Mekong River Commission

Regional Flood and Drought Management Centre

Wet Season Situation Report of the Mekong River

Analysis of the MRC - River Flood Forecasting System (RFFS)

Covering the period from 1st June to 31st October 2020

(Final)

Prepared by:

Regional Flood and Drought Management Centre

May 2021

Certification of Approval
of Internal RFDMC Technical Document

Wet Season Situation Report of the Mekong River
Covering the period from 1st June to 31st October 2020

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Abbreviation

CHIRPS-GEFS	Climate Hazards Center InfraRed Precipitation Global Ensemble Forecast System
CHRHMC	Central Highlands Regional Hydro-Meteorological Center
DFEWS	Drought Forecasting and Early Warning System (MRC)
DHRW	Department of Hydrology and River Works (Cambodia)
DMH	Department of Meteorology and Hydrology (Lao PDR)
DWR	Department of Water Resources (Thailand)
DOM	Department of Meteorology (Cambodia)
FFGS	Flash Flood Guidance System (MRC)
FTP	File Transfer Protocol
GFS	Global Forecast System
GIS	Geographic Information System
GPM	Global Precipitation Measurement
HYDMET	Data collection system
ICTZ	Intertropical Convergence Zone
JMA	Japan Meteorological Agency
LA(s)	Line Agency (-ies)
LMB	Lower Mekong River Basin
LTA	Long-Term Average
MAD	Mean Absolut Difference in centimetres
MC(s)	Member Country (ies)
MoU	Memorandum of Understanding
MRC	Mekong River Commission
MRCS	Mekong River Commission Secretariat
RFDMC	Regional Flood and Drought Management Centre
RFF	River Flood Forecast
RFFS	River Flood Forecasting System
RFMMC	Regional Flood Management and Mitigation Centre (former name of RFDMC)

SRE	Satellite Rainfall Estimates
SRHMC	Southern Regional Hydrometeorological Centre (Viet Nam)
TD	Technical Support Division
TSR	Tropical Storm Risk
SST	Sea Surface Temperature
URBS	Unified River Basin Simulator
WMO	World Meteorological Organizations

1 Introduction

1.1 Main objective of the report

In 2020, the Mekong River Commission (MRC) embarked on a new format of annual reports when the Joint Committee as the governing body of the MRC decided to integrate drought monitoring and management functions into the Regional Flood Management and Mitigation Centre (RFMMC) and to change the name of the centre into Regional Flood and Drought Management Centre (RFDMC). The new RFDMC is remaining in Phnom Penh where the previous RFMMC has been successfully operating for years. The decision was made to address the changing context of the basin and its vulnerability to more extreme weather events.

During the wet season 2020, from June to October, the RFDMC issued daily flood forecasts, weekly flood situation reports and early warning information during critical situations. Rainfall from 127 stations and water level data from 63 stations including 45 telemetry stations (Mekong-HYCOS stations) were shared by the MRC Member Countries (MCs), Cambodia, Lao PDR, Thailand and Viet Nam, to run daily flood forecast at 22 key mainstream stations (forecast points) in the Lower Mekong River Basin (LMB). The RFDMC communicates the results daily via bulletins by e-mail and on the flood pages of the MRC website to the National Mekong Committees (NMCs), Non-Governmental Organisations, the media and other stakeholders. The RFDMC's daily information provides government agencies and communities in Cambodia, Lao PDR, Thailand and Viet Nam with advanced notice of rising and falling water levels. Through online postings, telephone communication, dissemination of flood information as well as meetings/ workshops, the RFDMC strives to reach a wide audience throughout the entire LMB.

This report is produced by the RFDMC's flood forecasting team, analysing and verifying the summaries of rainfall and water levels, the general behaviour of the flood situation, as well as the accuracy and limitation of the flood forecasting operations at the RFDMC during the wet season 2020.

It is a combination of the three former seasonal reports, "Data Collection and Transfer Performance Evaluation Report", "System Performance Evaluation Report" and "Seasonal Flood Situation Report".

The analysis is based on the daily hydro-meteorological data provided by the MCs and on satellite data. All water levels indicated in this report refer to a above zero gauge of each station.

1.2 Further References

The Weekly Wet Season Situation Report in the LMB is available at:

http://ffw.mrcmekong.org/reportflood.php

The Mekong River water levels are updated daily and can be accessed from:
http://ffw.mrcmekong.org/bulletin_wet.php

Further information about the hydrological situation in the LMB can be found in the following reports of RFDMC:

- Annual Mekong Hydrology Report
- Seasonal Flash Flood Situation Report in the LMB
- Seasonal Drought Situation Report in the LMB

1.3 Sub-regions of the Lower Mekong River Basin

With a total catchment area of about 571,000 km^2, the LMB covers a large part of north-eastern Thailand, almost the entire countries of Lao PDR and Cambodia, and the southern tip of Viet Nam. The report is following the functional subdivision of the LMB into four geographic regions.

The Upper Part is the Northern Highlands form the upland region, covering north-eastern Myanmar, northern Thailand and the northern areas of Lao PDR, in between Chaing Saen and Vientiane/Paksane. Large tributaries, including the Nam Ta, Nam Ou, Nam Soung and Nam Khan, enter on the Mekong's left bank, while the Nam Mae Kok and Nam Mae Ing enter on the right bank.

The Middle Part is lying largely within north-eastern Thailand; the Khorat Plateau is a vast, low-lying terrain consisting mainly of sediment and eroded bedrock and surrounded by a rim of highly resistant sandstone, in between Thailand' Nakhon Phanom and Laos' Pakse. Here the Mekong River is joined by the Songkhram and Mun Rivers on the right bank and the Nam Ca Dinh, Se Bang Fai, and Se Bang Hieng Rivers on the left bank.

The Lower Part including the Tonle Sap Lake is the area starting from Stung Treng to Kampong Cham with the inflow from Pakse and the inflow of the 3S (Sekong, Sesan and Sre Pok) area, followed by the connection of the Tonle Sap lake at Phnom Penh Port.

During the wet season, the high flows in the Mekong River cause the Tonle Sap River to reverse its flow direction to flood the Lake. During the peak of the wet season, the Lake's surface area increases six-times, from around 2,500 km^2 to around 15,000 km^2, and its volume increases from around 1.5 km^3 to around 60-70 km^3. At the end of the wet season, the flow of the Tonle Sap River reverts to the downstream direction, draining excess water off the inundated floodplain surrounding the Lake.

The Mekong Delta is starting at Chaktomuk in Phnom Penh. Here the Bassac River, the largest distributary river channel, splits from the mainstream, marking the beginning of the Mekong Delta. Along their course, the Mekong and Bassac Rivers branch off into numerous smaller watercourses, and the delta expands to form a wedge-shaped plain that covers an area of 62,520 km^2.

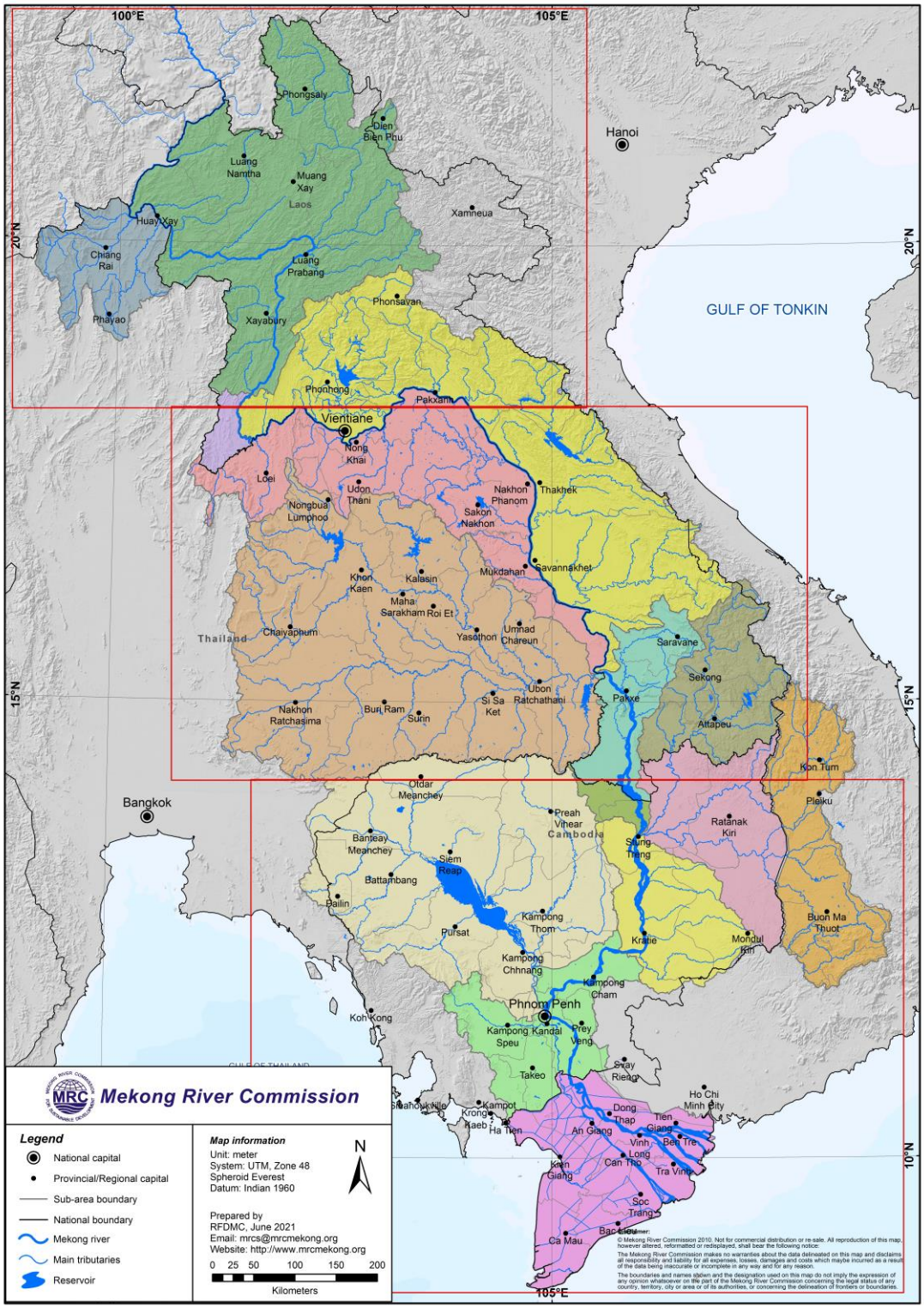


Figure 1: Sub-regions of the LMB

2 General Weather Patterns

2.1 Rainfall situation

During the five months of the wet season 2020, the critical rainfall in the LMB was spread from the months of July to November caused by the combined influence of the southwest monsoon, low-pressure troughs, the Inter Tropical Convergence Zone (ITCZs), storms and typhoons appearances in the East Sea.

Table 1 shows the onset and offset of the southwest monsoon in 2018, 2019, 2020 and LTA (2008-2018) at the hydrological stations along the Mekong mainstream. According to this, the onset was later than its LTA for all stations, similar as in 2019.

Table 2 shows the distribution of the total monthly rainfall during the wet season 2020 from June to October in the LMB compared to its LTA (2008-2018) and the total monthly rainfall in 2019. In 2020 the monthly rainfall in June and July was smaller than the LTA but in September and October higher.

The two table show that the spatial and temporal variation of rainfall was 'high', indicating that the intensity of heavy rainfalls along the LMB from upstream to downstream took place as a function of time.

Figure 2 shows the rainfall distribution, counting from January to October 2020 over the LMB. Rainfall in 2020 mainly was concentrated from the catchment upstream of Paksane to the lower part in Cambodia. **Figure 3** shows the monthly rainfall hyetograph over the LMB, compared with 2018, 2019 and LTA (2006-2019).

Table 1: Onset and offset of the southwest monsoon 2018, 2019 and 2020

Station	Average		2018		2019		2020	
	Onset	Offset	Onset	Offset	Onset	Offset	Onset	Offset
Chiang Saen	02-May	13-Oct	04-May	6-Oct	01-Jun	21-Sep	29-May	04-Oct
Luang Prabang	04-May	08-Oct	05-May	8-Oct	01-Jun	23-Sep	29-May	02-Oct
Chiang Khan	03-May	18-Oct	20-May	9-Oct	02-Jun	24-Sep	29-May	06-Oct
Vientiane	07-May	08-Oct	27-May	10-Oct	03-Jun	24-Sep	29-May	15-Oct
Nong Khai	08-May	09-Oct	27-May	10-Oct	03-Jun	24-Sep	29-May	15-Oct
Paksane	13-May	10-Oct	28-May	10-Oct	01-Jun	24-Sep	29-May	06-Oct
Nakhon Phanom	10-May	08-Oct	28-May	11-Oct	02-Jun	24-Sep	30-May	10-Oct
Thakhek	10-May	08-Oct	28-May	11-Oct	02-Jun	25-Sep	30-May	10-Oct
Mukdahan	10-May	13-Oct	29-May	12-Oct	02-Jun	25-Sep	31-May	29-Oct
Savannakhet	11-May	12-Oct	29-May	12-Oct	02-Jun	25-Sep	31-May	29-Oct
Khong Chiam	08-May	14-Oct	30-May	12-Oct	05-Jun	25-Sep	02-Jun	29-Oct
Pakse	13-May	15-Oct	28-May	11-Oct	06-Jun	26-Sep	03-Jun	29-Oct
Stung Treng	18-May	21-Oct	29-May	18-Oct	04-Jun	29-Sep	03-Jun	12-Nov
Kratie	21-May	24-Oct	29-May	17-Oct	03-Jun	04-Oct	01-Jun	11-Nov
Kompong Cham	18-May	26-Oct	30-May	14-Oct	02-Jun	06-Oct	02-Jun	22-Oct
Bassac Chaktomuk	21-May	06-Nov	31-May	15-Oct	05-Jun	12-Oct	02-Jun	20-Oct
Phnom Penh Port	21-May	06-Nov	31-May	15-Oct	05-Jun	12-Oct	11-Jun	21-Oct
Koh Khel	22-May	06-Nov	31-May	16-Oct	05-Jun	15-Oct	11-Jun	20-Oct
Neak Luong	24-May	04-Nov	31-May	17-Oct	05-Jun	16-Oct	11-Jun	22-Oct
Prek Kdam	24-May	02-Nov	31-May	17-Oct	03-Jun	16-Oct	11-Jun	18-Oct
Tan Chau	28-May	06-Nov	02-Jul	22-Oct	04-Jun	25-Oct	11-Jun	12-Nov
Chau Doc	28-May	06-Nov	02-Jul	22-Oct	04-Jun	25-Oct	11-Jun	13-Nov

Table 2: Total monthly rainfall (mm) in the LMB during wet season 2018, 2019, LTA and 2020

Month	Avg.LTA (2008-2019)	Obs.2018	Obs 2019	Obs 2020
Jan	6.29	17.92	11.65	2.31
Feb	3.63	21.02	10.32	0.97
Mar	17.37	59.76	19.00	14.04
Apr	53.79	115.57	57.34	37.41
May	127.27	216.19	148.95	101.69
Jun	171.78	276.14	168.04	123.23
Jul	249.07	362.78	212.84	117.43
Aug	237.40	331.66	364.45	232.31
Sep	234.05	216.70	259.84	248.92
Oct	122.41	102.00	67.99	259.60
Nov	46.77	30.50	31.18	38.78
Dec	11.44	24.75	3.55	10.48

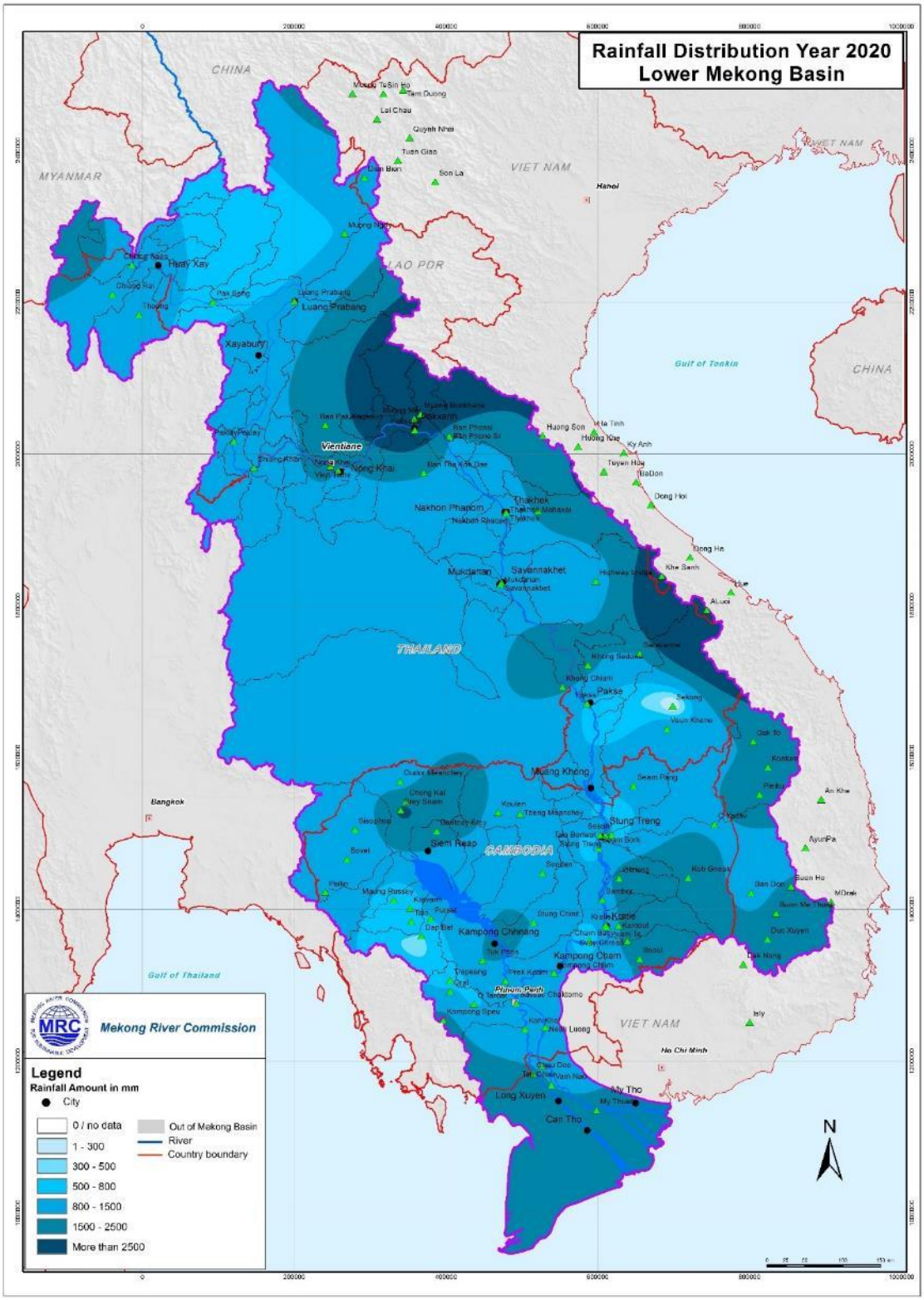


Figure 2: Total rainfall distribution in the LMB from Jan - Oct 2020

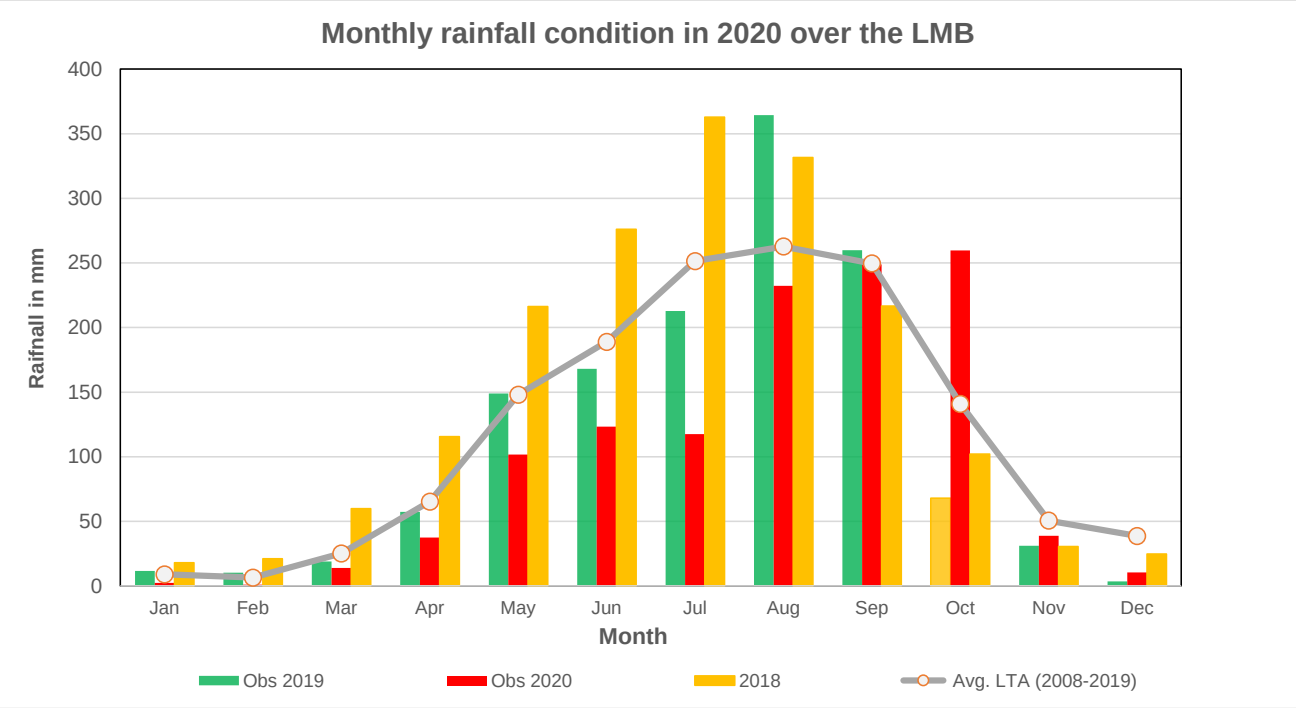


Figure 3: Monthly Rainfall in the LMB from January to Dec 2020

In the wet season 2020 the LMB faced the situation of less rainfalls during May, June and July, but in August to November, the situation gradually diminished with more than average rainfall at the end of the wet season. Most areas in the LMB had experienced drier conditions in dry season 2020. The conditions were aggravated by the late arrival of the Monsoon season which caused deficits in rainfall in parts of the basin during May and July. In May, the Mekong tributaries in Northeast Thailand, upper Cambodia and west side of the Mekong Delta received surplus rainfall. In June, significant rainfall deficits occurred in large parts of the LMB, with marked deficits in the areas close to Xayaburi, Nakhon Phanom and Thakhek. The west side of the basin including Northern Thailand, half of Northeast Thailand, the lower basin in Cambodia and Delta in Viet Nam, were wetter than average in June, influenced by the southwest Monsoon. In July, the deficit situation became worse where most parts of the LMB experienced dryer conditions compared with monthly averages.

