Lower Mekong Basin was concentrated in August and October, 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 one of "average years" (see figure 1). It can be observed that the total rainfall in the flood season 2010 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 2009.

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 (see Annex A: 1. Table and Graphs of monthly observed rainfall distribution in flood season 2010):

- The wet season started in early June; the heavy rain mostly occurred in upper reach of the LMB.
- During July - August, the intensive and continued rain covered the entire LMB and appeared more frequently in August.
- From September to October was the time of intensive rainfall in lower reach, especially from Kampong Cham to Tan Chau/Chau Doc.

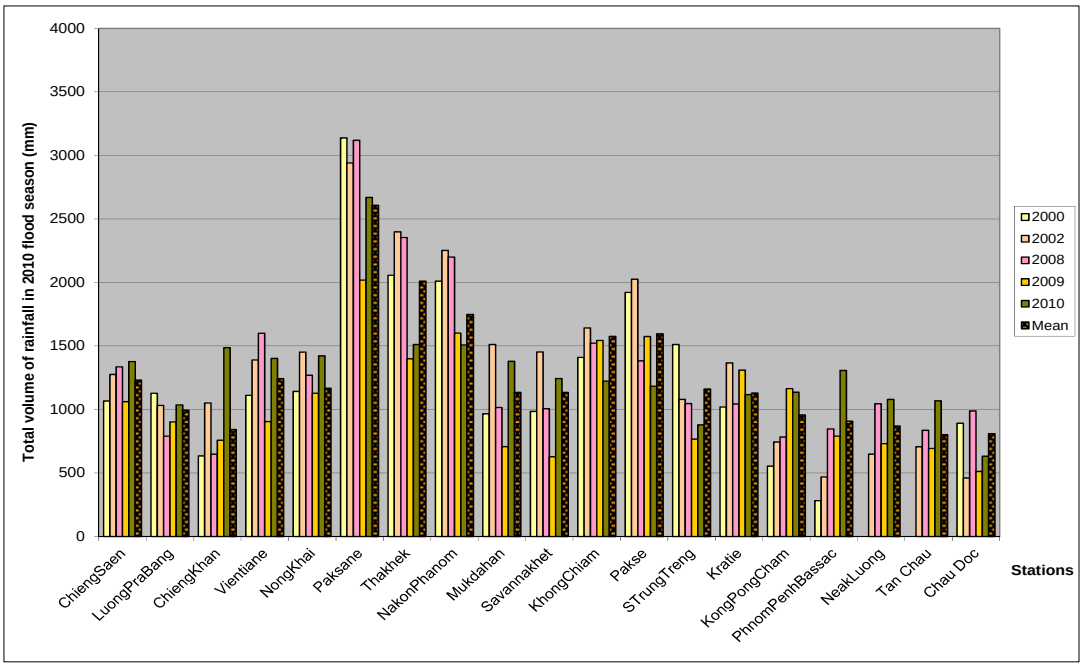


Figure 1-1 Total depth of rainfall in the flood season of the years 2000, 2002, 2008, 2009, 2010 and the long-term average flood seasonal rainfall.

In 2010, 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 from the end of July to the end of August and from the mid September to mid October. As a common phenomenon, there was after mid October a moderate to weak SW monsoon, which prevailed over lower parts of Thailand, Myanmar, Cambodia and Viet Nam.

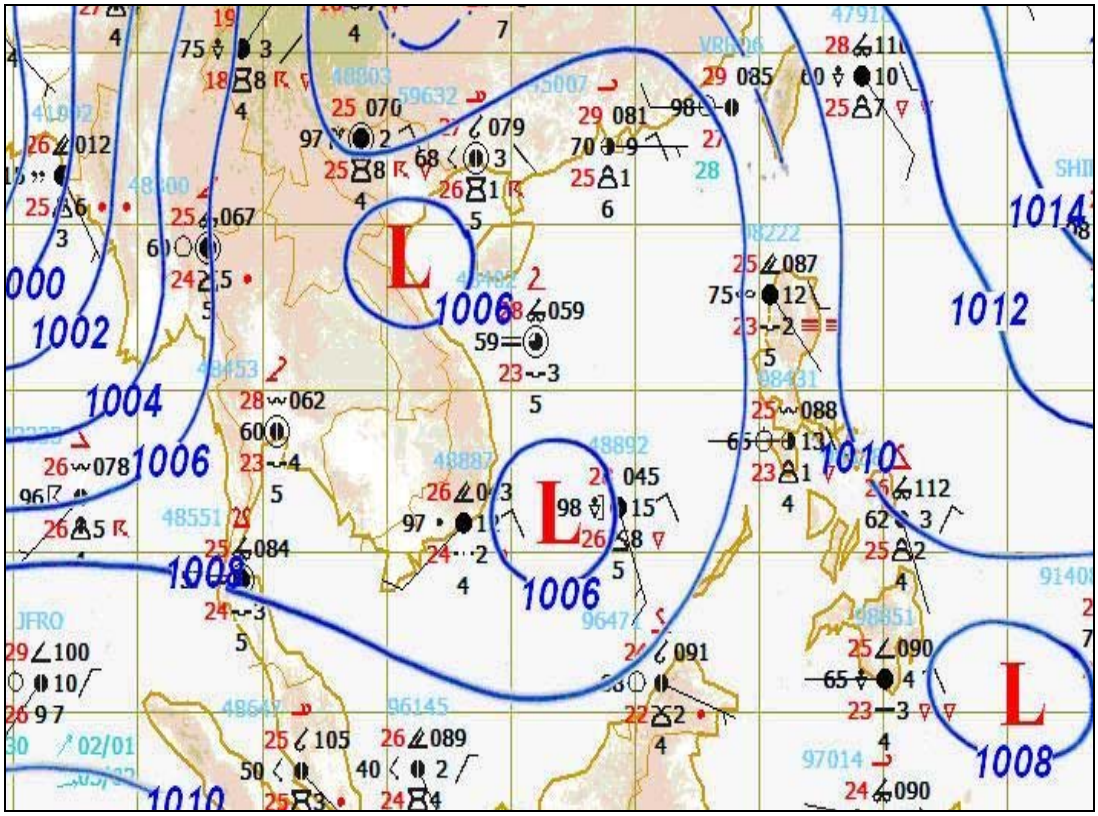


Figure 1-2 Weather map for Southwest Monsoon in the end of July.

- 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. During the flood season 2010, the frequent appearances of TLP and ITCZ during almost the entire flood season were one of the dominating factors which caused continuous heavy rain and rising water along the Mekong River. In August TLP and ITCZ were observed and had significant influence in the upper and middle reaches of the LMB while the influence on the lower reach took place mostly in October. Figure 1-3 shows an illustration of the appearances and influences of TLP and ITCZ to the LMB in August and October.

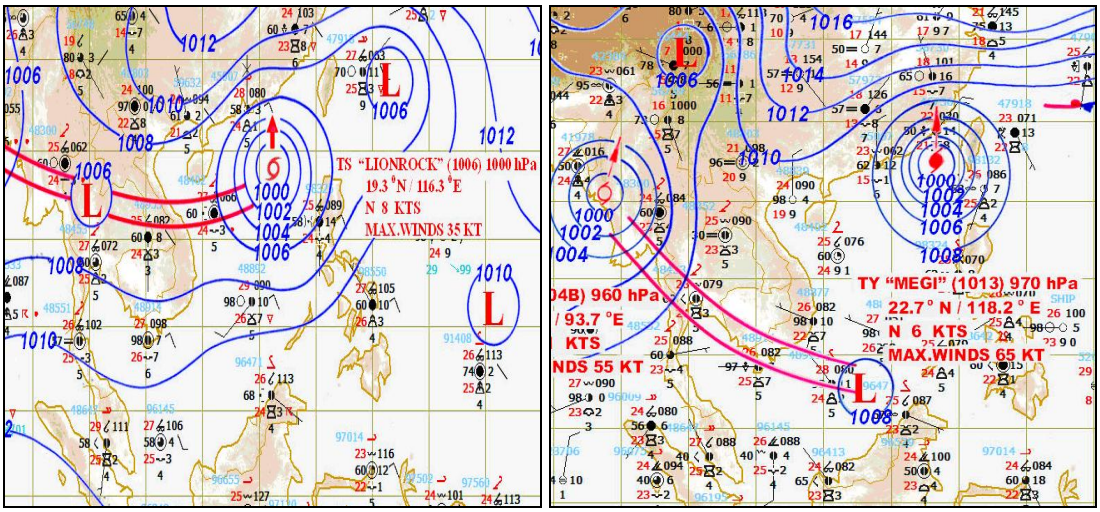


Figure 1-3 Weather maps for TLP and ITCZ in the end of August and in the mid of October.

Tropical depressions (TD), tropical storms (TS) and/or typhoons (TY): there were about 8 tropical depressions, storms and typhoons which came to the East Sea (South China Sea) and affected the Mekong River basin with different levels. Of these, the three storms *CONSON*, *CHANTHU* and *MINDULLE* were the most noticeable.

1. *CONSON* was formed on the 12th July as a tropical depression over the western North Pacific about 1200 km East of Manila. Moving westwards, it intensified that afternoon into a tropical storm and further developed in the evening into a severe tropical storm. *CONSON* crossed during the night of the 13th July the southern part of Luzon. In the afternoon of the 16th July after moving across South China Sea, *CONSON* upgraded into a typhoon. It then made landfall near Sanya, Hainan Island in the evening and skirted the coast of southwest Hainan at night. It landed during the night of the 17th July over Northern Vietnam and subsequently weakened. It was downgraded the next morning into a tropical depression and dissipated inland thereafter.

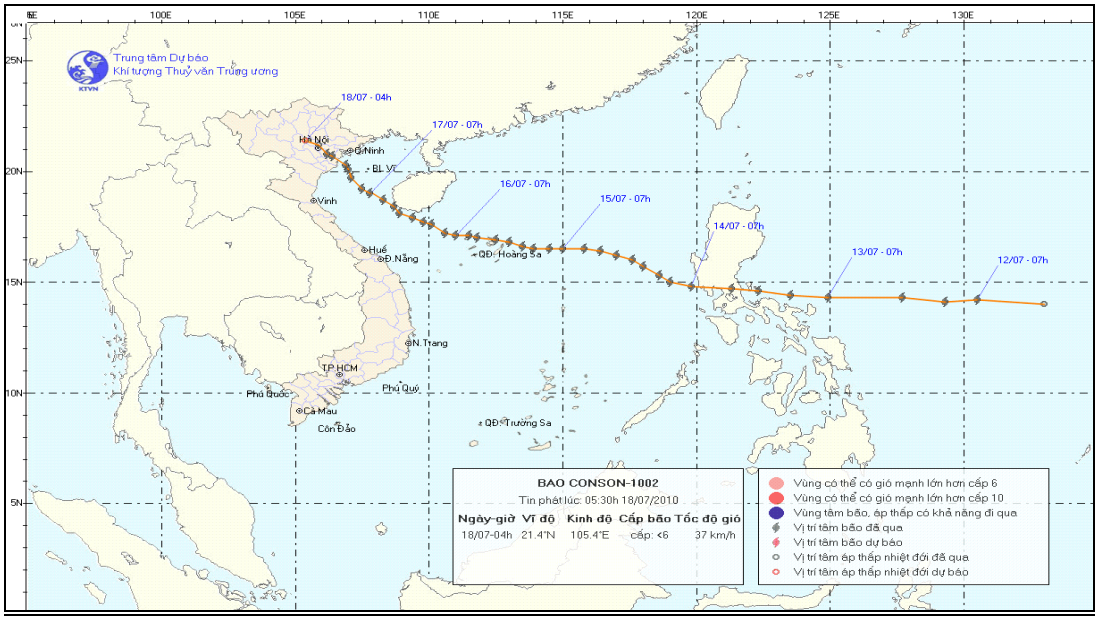


Figure 1-4 CONSON Storm Track.

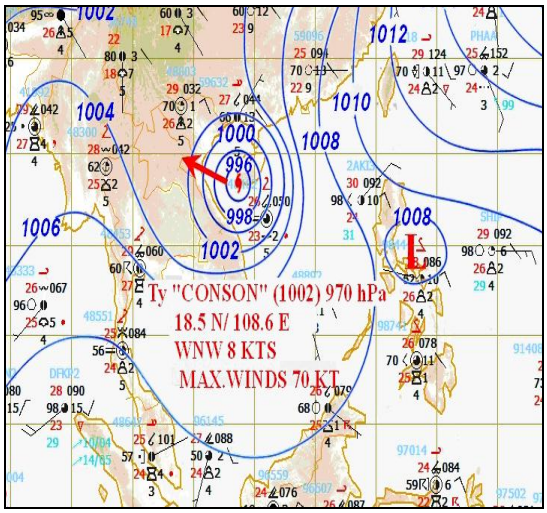


Figure 1-5 Weather map for *CONSON* Typhoon on 17th July 2010, before landing.

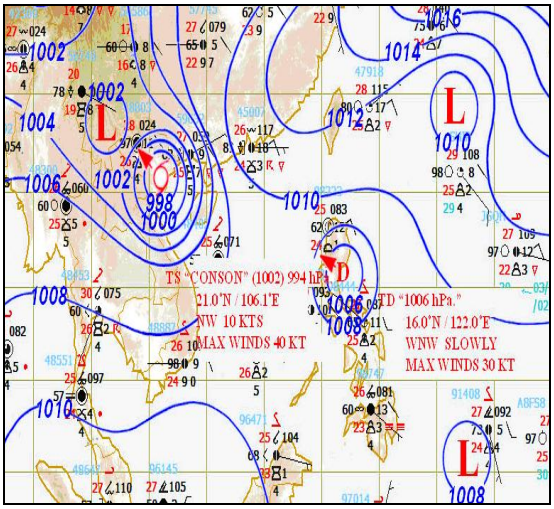


Figure 1-6 Weather map for CONSON Typhoon on 18th July 2010, after landing.

2. Tropical storm *CHANTHU* was formed on 19th July as a tropical depression over the central part of the South China Sea about 900 km south-southeast of Hong Kong. It intensified on 20th July into a tropical storm and on 21st July into a severe tropical storm and on 22nd July it became a typhoon, when travelling through the northern part of the South China Sea.

3. Tropical storm *CHANTHU* made landfall in the afternoon of 22nd July near Zhanjiang of China, and moved across Guangxi Province. *CHANTHU* weakened in the evening of the 23rd July and was downgraded into a tropical depression.

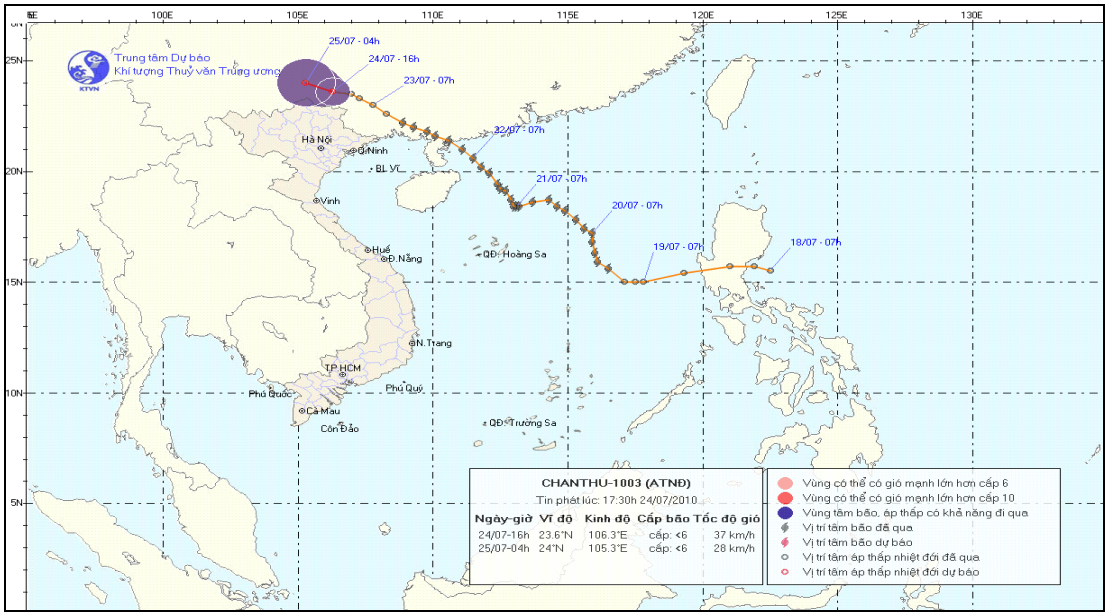


Figure 1-7 CHANTHU Storm Track.

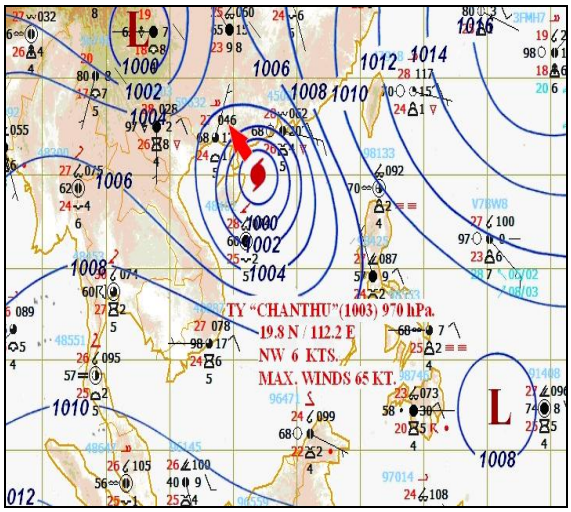


Figure 1-8 Weather map for CHANTHU Typhoon on 22nd July 2010, before landing.