Low pressure throughs and Inter Tropical Convergence Zone (ITCZ):

Low-pressure throughs and the ITCZ periodically appeared from September to October 2020 with a 7 to 14 days duration. The appearances of these phenomena caused tropical storms at the end of the wet season that brought heavy rainfall and rising water levels in some parts of the Lower Part from Pakse in Lao PDR to Kompong Cham in Cambodia.

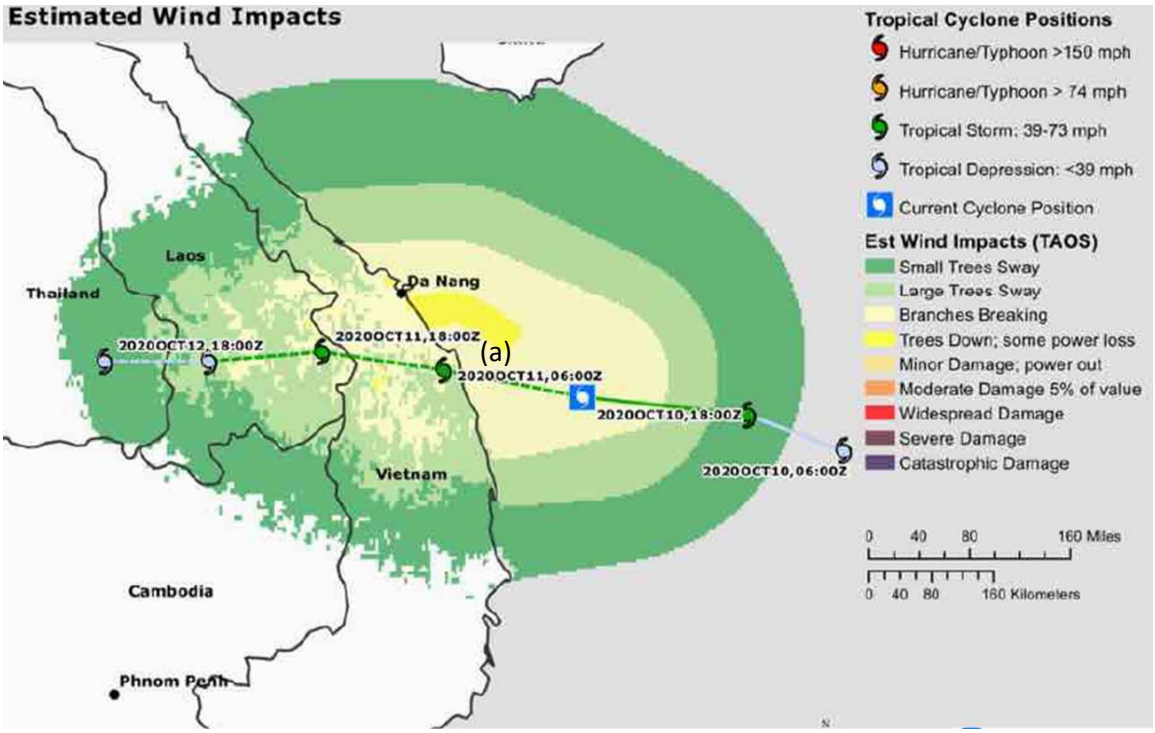
Number of tropical depressions, tropical storms and typhoons:

During the wet season 2020 there were about 9 tropical depressions and storms, that hit the Mekong region. **Table 3** shows the list of tropical depressions, storms and typhoons from July to November 2020 in the LMB.

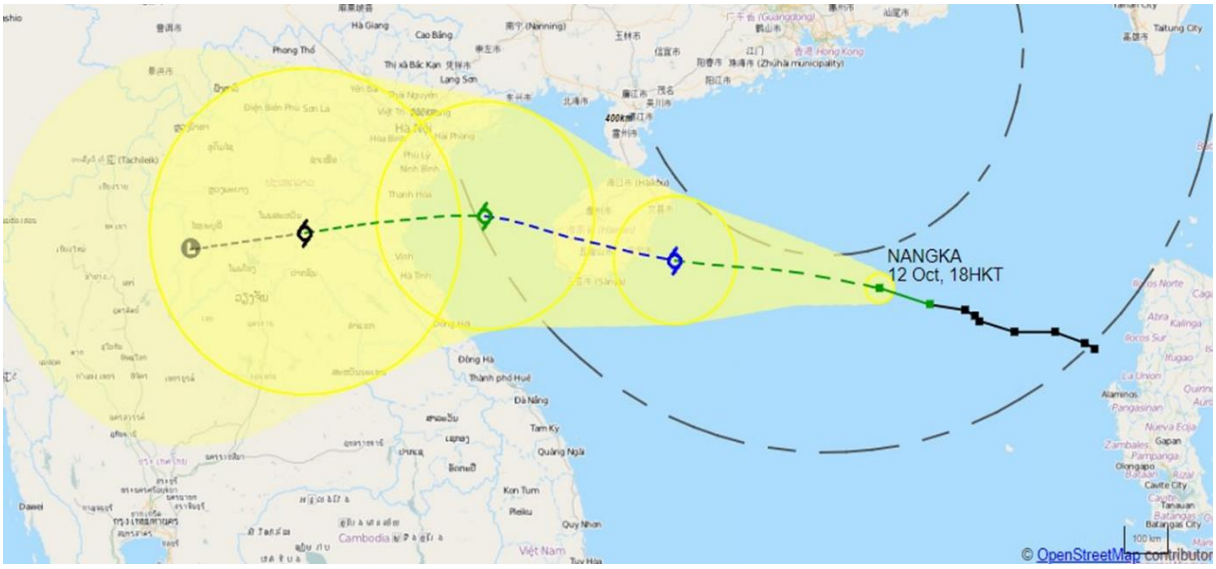
Table 3: List of tropical depressions, storms and typhoons in 2020

No	Name	Basin	Birth (UTC)	Death (UTC)	Duration
1	SINLAKU	W. N. Pacific	01-08-2020 0:00	02-08-2020 18:00	1 Days 18 Hours
2	NOUL	W. N. Pacific	15-09-2020 18:00	18-09-2020 18:00	3 Days 0 Hours
3	LINFA	W. N. Pacific	10-10-2020 18:00	11-10-2020 18:00	1 Days 0 Hours
4	NANGKA	W. N. Pacific	12-10-2020 6:00	14-10-2020 12:00	2 Days 6 Hours
5	SAUDEL	W. N. Pacific	20-10-2020 0:00	25-10-2020 18:00	5 Days 18 Hours
6	MOLAVE	W. N. Pacific	24-10-2020 18:00	29-10-2020 0:00	4 Days 6 Hours
7	GONI	W. N. Pacific	28-10-2020 18:00	05-11-2020 18:00	8 Days 0 Hours
8	ETAU	W. N. Pacific	08-11-2020 18:00	10-11-2020 9:00	1 Days 15 Hours
9	VAMCO	W. N. Pacific	09-11-2020 6:00	15-11-2020 15:00	6 Days 9 Hours

The 2 storms LINFA and NANGKA were bring heavy rainfall in the middle part from Khong Chiam in Thailand to Stung Treng in Cambodia, including the 3S area in Cambodia and Viet Nam. Their meteorological history will be shown in detail below. **Figure 4** illustrates the tropical storms LINFA (a) and NANGKA (b) over the LMB from September to October 2020.



(a) TS LINFA from 10 to 11 October 2020



(b) TS NANGKA from 12 to 14 October 2020

Figure 4: Weather map with tropical storms from Sep to Oct 2020 in the Mekong region
(Source: Thai Meteorological Department)

The characteristic of the tropical storms:

Tropical storm LINFA:

Based on JMA, LINFA developed as a weak tropical depression just east of the Philippines on 18:00 UTC of October 6. After crossing the Philippine archipelago of Luzon, the JTWC issued a tropical cyclone formation alert on October 9. Shortly thereafter, the JMA began operationally tracking the system around 12:00 UTC that day. Twelve hours later, the JMA started initiating advisories on the developing system. It slowly consolidated throughout the rest of the day. By 00:00 UTC of October 11 LINFA reached its peak intensity. However, this peak intensity only lasted for 6 hours, and it shortly later made landfall to the south of Da Nang, Viet Nam on 12:00 UTC of October 12 as indicated in **Figure 5.**

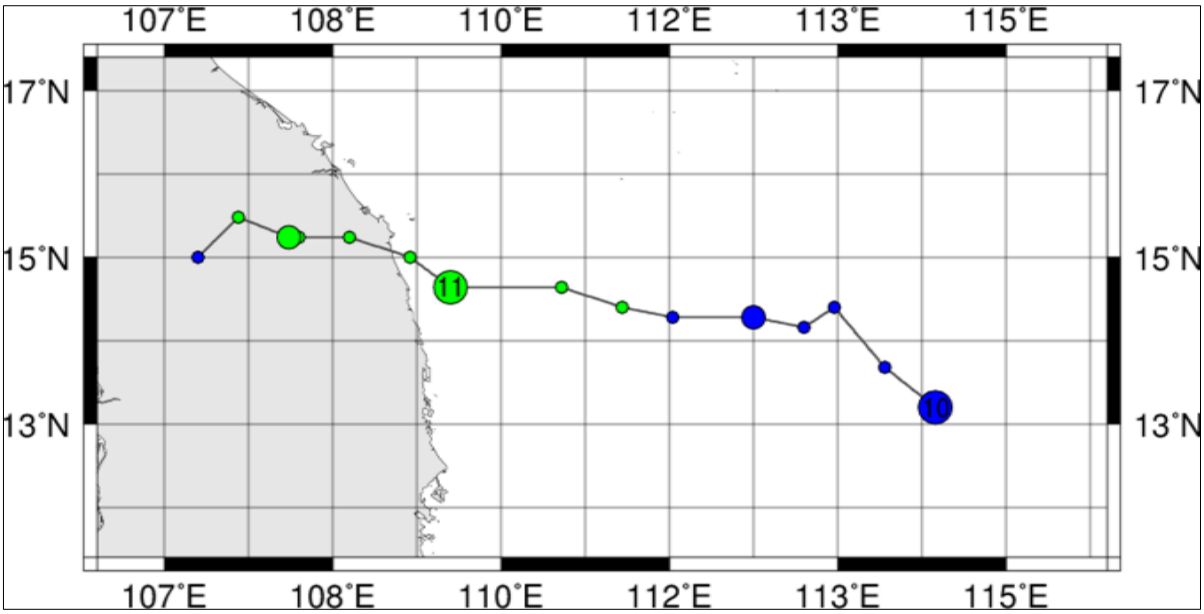


Figure 5: Track of tropical storm LINFA from the East Sea to the LMB

Tropical storm NANGKA: On October 11 2020 the JMA began tracking a tropical depression off the west coast of Luzon. On the same day at 21:00, the JTWC began issuing warnings on the system. On October 12, the system was declared a tropical storm by the JMA and was named NANGKA. At 19:20 CST (11:20 UTC) on October 13, NANGKA made landfall over Hainan Island (China). This system continued tracking westward, before making a second landfall in Ninh Binh province (northern part), Viet Nam on October 14. As the system tracked further inland it dissipated over Lao PDR on the same day. NANGKA's track is shown in the **Figure 6**.

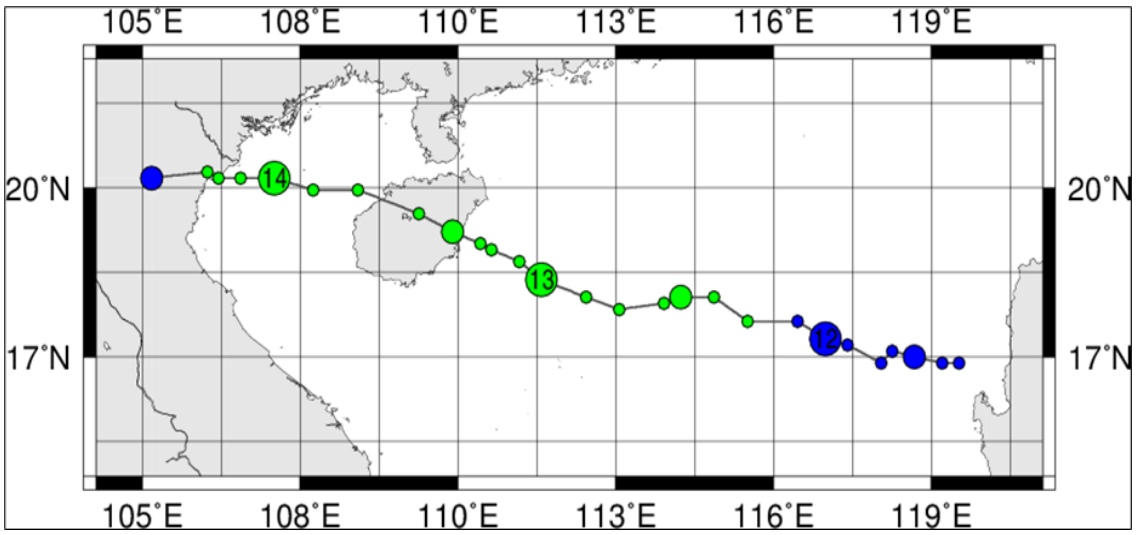


Figure 6: Track of tropical storm NANGKA from the East Sea to the LMB

3 Water Levels in the Lower Mekong River

In general, water levels at all mainstream key stations along the Mekong River were under their LTAs from the beginning of the wet season (01 June) until the end of December 2020. Only water level from Chiang Khan in Thailand to Pakse in Lao PDR and the stretch from Stung Treng to Kompong Cham in Cambodia were higher than their LTA levels from mid-October to December due to the heavy rainfall brought by the Tropical Storms (LINFA and NANGKA). At the middle of October and early November, following the LINFA and NANGKA, the water levels rose significantly in the middle and downstream parts at Khong Chiam, Pakse, Stung Treng and some stations in the low-lying area of the Mekong Delta. **Annex A** shows the water levels hydrographs at each key station along the Mekong river and its main tributaries, the Bassac and the Tonle Sap compared to other years and Min, Max, LTA. The water levels in wet season 2020 reached flood level at Thailand's Khong Chiam , Lao's Pakse, Cambodia's Stung Treng, Kratie and Kompong Cham from October 10 to the end of December 2020. **Table 4** presents the flood peaks and flood characteristics at each key station along the Mekong mainstream in 2020.

Table 4: Flood peaks of the key stations from Jun to December 2020

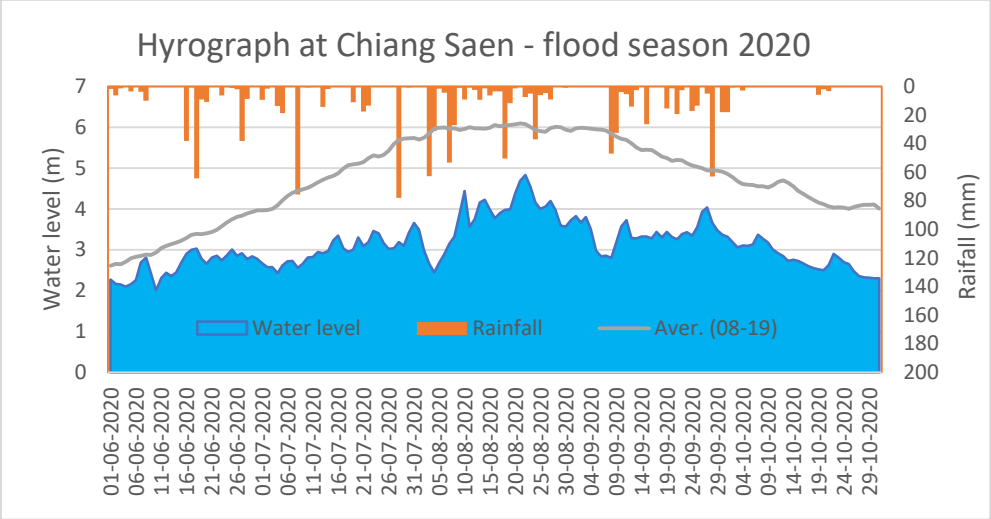
Stations	Number of Flood events	Beginning of Flood Event		Peak of Flood Event		Rising time	Flood Amplitude (m)	Intensity of Flood Rising			Comment
		Date	H_b (m)	Date	H_p (m)	T_p (day)		Interval of I_{max} (Date)	I_{max} (m/day)	Iaverage (m/day)	
Chiang Saen	No Flood event	(from June to Oct 2020)									
		01-Jun	2.27	22-Aug	4.83	82	2.56	No	No	No	Below LTA Level
Luang Prabang	No Flood event	(from June to Oct 2020)									
		01-Jun	8.12	26-Aug	11.87	86	3.75	No	No	No	Below LTA Level
Chiang Khan	No Flood event	(from June to Oct 2020)									
		01-Jun	3.74	22-Aug	11.23	82	7.49	No	No	No	Below LTA Level
Vientiane	No Flood event	(from June to Oct 2020)									
		01-Jun	1.46	23-Aug	8.75	83	7.29	No	No	No	Below LTA Level
Nong Khai	No Flood event	(from June to Oct 2020)									
		01-Jun	1.36	24-Aug	8.84	84	7.48	No	No	No	Below LTA Level
Paksane	No Food event	(from June to Oct 2020)									
		01-Jun	3.36	25-Aug	10.67	85	7.31	No	No	No	Below LTA Level
Nakhon Phanom	No Food event	(from June to Oct 2020)									
		01-Jun	1.82	25-Aug	9.27	85	7.45	No	No	No	Below LTA Level
Thakhet	No Food event	(from June to Oct 2020)									
		01-Jun	3.1	25-Aug	10.37	85	7.27	No	No	No	Below LTA Level
Mukdahan	No Food event	(from June to Oct 2020)									
		01-Jun	2.15	27-Aug	8.79	87	6.64	No	No	No	Below LTA Level
Savannakhet	No Flood event	(from June to Oct 2020)									
		01-Jun	1.16	26-Aug	7.52	86	6.36	No	No	No	Below LTA Level
Khong Chiam	Flood event	(from 10 Oct to Dec 2020)									Tropical Storms LINFA and NANGKA
		22-Oct	8.30	27-Oct	8.05	5	-0.25	21-27/Oct		-0.05	Above Flood level
Pakse	Flood event	(from 10 Oct to Dec 2020)									Tropical Storms LINFA and NANGKA
		12-Oct	6.35	31-Dec	5.88	80	-0.47	12-31/Oct		-0.01	Close to Max level
Stung Treng	Alarm event	(from 10 Oct to Dec 2020)									Tropical Storms LINFA and NANGKA
		20-Oct	8.79	31-Oct	7.26	11	-1.53	20-31/Oct		-0.14	Reached to Max level
Kratie	Alarm event	(from 10 Oct to Dec 2020)									Tropical Storms LINFA and NANGKA
		22-Oct	19.05	31-Oct	16.19	9	-2.86	22-31/Oct		-0.32	Above Max level
Kompong Cham	Alarm event	(from 10 Oct to Dec 2020)									Tropical Storms LINFA and NANGKA
		17-Oct	11.13	31-Oct	10.38	14	-0.75	17-31/Oct		-0.05	Above LTA level
Koh Khel	Alarm event	(from 10 Oct to Dec 2020)									Tropical Storms LINFA and NANGKA
		21-Oct	6.72	31-Oct	6.22	10	-0.50	21-31/Oct		-0.05	Above LTA level

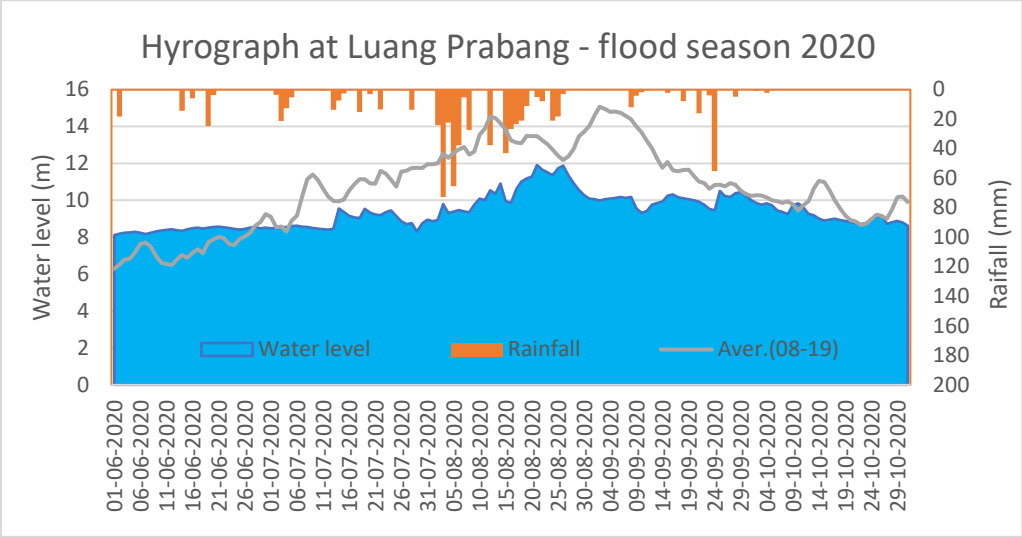
However, observed peak water levels clearly occurred in accordance with the rainfall in October and November due to Tropical Strom of LINFA and NANGKA. As a result, several flooding cases in tributary basins were reported in all four MCs of the LMB following the storm events. Water level in the Upper

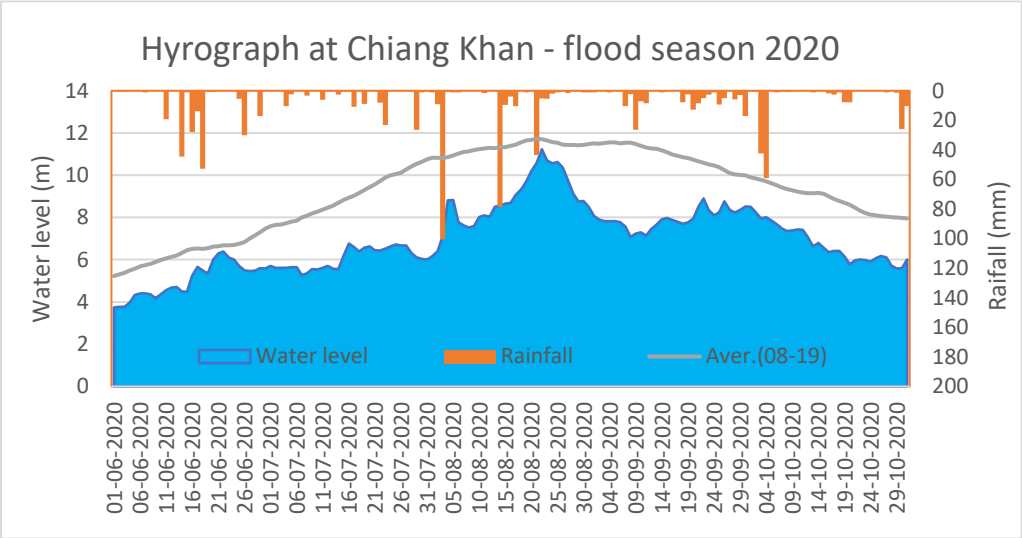
part

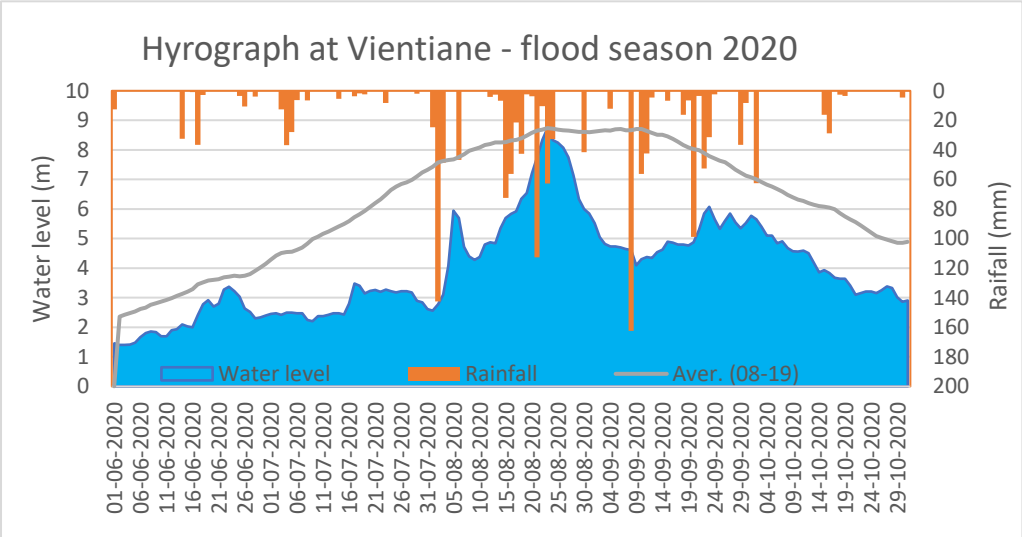
Water levels in the upper part from Chiang Saen to Paksane during the wet season 2020 were considered below their LTAs and even lower than their historical minimum levels. Water levels at Chiang Saen, Chiang Khan, Vientiane, Nong Khai and Paksane were below their historical long-term minimum levels during the wet season 2020.