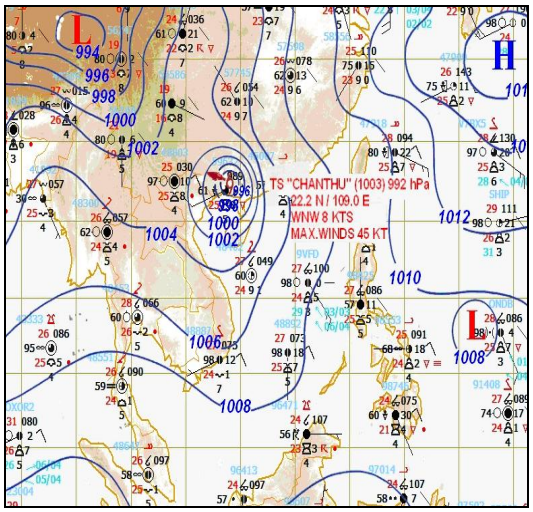


Figure 1-9 Weather map for CHANTHU Typhoon on 23rd July 2010, after landing.

4. Tropical storm *MINDULLE* was formed on 23rd August, 2010 in South China Sea. It landed on 24th August over Nghe An Province, Viet Nam and then moved west-north-westward. The TS was downgraded on 26th August into low pressure after travelling through the northern part of Lao PDR. Figure 1-10 presents the storm track of TS *MINDULLE*. Weather maps of the TS before and after landing over the northern part of Central Viet Nam are showed in Figure 1-11 and 1-12 respectively.

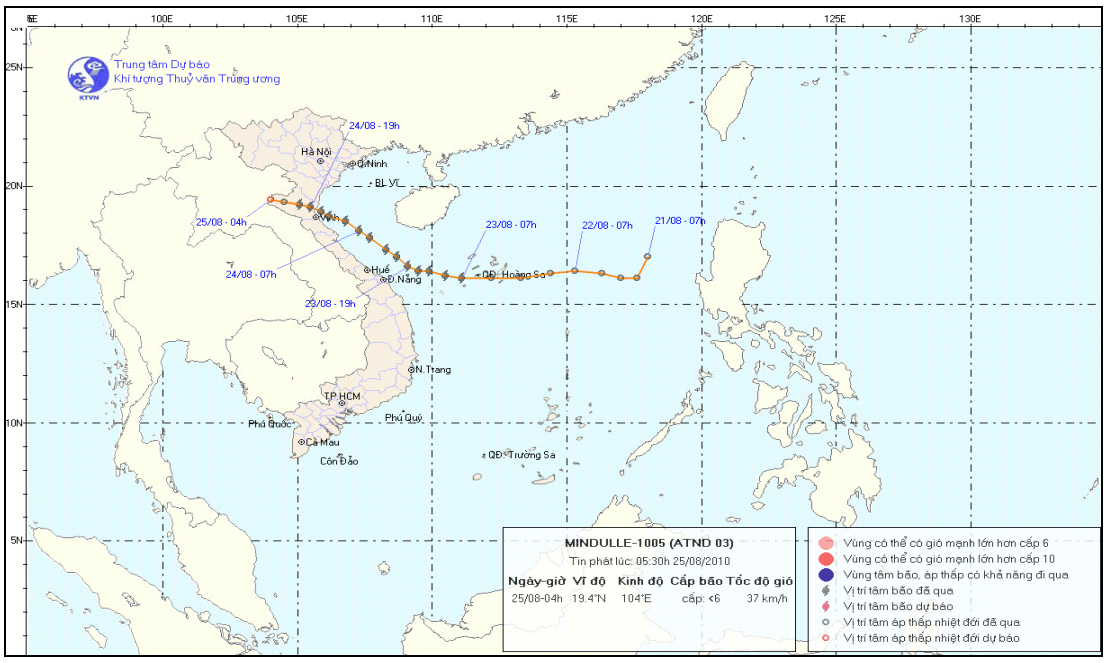


Figure 1-10 MINDULLE Storm Track.

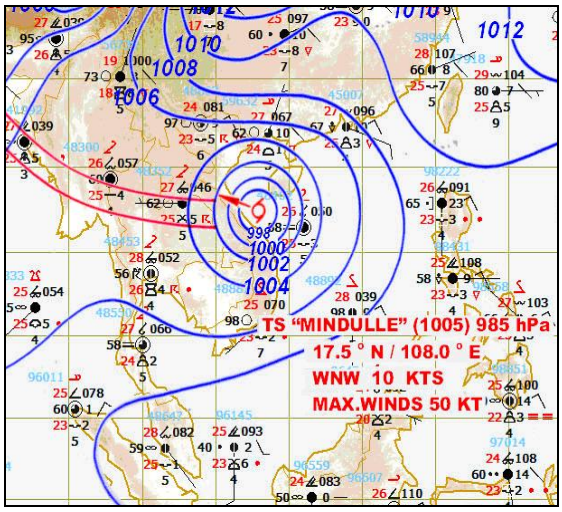


Figure 1-11 Weather map for MINDULLE Tropical Storm on 24th August 2010, before landing.

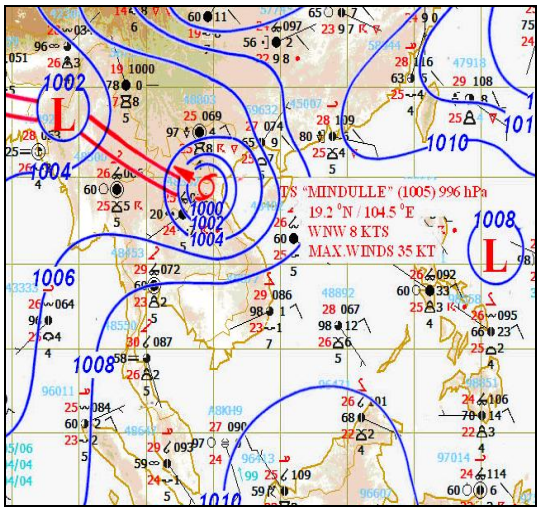


Figure 1-12 Weather map for MINDULLE Tropical Storm on 25th August 2010, after landing.

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 2010 flood season started later than in previous flood years. The first flood event occurred mid July with the appearances and influences of two tropical storms: *CONSON* and *CHANTHU,* and low pressures.

In general terms, the water levels at most stations in the upper and middle reaches of LMB were from June to August below the long-term average, and were from September until the end of flood season around the long-term average, while water levels at stations in lower reach were most of the time during the flood season below the long-term average. Regarding the downstream stations at Tan Chau and Chau Doc, the water levels were below the long-term average. The water levels at those stations were during the period 19th to 30th October above the alarm levels of 3.0m and 2.5m respectively (as defined by the national agencies). Annex C presents Flood Season Water Level Graphs; the hydrographs of 22 main hydrological stations along the Mekong River.

During the first two months of the flood season, water levels at most stations in lower reach from Kampong Cham to Tan Chau/Chau Doc were much lower than the long-term average. These reached the lowest water levels during the recent 30 years, from 1980 until now. In Annex C hydrographs are presented of the Mekong River at mainstream stations during the flood season from 1st June to 31st October in 2010 (orange), in the years of low

water levels i.e. 1992 (dark blue) and 1998 (green), in the years of high water levels i.e. 2000 (red), water levels of the previous year 2009 (light blue), and the long-term average of water levels from 1980 (with exception of Jinghong). Low water levels during the flood season are an inevitable consequence of low water levels along the Mekong River during the dry season 2009-2010.

Table 1 shows the flood peaks of main locations along the Mekong mainstream during the 2010 flood season.

Table 1-1 Flood Peaks of 2010.

ID	Station	Alarm level	Flood Level	Day/Month of Peak	Hmax (m)	Comment
010501	Chiang Saen	11.50	11.80	25-July	6.55	Below alarm level
011201	Luang Prabang	17.50	18.00	30-August	12.72	Below alarm level
011903	Chiang Khan	17.32	17.40	31-August	12.57	Below alarm level
011901	Vientiane	11.50	12.50	31-August	10.18	Below alarm level
012001	Nong Khai	11.40	12.20	01-September	11.25	Below alarm level
012703	Paksane	13.50	14.50	02-September	12.65	Below alarm level
013101	Nakhon Phanom	12.60	12.70	01-September	10.75	Below alarm level
013102	Thakhek	13.00	14.00	02-September	11.78	Below alarm level
013402	Mukdahan	12.50	12.60	02-September	10.81	Below alarm level
013401	Savanakhet	12.00	13.00	02-September	9.61	Below alarm level
013801	Khong Chiam	16.00	16.20	04-September	12.90	Below alarm level
013901	Pakse	11.00	12.00	04-September	10.74	Below alarm level
014501	Stung Treng	10.70	12.00	05-September	9.07	Below alarm level
014901	Kratie	22.00	23.00	06-September	19.56	Below alarm level
019803	Kampong Cham	15.20	16.20	06-September	13.44	Below alarm level
020101	Phnom Penh Port	10.50	12.00	22-October	7.61	Below alarm level
033401	Phnom Penh Bassac	9.50	11.00	23-October	8.49	Below alarm level
033402	Koh Khel	7.40	7.90	22-October	6.89	Below alarm level
019806	Neak Luong	7.50	8.00	23-October	5.93	Below alarm level
020102	Prek Dam	9.50	10.00	23-October	7.58	Below alarm level
019803	Tan Chau	3.00	4.20	23-October	3.15	Above alarm level
039801	Chau Doc	2.50	3.50	24-October	2.69	Above alarm 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 2010 flood season, water levels at stations Chiang Sean and Luang Prabang were most of the time below the long-term average, except for some periods in September and October, while water levels at Chiang Khan, Vientiane/Nong Khai were below the long-term average from June to August and around the long-term average during September and October. There were two flood events with amplitudes over 2 meters which occurred at these stations (see more detail in Annex A, Part 3, Table A2).

During the second half of July, moderate to heavy rainfall occurred in this region. Some recorded rainfalls were over 200mm, such as at Chiang Sean (246mm), at Pak Beng

(214mm), at Luang Prabang (219mm), at Muong Ngoy (265mm) and at Ban Pak Kanhoung (271mm). Therefore, the water level rising occurred at all stations from Chiang Saen to Vientiane/ Nong Khai; water levels at Chiang Sean reached the 2010 flood peak during this period (See Table 1: Flood Peaks of 2010). It should be noted that flood amplitudes for the stations Luang Prabang, Chiang Khan, Vientiane and Nong Khai were over 4m (See Annex A, Part 3, Table A2).

Continuous occurrences of low pressures as well as ITCZ across upper Lao PDR, Northern Thailand, Viet Nam and Myanmar from the end of August to the midst of September resulted in intensive rainfalls in Northern Thailand, upper parts of Lao PDR, Viet Nam and the middle of the LMB. The amount of rainfall in this region was recorded from the 9th to the 16th July at Chiang Saen (208mm); at Chiang Khan (191mm); at Ban Pak Kahoung (318mm). A flood event occurred at those stations with flood amplitudes over 2m (See Annex A, Part 3, Table A2).

For stations from Paksane to Pakse

From June to the end of August water levels of most stations were below the long-term average and from September to the end of October somewhat around the long-term average.

During the second half of July, due to significant influences of two tropical storms *CONSON* and *CHANTHU* together with the frequent occurrences of low pressures and intensive SW monsoon activities, intensive rainfall occurred in this region particularly from Paksane to Nakon Phanom/Thakhet with recorded rainfalls from 15 to 25 July at Paksane (423mm); Thakhet (282mm); Nakon Phanom (254mm); Muong Mai (481mm); Muong Kao (525mm); Ban Phone Si (289mm), and at Mahaxai (330mm). Water levels for stations from Paksane to Pakse rose quickly during the mid of July and the beginning of August with flood amplitudes from 4 to 5m (See Annex A, Part 3, Table A3).

Otherwise, intensive rainfalls and flood on left bank tributaries of Lao PDR represented the main contribution to flood on the Mekong mainstream downstream of Paksane station, such as at Nam Sane, Nam Nhiep, Nam Ca Dinh and Se Bang Fai rivers; this is illustrated through hydrograph and rain chart at respective stations Muong Kao, Muong Mai, Ban Phone Si and Mahaxai (Figure 1-13).

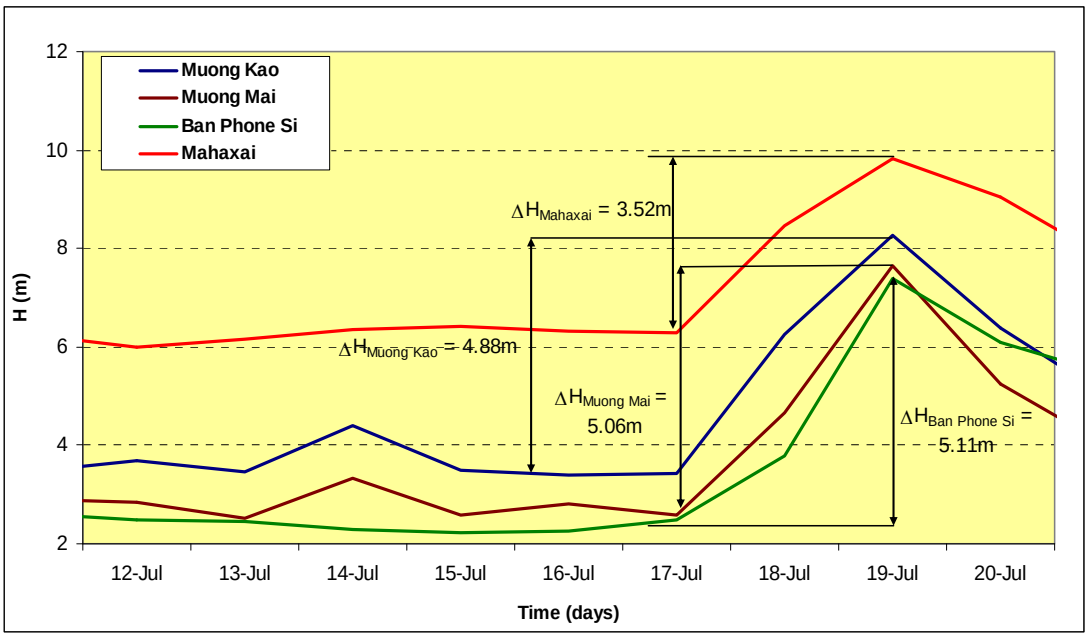


Figure 1-13 Flood on tributaries: Nam Sane at Muong Kao, Nam Nhiep at Muong Mai, Nam Ca Dinh at Ban Pho Si and Se Bang Fai at Mahaxai.

From mid August to mid September, as a result of frequent appearances of Inter Tropical Convergence Zone (ITCZ), low pressures and tropical storm *MINDULLE*, continuous heavy rainfall and water level rising occurred in this region. Water levels at stations between Khong Chiam and Pakse rose quickly from the 22nd August to the 4th September. The flood amplitudes on the main stream were 3.28m at Khong Chiam and 2.79m at Pakse. The flood water from tributary as Se Done River contributed noticeably to flood on the mainstream (See Figure 1-14).

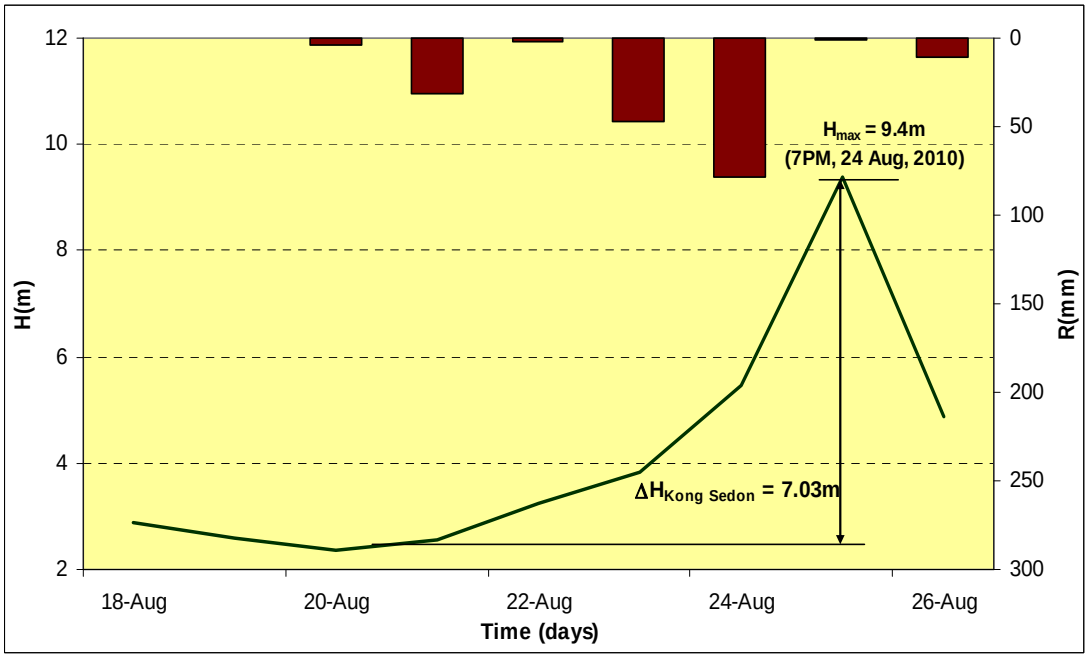


Figure 1-14 Flood on tributary Se Done River at Khong Sedon.

A number of flood events with amplitudes over 2m are presented in Annex A, Table A3.

For stations from Stung Treng to Kampong Cham

During the flood season 2010, almost all stations recorded water levels that most of the time were below the long-term average, with exception of the second half of October, when water levels at those stations were somewhat around the long-term average.

From mid July to the beginning of August, as a result of the flood waters from upper and middle reaches of LMB, water levels at those stations rose with average intensities of 0.2m/day at Strung Treng; 0.35m/day at Kratie; 0.29m/day at Kampong Cham and the flood amplitudes were 2.90m; 5.43m and 4.64m respectively.

During the first week of the October, by the influence of ITCZ and strong SW monsoon activities as well as flood waters from upstream stations and contribution from the tributaries Se Kong and Sre Pok, water levels at stations Kratie increased quickly with a flood amplitude over 2m and average intensity of 0.46m/day. Figure 15 presents flood on tributaries Se Kong and Sre Pok rivers.

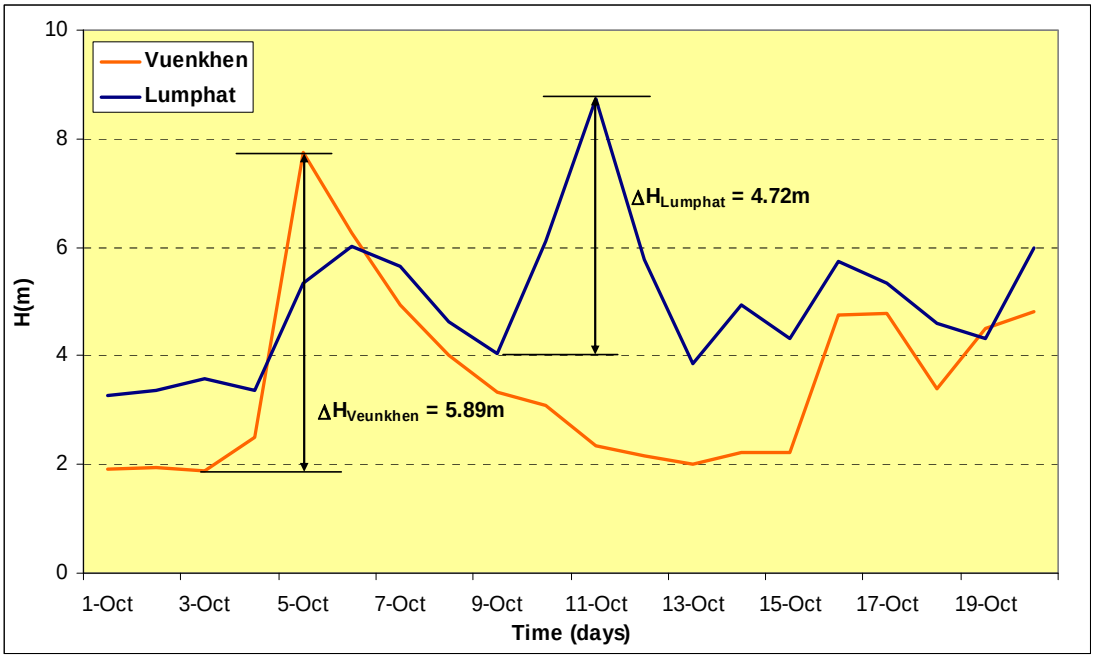


Figure 1-15 Flood on tributaries: Se Kong at Veun Khen, Sre Pok at Lumphat.

For stations from Phnom Penh to Koh Khel/Neak Luong

During the flood season 2010, all stations recorded water levels that remained below the long-term average.

During the months of June and July water levels at those stations were not only lower than the long-term average, but also lower than water levels in 1992 and 1998, which are years of low water levels within 30 year observation (See Annex C: Flood Season Water Level Graphs).

From the end of July to mid September, as a result of flood waters from the upper and middle reaches of the LMB, water levels of stations at downstream rose steadily with average intensity of 0.15 - 0.2m/day.

By the influences of flood waters from middle reach and the appearances of weather patterns caused heavy rain such as ITCZ, active monsoon troughs, water levels of those stations increased from the 7th to the 24th October and reached the 2010 flood peak during 22nd to 23rd October. All stations recorded levels that remained below the alarm levels.

Tan Chau and Chau Doc

During the flood season 2010 stations recorded water levels that remained below the long-term average, even though water levels at these stations are affected by tidal regime. This is 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 the 19th to the 30th October water levels at these stations were recorded that were above the respective alarm levels.

2. Flood Forecast in 2010

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 input for the Mekong Flood Forecasting System (FFS). The performance indicators are shown in the tables and graphs of the forecast achievement, Annex B.

The results of the evaluation show that the data from LAs normally arrived before 9 AM (See 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 for more details Table B3 and graphs in Accuracy and 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 2010 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 ITCZ during low pressures.

Performance indicators of bulletin delivery (See Annex B, Table B3 and Figure B4) show 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 the first two months 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 LAs usually occurred during the early 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.

During the 2010 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 there were during the 2010 flood season 6 stations without forecasts.

2.2 Accuracy and limitations in forecasting

During the 2010 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, Table B1). The evaluation of forecast achievement is presented in Table B2 by indicating the % of days “successful” against a respective benchmark. In general, the forecast errors for all lead time

at almost all stations along the Mekong River did not show large differences, except for Neak Luong, Tan Chau and Chau Doc, where the accuracy for 3-5 day forecasts lead time was less than expected, if following the benchmarks of success. Based on the weekly flood situation reports, the large errors on 3-5 day forecasts at three those stations mainly occur during the two first months of flood season.

Through forecast performances at other stations in the lower reach of Mekong River, it can be seen that the use of a regression model is quite promising. Stations downstream of Phnom Penh Bassac show average errors for 1-day and 2-day forecasts smaller than 0.03m and 0.10m respectively, while average errors for 5-day forecasts are smaller than 0.25m and even smaller than 0.2m at stations downstream from Koh Khel.

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 forecast performances by mean absolute error in using original forecast results from both URBS and Regression, and URBS and ISIS are presented in Figures 2-1 and 2-2 respectively. It is easily realized that the average error for 3-day to 5-day forecasts at Tan Chau and Chau Doc were over 0.2m. It didn't achieve the benchmarks of success at those two stations, as is shown in Table 2, Annex B.

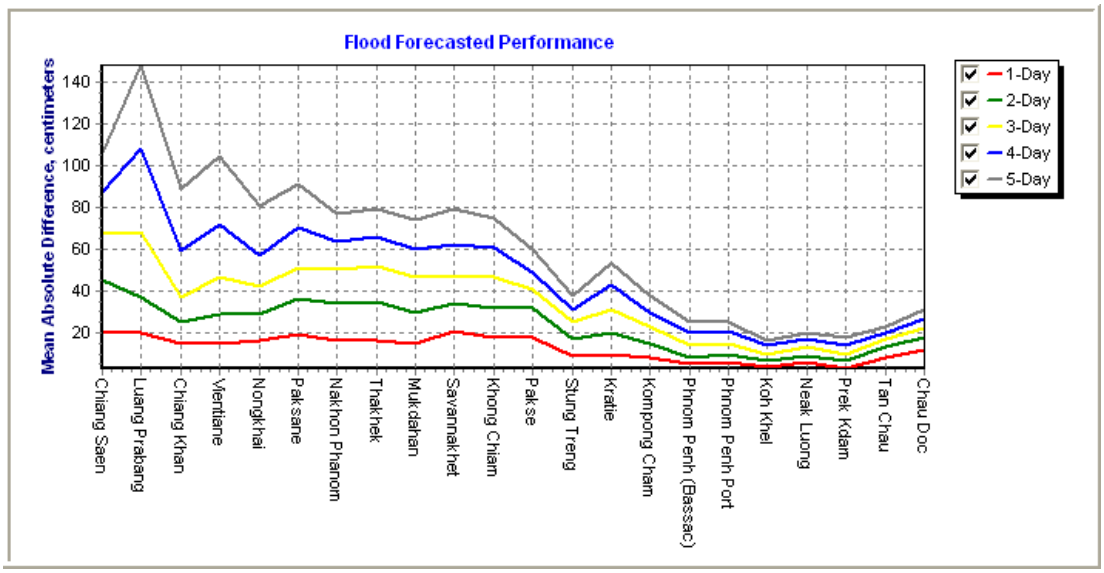


Figure 2-1 Forecast performance based on original results by URBS and Regression.

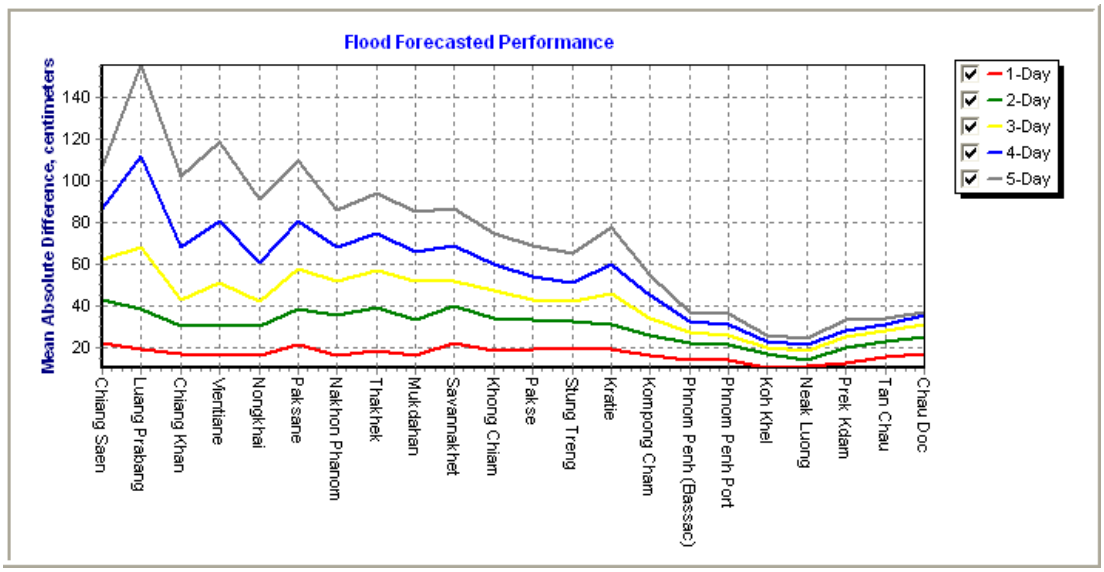


Figure 2-2 Forecast performance based on original results by URBS and ISIS.

2. *The high variability of satellite rainfall estimate (SRE) and Numerical Weather Prediction (MWP):* SRE rainfall is used, as the NWP model provided a 7-day GFS rainfall forecast. Throughout the 2010 flood season, the output for the URBS model, as can be seen from the results of daily forecast, is really sensitive to both SRE and NWP. SRE can be either under- or overestimated if compared with the observed rainfall. NWP can 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 occur. Based on weekly investigation of the forecasting team, the original forecast results calculated from the model caused relatively large errors compared with observations. This is a practical difficulty for forecaster-in-charge in forecast adjustment.
3. *The quality and accuracy of forecast is also determined by the quality of forecast adjustment, which is usually performed by forecaster-in-charge so their knowledge, expertise and experience is 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 2010 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. The flood forecasting team of the RFMMC has been testing the tool by using the corrected SRE as input of flood forecast system. Through initial testing evaluation, this exercise provided somewhat better result in forecasting for stations in the upper part of LMB. The bias correction tool will be ready for use in next flood season 2011.

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 2010-2011.
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 2011, 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 2010 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: Jinghong and Manan of China. Analyse the impact of water release from dams to the water levels at Jinghong 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 Sre Pok River at Lumphat, 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 2010 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 5-day forecasts at hydrological stations affected by tidal from Neak Luong to Tan Chau/Chau Doc are quite high, based on benchmarks of success (see Annex A, Part 3, Table A2). Therefore, additional reference of tidal regime forecast documentation in 2011 provided by National Centre for Hydro-meteorology of Viet Nam can be referred to 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 2010;
- Graphs for monthly rainfall in flood season from 2000 to 2010 and long-term average along the Mekong River;
- Tables of flood event characteristics along the Mekong River during flood season 2010.

Annex B

- Graph for accuracy;
- 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 2010

Table A 1 Monthly observed rainfall in flood season 2010.

Unit in mn

2010	Jinghong (*)	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
June	58.0	243.8	154.4	97.2	262.5	201.4	573.5	175.1	167.5	197.9	215.6	211.6	164.7	99.2	167.4	316.2	172.1	No data	191.1	98.2	176.7	174.7	103.0
July	360.0	311.4	278.4	289.5	198.2	213.5	619.2	411.2	386.3	113.5	158.0	229.6	182.8	173.4	185.2	159.3	246.3		109.1	163.9	73.1	113.2	125.9
Aug.	182.8	449.7	401.6	455.0	669.7	659.0	736.8	513.0	524.0	641.9	507.9	380.2	458.2	233.4	323.9	236.5	278.7		135.5	230.1	173.7	178.0	88.6
Sep.	124.0	293.1	145.6	430.7	199.9	302.1	613.9	219.5	230.2	209.8	166.7	222.6	209.7	121.8	214.0	137.5	165.6		183.9	229.0	122.5	269.8	150.6
Oct.	23.0	78.5	55.0	213.9	71.6	45.4	125.7	189.7	202.9	215.7	194.6	179.6	167.4	250.4	230.2	288.5	443.8		552.5	357.8	425.6	332.8	163.5
Season	**747.8**	**1376.5**	**1035.0**	**1486.3**	**1401.9**	**1421.4**	**2669.1**	**1508.5**	**1510.9**	**1378.8**	**1242.8**	**1223.6**	**1182.8**	**878.2**	**1120.7**	**1138.0**	**1306.5**		**1172.1**	**1079.0**	**971.6**	**1068.5**	**631.6**

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

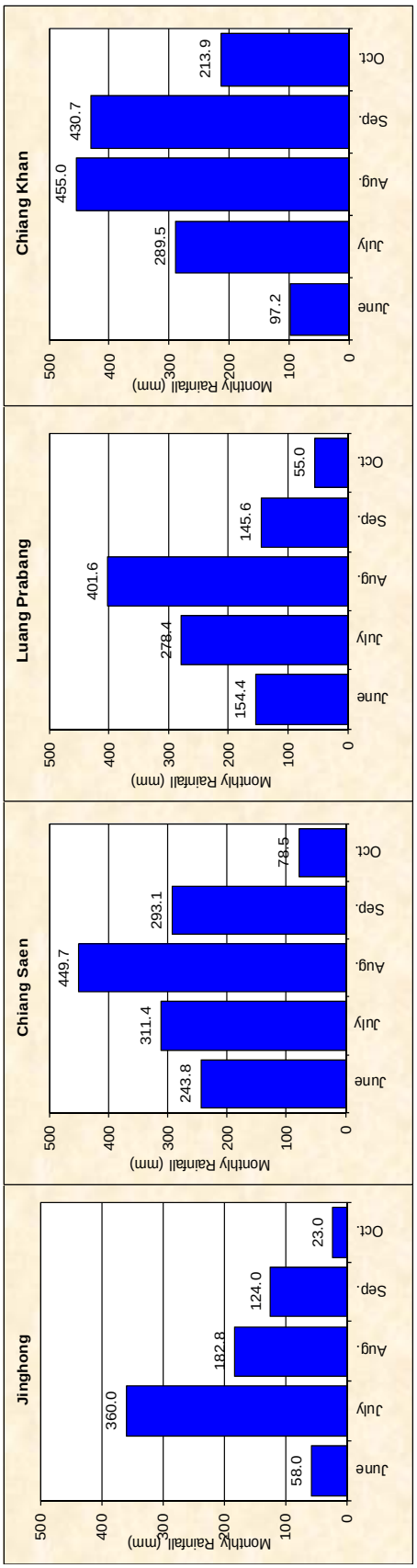


Figure A 1 Monthly rainfall distribution for Jinghong, Chiang Saen, Luang Prabang and Chiang Khan.

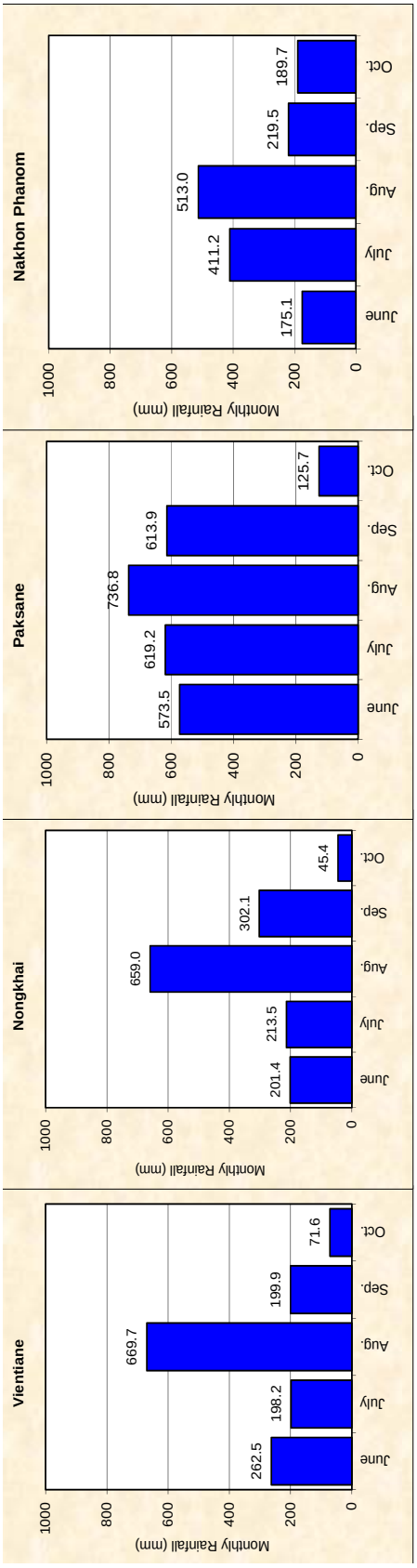


Figure A 2 Monthly rainfall distribution for Chiang Khan, Vientiane, Nongkhai, Paksane and Nakon Phanom.