The trend of water levels from Chiang Sean to Paksane decreased due to the low inflows from upstream and less rainfall from the catchments. In general concept, water level at Chiang Sean relies on the inflow at Jinghong Hydropower Station on Lancang river and its catchment rainfall (Adamson. 2010). Chiang Saen station mostly relied on rainfall and inflows from upstream and tributaries. The Southwest Monsoon season in 2020 began on 18 May 2020 as announced by Thai Meteorological Department (TMD). The total rainfall in May (102 millimetres), June (123 mm) and July (117 mm) was lower than the long-term average values by 33%, 37% and 57%, respectively. But the rainfall in August (232 mm), September (249 mm), and October (260 mm) was as high as the long-term averages or even above them. **Figure 7** shows the water levels hydrograph associated with the rainfall in the upper part of the Mekong River from Chiang Saen to Paksane, compared with their LTA. Water levels from Thailand's Chaing Saen to Lao PDR's Paksane were below their LTAs, during the wet season 2020. The trend of water level at Luang Prabang Station sometimes higher or lower to its historical maximum and LTA values. It has been observed since early 2019. The phenomenon was potentially caused by upstream dam operations, downstream Xayaburi dam, and heavy rainfall in the surrounding areas. Being situated between the upstream (Nam Beng, Nam Ou, Nam Suong, and Nam Khan) and downstream (Xayaburi) hydropower dams, the Luang Prabang station has a unique characteristic as it is influenced by the operations of all its surrounding dams. **Thus, the water level at this station can possibly change very rapidly during the early of wet and dry season.**




Hyrograph at Luang Prabang - flood season 2020
Water level (m)
Raifall (mm)
Water level
Rainfall
Aver.(08-19)


Hyrograph at Chiang Khan - flood season 2020
Water level (m)
Raifall (mm)
Water level
Rainfall
Aver.(08-19)


Hyrograph at Vientiane - flood season 2020
Water level (m)
Raifall (mm)
Water level
Rainfall
Aver. (08-19)

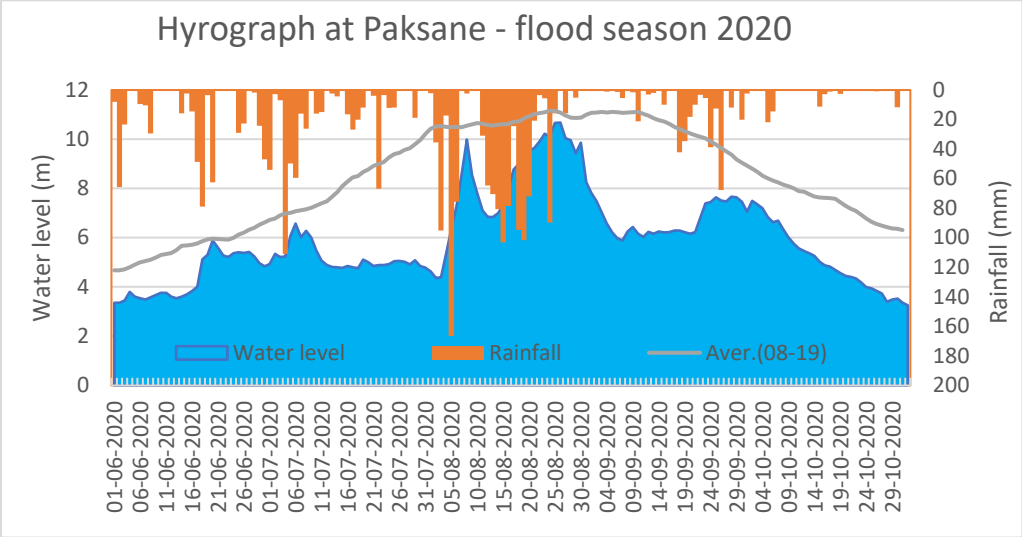


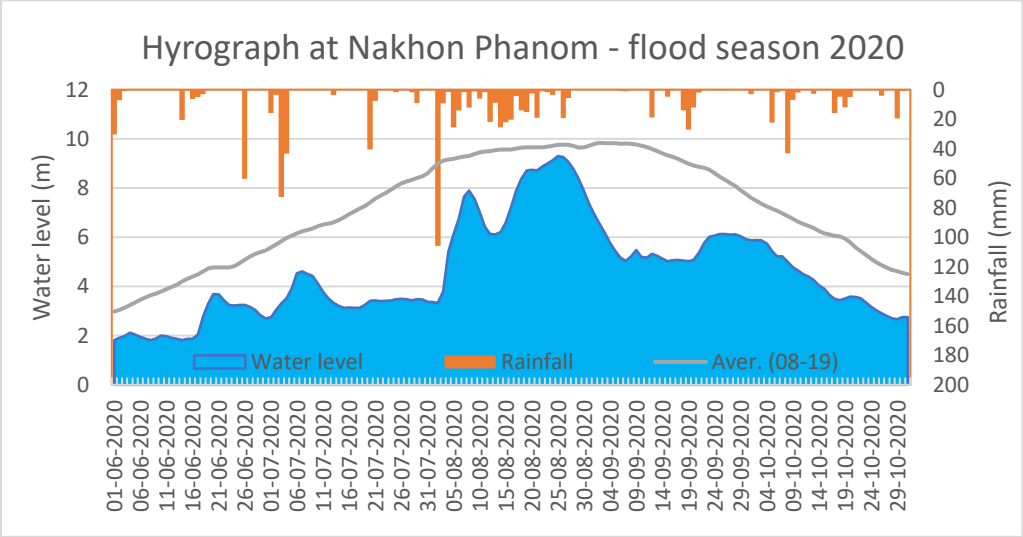
Figure 7: Water level hydrographs with rainfall in the Upper Part

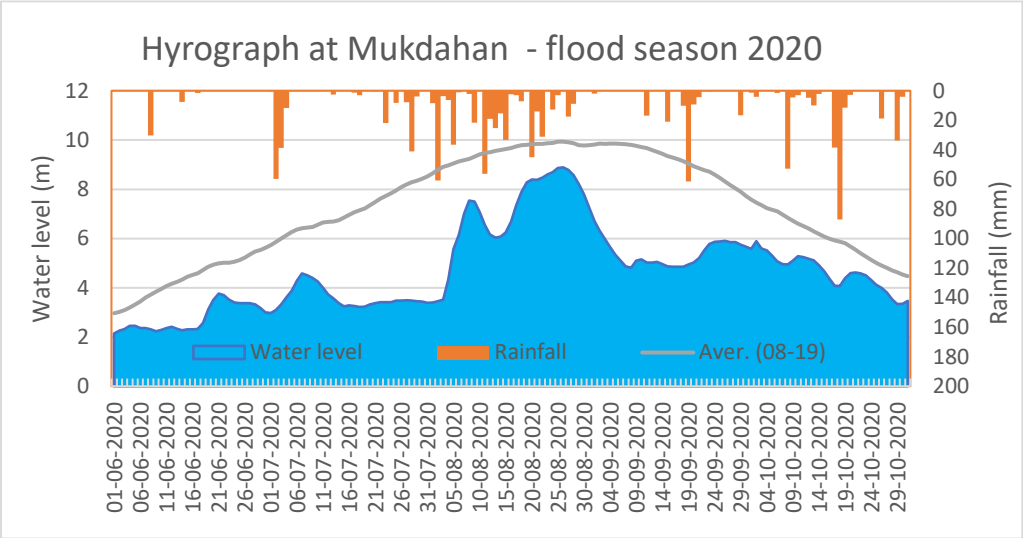
3.1 Water level in the Middle part

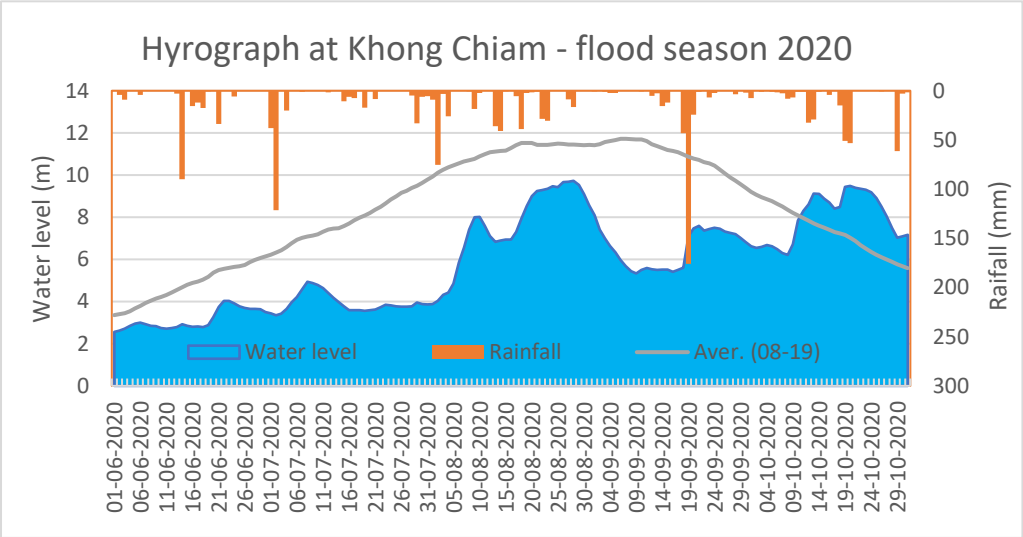
The mainstream flows tended to be lower than the averages throughout the wet season of 2020. By considering the date the river flows surpassed their annual average value as the onset date of the wet season, this 2020 wet season onset date was found to be about three weeks later than the average for all the mainstream stations of the LMB.

Water levels during the wet season in 2020 in the middle part from Nakhon Phanom to Mukdahan stations followed the same trend as upstream stations, in which water levels significantly decreased and stayed below their historical minimum levels (1980-2019).

However, it was observed that water levels at the middle part from Nakhon Phanom to Pakse raised with different levels, in which the stations at Nakhon Phanom to Mukdahan did not reach their LTAs but the water levels at the stations Khong Chiam and Pakse reached over their LTA levels (see **Figure 9**). The flood events happened at Khong Chiam and Pakse from October 10 to November 5, 2020 due to the tropical storms LINFA and NANGKA which brought heavy rainfall during just a short period. The total maximum rainfall in this area reached over 450 mm in early October 2020. However, the total rainfall distribution in the middle part was about 700 mm. **Figure 8** shows the water level hydrographs associated with rainfall in the middle part of the Mekong River from Nakhon Phanom to Pakse in wet season 2020.


Hyrograph at Nakhon Phanom - flood season 2020
Water level (m)
Rainfall (mm)
Water level
Rainfall
Aver. (08-19)


Hyrograph at Mukdahan - flood season 2020
Water level (m)
Rainfall (mm)
Water level
Rainfall
Aver. (08-19)


Hyrograph at Khong Chiam - flood season 2020
Water level (m)
Raifall (mm)
Water level
Rainfall
Aver. (08-19)

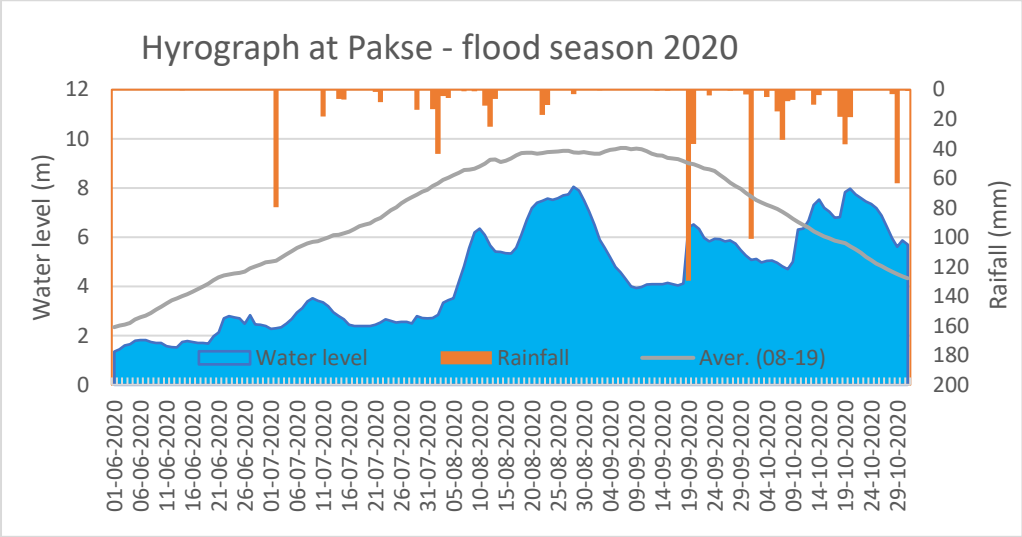
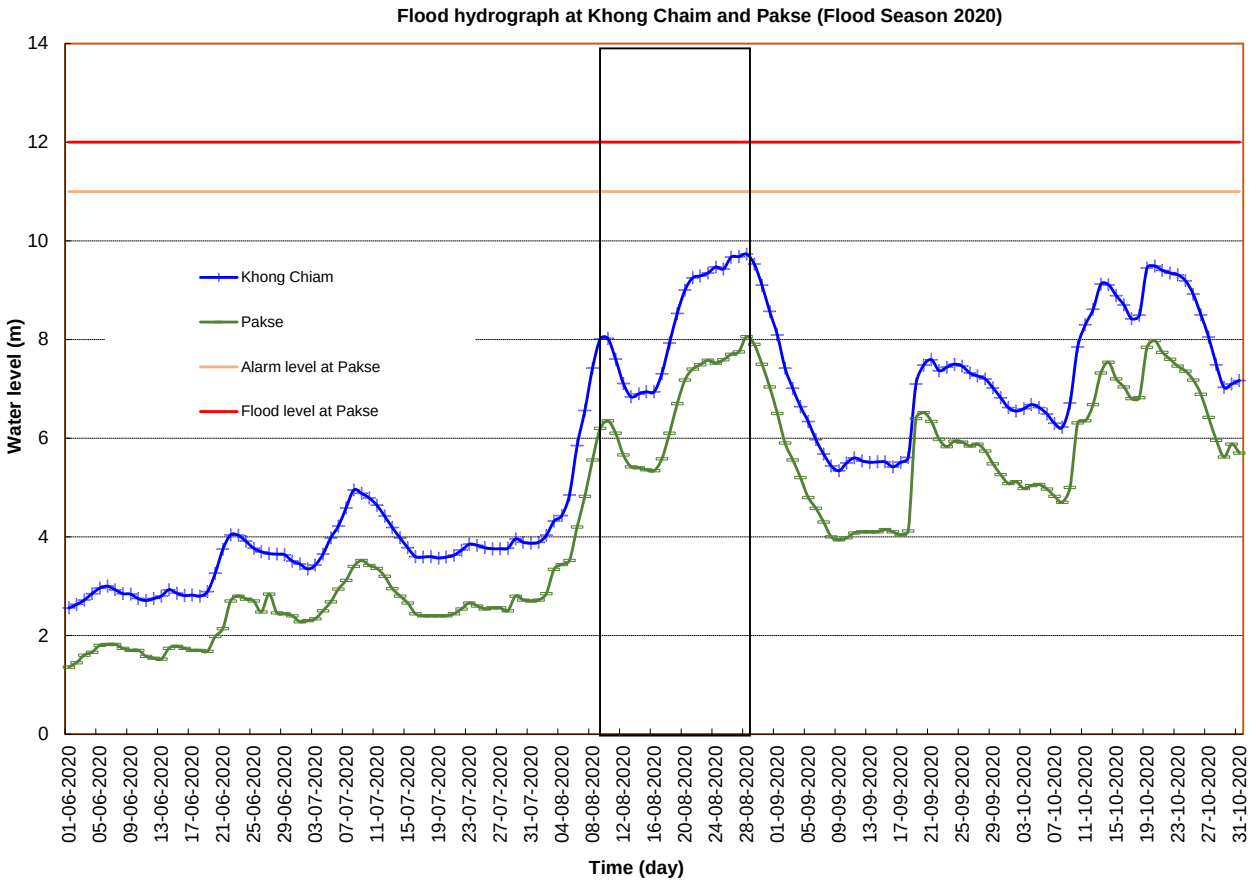


Figure 8: Water level hydrographs with rainfall in the Middel Part



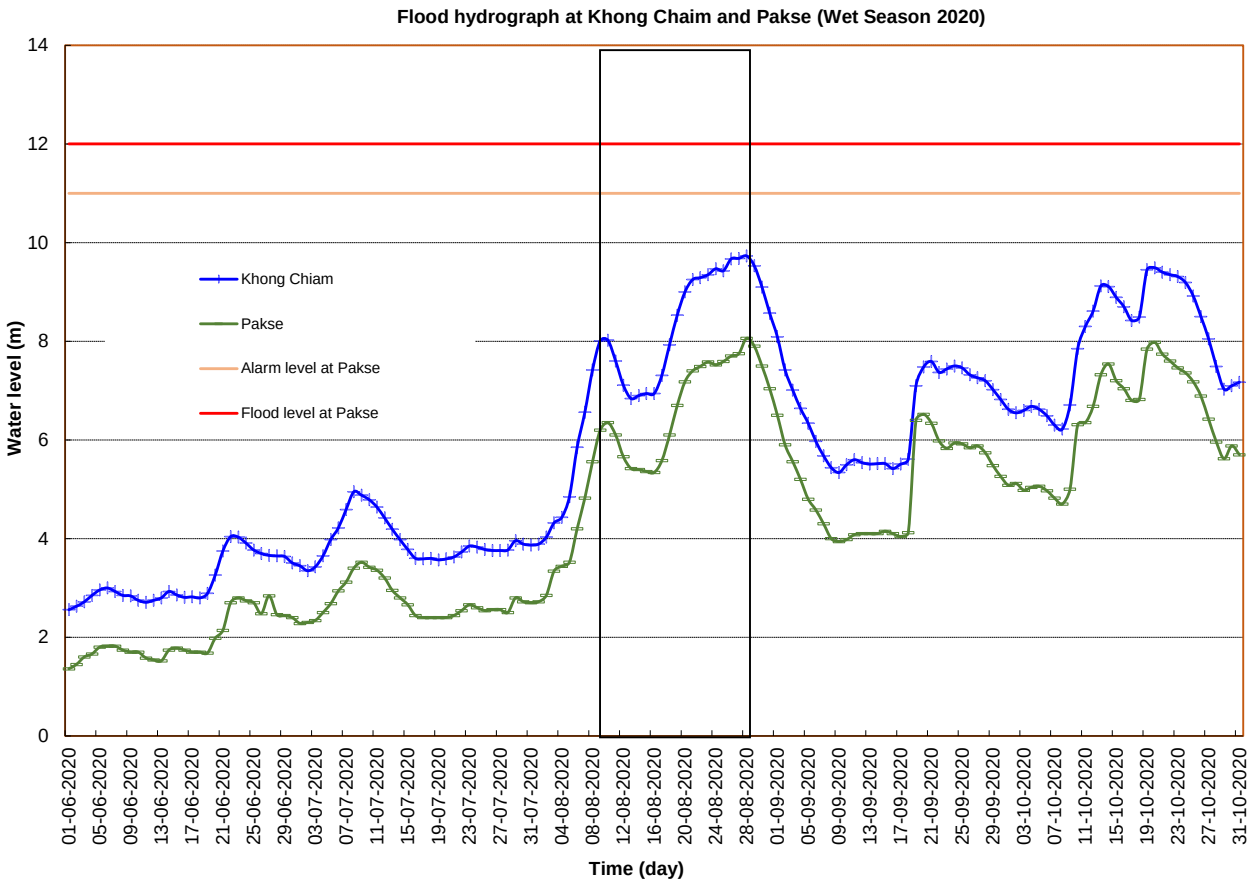


Figure 9: Hydrograph at Khong Chiam and Pakse

3.2 Water Level in the Lower part

From Stung Trend to Kompong Cham, the maximum water levels were considered high from 12 to 27 October 2020, in which water levels at these stations reached over their maximum levels due to heavy rainfall caused by Tropical Storm of LINFA. This was triggered by heavy rainfall in mid October due to the storm LINFA , NANGKA and inflow from Pakse and upstream of the 3S (Sekong, Sesan and Srepok) area.

Figure 10 presents the water level hydrographs and total rainfall and the peak hydrograph from Stung Treng to Kompong Cham. **Table 6** shows the flood event characteristics in the Lower Part from Stung Treng to Koh Khel in Cambodia.