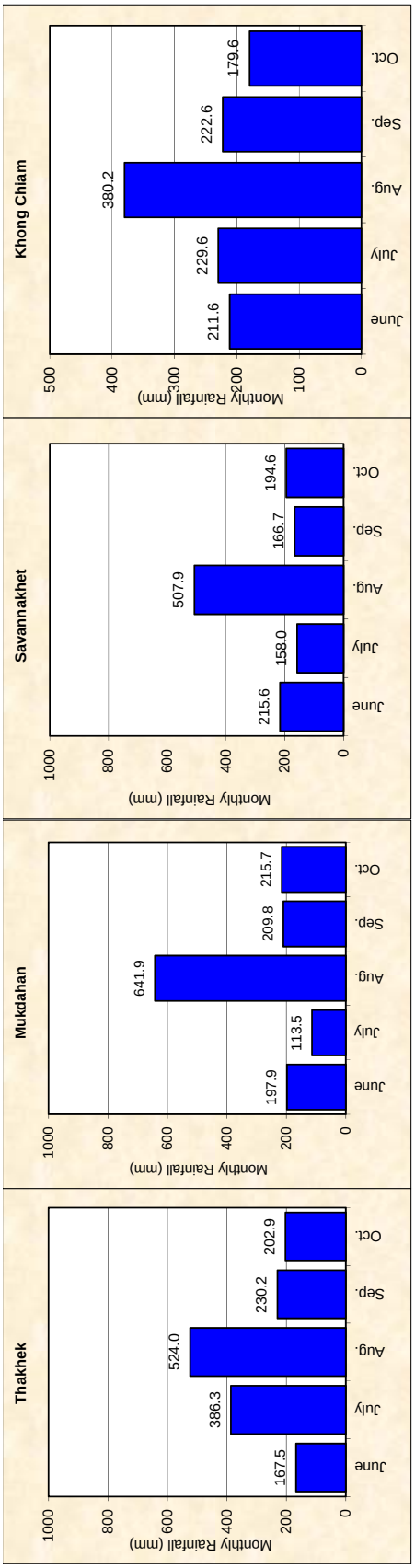


Figure A 3 Monthly rainfall distribution for Thakhek, Mukdahan, Savannakhet and Khong Chiam.

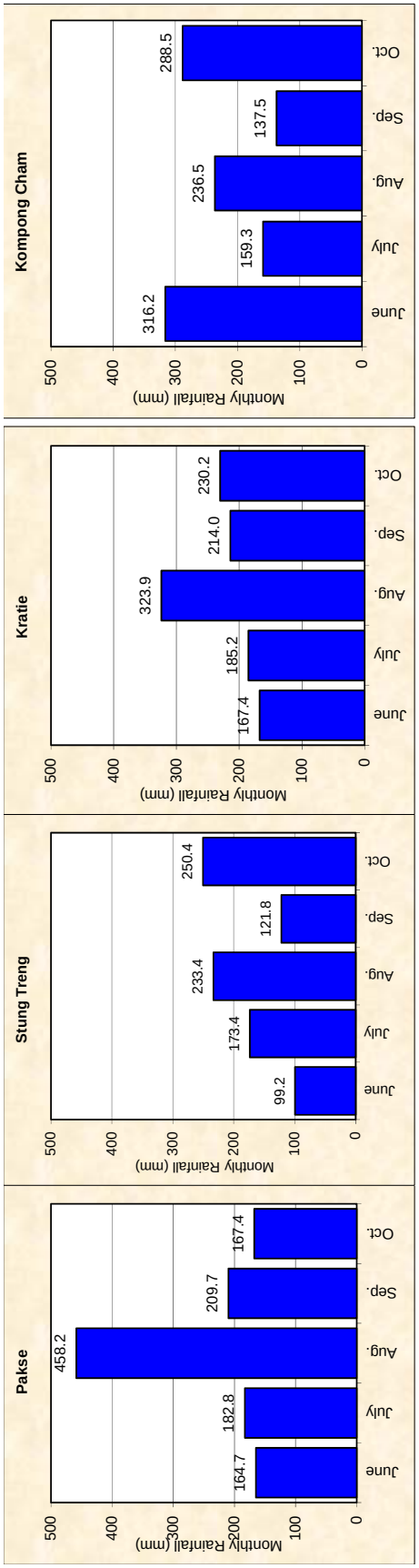


Figure A 4 Monthly rainfall distribution for, Pakse, Stung Treng, Kratie and Kampong Chiam.

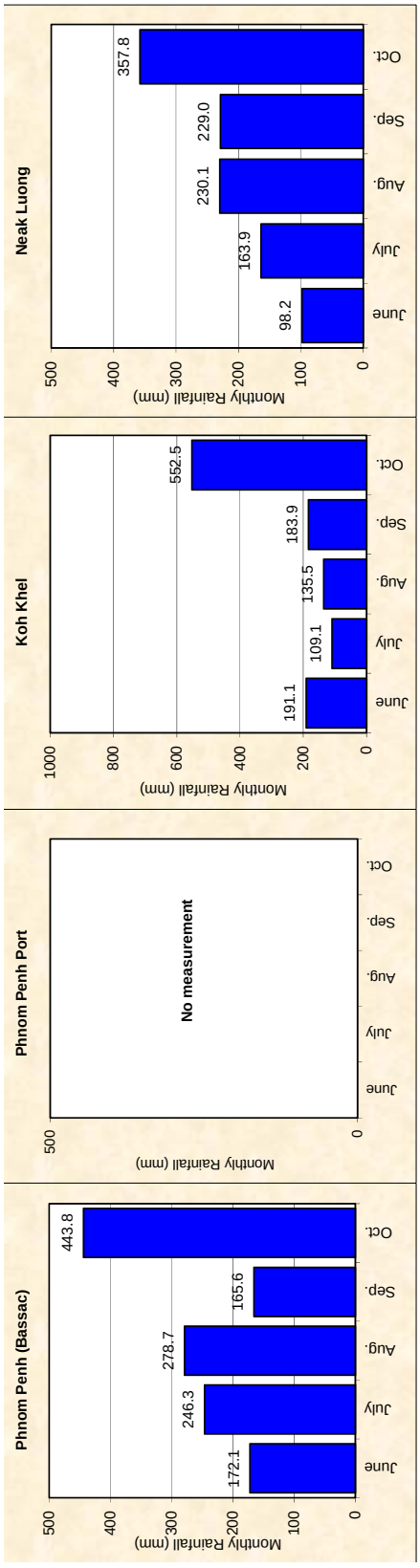


Figure A 5 Monthly rainfall distribution for Phnom Penh (Bassac and Port), Koh Khel and Neak Luong.

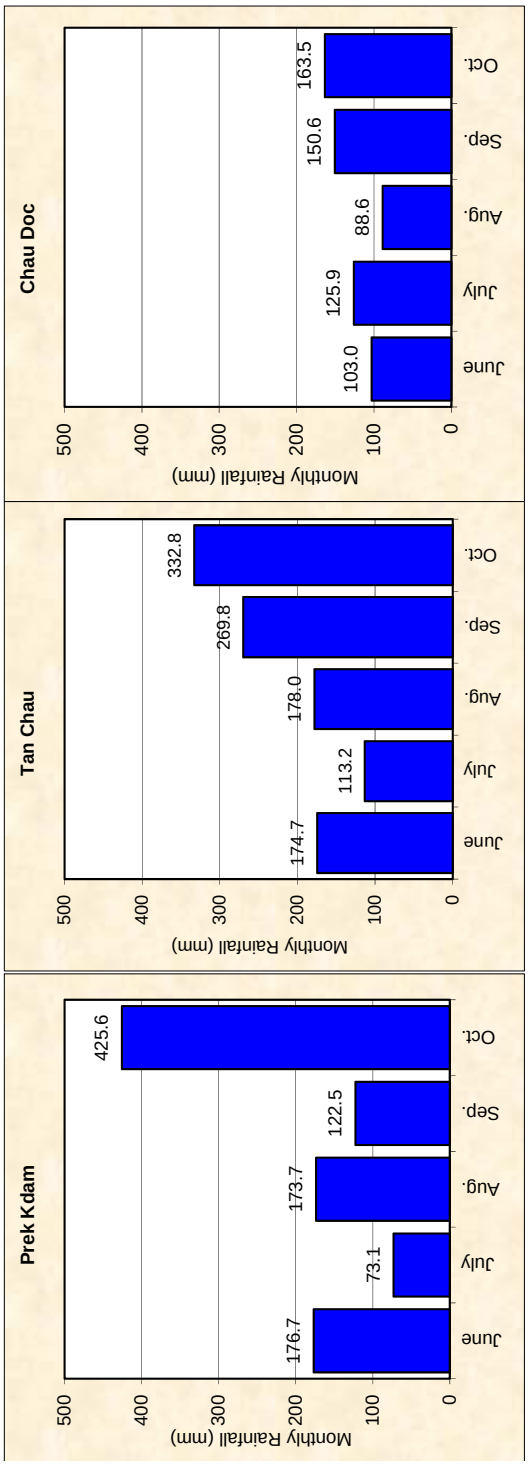


Figure A 6 Monthly rainfall distribution for Prek Kdam, Tan Chau and Chau Doc.

2. Graphs for monthly rainfall in flood season from 2000 to 2010 and long-term average along the Mekong River

Figure A 7 Monthly rainfall in June for main stations along the Mekong River.

Figure A 7 (cont.)

Figure A 8 Monthly rainfall in July for main stations along the Mekong River.

Figure A 8 (cont.)

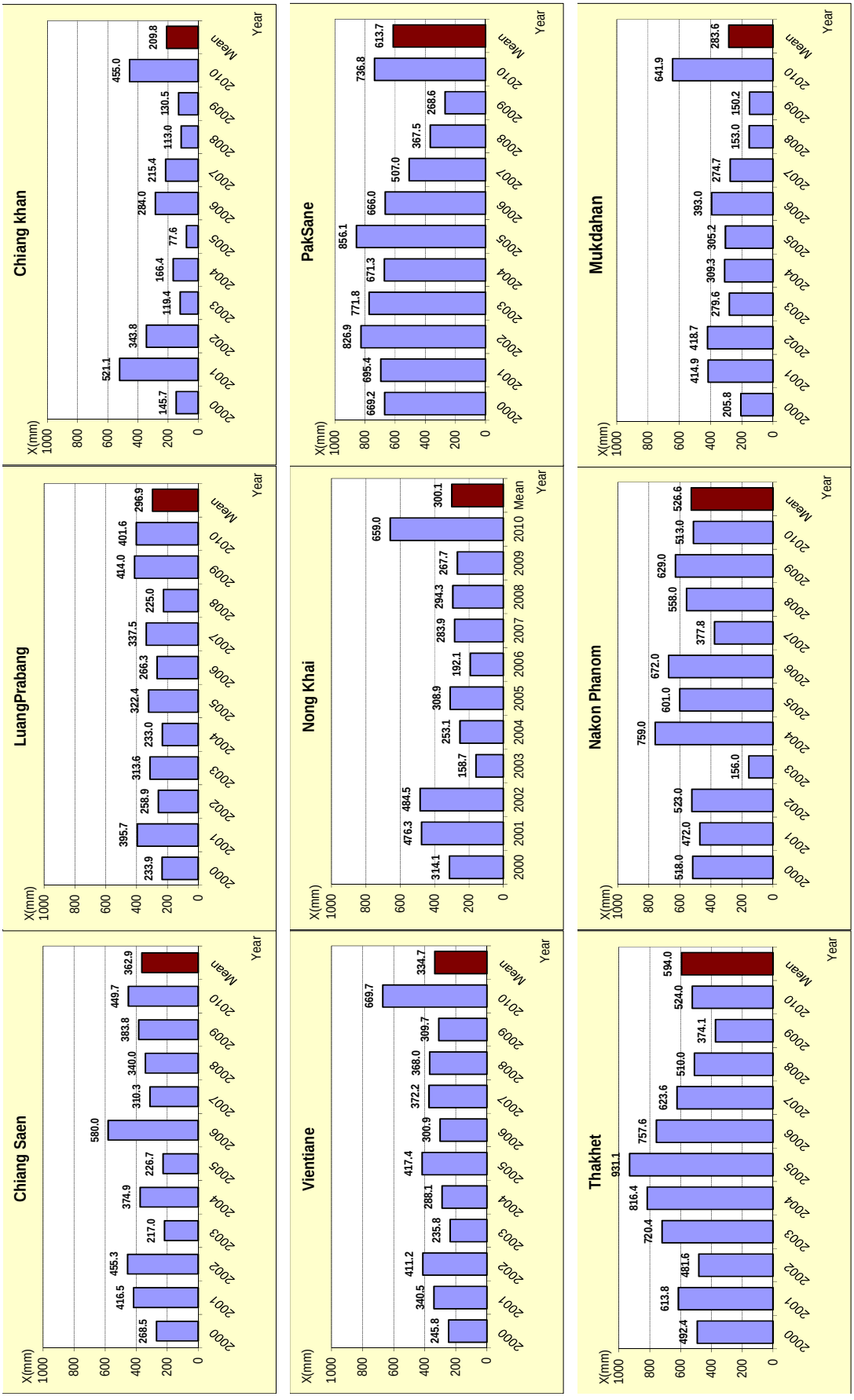


Figure A 9 Monthly rainfall in August for main stations along the Mekong River.

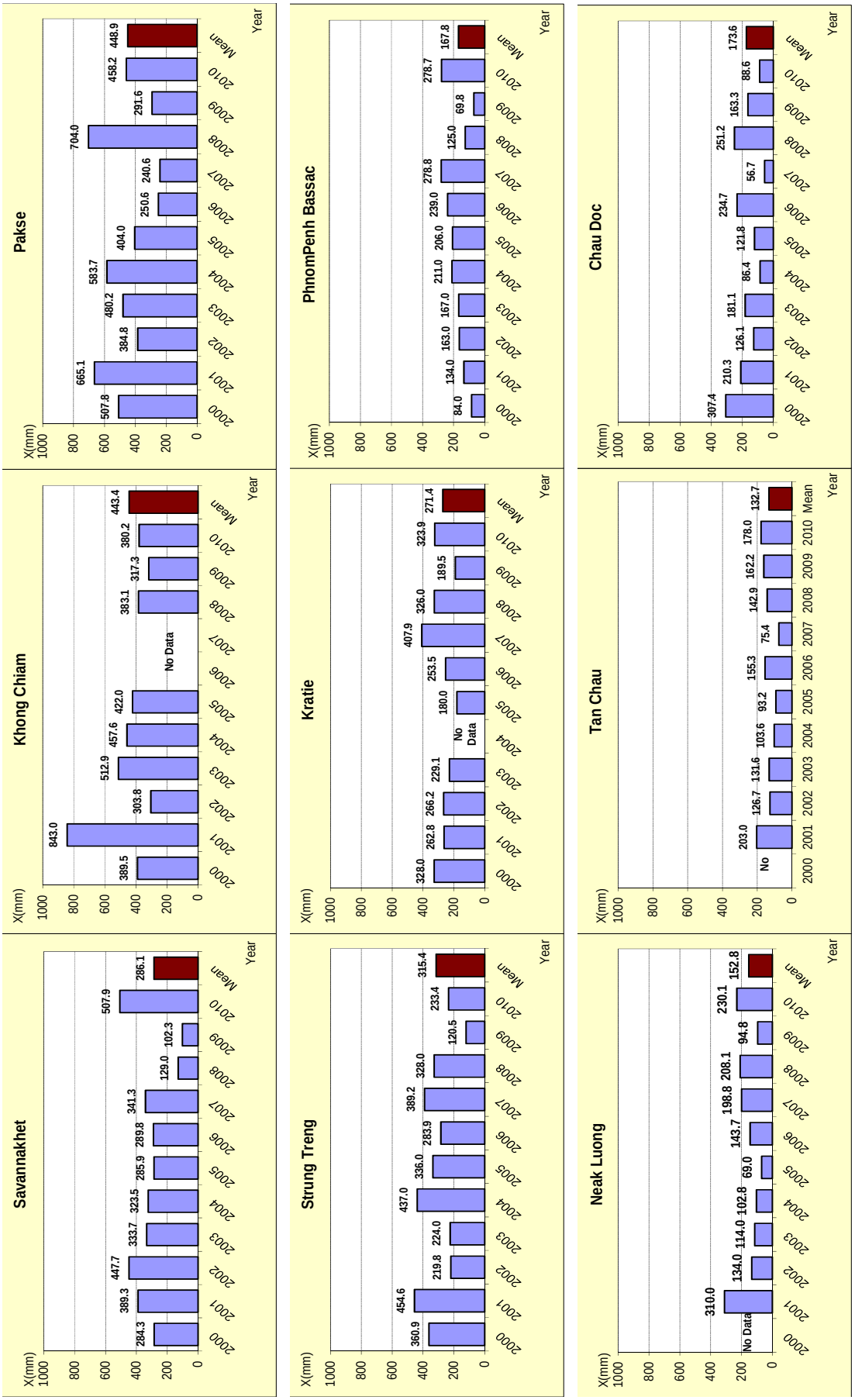


Figure A 9 (cont.)