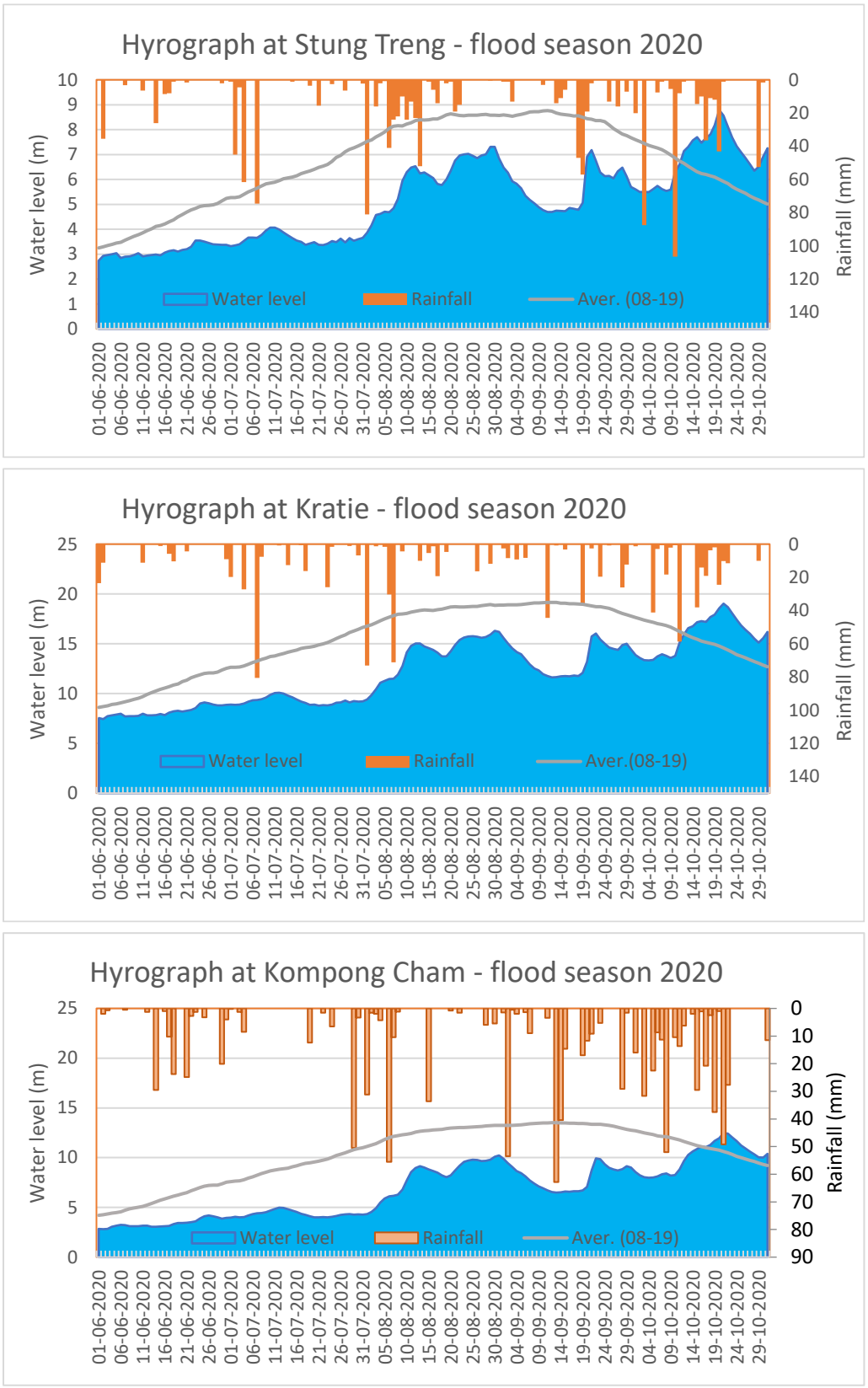


Figure 10: Water level hydrographs with rainfall in the Lower Part (Stung Treng to Kampong Cham)

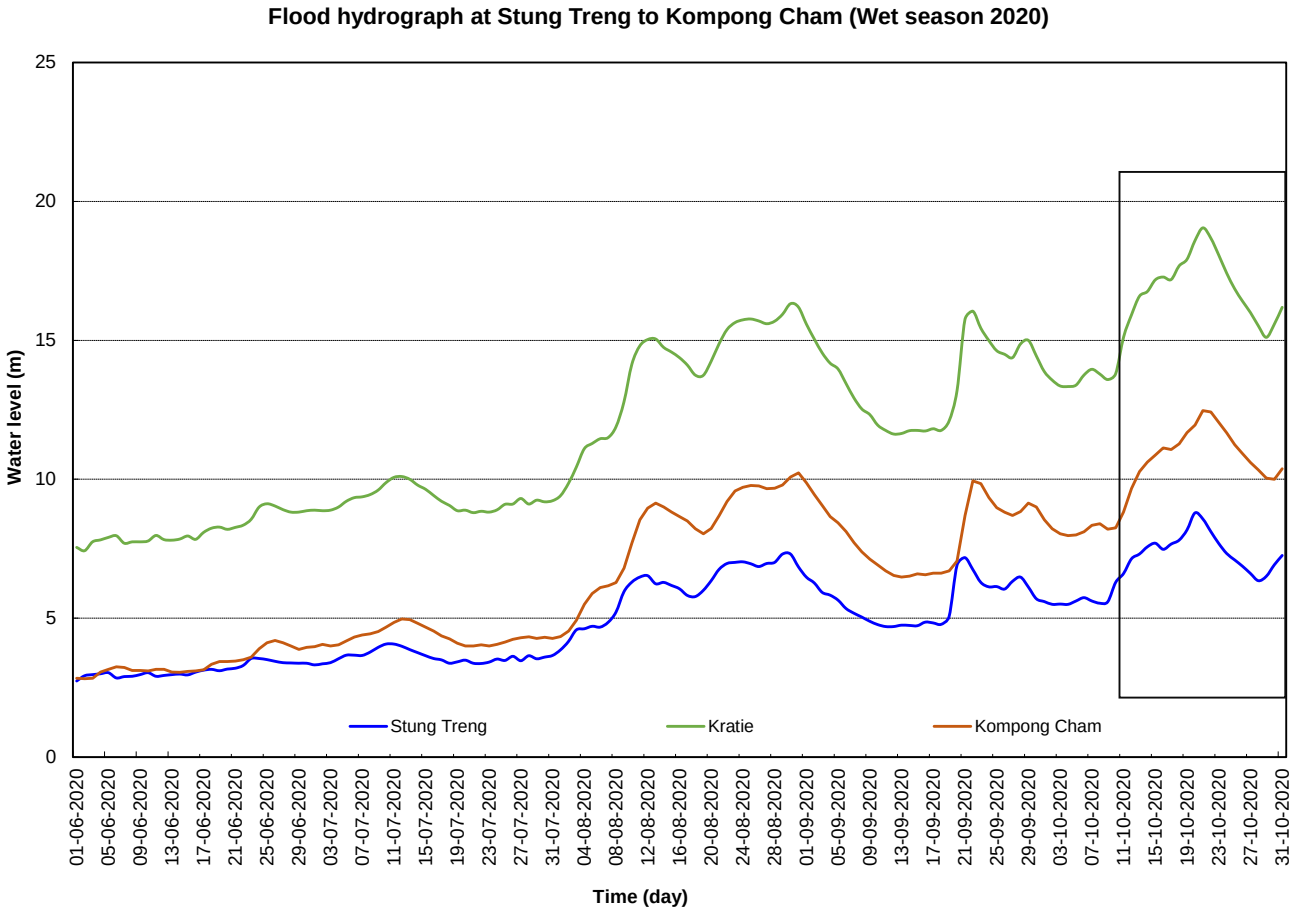
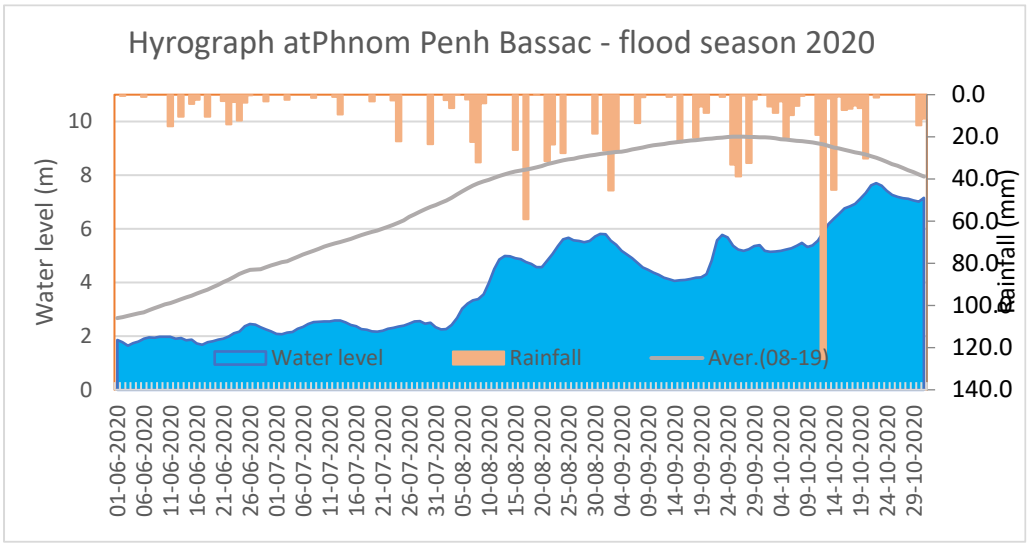
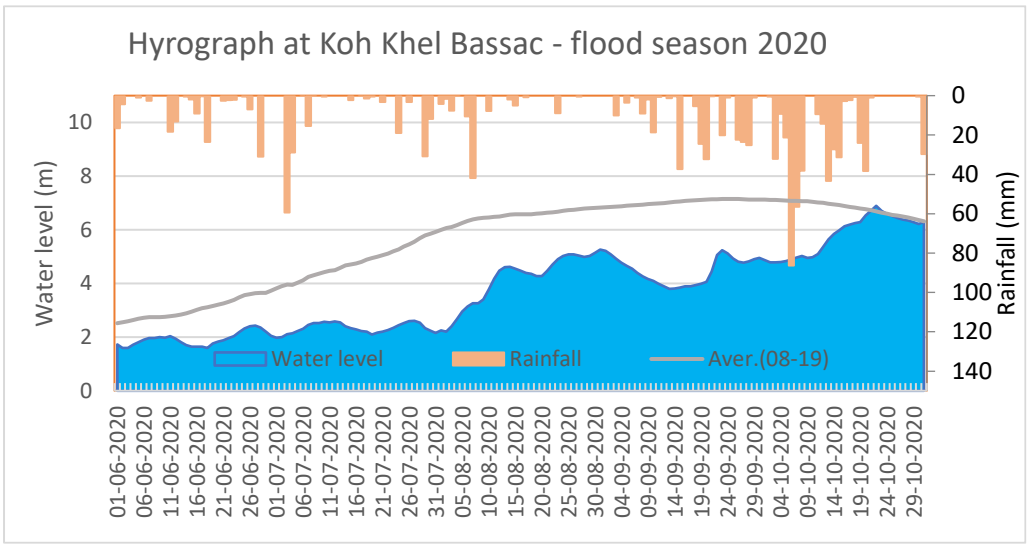
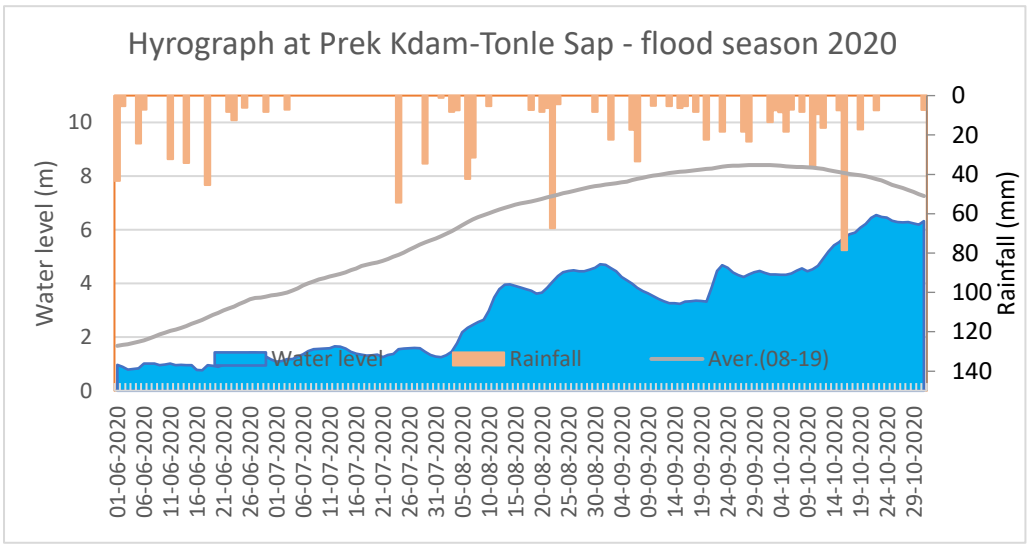


Table 5: Hydrograph from Stung Treng to Phnom Penh Port

Water levels during the wet season 2020 at Phnom Penh Bassac and Koh Khel on the Bassac River, Neak Luong on the Mekong, and Prekdam and Phnom Penh Port on the Tonle Sap River were influenced mostly by inflow and rainfall from upstream. During the wet season, water levels at Phnom Penh Bassac, Prekdam and Neak Luong increased up to their LTAs. At Koh Khel water levels were close to its Alarm Level on 16 October 2020. **Figure 11** shows the water level hydrographs at these stations with the total rainfall from Phnom Penh Bassac, Koh Khel, Prekdam and Neak Luong downstream of the Mekong River in Cambodia. Total maximum rainfall in this area was about 250 mm at the flood peak period by October 2020.


Hyrograph atPhnom Penh Bassac - flood season 2020
Water level (m)
Rainfall (mm)
Water level
Rainfall
Aver.(08-19)


Hyrograph at Koh Khel Bassac - flood season 2020
Water level (m)
Rainfall (mm)
Water level
Rainfall
Aver.(08-19)


Hyrograph at Prek Kdam-Tonle Sap - flood season 2020
Water level (m)
Rainfall (mm)
Water level
Rainfall
Aver.(08-19)

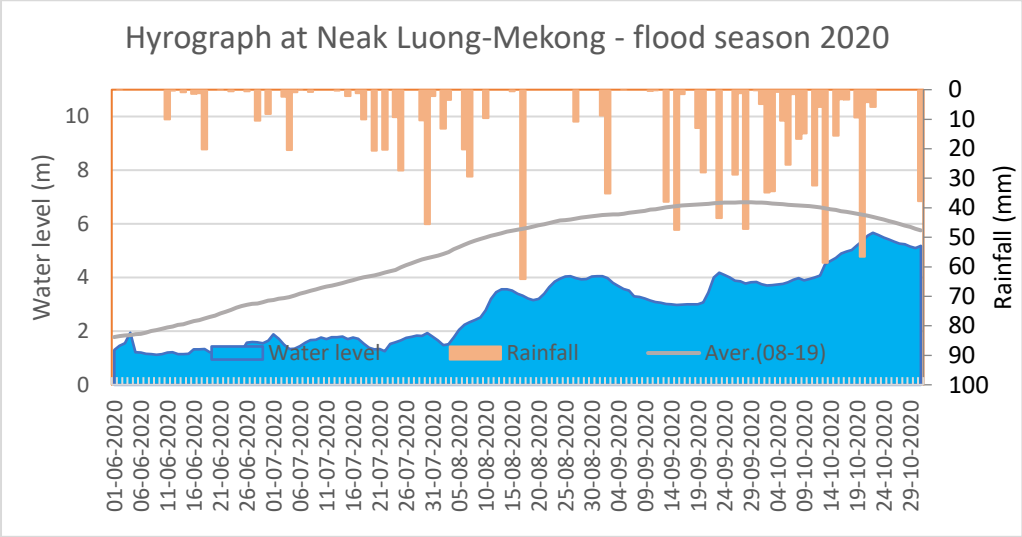


Figure 11: Water level hydrographs with rainfall in the Lower Part

3.3 Water Level in the Mekong Delta

In the Mekong Delta there are two tide cycles per day. Examination of the data shows that there are also two tide cycles per month. At Tan Chau and Chau Doc, the high cycle peaks are just over 1.2 m gauge height while the low cycle peaks are around 0.5 m or slightly lower (FMMP, 2013). It was observed that, at Tan Chau and Chau Doc, there was evidence of tidal influence even at the peak of the wet season in early October. Close examination of the recorded hourly water levels around this time indicated that this influence of the daily tide has an effect of less than 50 mm on the level of the flood peak on a particular day. This means that the highest water levels at Tan Chau and Chau Doc during high flows will be co-incident with the highest tide of the day and will only be about 50 mm higher than the water level co-incident with the lowest tide of the day.

From the beginning of June to October 2020 water levels at these stations were fluctuating below their LTAs but did not follow the same trend as previous years. However, at the end of September water levels at these stations reached Alarm Levels at about 3 m to 3.5 m.

Figure 12 shows the water levels hydrographs with total rainfall at Tan Chau and Chau Doc.

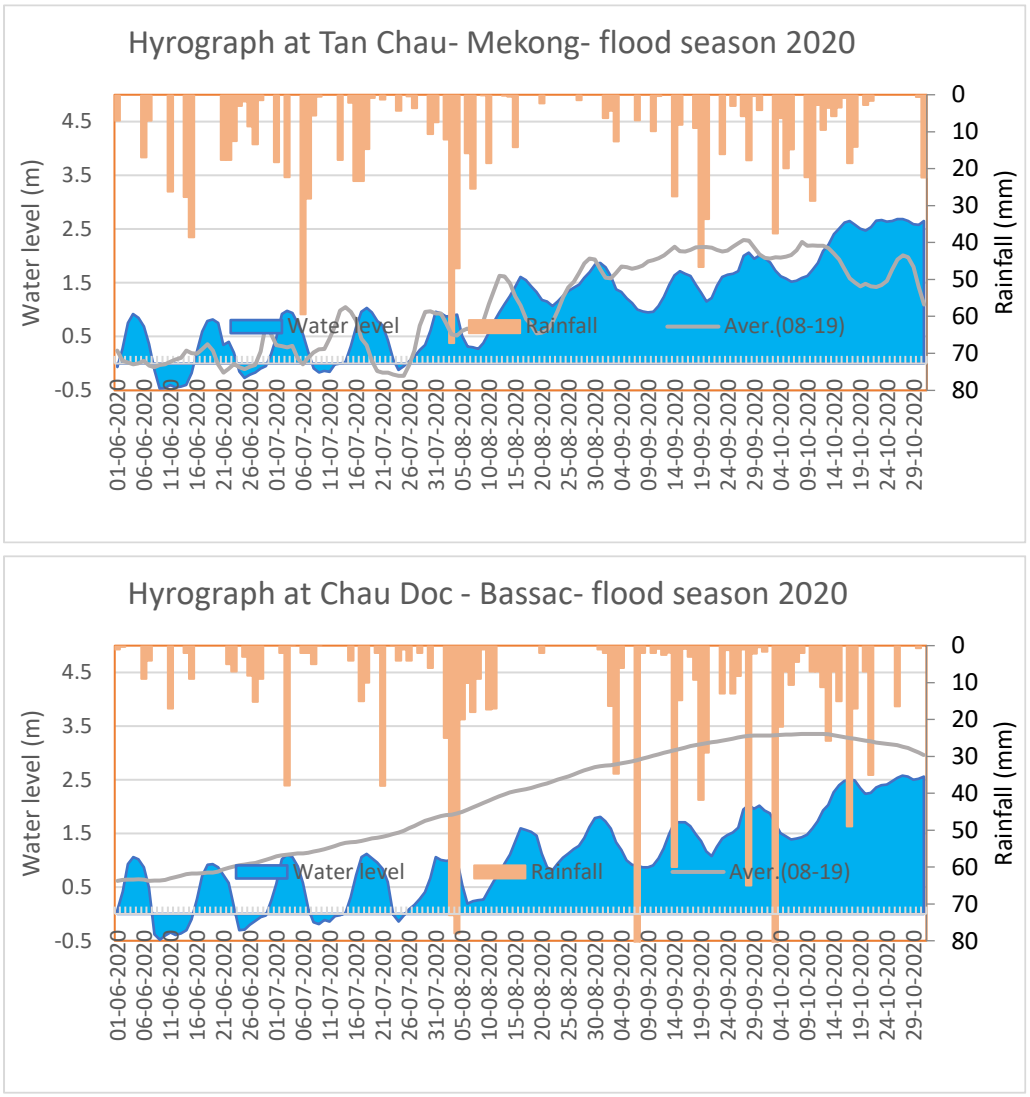


Figure 12: Water level hydrographs with rainfall in the Mekong Delta

4 Data Collection from Line Agencies (LAs)

Hydro-meteorological data collection is a core activity of the Mekong River Commission (MRC) since the establishment of the Mekong Committee in 1957. The daily data collection consists of observed water levels and rainfall data collected from the LAs.

The MRC has established data sharing memorandums of understanding (MoUs) with the principal water resource agencies in each MC. They provide a formal agreement between the MRCS and the MCs for data collection and transfer from the national LA to the RFDMC. The objective of these MoUs is to secure understanding and agreement in principle to deliver from the MCs directly to the RFDMC daily real time and near-real time water level and rainfall data (operational data) to be used in the production of the flood and drought monitoring and forecasting. The data serves as main input for the MRC-RFFS. **Table 6** shows the national LAs of each MC that provided daily and weekly operational data to the MRC.

Table 6: Name of National LAs

Country	National Line Agencies
Cambodia:	Department of Meteorology (DOM), Ministry of Water Resources and Meteorology
Lao PDR:	Department of Meteorology and Hydrology (DMH), Ministry of Natural Resources and Environment
Thailand:	Department of Water Resources (DWR), Ministry of Natural Resources and Environment
Viet Nam:	1.Central Highlands Regional Hydro-Meteorological Center and,
	2. Southern Regional Hydrometeorological Centre (SRHC)

All the gauged manual and automatic water level and rainfall data is collected by the HYDMET system as a data collection software with import/export routines for data transfer from the LAs of each MC to the RFDMC. The data transfer is based on an FTP server. The following data is transferred:

1. **Manual water level** from 63 stations **and rainfall data** from 127 stations are sent by the Line Agencies (LAs) of each MC. Two recordings a day of the water level (7 am and 7 pm) and 24-hr rainfall data are received every day till 9:00 am local time during the wet season starting from 1st June to 31st October and weekly on Monday during dry season.
2. **Automatic water levels and rainfall data** from the MCs are sent automatically every 15-minutes time-steps from 58 stations from the telemetric stations network, 45 stations belong to the Mekong-Hydro Meteorological Cycle Observation System (Mekong-HYCOS) and 13 stations belong to drought project.

Table 7 shows the received operational data via the HYDMET system from each MC and China.

Table 7: Number of Hydro-meteorological stations by MC sending data to RFDMC during wet season 2020

Country	Number of Water level Stations	Number Telemetry Stations
Cambodia	15	12
Lao PDR	26	12
Thailand	13	11
Viet Nam	9	10
China	2	
Total	**63**	**45**

Country	Number of Rainfall Stations
Cambodia	42
Lao PDR	28
Thailand	13
Viet Nam	42
China	2
Total	**127**

Figure 13 and **Figure 14** show the water level and rainfall data stations, sending data to RFDMC via the HYDMET system.

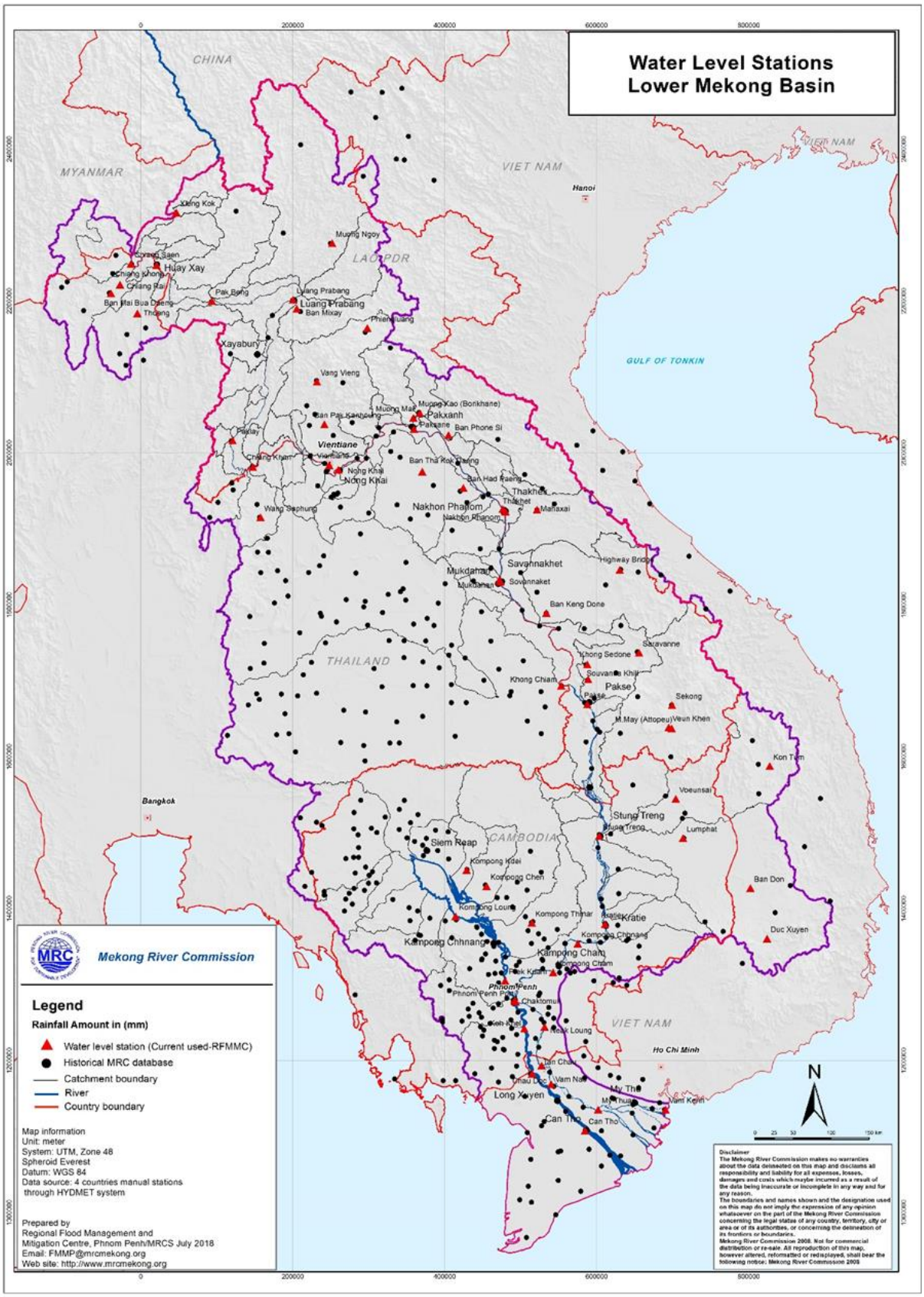


Figure 13: Map of water level stations sending data during wet season 2020

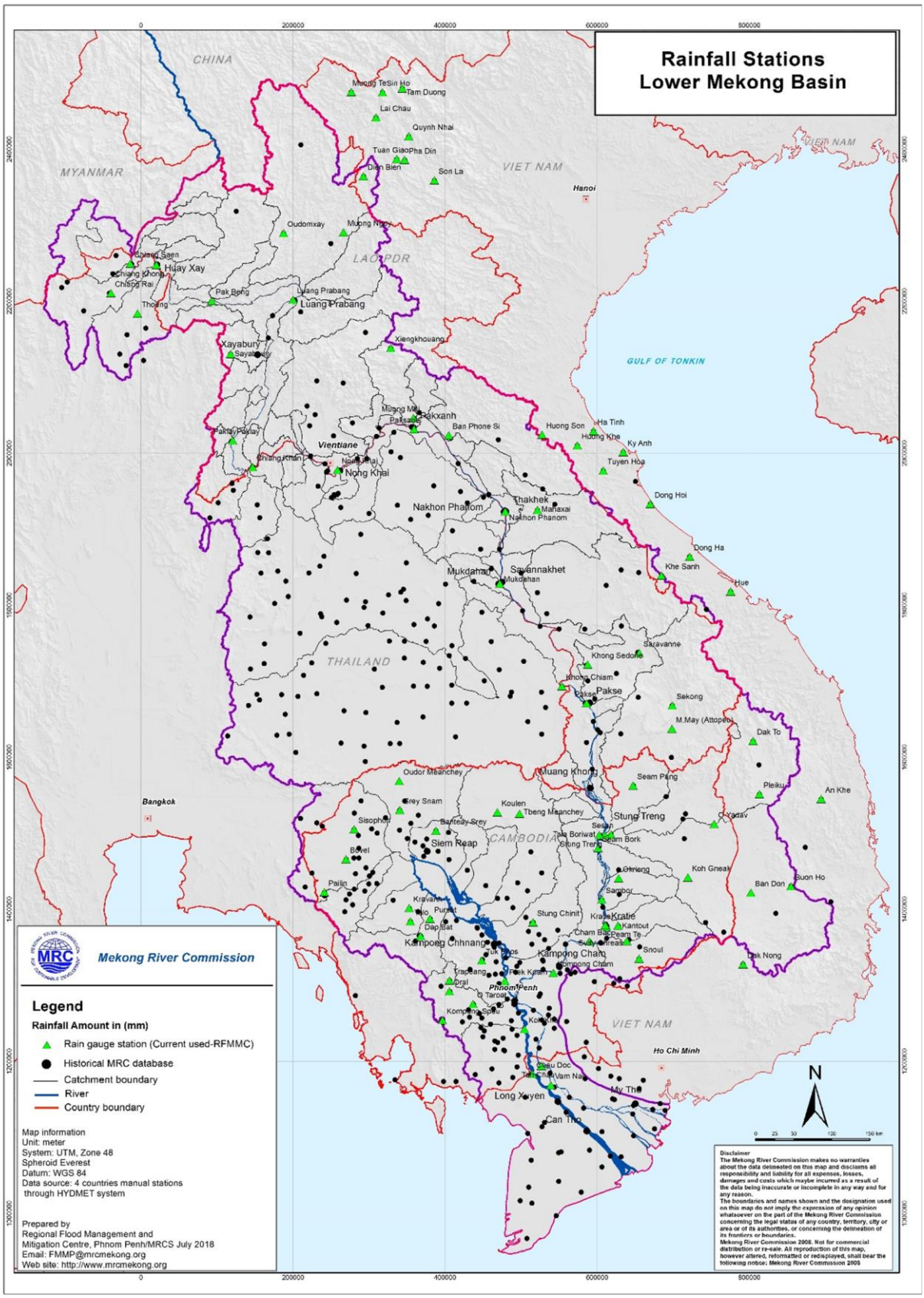


Figure 14: Map of rainfall stations sending data during wet season 2020

As normal practise, hydro-met data should arrive before 09:00 am. However, in 2020 there were some problems of data sending on time due to low internet frequencies at countries levels, software problems and human issues (late data transfer from observers).

4.1 Data transfer from stations to the DHRW data terminal (Cambodia)

Table 8: Number of Late Arrival Data and Missing Data of DHRW

Stations	Total	Missing	On-time(9:00)	Late-time (after 09:00
Stung Treng	153	0	151	2
Kratie	153	0	151	2
Kompong Cham	153	0	151	2
Chaktomuk	153	0	151	2
Phnom Penh Port	153	0	151	2
Neak Loung	153	0	151	2
Koh Khel	153	0	151	2
Prek Kdam	153	0	151	2
Kompong Loung	153	0	151	2
Voeunsai	153	0	150	3
Kompong Chen	153	0	148	5
Kompong Chhnang	153	0	151	2
Kompong Kdei	153	6	149	4
Kompong Thmar	153	0	152	1
Lumphat	153	0	151	2

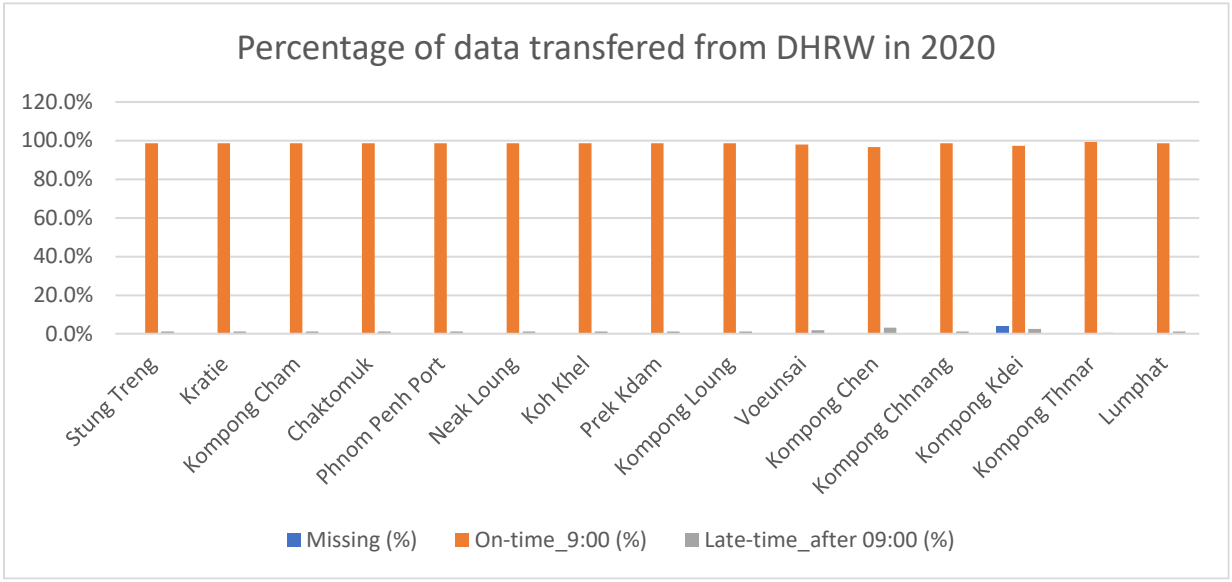


Figure 15: Percentage of Timely Arrival Data (before 8.30 am), Late Arrival Data and Missing Data collected on the Hydmet at DHWR data terminal during wet season 2020 *(histogram)*

4.2 Data transfer from stations to DOM data terminal (Cambodia)

Table 9: Number of Late Arrival Data and Missing Data of DOM

Stations	Total	Missing	On-time(9:00)	Late-time (after 09:00)
Banteay Srey	153	0	141	12
Sadan	153	0	141	12
Sambor	153	0	141	12
Snoul	153	0	141	12
Srey Snam	153	0	141	12
Talo	153	0	141	12
Sre Noy	153	0	141	12
Sisophon	153	0	141	12
Okrieng	153	0	141	12
O Yadav	153	0	141	12
Koh Gneak	153	0	141	12
Koulen	153	0	140	13
Tbeng Meanchey	153	0	140	13
Oudor Meanchey	153	0	140	13
Kompong Speu	153	0	140	13
Oral	153	0	140	13
O Taroat	153	0	140	13
Trapeang	153	0	140	13
Pailin	153	0	140	13
Pursat	153	0	140	13
Mung Russey	153	0	141	12
Dap Bat	153	0	141	12
Kravanh	153	0	141	12
Tuk Phos	153	0	141	12
Stung Chinit	153	0	141	12
Cham Bac	153	0	141	12
Peam Te	153	0	141	12
Svay Chreas	153	0	141	12
Kantout	153	0	141	12
Seam Bork	153	0	141	12
Tala Boriwat	153	0	141	12
Sesan	153	0	141	12
Seam Pang	153	0	141	12
Bovel	153	0	141	12

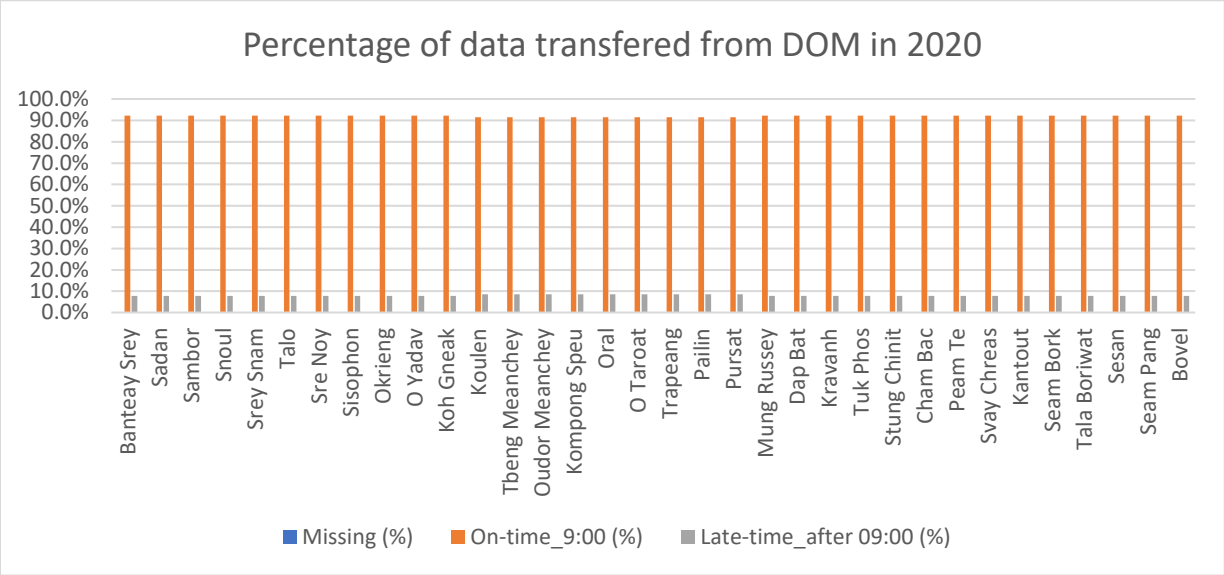


Figure 16: Percentage of Timely Arrival Data (before 8.30 am), Late Arrival Data and Missing Data collected on the Hydmet at DOM data terminal during wet season 2020 *(histogram)*

4.3 Data transfer from stations to the DMH data terminal (Lao PDR)

Table 10: Number of Late Arrival Data and Missing Data of DMH

Stations	Total	Missing	On-time(9:00)	Late-time (after 09:00)
Xieng Kok	153	153	153	0
Pak Beng	153	0	137	16
Luang Prabang	153	0	137	16
Paklay	153	0	135	18
Vientiane	153	0	138	15
Paksane	153	0	137	16
Thakhet	153	0	136	17
Sovannaket	153	0	136	17
Pakse	153	0	134	19
Ban Pak Kanhoung	153	0	136	17
Muong Mai	153	0	137	16
Ban Phone Si	153	0	137	16
Muong Kao (Borikhane)	153	0	137	16
Mahaxai	153	86	136	17
Khong Sedone	153	0	137	16
Saravanne	153	4	138	15
Veun Khen	153	0	132	21
M.May (Attopeu)	153	0	132	21
Muong Ngoy	153	0	137	16
Ban Mixay	153	153	153	0
Sayaboury	153	153	153	0
Vang Vieng	153	153	153	0
Phiengluang	153	4	134	19
Oudomxay	153	153	153	0
Moung Namtha	153	153	153	0
Xiengkhouang	153	153	153	0
Ban Keng Done	153	153	153	0
Highway Bridge	153	0	133	20
Ban Kengkok	153	60	140	13
Souvanna Khill	153	11	138	15
Muong Techpon	153	153	153	0
Sekong	153	0	138	15

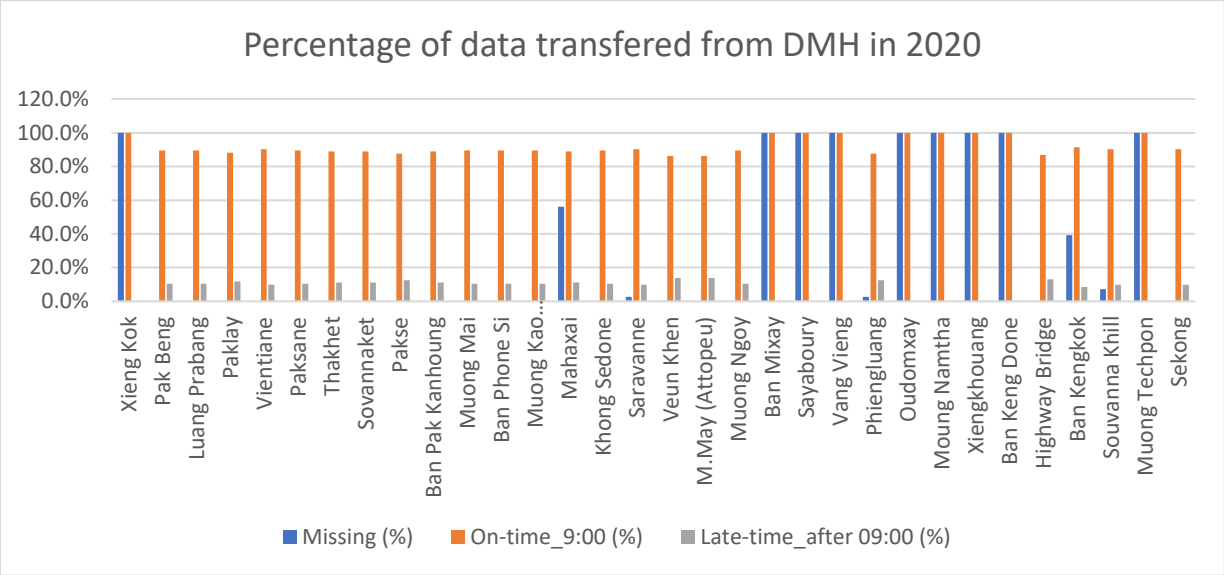


Figure 17: Percentage of Timely Arrival Data (before 8.30 am), Late Arrival Data and Missing Data collected on the Hydmet at DMH data terminal during wet season 2020 *(histogram)*

4.4 Data transfer from stations to the DWR data terminal (Thailand)

Table 11: Number of Late Arrival Data and Missing Data of DWR

Stations	Total	Missing	On-time(9:00)	Late-time (after 09:00)
Chiang Saen	153	0	151	2
Chiang Khong	153	0	151	2
Chiang Khan	153	0	151	2
Nong Khai	153	0	151	2
Nakhon Phanom	153	0	151	2
Mukdahan	153	0	151	2
Khong Chiam	153	0	151	2
Ban Mai Bua Daeng	153	0	148	5
Thoeng	153	0	148	5
Wang Saphung	153	0	151	2
Ban Tha Kok Daeng	153	92	120	33
Ban Had Paeng	153	92	120	33
Chiang Rai	153	0	148	5

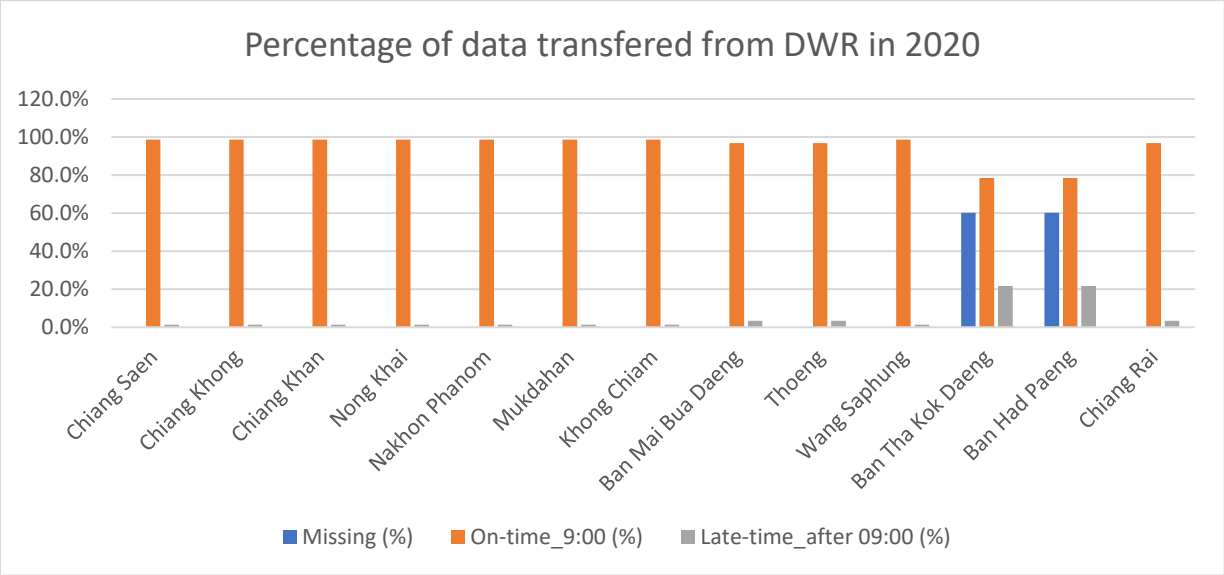


Figure 18: Percentage of Timely Arrival Data (before 8.30 am), Late Arrival Data and Missing Data collected on the Hydmet at DWR data terminal during wet season 2020

4.5 Data transfer from stations to the SRHMC data terminal (Viet Nam)

Table 12: Number of Late Arrival Data and Missing Data of SRHMC

Stations	Total	Missing	On-time(9:00)	Late-time (after 09:00)
Tan Chau	153	0	151	2
Chau Doc	153	0	152	1
Vam Nao	153	0	151	2
My Thuan	153	0	151	2
Can Tho	153	0	152	1
Vam Kenh	153	0	152	1