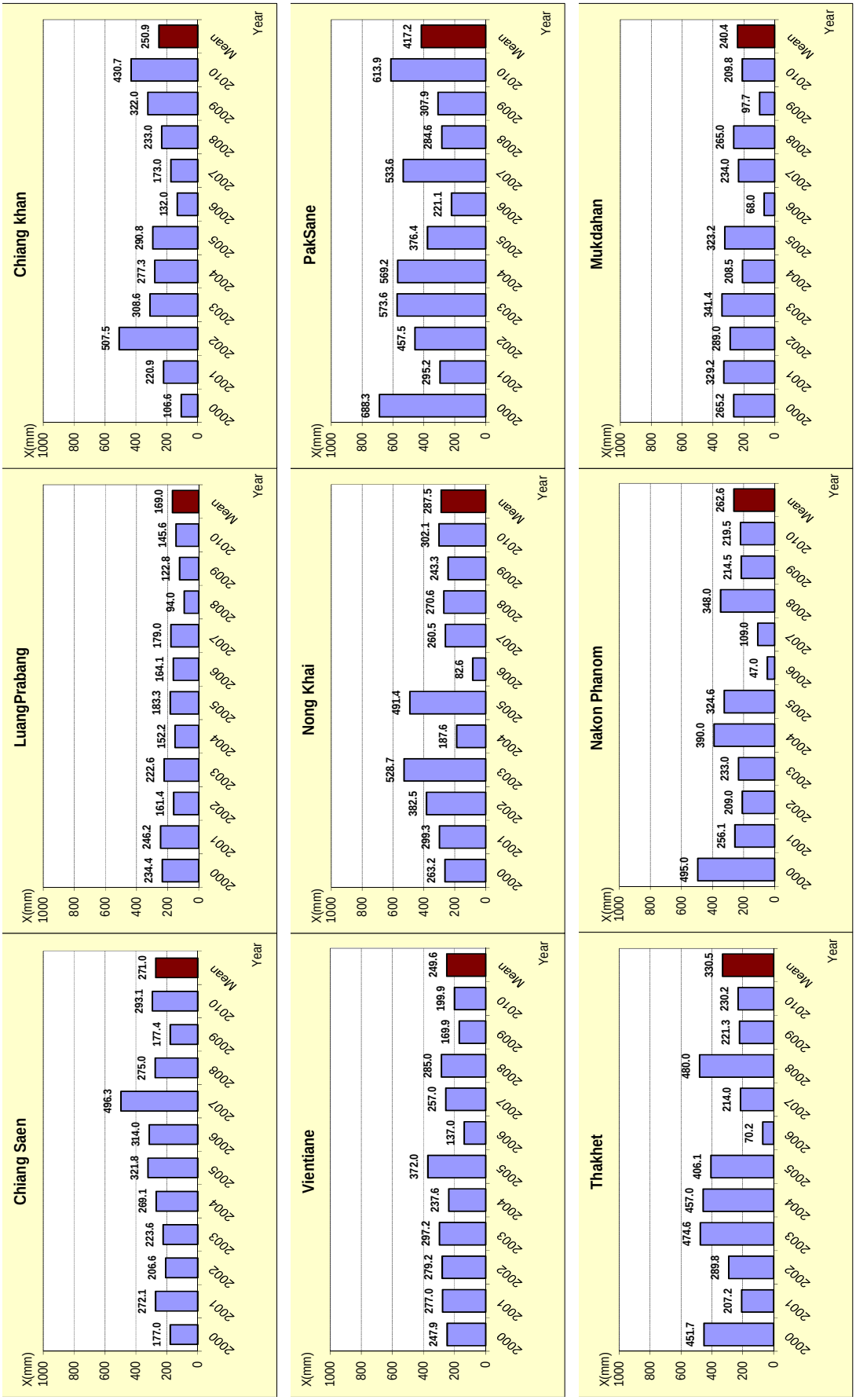


Figure A 10 Monthly rainfall in September for main stations along the Mekong River.

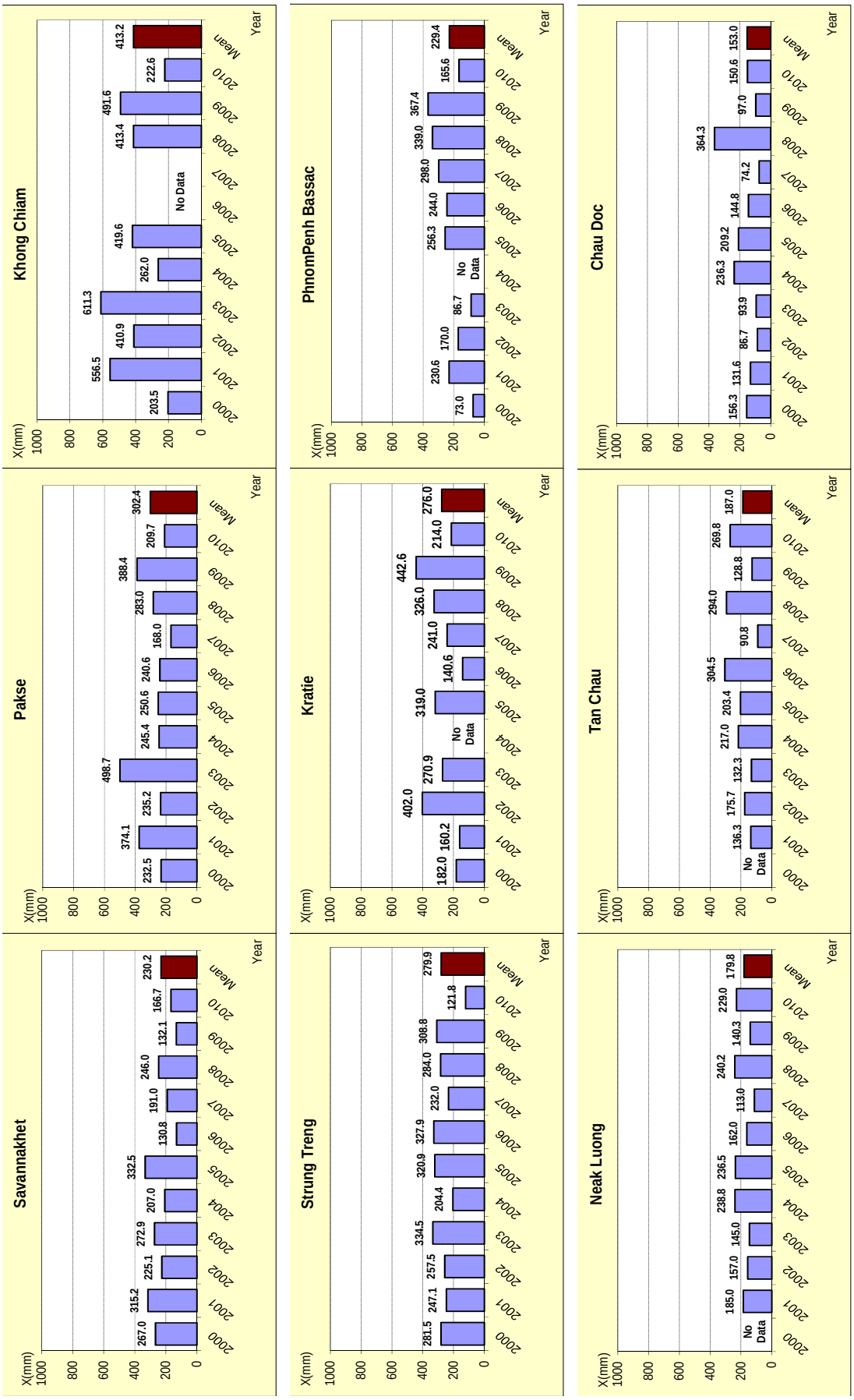


Figure A 10 (cont.)

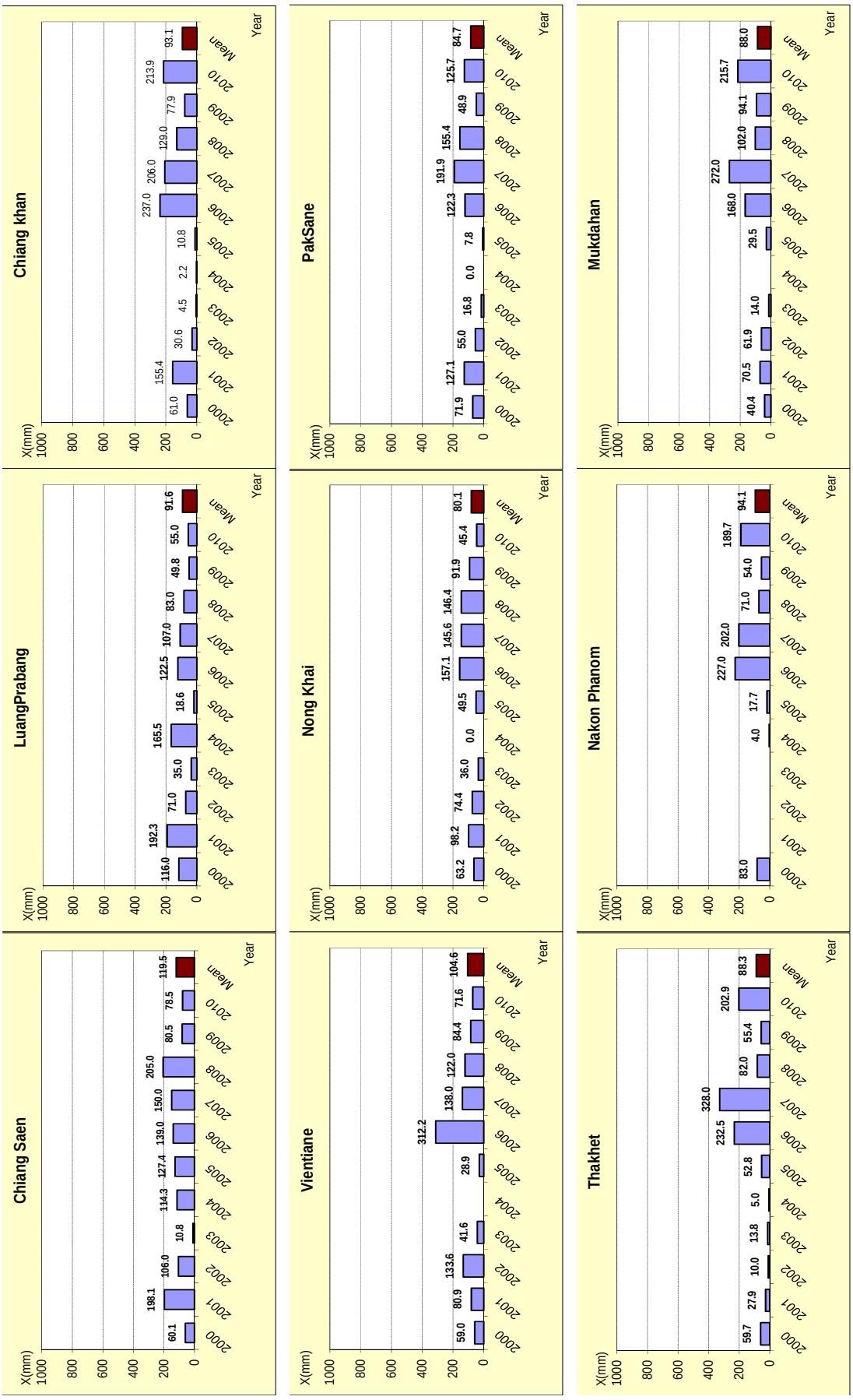


Figure A 11 Monthly rainfall in October for main stations along the Mekong River.

Figure A 11 (cont.)

3. Tables of flood event characteristics along the Mekong River during flood season 2010

Table A 2 The characteristics of flood events for station from Chiang Saen to Vientiane/Nong Khai.

ID	Station	Beginning of flood event		Peak of flood event		Remaining Time	Flood Amplitude	Intensity of Flood Rising			Comment
		Date	H_B (m)	Date	H_P (m)	ΔT (day)	ΔH (m)	Appearence time of I_{max}(day)	I_{max} (m/day)	$I_{Average}$ (m/day)	
010501	Chiang Saen	14-Jul	3.58	25-Jul	6.55	11	2.97	24 Jul - 25 Jul	1.34	0.27	ITCZ + LP
		6-Sep	4.19	17-Sep	6.38	11	2.19	14 Sep - 15 Sep	0.55	0.20	
011201	Luang Prabang	14-Jul	5.94	27-Jul	11.44	13	5.5	25 Jul - 26 Jul	1	0.42	ITCZ + LP
		9-Sep	8.91	18-Sep	12.46	9	3.55	16 Sep - 17 Sep	0.9	0.39	
011903	Chiang Khan	17-Jul	6.34	29-Jul	10.66	12	4.32	27 Jul - 28 Jul	0.79	0.36	ITCZ + LP
		11-Sep	9.12	19-Sep	12.03	8	2.91	15 Sep - 16 Sep	0.97	0.36	
011901	Vientiane	19-Jul	3.33	29-Jul	7.68	10	4.35	28 Jul - 29 Jul	0.83	0.44	ITCZ + LP
		12-Sep	6.24	19-Sep	9.62	7	3.38	16 Sep - 17 Sep	1	0.48	
012001	Nong Khai	19-Jul	4.26	29-Jul	8.58	10	4.32	27 Jul - 28 Jul	0.81	0.43	ITCZ + LP
		12-Sep	7.37	19-Sep	10.85	7	3.48	16 Sep - 17 Sep	0.98	0.50	

Table A 3 The characteristics of flood events for stations from Paksane to Pakse.

ID	Station	Beginning of flood event		Peak of flood event		Remaining Time	Flood Amplitude	Intensity of Flood Rising			Comment
		Date	H_B (m)	Date	H_P (m)	ΔT (day)	ΔH (m)	Appearence time of I_{max}(day)	I_{max} (m/day)	$I_{Average}$ (m/day)	
012703	Paksane	13-Jul	5.01	31-Jul	10.13	18	5.12	18 Jul - 19 Jul	1.69	0.28	ITCZ + LP + TS
		13-Sep	9.75	19-Sep	12.2	6	2.45	14 Sep - 15 Sep	1.05	0.41	
013101	Nakhon Phanom	15-Jul	3.13	31-Jul	7.92	16	4.79	19 Jul - 20 Jul	1.94	0.30	ITCZ + LP + TS
		16-Oct	5.34	19-Oct	7.55	3	2.21	18 Oct - 19 Oct	0.98	0.74	
013102	Thakhek	15-Jul	4.36	31-Jul	9.05	16.5	4.69	18 Jul - 19 Jul	1.5	0.28	ITCZ + LP + TS
		16-Oct	6.54	19-Oct	8.7	3	2.16	18 Oct - 19 Oct	0.9	0.72	
013402	Mukdahan	18-Jul	2.12	1-Aug	6.75	14	4.63	19 Jul - 20 Jul	2.53	0.33	ITCZ + LP + TS
		17-Oct	5.64	20-Oct	7.64	3	2	18 Oct - 19 Oct	1.02	0.67	
013401	Savanakhet	15-Jul	3.25	1-Aug	7.58	17	4.33	19 Jul - 20 Jul	1.38	0.25	ITCZ + LP + TS
		16-Oct	4.68	19-Oct	6.92	3	2.24	18 Oct - 19 Oct	1.29	0.75	
013801	Khong Chiam	17-Jul	3.48	2-Aug	8.1	16	4.62	20 Jul - 21 Jul	1.25	0.29	ITCZ + LP + TS
		21-Aug	9.62	4-Sep	12.9	14	3.28	24 Aug - 25 Aug	0.86	0.23	
		4-Oct	8.58	7-Oct	11.04	3	2.46	05 Oct - 06 Oct	1.47	0.82	
		16-Oct	7.62	20-Oct	9.8	4	2.18	17 Oct - 18 Oct	0.78	0.55	
013901	Pakse	17-Jul	2.45	3-Aug	6.55	17	4.1	20 Jul - 21 Jul	1.12	0.24	ITCZ + LP + TS
		23-Aug	7.95	4-Sep	10.74	11.5	2.79	24 Aug - 25 Aug	0.82	0.24	
		4-Oct	6.93	8-Oct	9.04	4	2.11	05 Oct - 06 Oct	1.22	0.53	

Table A 4 The characteristics of flood events for stations from Strung Treng to Kampong Cham.

ID	Station	Beginning of flood event		Peak of flood event		Remaining Time	Flood Amplitude	Intensity of Flood Rising			Comment
		Date	H_B (m)	Date	H_P (m)	ΔT (day)	ΔH (m)	Appearence time of I_{max}(day)	I_{max} (m/day)	$I_{Average}$ (m/day)	
014501	**Stung Treng**	19-Jul	3.42	3-Aug	6.32	14.5	2.9	27 Jul - 28 Jul	0.6	0.20	
		24-Aug	6.98	5-Sep	9.04	11.5	2.06	25 Aug - 26 Aug	0.68	0.18	
		4-Oct	6.24	8-Oct	7.86	3.5	1.62	06 Oct - 07 Oct	0.73	0.46	
014901	**Kratie**	20-Jul	9.05	4-Aug	14.48	15.5	5.43	22 Jul - 23 Jul	1.08	0.35	
		25-Aug	16.05	6-Sep	19.56	12	3.51	26 Aug - 27 Aug	0.9	0.29	
		4-Oct	15.38	9-Oct	17.61	5	2.23	07 Oct - 08 Oct	0.88	0.45	
019803	**Kompong Cham**	20-Jul	4.39	5-Aug	9.03	16	4.64	23 Jul - 24 Jul	0.96	0.29	
		8-Aug	8.35	16-Aug	10.56	8.5	2.21	10 Aug - 11 Aug	0.45	0.26	
		23-Aug	10.35	7-Sep	13.43	15	3.08	26 Aug - 27 Aug	0.63	0.21	

Table A 5 The characteristics of flood events for stations from Phnom Penh Bassac/Phnom Penh Port to Koh Khel/Neak Luong.