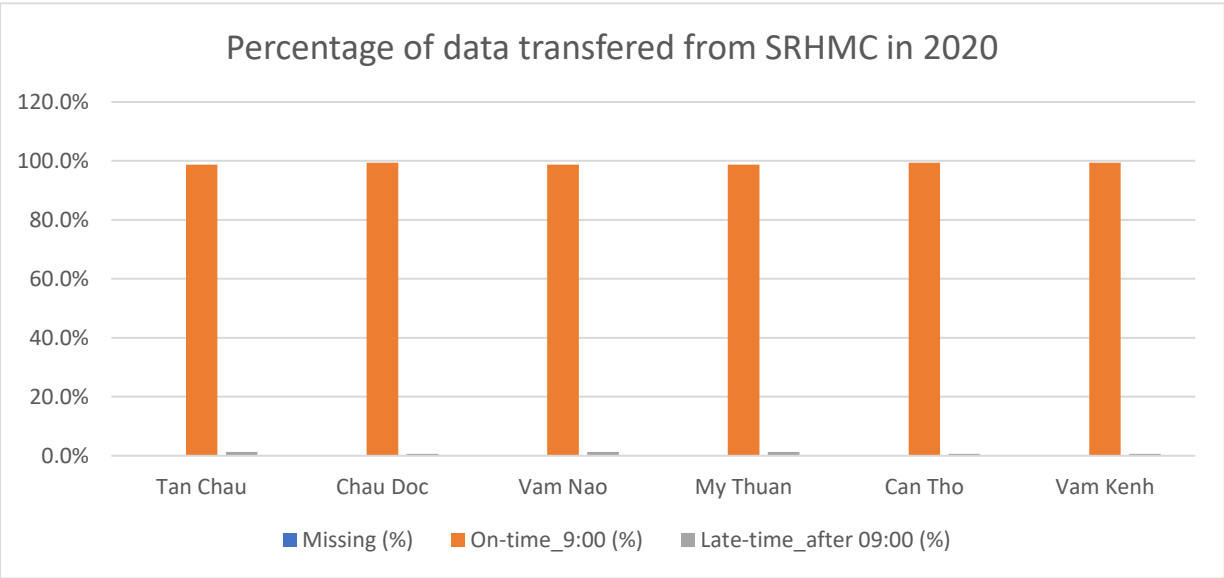


Figure 19: Percentage of Timely Arrival Data (before 8.30 am), Late Arrival Data and Missing Data collected on the Hydmet at SRHMC data terminal during wet season 2020 *(histogram)*

4.6 Data transfer from stations to the Hydro-Meteorological Service (HMS) data terminal (Viet Nam)

Table 13: Number of Late Arrival Data and Missing Data of HMS

Stations	Total	Missing	On-time(9:00)	Late-time (after 09:00)
Ban Don	153	0	148	5
Kon Tum	153	0	148	5
Duc Xuyen	153	0	148	5
Muong Te	153	0	148	5
Tam Duong	153	0	148	5
Sin Ho	153	0	148	5
Lai Chau	153	0	148	5
Tuan Giao	153	0	148	5
Dien Bien	153	0	148	5
Quynh Nhai	153	0	148	5
Khe Sanh	153	0	148	5
Son La	153	0	148	5
Huong Khe	153	0	148	5
Ha Tinh	153	0	148	5
Ky Anh	153	0	148	5
Tuyen Hoa	153	0	148	5
Dong Hoi	153	0	148	5
Dong Ha	153	0	148	5
A Luoi	153	0	148	5
Hue	153	0	148	5
Dak To	153	0	148	5
Pleiku	153	0	148	5
An Khe	153	0	148	5
Ayunpa	153	0	148	5
Buon Me Thuoc	153	0	148	5
Mdrak	153	0	148	5
Dak Nong	153	0	148	5
Buon Ho	153	0	148	5
Huong Son	153	0	148	5
Pha Din	153	0	148	5
Yen Chau	153	0	148	5
Mai Chau	153	0	148	5
Tuong Duong	153	0	148	5
Con Cuong	153	6	148	5
Tay Ninh	153	6	148	5
Phuoc Long	153	6	148	5
Dong Xoai	153	6	148	5
Ialy	153	6	148	5

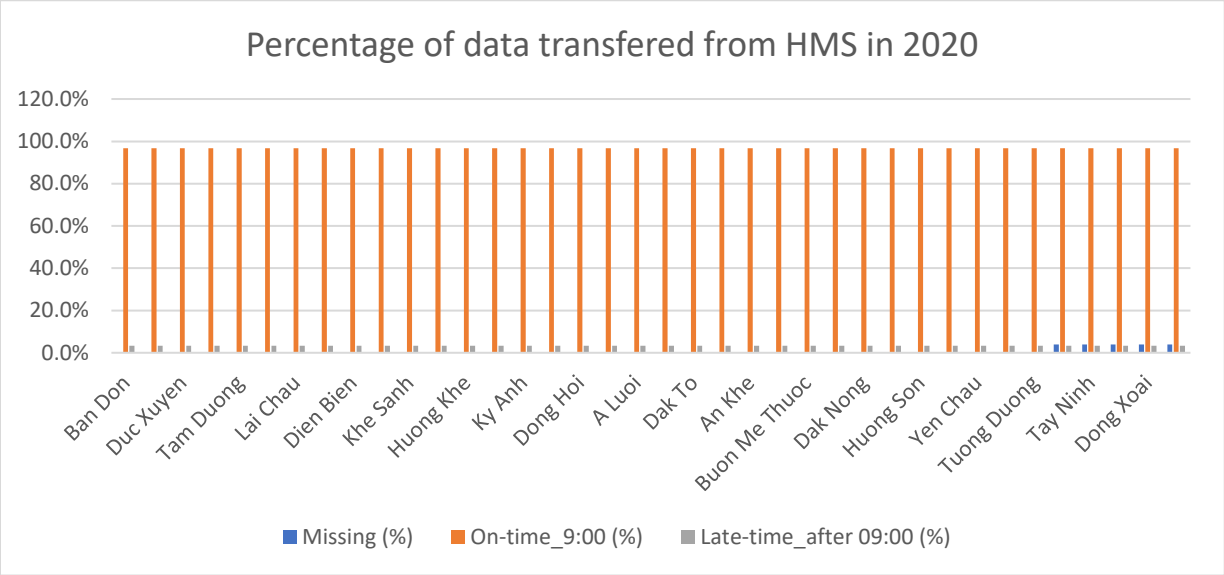


Figure 20: Percentage of Timely Arrival Data (before 8.30 am), Late Arrival Data and Missing Data collected on the Hydmet at HMS data terminal during wet season 2020 *(histogram)*

5 Performance of the River Flood Forecasting System (MRC-RFFS)

This chapter analysis the performance of the MRC-RFFS and the accuracy of the River Flood Forecasts (RFFs) issued by the RFDMC in the wet season 2020.

5.1 Analysis of Dissemination

The performance indicators for timely dissemination of the daily bulletin (see **Table 14** and **Figure 21** to **Figure 23.** Table 14: Overview of performance indicators from Jun to Oct 2020 show that the flood bulletins, containing flood situation information, were disseminated timely to the registered LAs, MRC website, and other interested stakeholders around 10:30 am. This corresponds to the defined timeframe of the operational procedures.

However, sometimes the bulletin was disseminated later than 10:30 am due to three main factors:

- Late transfer and incomplete data from LA's during wet season due to human issue (observers, focal point for data collection and transferring),
- Internet network cut-off at specific areas in the MCs and tool download (HYDMET) was stuck or stood still,
- Critical weather situations in the LMB, flow influenced by hydropower operation and or the significant tidal effect in the Mekong delta resulted in difficulties for the forecaster-in-charge to conduct the analysis and adjustment of the forecast results on time, leading to the late bulletin dissemination.

Table 14: Overview of performance indicators from Jun to Oct 2020

	FF time sent				Arrival time of input data								Missing data (number-mainstream and trib.st.)							
2020	FF completed and sent (time)	Stations without forecast	FF2 completed and sent (time)	Weather data available (time)	NOAA data/2dataset	China	Cambodia - DHRW	Cambodia - DOM	Lao PDR - DMH	Thailand - DWR	Viet Nam - SRHMC	Viet Nam - HMS	NOAA data/2dataset	China/2	Cambodia - DHRW/15	Cambodia - DOM/34	Lao PDR - DMH/32	Thailand - DWR/13	Viet Nam - SRHMC/6	Viet Nam - HMS/39
June	10:08	0	-	-	08:15	07:10	07:20	07:51	08:32	08:32	07:01	08:19	0	0	0	0	13	2	0	0
July	10:10	0	-	-	08:15	07:10	07:29	08:29	08:30	08:42	07:01	08:09	0	0	0	0	11	2	0	0
August	10:10	0	-	-	08:15	07:10	06:12	08:13	08:34	08:40	07:01	08:07	0	0	0	0	10	2	0	0
September	10:03	0	-	-	08:15	07:10	07:19	07:18	08:32	08:19	07:01	08:09	0	0	0	0	19	2	0	0
October	09:49	0	-	-	08:15	07:10	07:03	07:43	08:35	08:06	07:02	08:22	0	0	0	0	10	2	0	0

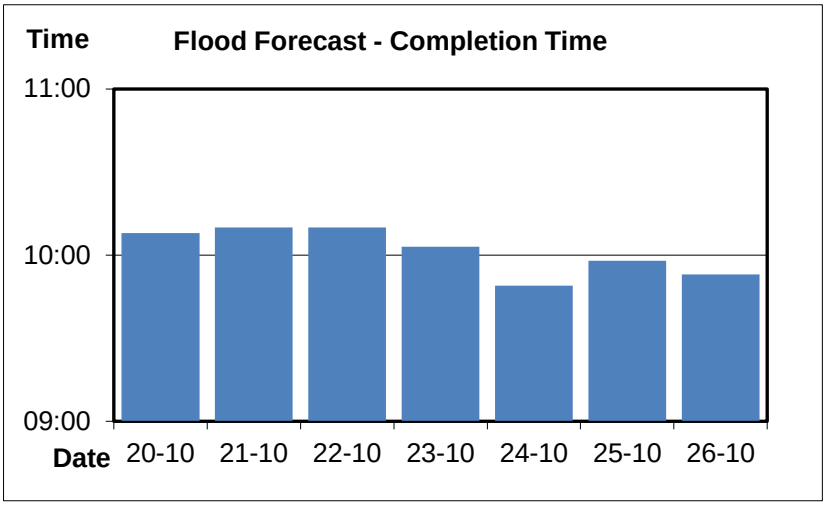


Figure 21: Flood forecast completion time from Jun to Oct 2020

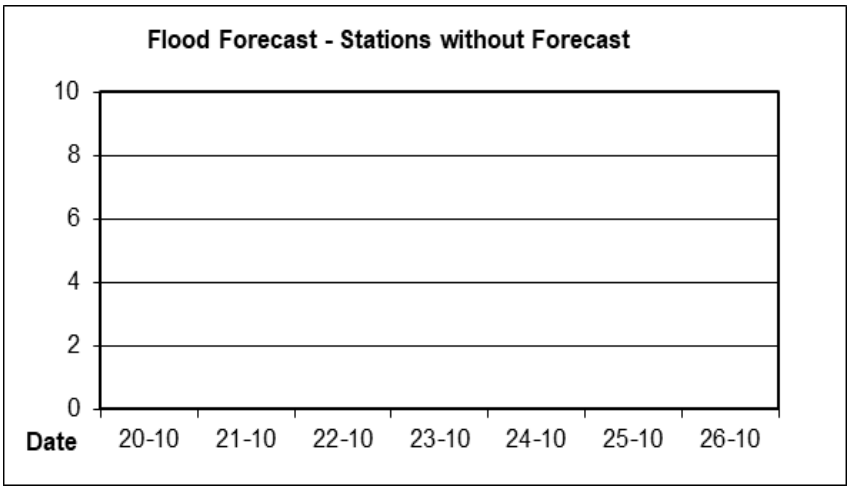


Figure 22: Number of flood forecast stations without forecast from Jun to Oct 2020

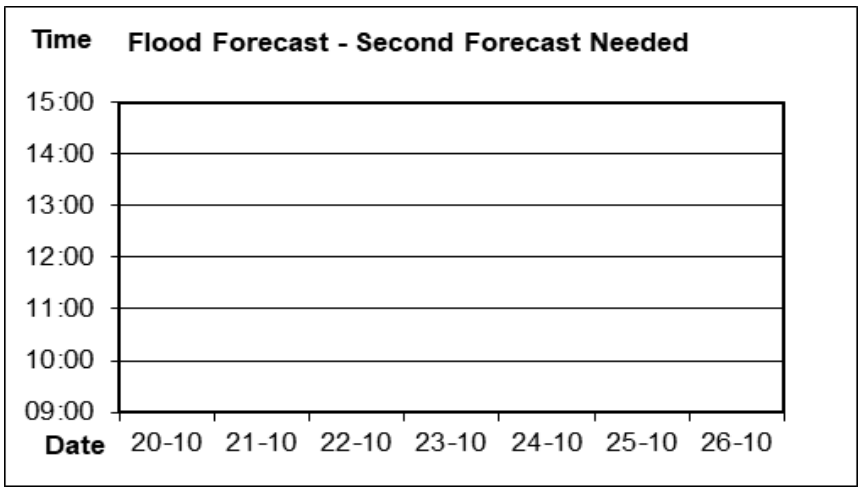


Figure 23: Number of flood forecast stations where second forecast was needed from Jun to Oct 2020

5.2 Analysis of the Accuracy of the River Flood Forecast (RFF)

Accuracy is an important factor to establish the quality of the forecast results, and is described here as the Mean Absolut Difference (MAD) in centimetres between the approved results of the MRC-RFFS ('adjusted' or 'not adjusted' by the Flood Forecaster in charge) and the measured and reported water levels by the LAs. The 'adjustment' by the Flood Forecaster in charge takes into consideration known biases in input data and the knowledge of the response of the model system and the hydrology of the LMB.

5.2.1 General analysis of the Wet Season 2020

Figure 24 shows in a graphic the average flood forecasting accuracy for the wet season 2020 for all key stations and forecasting lead-times.

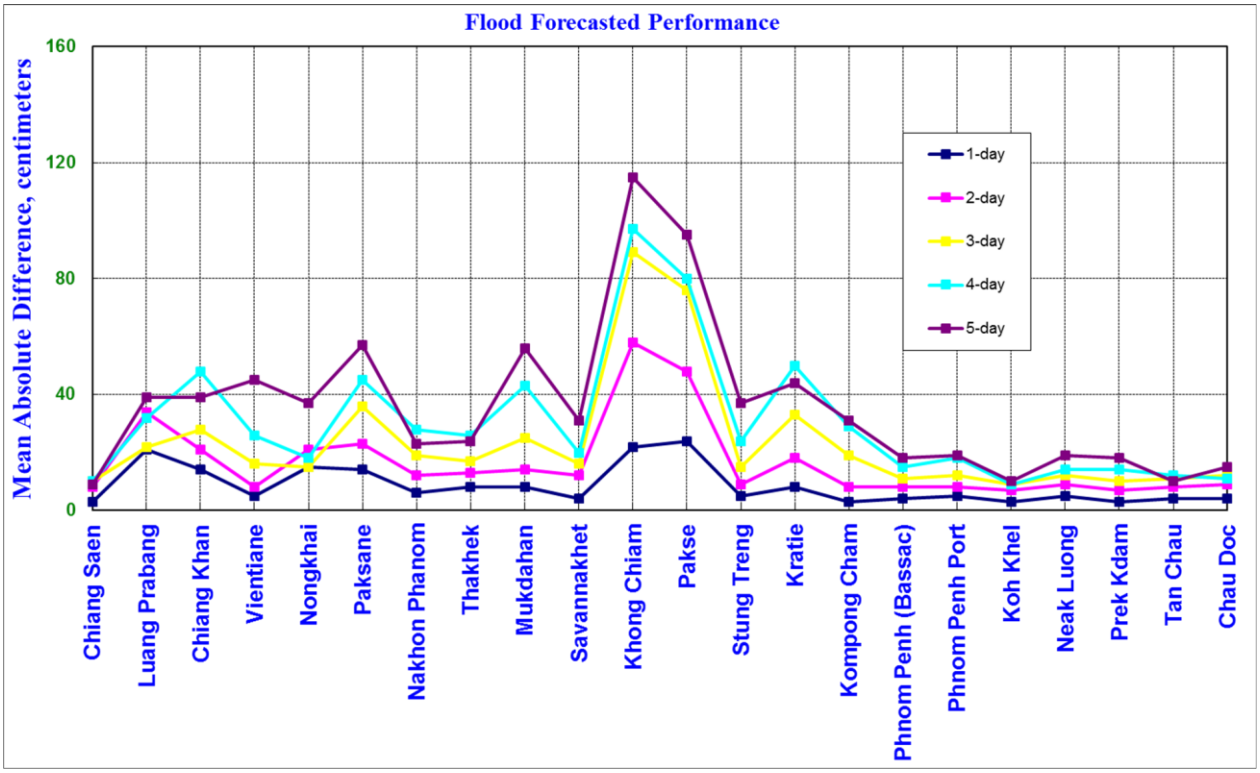


Figure 24: Average RFF accuracy along the Mekong mainstream from Jun to Oct 2020

In general, the accuracy was 'good' during the wet season 2020 for all forecast lead times. However, the accuracy for 3, 4 and 5 day of forecasted values was considered overestimated for the stations at Khong Chiam to Pakse and the Tidal stations of Tan Chau and Chau Doc. Forecast errors for 3 - 5-day lead times were less than 1.20 m for Khong Chiam station, while at the day 4 and day 5 from Chaing Sean to Sannakhet stations the were roughly from 0.40 to 0.50 m. The part of the LMB from Stung Treng in Cambodia to Tan Chau and Chau Doc in Vietnam, the forecasted day 4 and day 5 were from 0.30 m to 0.40 m which considered very good.

Accuracy is especially influenced by heavy rainfall caused by storms and hydropower operations from upstream (Xayaburi), tributaries inflows and the lower part of the Mekong floodplain.

Luang Prabang, Chiang Khan and Paksane stations have been affected by hydropower operations of Xayaburi and Nam Nguem (water retention and release). Rainfall always accumulates at this spot, which could cause rapid high-water levels.

Rapid fluctuations of water levels at Tan Chau and Chau Doc stations due to daily tidal effects of the sea in the Mekong Delta make accuracy challenging at these stations.

In order to assess the quality of the results, a performance indicator, so called benchmark, was implemented at the RFDMC since 2009 The defined indicators vary between forecasting stations and lead time. The numeric values of the benchmark are presented in **Table 15**.

Table 15: Benchmark for RFF accuracy from 2009 (MAD in m)

Station		Chiang Saen	Chiang Khong	Luang Prabang.	Chiang Khan	Vientiane	Nong Khai	Paksane	Nakhon Phanom	Thakhek	Savannakhet	Mukdahan	Khong Chiam	Pakse	StungTreng	Kratie	Kampong Cham	Phnom Penh Port	Prek Kdam	Neak Luong	Tan Chau	Chaktomouk	Koh Khel	Chau Doc
ne (days)	1	0.25	0.25	0.25	0.25	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	2	0.5	0.5	0.5	0.5	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	3	0.5	0.5	0.5	0.5	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	4	0.75	0.75	0.75	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.25	0.25	0.25	0.1	0.1	0.1	0.1
	5	0.75	0.75	0.75	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.25	0.25	0.25	0.25	0.25	0.25	0.25

The forecast achievement in wet season 2020 in MAD is presented in **Table 16** and indicated in % of days that the forecast at a particular station for a lead-time is successful against the respective benchmark are presented in **Table 17**.

Table 16: Average RFF accuracy from Jun to Oct 2020 (MAD in cm)

2020	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	57.1	57.1	71.4	57.1	57.1	57.1	42.9	71.4	71.4	71.4	71.4	71.4	71.4	57.1	57.1	28.6	57.1	57.1	57.1	57.1	57.1	42.9	***59.1***
2-day	50.0	66.7	66.7	66.7	33.3	33.3	50.0	50.0	66.7	83.3	66.7	66.7	66.7	50.0	66.7	83.3	83.3	50.0	50.0	66.7	66.7	50.0	***60.6***
3-day	40.0	60.0	60.0	80.0	40.0	60.0	60.0	60.0	60.0	80.0	60.0	60.0	60.0	60.0	60.0	80.0	80.0	40.0	80.0	40.0	60.0	60.0	***60.9***
4-day	50.0	50.0	50.0	75.0	50.0	50.0	50.0	50.0	75.0	75.0	75.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	***54.5***
5-day	66.7	66.7	66.7	33.3	66.7	66.7	66.7	66.7	66.7	66.7	66.7	66.7	33.3	33.3	33.3	33.3	33.3	33.3	33.3	33.3	66.7	33.3	***51.5***

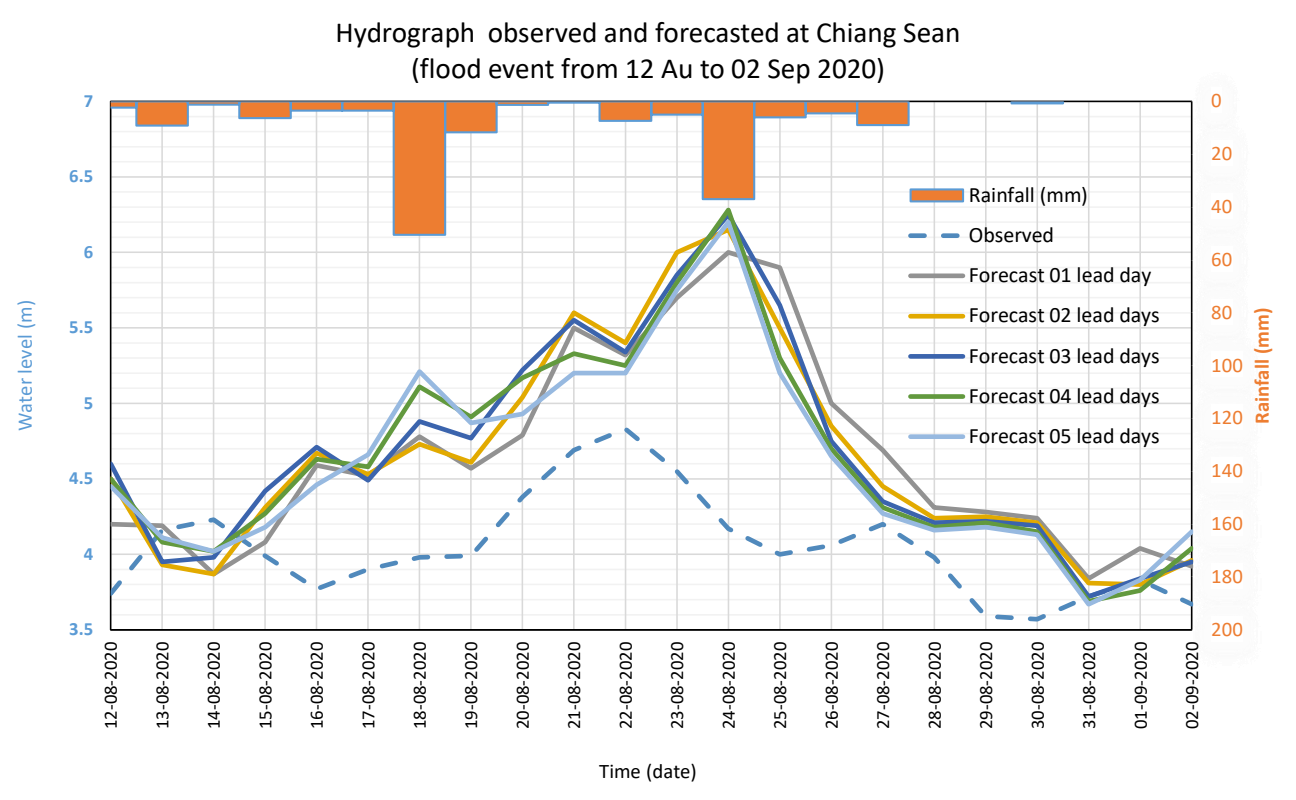
Table 17: Average forecast achievement wet season 2020 based on the benchmark (Unit in %)

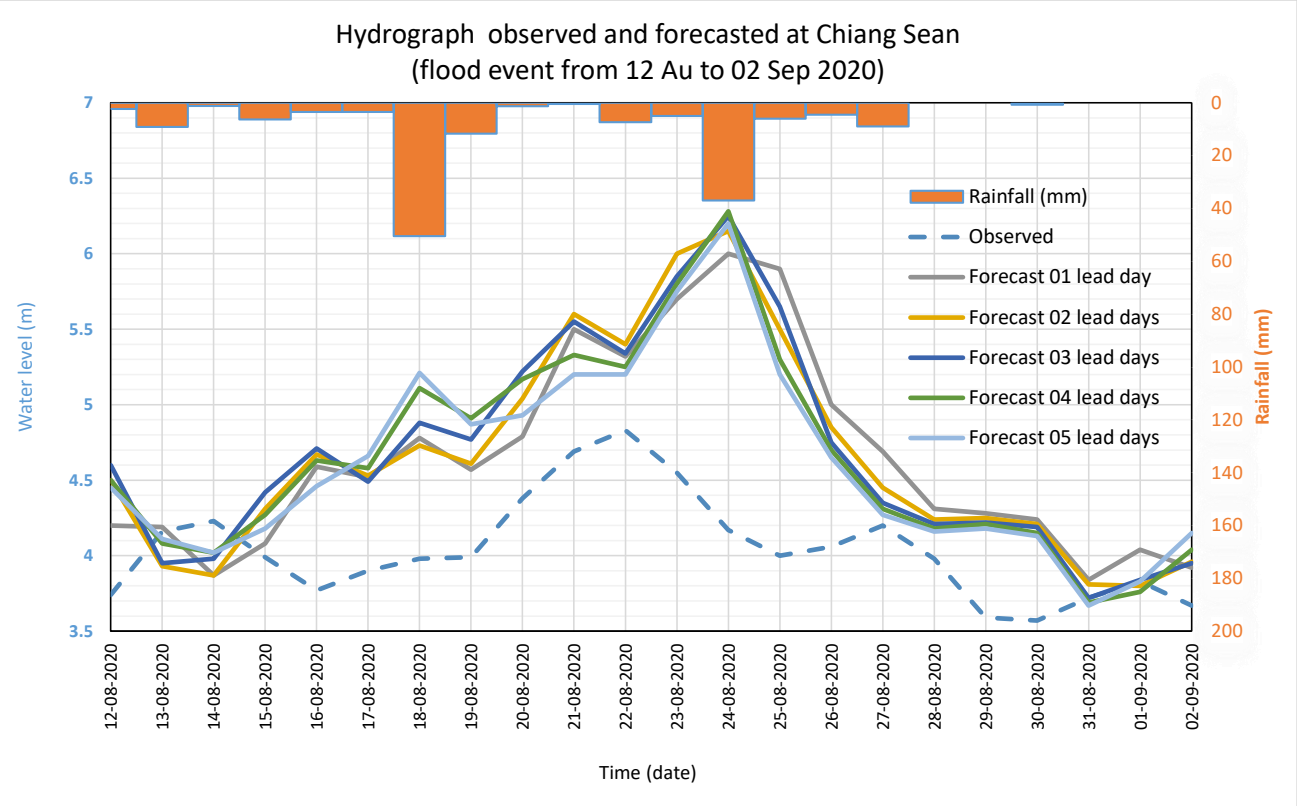
2020	Chiang Saen	Luang Prabang	Chiang Khan	Vientiane	Nongkhai	Paksane	Nakhon Phanom	Thakhek	Mukdahan	Savannakhet	Khong Chiam	Pakse	Stung Treng	Kratie	Kompong Cham	Phnom Penh (Bassac)	Phnom Penh Port	Koh Khel	Neak Luong	Prek Kdam	Tan Chau	Chau Doc	*Average*
1-day	57.1	57.1	71.4	57.1	57.1	57.1	42.9	71.4	71.4	71.4	71.4	71.4	71.4	57.1	57.1	28.6	57.1	57.1	57.1	57.1	57.1	42.9	***59.1***
2-day	50.0	66.7	66.7	66.7	33.3	33.3	50.0	50.0	66.7	83.3	66.7	66.7	66.7	50.0	66.7	83.3	83.3	50.0	50.0	66.7	66.7	50.0	***60.6***
3-day	40.0	60.0	60.0	80.0	40.0	60.0	60.0	60.0	60.0	80.0	60.0	60.0	60.0	60.0	60.0	80.0	80.0	40.0	80.0	40.0	60.0	60.0	***60.9***
4-day	50.0	50.0	50.0	75.0	50.0	50.0	50.0	50.0	75.0	75.0	75.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	***54.5***
5-day	66.7	66.7	66.7	33.3	66.7	66.7	66.7	66.7	66.7	66.7	66.7	66.7	33.3	33.3	33.3	33.3	33.3	33.3	33.3	33.3	66.7	33.3	***51.5***

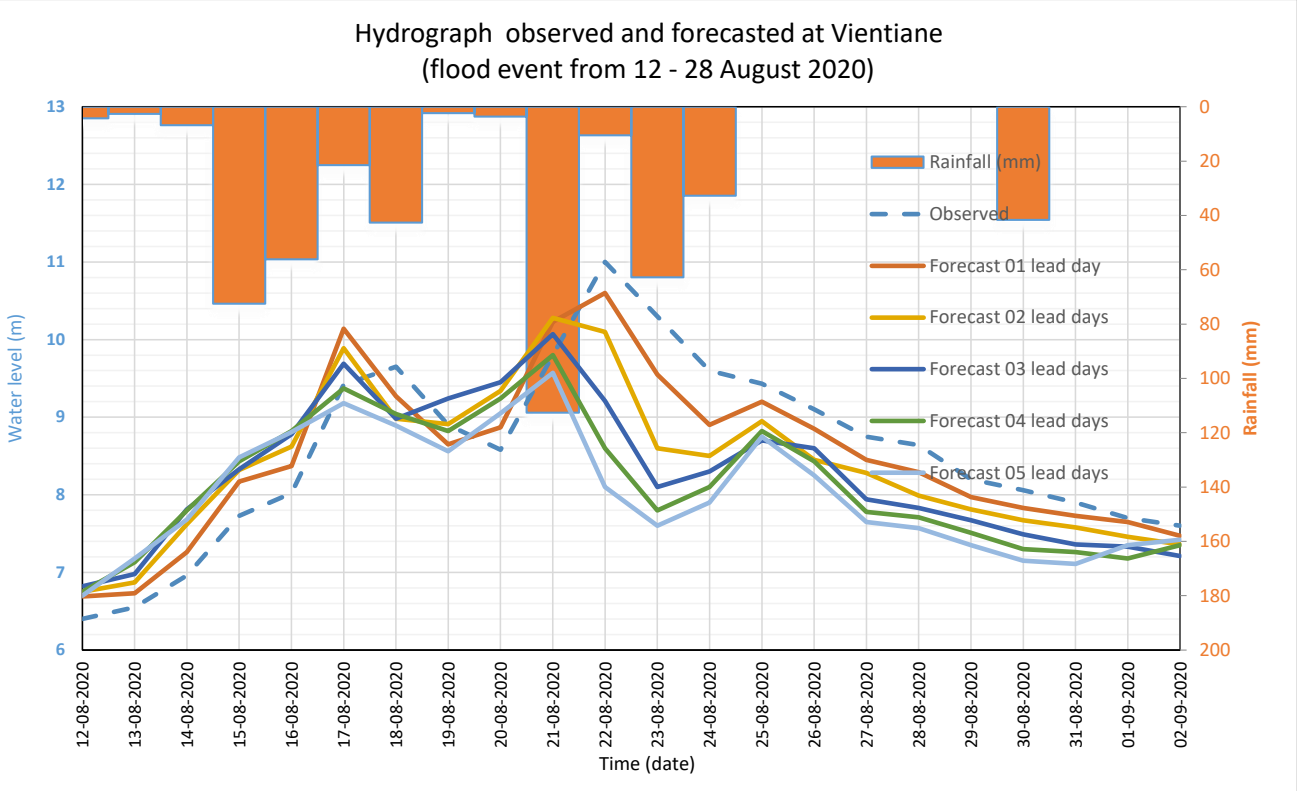
Like other wet seasons, the degree of accuracy for the wet season in 2020 varied from station to station. The shorter the lead time, the more accurate the flood forecast.

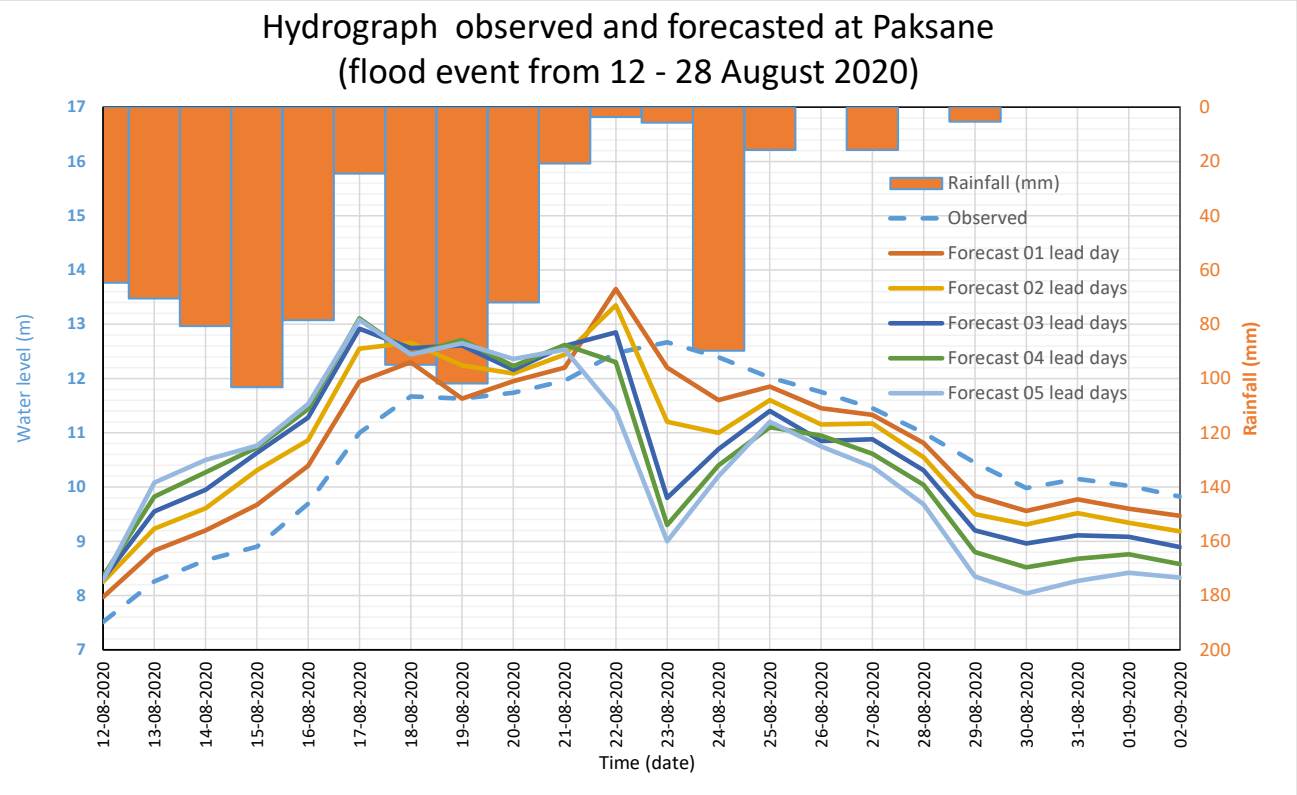
5.2.2 Analysis of the Flood Events

To analyse the forecast accuracy during the flood events following the Tropical Storm of LINFA and the NANGKA (see **Chapter 2.1**), **Figure 25** shows the water levels condition hydrograph at specific stations from Chaing Sean in Thailand, Veintaine in Lao PDR to Mukdahan in Thailand in a specific period from 12 August to 02 September 2020, compared with forecasted day-1 to day-5 and observed values with rainfall hyetographs. There was no flood during the wet season 2020 in the upper part from Vientiane to Mukdahan, except in Khong Chiam in Thailand to Stung Treng in Cambodia where influent by the tropical storms of LINFA and NANGKA at the sent of wet season in October 2020. The characteristic of flood event at these stations are detail descripted in section 3, specifying the period of flood event from upstream to downstream where most effected area from Khong Chiam in Thailand to Stung Treng and Kratie in Cambodia.




Hydrograph observed and forecasted at Chiang Sean
(flood event from 12 Au to 02 Sep 2020)
Water level (m)
Rainfall (mm)
Time (date)
Rainfall (mm)
Observed
Forecast 01 lead day
Forecast 02 lead days
Forecast 03 lead days
Forecast 04 lead days
Forecast 05 lead days


Hydrograph observed and forecasted at Vientiane
(flood event from 12 - 28 August 2020)
Water level (m)
Rainfall (mm)
Time (date)
Rainfall (mm)
Observed
Forecast 01 lead day
Forecast 02 lead days
Forecast 03 lead days
Forecast 04 lead days
Forecast 05 lead days


Hydrograph observed and forecasted at Paksane
(flood event from 12 - 28 August 2020)
Water level (m)
Rainfall (mm)
Time (date)
Rainfall (mm)
Observed
Forecast 01 lead day
Forecast 02 lead days
Forecast 03 lead days
Forecast 04 lead days
Forecast 05 lead days
17
16
15
14
13
12
11
10
9
8
7
0
20
40
60
80
100
120
140
160
180
200
12-08-2020
13-08-2020
14-08-2020
15-08-2020
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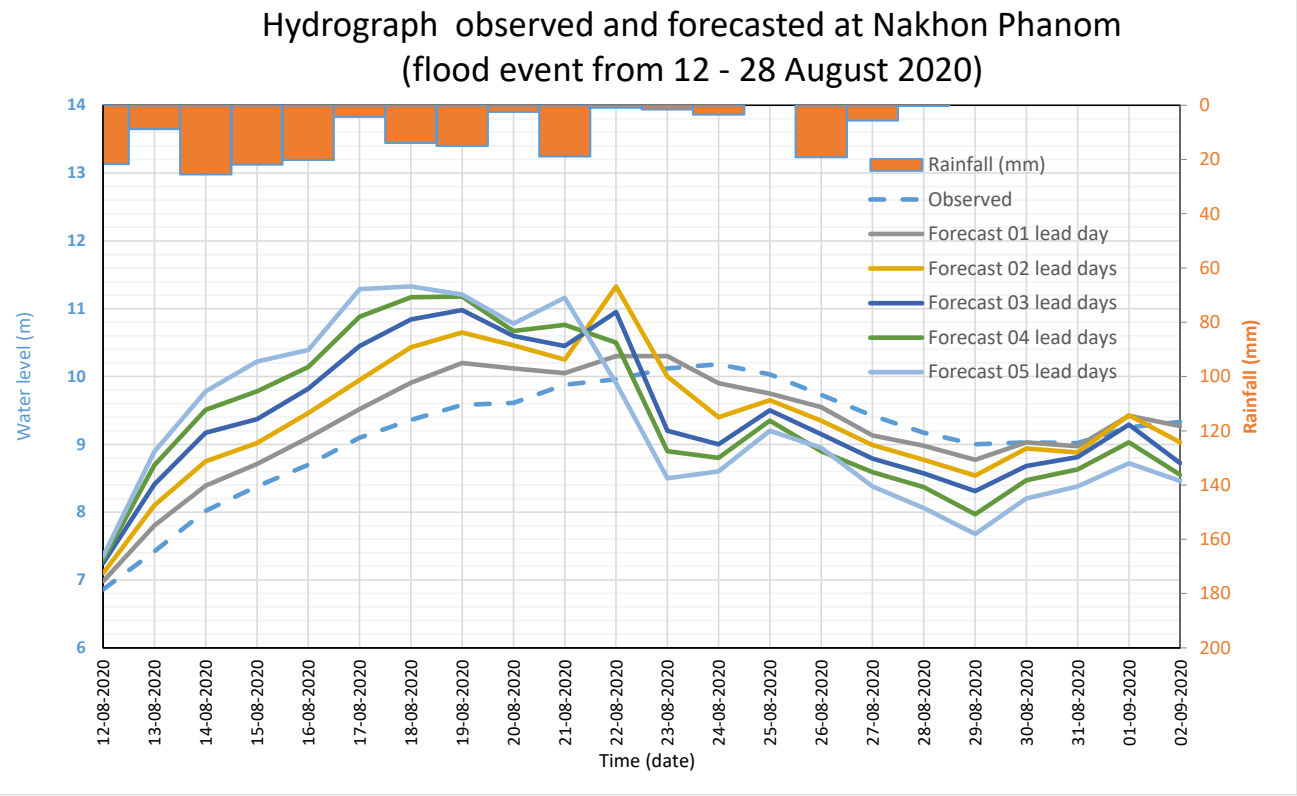
02-09-2020


Hydrograph observed and forecasted at Nakhon Phanom
(flood event from 12 - 28 August 2020)
Water level (m)
Rainfall (mm)
Time (date)
Rainfall (mm)
Observed
Forecast 01 lead day
Forecast 02 lead days
Forecast 03 lead days
Forecast 04 lead days
Forecast 05 lead days
14
13
12
11
10
9
8
7
6
0
20
40
60
80
100
120
140
160
180
200
12-08-2020
13-08-2020
14-08-2020
15-08-2020
16-08-2020
17-08-2020
18-08-2020
19-08-2020
20-08-2020
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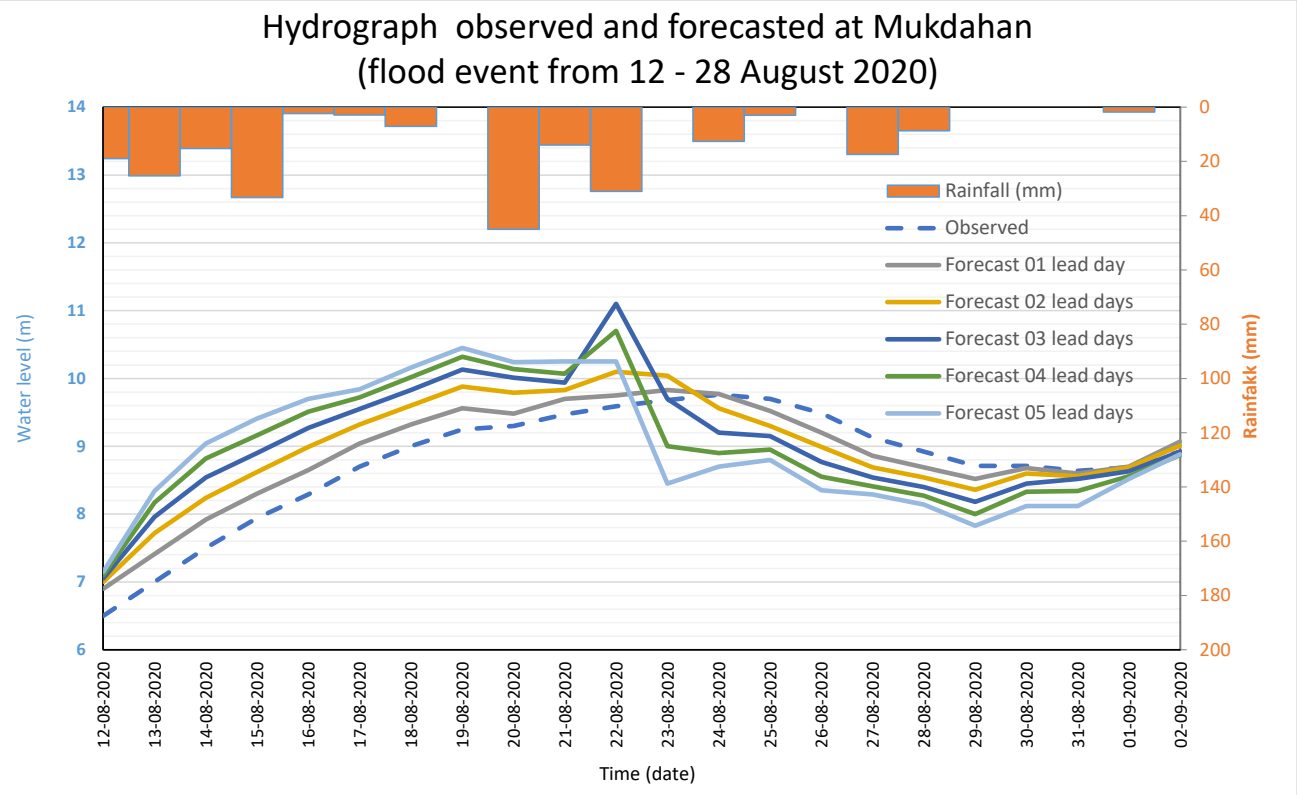


5.2.3 Figure 25 Observed and Forecasted water levels from Vientiane in Lao PDR to Mukdahan in Thailand

Analysis of the Modelling

This chapter describes the analysis of the modelling used in the MRC-RFFS.

Three models are available for flood forecasting in the MRC-RFFS:

1. URBS model for upstream stations from Chiang Saen to Stung Treng;
2. ISIS model for downstream stations from Kratie to the Delta;
3. Regression Model, which is used to combine the URBS and the ISIS.

Figure 26 presents all the stations of the river forecasting with the specific model applied.