ID	Station	Beginning of flood event		Peak of flood event		Remaining Time	Flood Amplitude	Intensity of Flood Rising			Comment
		Date	H_B (m)	Date	H_P (m)	ΔT (day)	ΔH (m)	Appearence time of I_{max}(day)	I_{max} (m/day)	$I_{Average}$ (m/day)	
033401	**Phnom Penh Bassac**	22-Jul	2.52	5-Aug	5.15	14	2.63	24 Jul - 25 Jul	0.42	0.19	
		8-Aug	4.89	15-Aug	6.23	7	1.34	12 Aug - 13 Aug	0.28	0.19	
		23-Aug	6.23	7-Sep	8.08	15	1.85	27 Aug - 28 Aug	0.3	0.12	
020101	**PhnomPenh Port**	22-Jul	1.62	6-Aug	4.36	15	2.74	24 Jul - 25 Jul	0.43	0.18	
		8-Aug	3.99	16-Aug	5.36	8	1.37	12 Aug - 13 Aug	0.28	0.17	
		23-Aug	5.35	7-Sep	7.3	14.5	1.95	27 Aug - 28 Aug	0.27	0.13	
033402	**Koh Khel**	22-Jul	2.46	5-Aug	4.78	14.5	2.32	24 Jul - 25 Jul	0.43	0.16	
		8-Aug	4.43	16-Aug	5.56	8	1.13	12 Aug - 13 Aug	0.34	0.14	
		23-Aug	5.51	7-Sep	6.8	15	1.29	27 Aug - 28 Aug	0.25	0.09	
019806	**Neak Luong**	22-Jul	1.85	5-Aug	3.44	14.5	1.59	24 Jul - 25 Jul 29 Jul - 30 Jul	0.27	0.11	
		9-Aug	3.16	16-Aug	4.3	7.5	1.14	13 Aug - 14 Aug	0.29	0.15	
		23-Aug	4.2	6-Sep	5.62	14	1.42	27 Aug - 28 Aug	0.24	0.10	
020102	**Prek Dam**	22-Jul	1.66	5-Aug	4.13	14.5	2.47	24 Jul - 25 Jul	0.46	0.17	
		9-Aug	3.16	17-Aug	4.3	8.5	1.14	11 Aug - 12 Aug	0.24	0.13	
		23-Aug	5.16	8-Sep	6.79	16.4	1.63	27 Aug - 28 Aug	0.19	0.10	

Table A 6 The characteristics of flood events for stations from Tan Chau and Chau Doc (**).

ID	Station	Beginning of flood event		Peak of flood event		Remaining Time	Flood Amplitude	Intensity of Flood Rising			Comment
		Date	H_B (m)	Date	H_P (m)	ΔT (day)	ΔH (m)	Appearence time of I_{max}(day)	I_{max} (m/day)	$I_{Average}$ (m/day)	
019803	Tan Chau	4-Jun	-0.21	10-Jun	0.71	6	0.92	07 Jun - 08 Jun	0.26	0.15	Tidal influence
		19-Jun	0.14	23-Jun	0.82	4	0.68	21 Jun - 22 Jun	0.22	0.17	
		3-Jul	0	9-Jul	0.86	6	0.86	07 Jul - 08 Jul	0.25	0.14	
		27-Aug	1.86	9-Sep	2.76	13	0.9	27 Aug - 28 Aug 4 Sep - 5 Sep 5 Sep - 6 Sep	0.11	0.07	
039801	Chau Doc	4-Jun	-0.33	10-Jun	0.77	6	1.1	07 Jun - 08 Jun	0.3	0.18	Tidal influence
		19-Jun	-0.01	24-Jun	0.85	5	0.86	21 Jun - 22 Jun	0.27	0.17	
		5-Jul	0	9-Jul	0.88	4	0.88	07 Jul - 08 Jul	0.32	0.22	
		27-Aug	1.4	8-Sep	2.2	12	0.8	05 Sep - 06 Sep	0.11	0.07	

(**) Water levels at Tan Chau and Chau Doc are influenced by tidal, the WL in the table A6 were recorded at 7AM during 2009 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 to 5-day forecasts at Neak Luong, Tan Chau and Chau Doc was less than expected. The detail analysis is presented in paragraph 2.2.

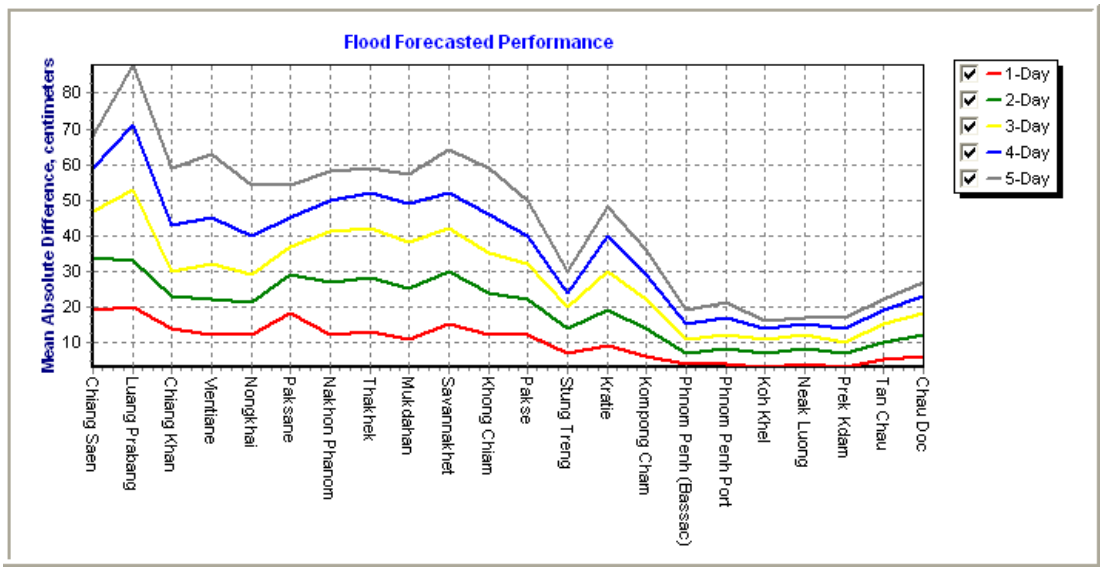


Figure B 1 Average flood forecast accuracy along the Mekong mainstream.

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 (see Table B2).

Table B 1 Achievement of daily forecast against benchmarks.

	Chiang Saen	Luang Prabang	Chiang Khan	Vientiane	Nongkhai	Paksane	Nakhon Phanom	Thakhek	Mukdahan	Savannakhet	Khong Chiam	Pakse
1-day	92.1	93.4	86.8	89.5	88.2	78.3	90.8	89.5	88.8	87.5	89.5	89.5
2-day	91.4	90.7	64.9	66.9	70.2	57.6	83.4	84.1	88.7	87.4	88.7	93.4
3-day	78.0	86.7	76.7	82.7	84.7	72.7	72.7	74.7	76.0	74.7	88.7	94.0
4-day	79.2	84.6	81.9	66.4	69.8	64.4	61.7	66.4	76.5	79.9	79.9	88.6
5-day	77.0	83.1	70.3	71.6	77.0	73.0	71.6	75.0	73.6	75.0	68.2	82.4

	Stung Treng	Kratie	Kompong Cham	Phnom Penh (Bassac)	Phnom Penh Port	Koh Khel	Neak Luong	Prek Kdam	Tan Chau	Chau Doc	***Average***
1-day	82.2	71.1	80.9	94.7	91.4	94.1	90.1	94.7	86.2	80.3	***87.7***
2-day	84.1	70.9	82.1	76.8	70.9	80.1	74.8	75.5	66.2	60.3	***77.7***
3-day	91.3	82.7	67.3	57.3	54.7	66.0	51.3	62.0	53.3	46.0	***72.5***
4-day	86.6	69.1	83.9	81.9	78.5	86.6	39.6	88.6	43.0	36.2	***72.4***
5-day	83.8	62.2	74.3	70.9	67.6	81.1	37.8	77.0	35.8	34.5	***69.2***

Table B 2 Benchmarks of success (indicator of accuracy in mean absolute error).

	Chiang Saen	Luang Prabang	Chiang Khan	Vientiane	Nongkhai	Paksane	Nakhon Phanom	Thakhek	Mukdahan	Savannakhet	Khong Chiam	Pakse
1-day	50	50	25	25	25	25	25	25	25	25	25	25
2-day	75	75	25	25	25	25	50	50	50	50	50	50
3-day	75	100	50	50	50	50	50	50	50	50	75	75
4-day	100	*125*	75	50	50	50	50	50	75	75	75	75
5-day	100	*150*	75	75	75	75	75	75	75	75	75	75

	Stung Treng	Kratie	Kompong Cham	Phnom Penh (Bassac)	Phnom Penh Port	Koh Khel	Neak Luong	Prek Kdam	Tan Chau	Chau Doc
1-day	10	10	10	10	10	10	10	10	10	10
2-day	25	25	25	10	10	10	10	10	10	10
3-day	50	50	25	10	10	10	10	10	10	10
4-day	50	50	50	25	25	25	10	25	10	10
5-day	50	50	50	25	25	25	10	25	10	10

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).

In the future these indicators will be adjusted against a set of performance indicators that is established by combining international standards and the specific circumstances in the Mekong River Basin. An expert mission to establish these performance indicators and future benchmarks was conducted in the fourth quarter of 2009 and the result of the mission will be presented to the MRC member countries during a regional consultation meeting in the first

Performance

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

Table B 3 Overview of performance indicators for flood season 2010 from June to October.

2010	Flood Forecast: time sent			Arrival time of input data (average)										Missing data (number)							
	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	10:43	0	0	08:55	08:13	09:28	08:12	08:20	08:42	08:26	07:33	30	7	30	30	30	30	30
July	10:44	2	0	09:42	08:12	10:12	08:04	07:43	08:31	08:24	07:25	31	31	31	31	31	30	31
August	10:42	0	0	09:16	08:13	08:21	07:54	05:45	08:39	08:14	07:26	31	31	31	31	31	31	31
September	10:20	0	0	09:09	08:13	08:25	07:54	05:54	08:35	08:07	07:32	30	30	30	30	30	30	30
October	10:19	4	0	09:09	08:16	08:18	07:53	06:01	08:40	08:08	07:25	31	18	31	31	31	31	31
Season	**10:33**	**6**	**0**	**09:14**	**08:13**	**08:53**	**07:59**	**06:27**	**08:37**	**08:15**	**07:28**	**153**	**117**	**153**	**153**	**153**	**152**	**153**

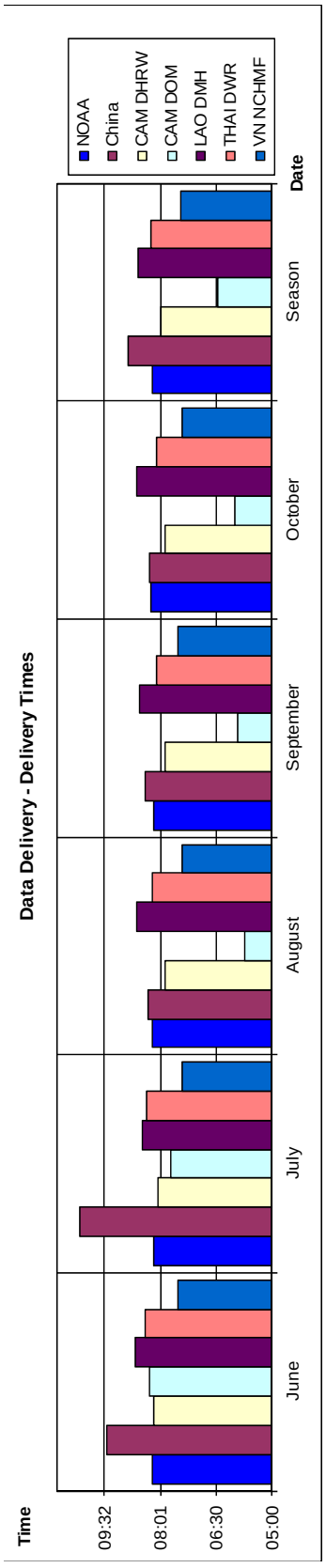


Figure B 2 Data delivery times for flood season 2010 from June to October.

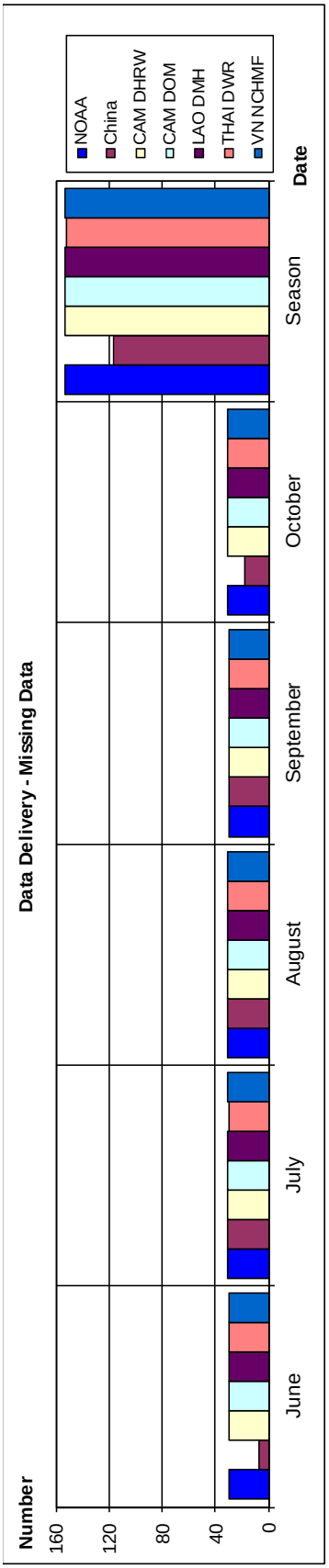


Figure B 3 Missing data for flood season 2010 from June to October.

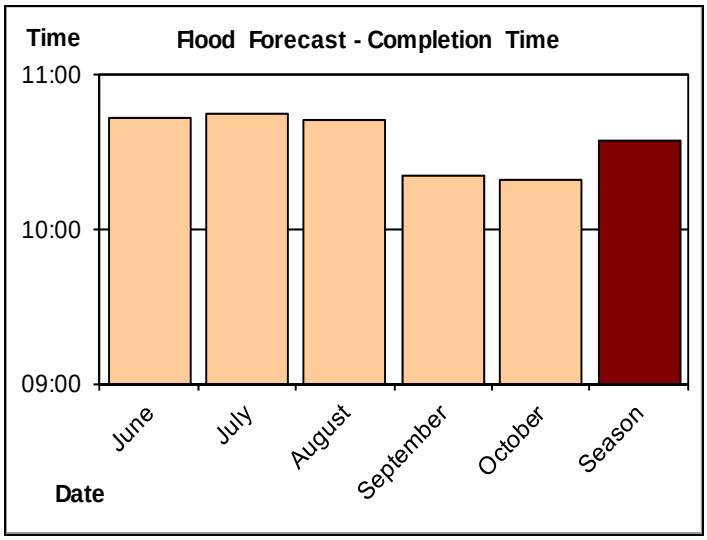


Figure B 4 Flood forecast completion time.

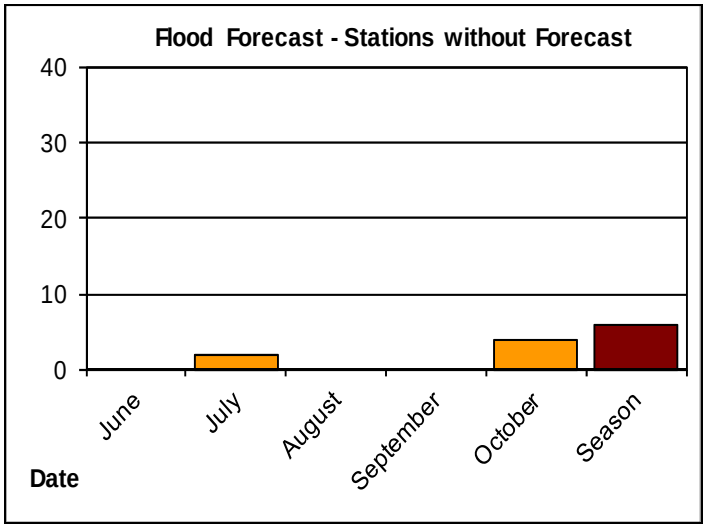


Figure B 5 Flood forecast stations without forecast.

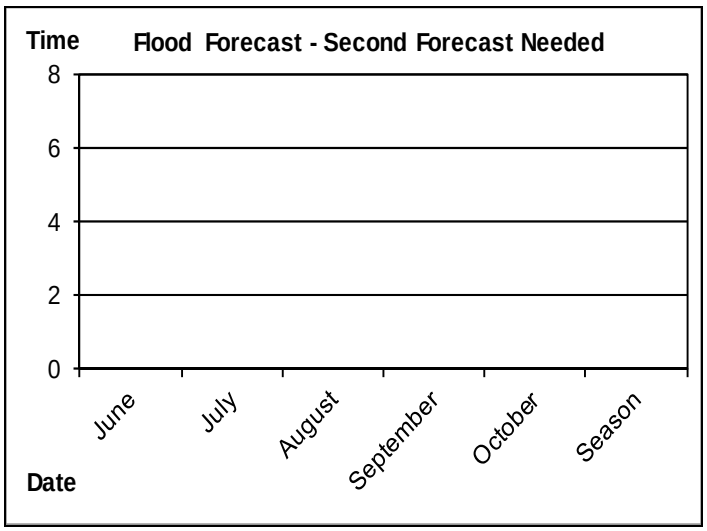


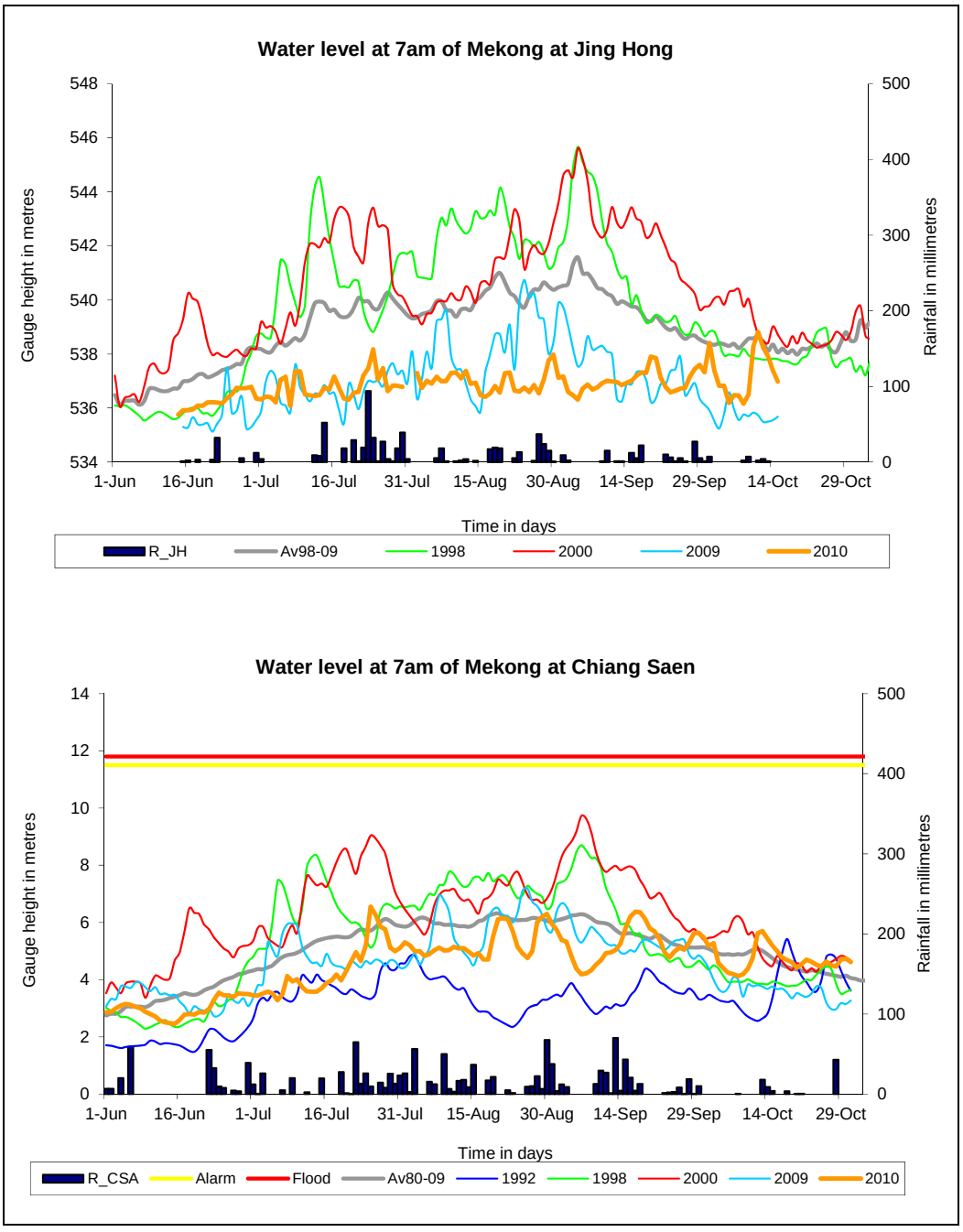
Figure B 6 Second forecast needed.

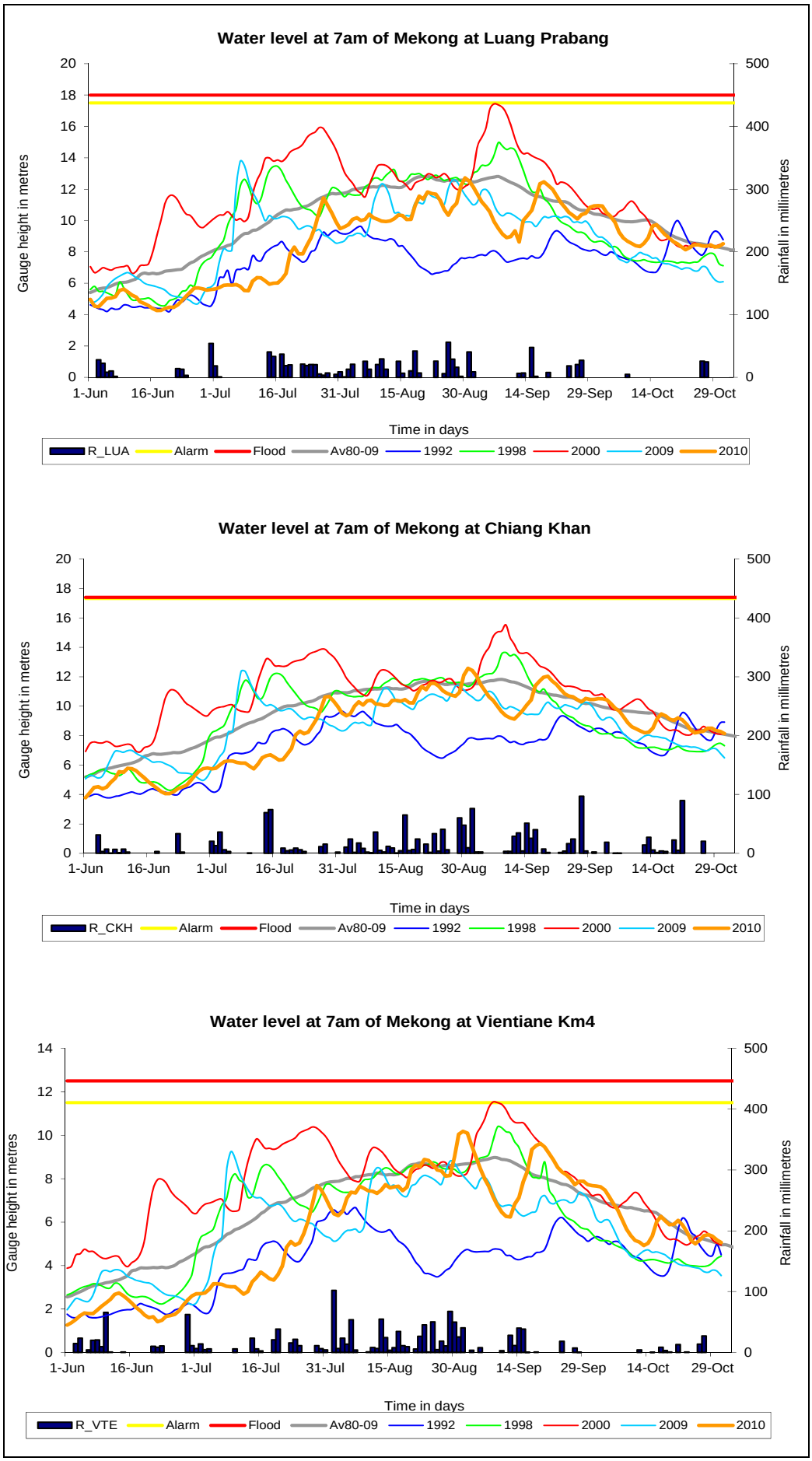
Annex C Flood Season Water Level Graphs

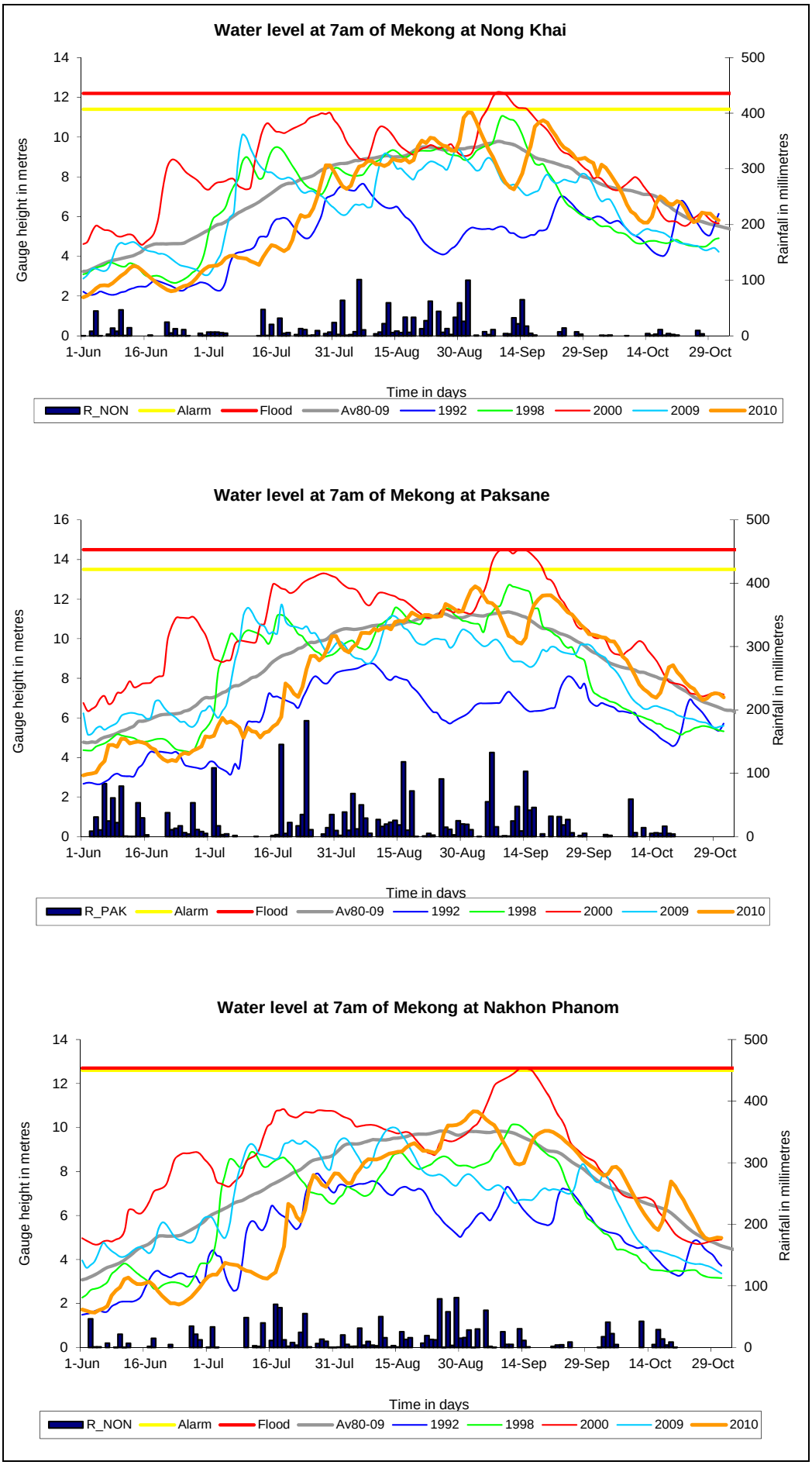
This Annex has the water level and rainfall graphs of the report date. These graphs are distributed daily by email together with the Flood Bulletins.

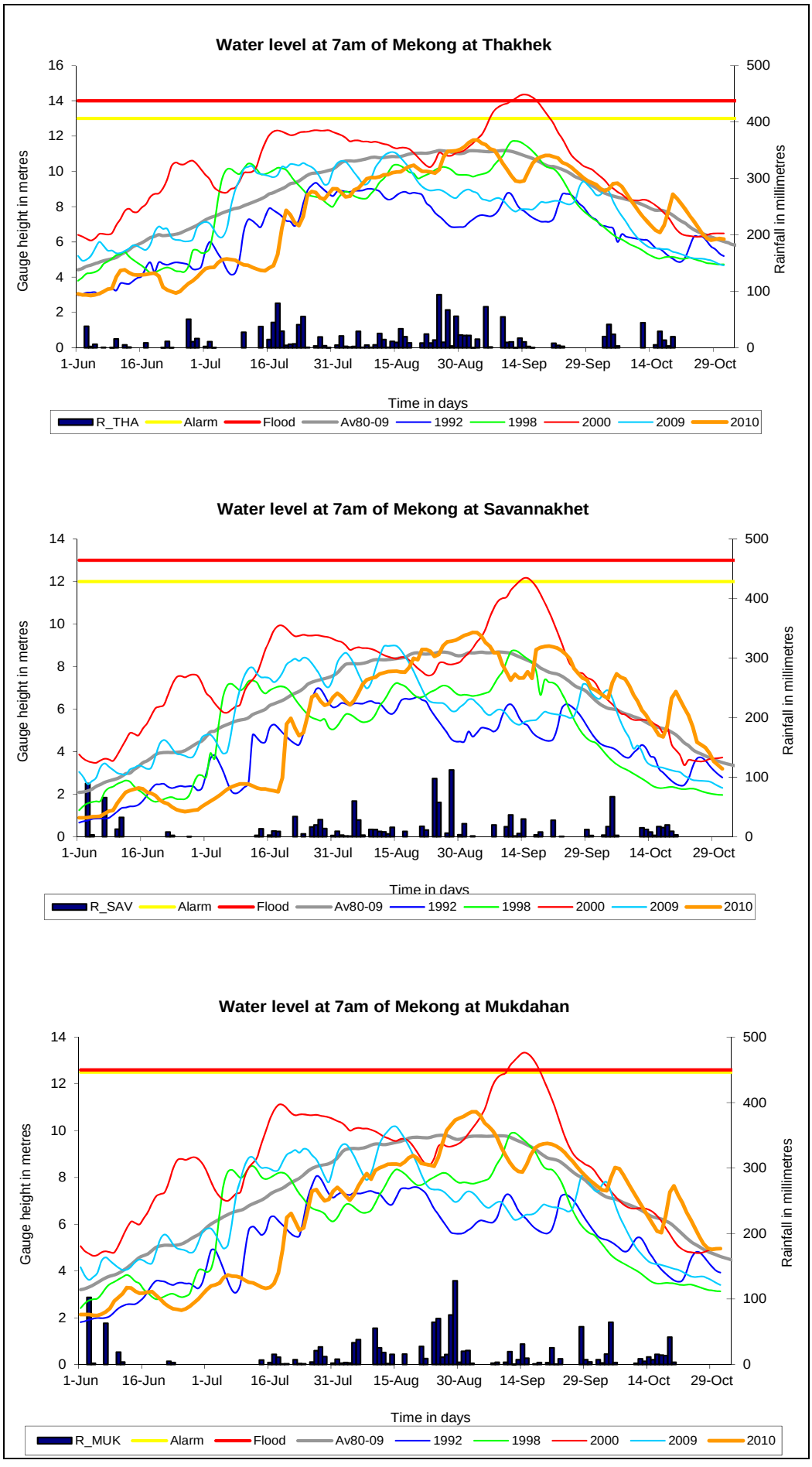
HYDROGRAPHS OF THE MEKONG AT MAINSTREAM STATIONS

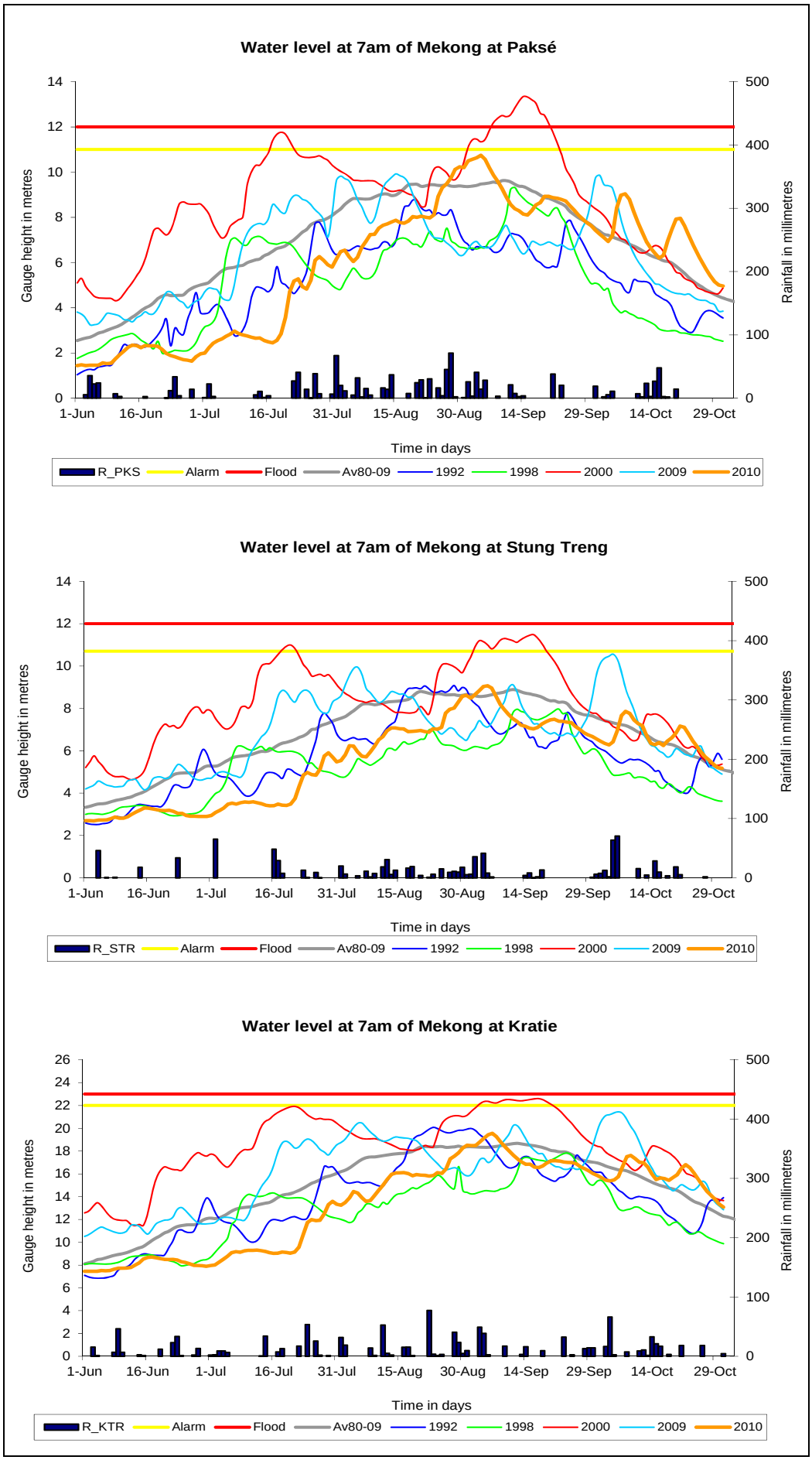
IN FLOOD SEASON FROM 1 JUNE TO 31 OCTOBER

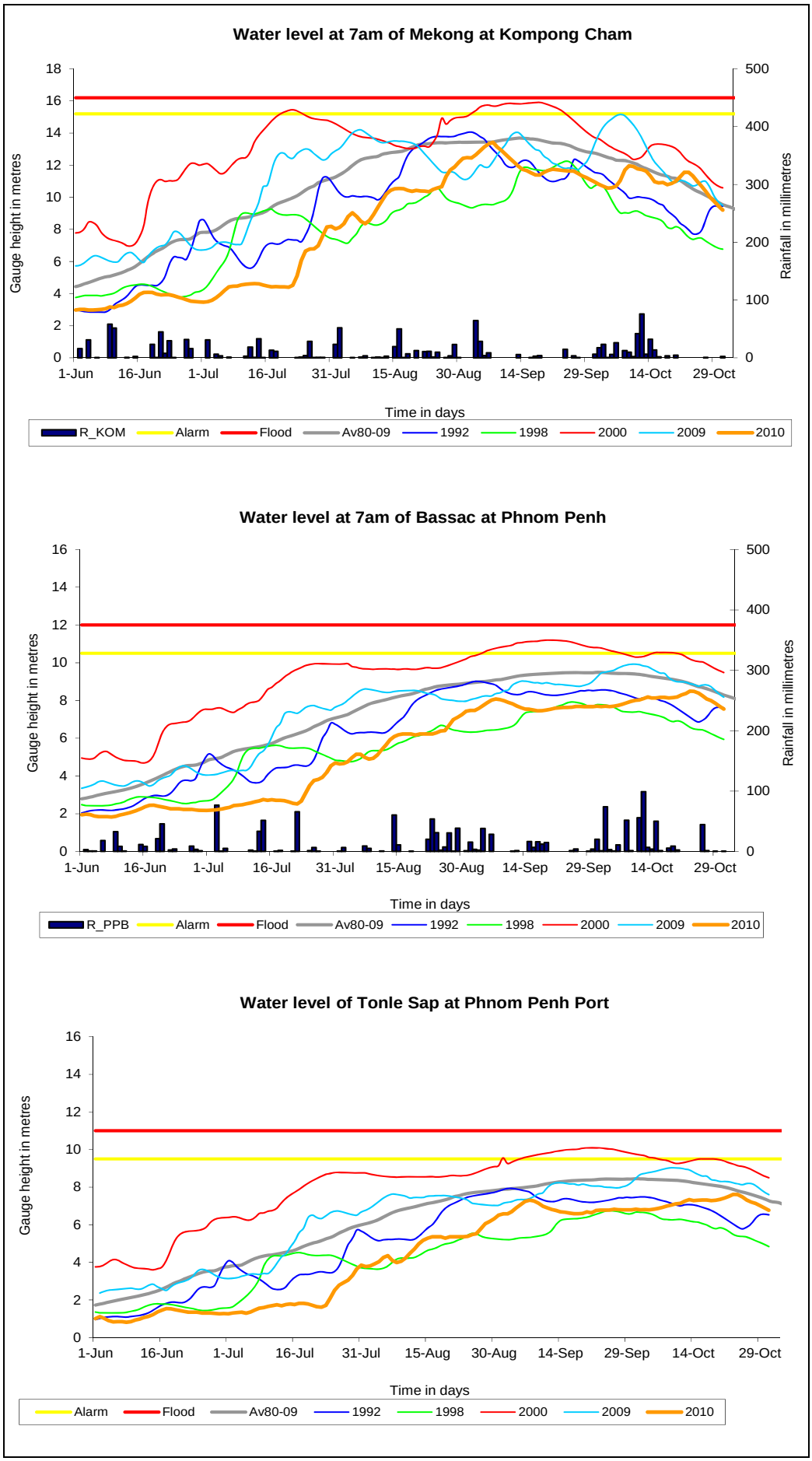


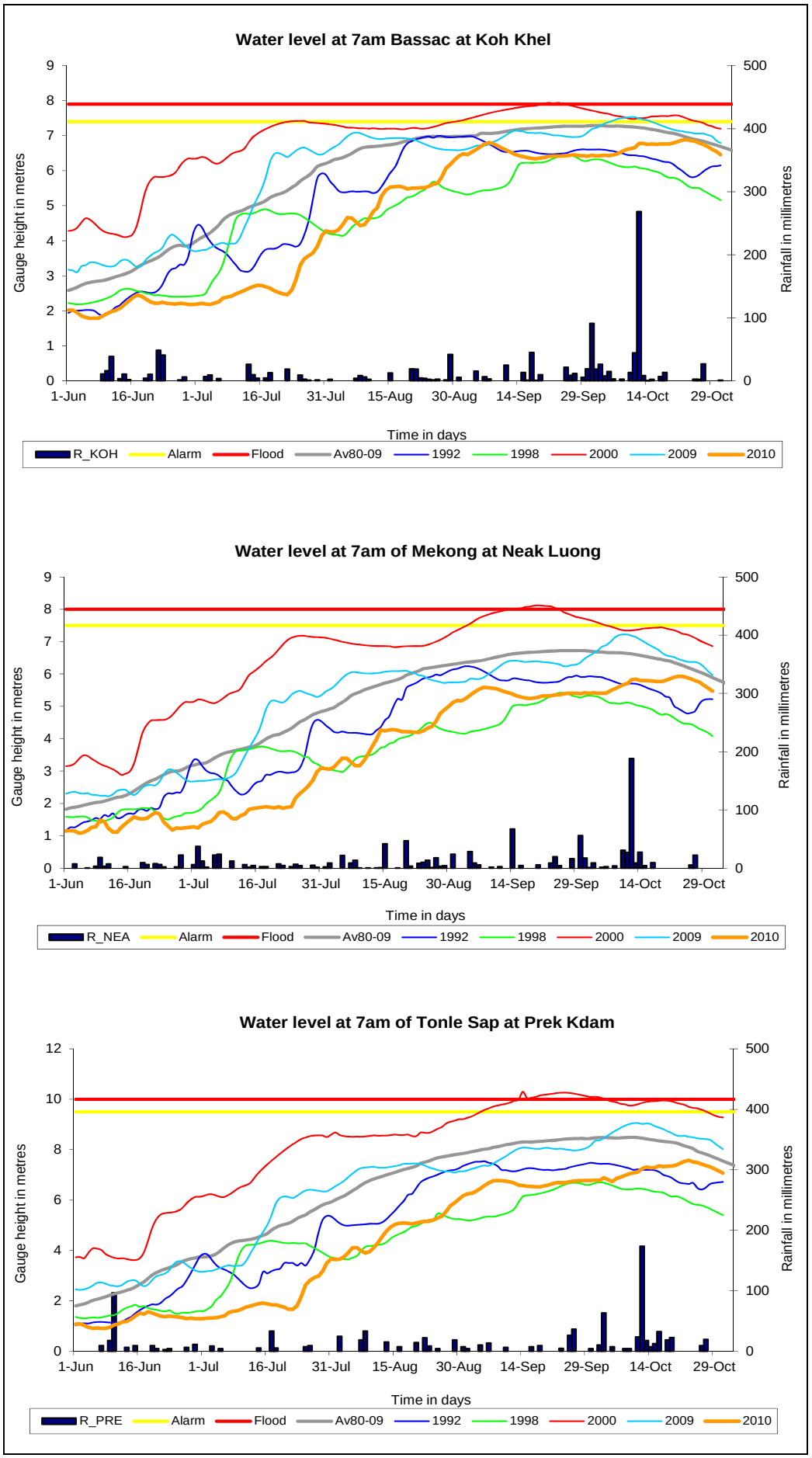

Water level at 7am of Mekong at Luang Prabang
Gauge height in metres
Rainfall in millimetres
Time in days
R_LUA
Alarm
Flood
Av80-09
1992
1998
2000
2009
2010
Water level at 7am of Mekong at Chiang Khan
Gauge height in metres
Rainfall in millimetres
Time in days
R_CKH
Alarm
Flood
Av80-09
1992
1998
2000
2009
2010
Water level at 7am of Mekong at Vientiane Km4
Gauge height in metres
Rainfall in millimetres
Time in days
R_VTE
Alarm
Flood
Av80-09
1992
1998
2000
2009
2010

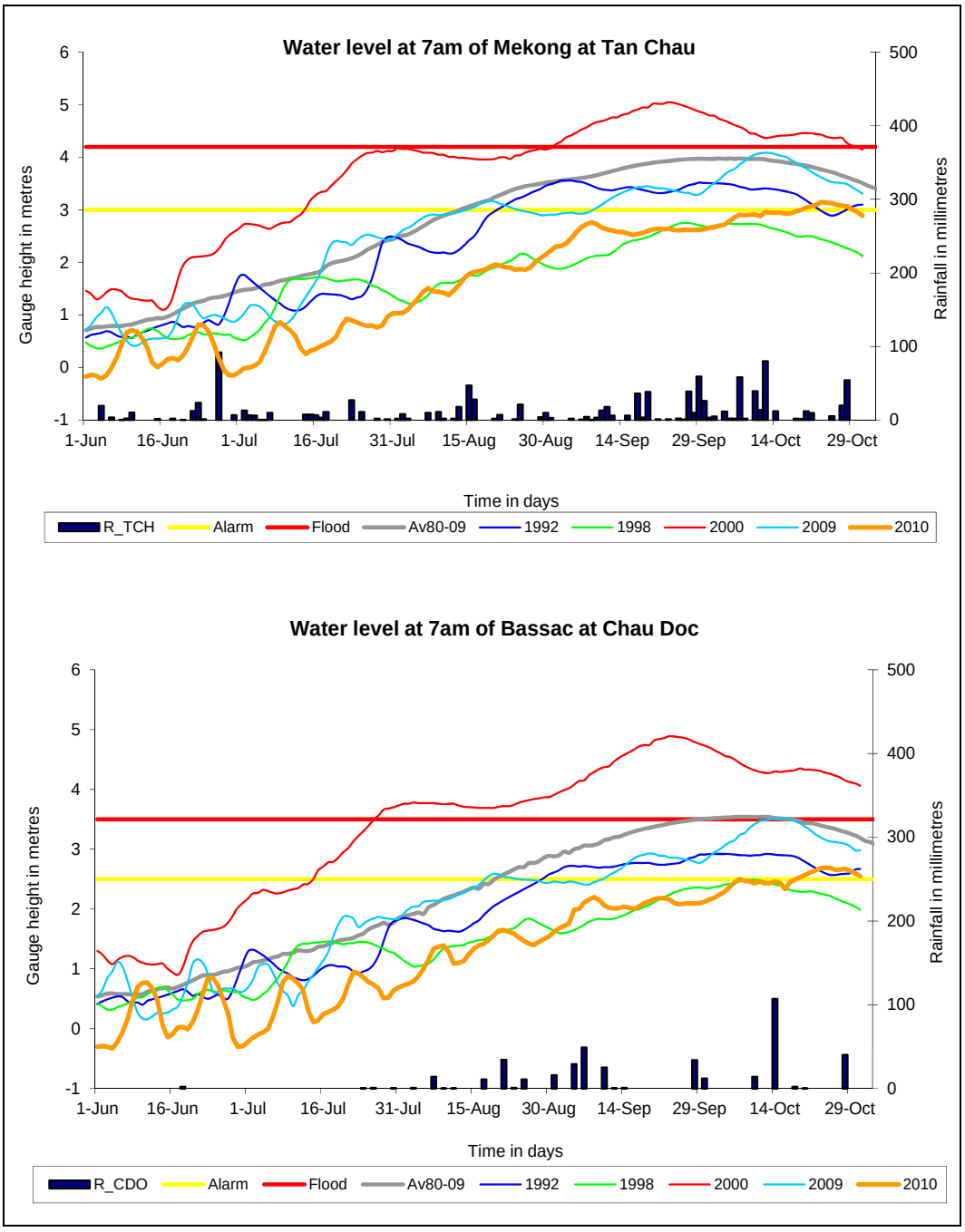

Water level at 7am of Mekong at Nong Khai
Gauge height in metres
Rainfall in millimetres
Time in days
1-Jun
16-Jun
1-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
R_NON
Alarm
Flood
Av80-09
1992
1998
2000
2009
2010
Water level at 7am of Mekong at Paksane
Gauge height in metres
Rainfall in millimetres
Time in days
R_PAK
Alarm
Flood
Av80-09
1992
1998
2000
2009
2010
Water level at 7am of Mekong at Nakhon Phanom
Gauge height in metres
Rainfall in millimetres
Time in days
R_NON
Alarm
Flood
Av80-09
1992
1998
2000
2009
2010


Water level at 7am of Mekong at Thakhek
Gauge height in metres
Rainfall in millimetres
Time in days
R_THA
Alarm
Flood
Av80-09
1992
1998
2000
2009
2010
Water level at 7am of Mekong at Savannakhet
Gauge height in metres
Rainfall in millimetres
Time in days
R_SAV
Alarm
Flood
Av80-09
1992
1998
2000
2009
2010
Water level at 7am of Mekong at Mukdahan
Gauge height in metres
Rainfall in millimetres
Time in days
R_MUK
Alarm
Flood
Av80-09
1992
1998
2000
2009
2010


Water level at 7am of Mekong at Paksé
Gauge height in metres
Rainfall in millimetres
Time in days
1-Jun
16-Jun
1-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
R_PKS
Alarm
Flood
Av80-09
1992
1998
2000
2009
2010
Water level at 7am of Mekong at Stung Treng
Gauge height in metres
Rainfall in millimetres
Time in days
R_STR
Alarm
Flood
Av80-09
1992
1998
2000
2009
2010
Water level at 7am of Mekong at Kratie
Gauge height in metres
Rainfall in millimetres
Time in days
R_KTR
Alarm
Flood
Av80-09
1992
1998
2000
2009
2010


Water level at 7am of Mekong at Kompong Cham
Gauge height in metres
Rainfall in millimetres
Time in days
R_KOM
Alarm
Flood
Av80-09
1992
1998
2000
2009
2010
Water level at 7am of Bassac at Phnom Penh
Gauge height in metres
Rainfall in millimetres
Time in days
R_PPB
Alarm
Flood
Av80-09
1992
1998
2000
2009
2010
Water level of Tonle Sap at Phnom Penh Port
Gauge height in metres
Time in days
Alarm
Flood
Av80-09
1992
1998
2000
2009
2010


Water level at 7am Bassac at Koh Khel
Gauge height in metres
Rainfall in millimetres
Time in days
1-Jun
16-Jun
1-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
R_KOH
Alarm
Flood
Av80-09
1992
1998
2000
2009
2010
Water level at 7am of Mekong at Neak Luong
Gauge height in metres
Rainfall in millimetres
Time in days
R_NEA
Alarm
Flood
Av80-09
1992
1998
2000
2009
2010
Water level at 7am of Tonle Sap at Prek Kdam
Gauge height in metres
Rainfall in millimetres
Time in days
R_PRE
Alarm
Flood
Av80-09
1992
1998
2000
2009
2010


Water level at 7am of Mekong at Tan Chau
Gauge height in metres
Rainfall in millimetres
Time in days
1-Jun
16-Jun
1-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
R_TCH
Alarm
Flood
Av80-09
1992
1998
2000
2009
2010
Water level at 7am of Bassac at Chau Doc
Gauge height in metres
Rainfall in millimetres
Time in days
R_CDO
Alarm
Flood
Av80-09
1992
1998
2000
2009
2010