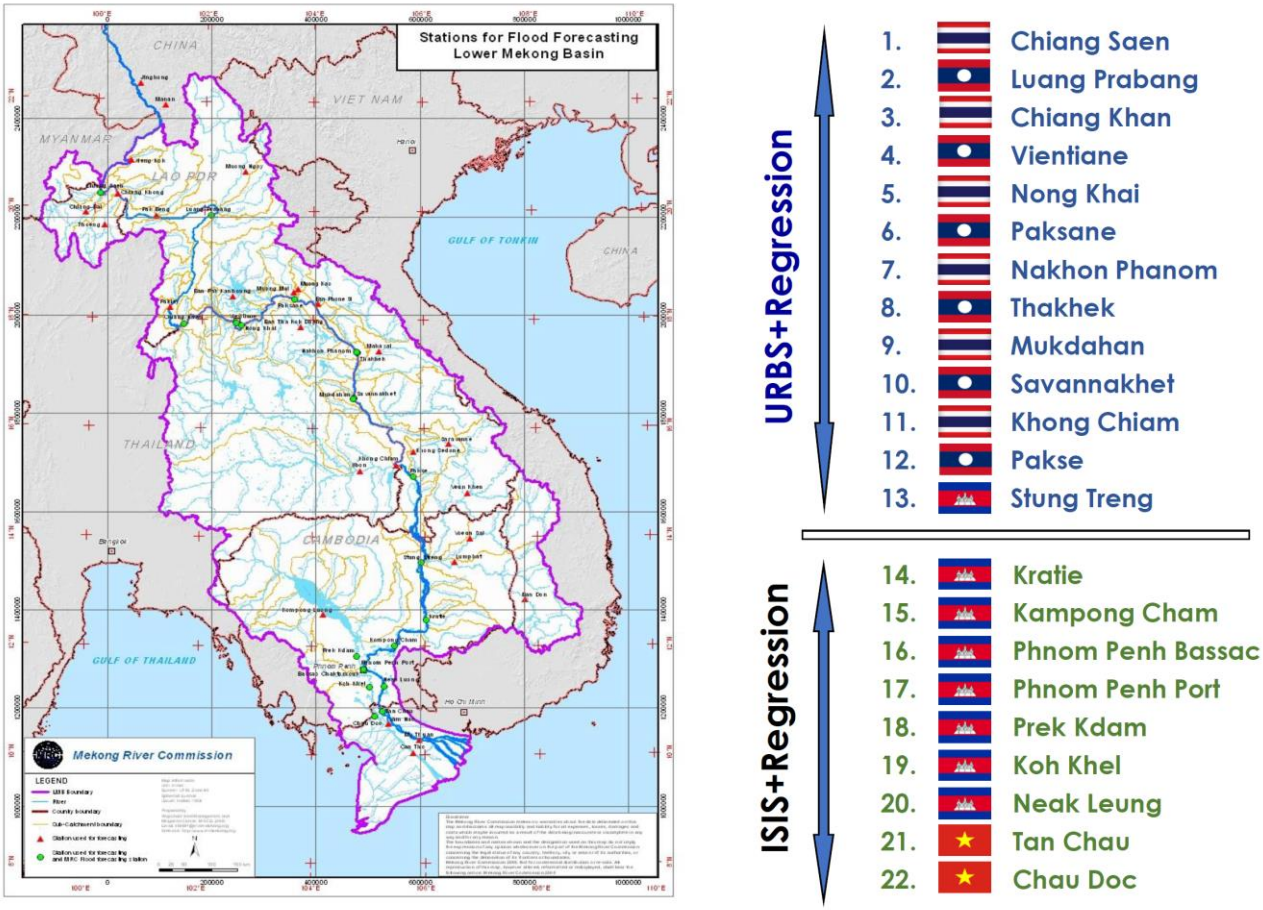


Figure 26: Forecasting stations and model application in the LMB

Since in the lower part of the LMB there are two model approaches available, the hydrodynamic model ISIS and the Regression model, the evaluation of the wet season 2020 was used for a comparison between the two models.

The manual hydro-met data as well as Satellite Rainfall Estimations (SRE) and Numerical Weather Prediction from the Global Forecast System (GFS) as input for the MRC-RFFS are the most important elements for the flood forecasting outputs. Because of the high variability of the SRE data, it was merged with the observed rainfall data based on a bias-correction method.

To verify the importance of the bias correction, the model was run in 2020 with the original SRE and

the corrected SRE. **Figure 27** and **Figure 28** show the model performances of near-real time of satellite rainfall estimated data, comparing the forecast accuracy for 1 to 5-days lead time at the key stations along Mekong River during the wet season 2020 comparing the MAD of the forecasts based on original SRE and corrected SRE.

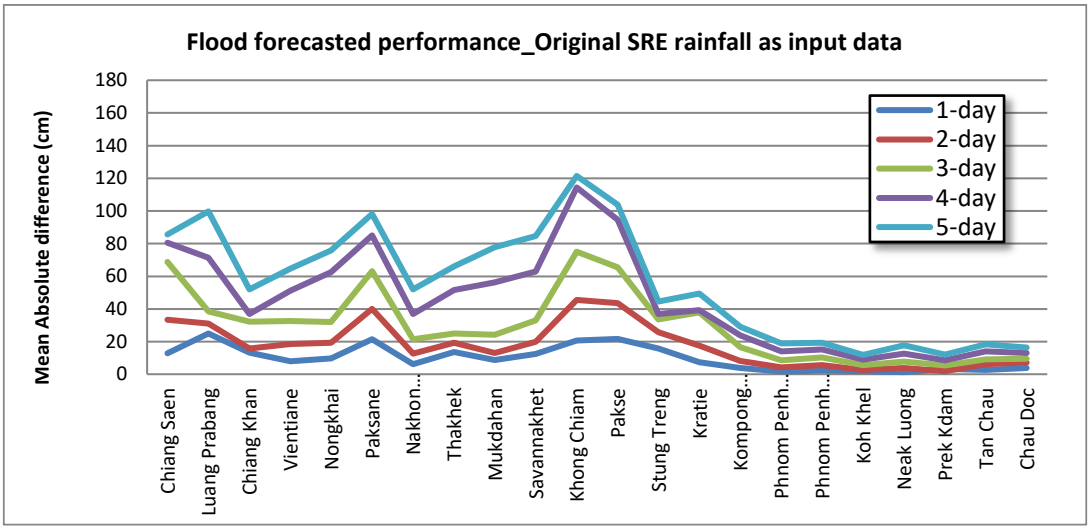


Figure 27 Forecast accuracy based on original SRE from Jun to Oct 2020

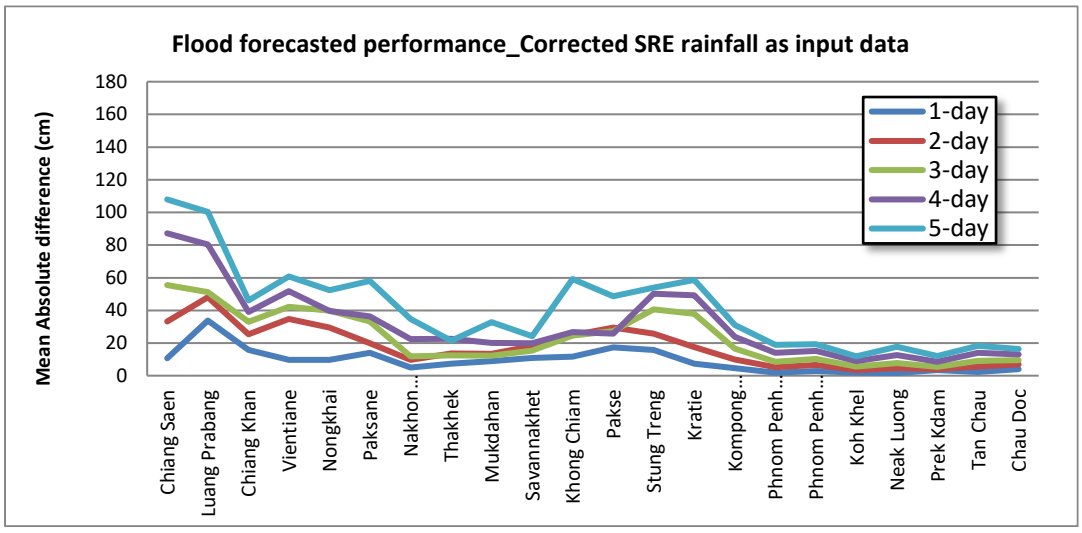


Figure 28 Forecast accuracy based on Corrected SRE from Jun to Oct 2020

The analysis shows clearly that accuracy increases significantly with the bias corrected SRE between the stations Chiang Khan and Pakse.

5.2.4 Recommendations to improve the RFF Accuracy

Following the investigations and comments of the forecaster-in-charge in the weekly reports throughout the wet season 2020, it was found that the high variability in SRE and GFS were the main reasons which led to large errors of forecast results, especially during heavy rains as tropical storms, southwest monsoon and ITCZ. Satellite rainfall data was not representative of the actual rainfall at ground stations in some areas of the Mekong region. SRE provide a highly variable rainfall estimation leading to high variation of forecast results, especially at stations in the upper and middle reaches, when critical weather patterns such as tropical storms occur.

For the upcoming flood season 2021 the SERVIR-Mekong is supporting the MRC in adopting improved satellite derived products. This includes the provision of high resolution and bias corrected Global Precipitation Measurements (GPM) precipitation data. Additionally, the Asian Disaster Preparedness Center (ADPC) is supporting the RFDMC to test also the use of 15 days rainfall forecasts from the CHIRPS-GEFS (Climate Hazards Center InfraRed Precipitation - Global Ensemble Forecast System).

The quality and accuracy of the forecast is also determined by the quality of forecast adjustment, which is usually performed by the forecaster-in-charge. So, the knowledge, expertise and experiences of the forecaster are also a prominent determinant of the final forecast results.

6 Summary and Conclusions

The following lessons have been learned by the flood forecasting team of the RFDMC from the wet season 2020:

- The availability and quality of both hydrological and meteorological data as inputs for the models are always the highest priority because these are the deciding factors for forecast results and accuracy. A Senior International Satellite Precipitation Expert has developed a tool for bias correction of the SRE data in 2010. The corrected SRE is used in the MRC-RFFS as rainfall inputs. The tool depends very much on observed rainfall data provided from the LAs. Therefore, strengthening the relationship and cooperation with the LAs in order to improve the exchange of observed water level and rainfall data from the stations in the LMB is very important.
- The data from the stations in the upstream of the Mekong River in China is crucial for the analyses and forecasts in the LMB, not only during the wet season but also during the dry season. In the flood forecasting they are especially important for the upper parts of the Mekong river at Chiang Saen.
- The model could be improved by calibration based on updated rating curves, and additional data input from dam operation (curves and other parameters) that belong to the MCs. The correctness and consistency of the results should be tested and verified over the upcoming wet season.
- The forecaster-in-charge should get a better understanding of the sub-basin characteristics and flow regime of left bank tributaries in the middle part of the LMB, where frequently intensive rainfall and flooding occurs. The forecaster should understand more about the influences of tidal regime at the downstream reaches in the LMB.

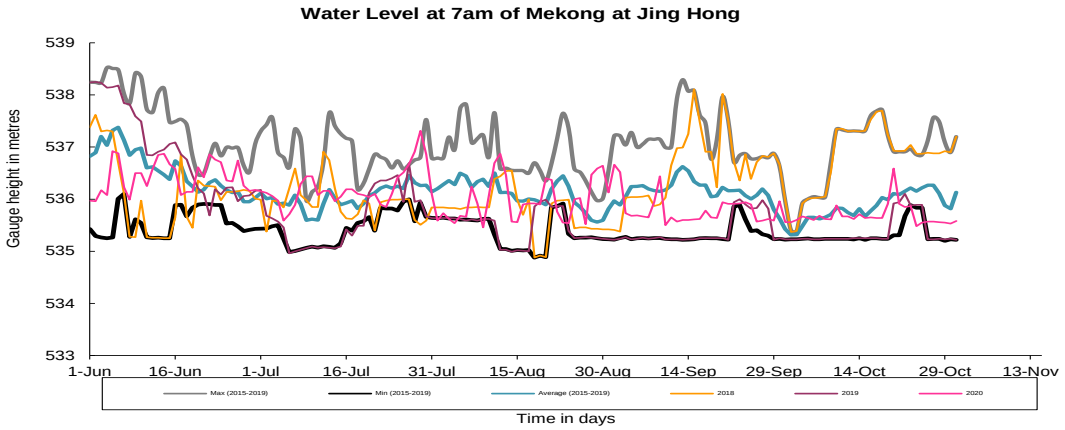
In order to improve the accuracy of the flood forecasting for next wet season 2021, the following additional actions need to be considered:

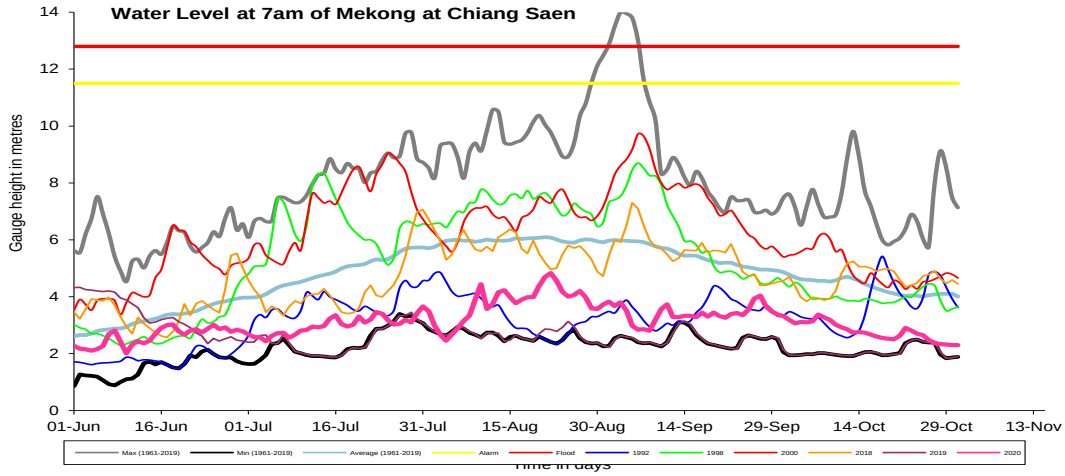
- Continue to efficiently use water level and rainfall data from the two Upper Mekong stations (Jinghong and Manan) based on the agreement between MRCS and China.
- Analyse the impact of water release from dams to water level changes at stations in the upper part, such as at Chiang Saen, Vientiane, Nong Khai especially during transitional period between dry and wet season.
- Watch and closely follow situations of the sudden increases of water levels on the 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 in order to better understand the impacts of weather patterns with intensive rainfall, like typhoons or tropical depressions coming from the East Sea, and/or the formation of low-pressure trough and ITCZ and the critical activity of the southwest monsoon.

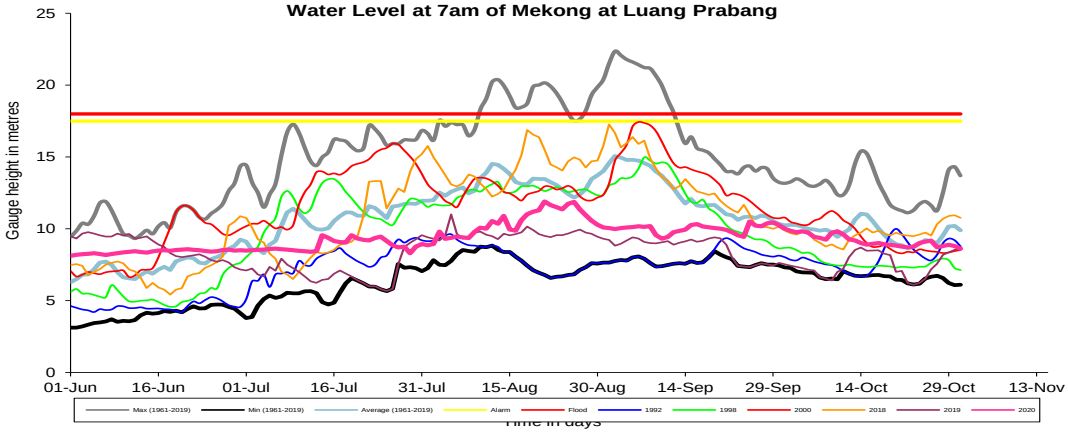
- Through forecast results of water levels during the wet season 2019 at downstream stations the Regression Model was evaluated as 'fairly good', it should be explained more in detail why the errors for 3-day and 4-day forecasts at Tan Chau and Chau Doc, where water levels are affected by the tide, were that "high". Although, the flood forecaster referred to the tidal regime in the forecast documentation 2020 provided by National Centre for Hydrometeorology of Viet Nam.
- Learn more about the weather products of rainfall forecast published on the websites of the World Meteorological Organization (WMO) and their practical applications.
- Study the possibility of having 2nd run of daily flood forecast, medium-term forecast (6 - 10 days) and seasonal forecast (1 month to 3 months) with data availability and other requirements of the system. This can be done based on further evaluations of the system's performance by using historical rainfall patterns.
- Upgrading automatic stations at the 7 mainstream stations Paksane, Thakhek, Savannakhet, Kampong Cham, Phnom Penh Port, Koh Khel and Neak Luong. These existing stations are equipped with staff-gauges manual readings which are difficult to track on hourly fluctuation and early warning information.

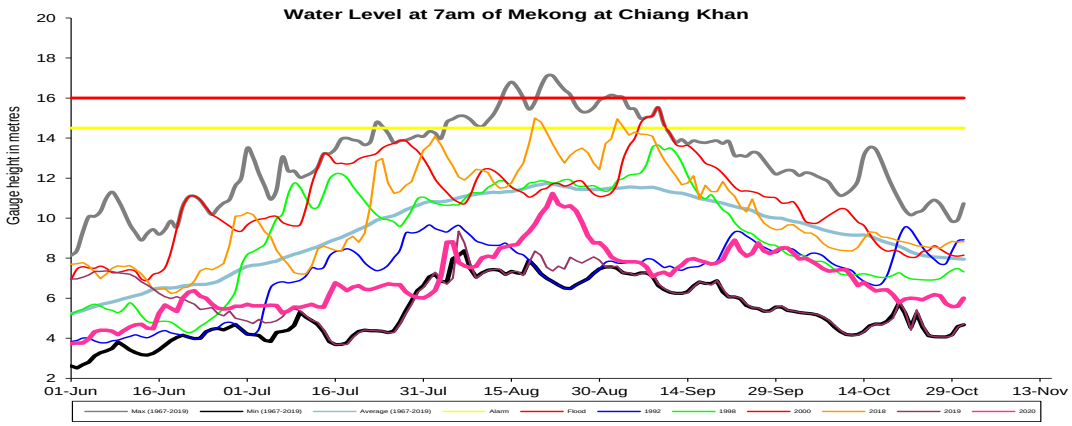
Annex A Water Level Hydrographs

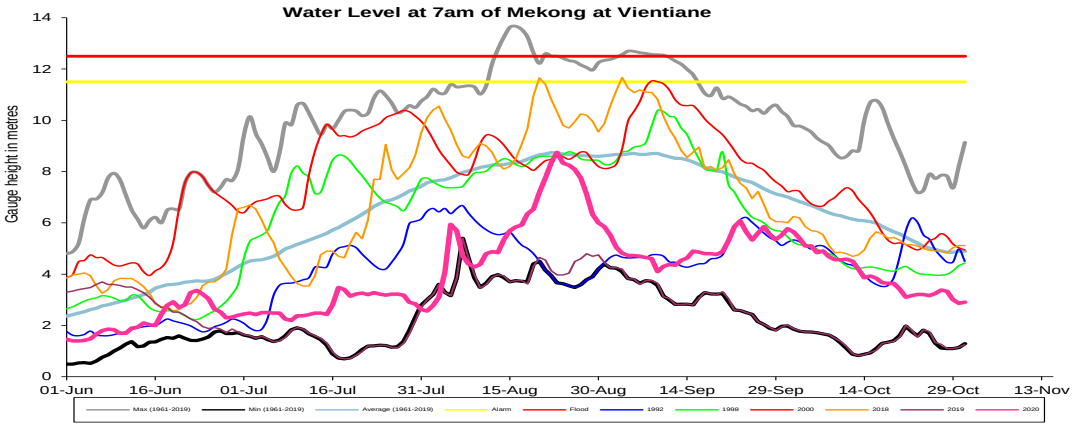
Water level hydrographs of each the key station covering the entire wet season 2020 from June to October compared with their LTAs (1995-2019) and other specific years (2017 and 2019). These water level graphs have been distributed daily by email together with the Flood Bulletins to all MCs and relevant stakeholders, who listed for receiving daily bulletin of the MRCS.

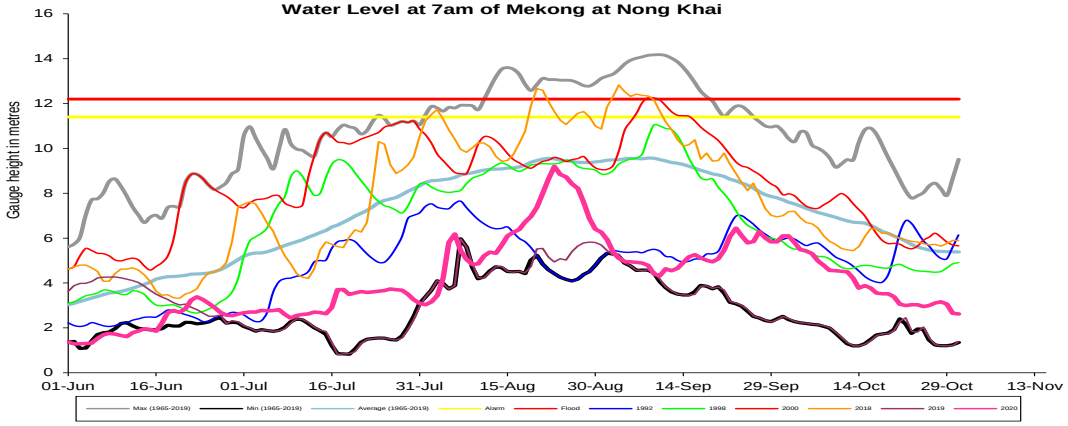


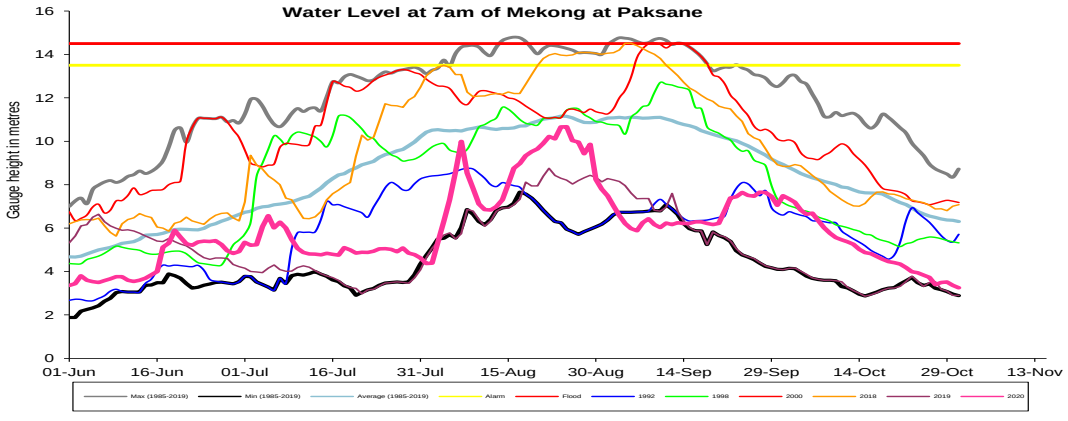


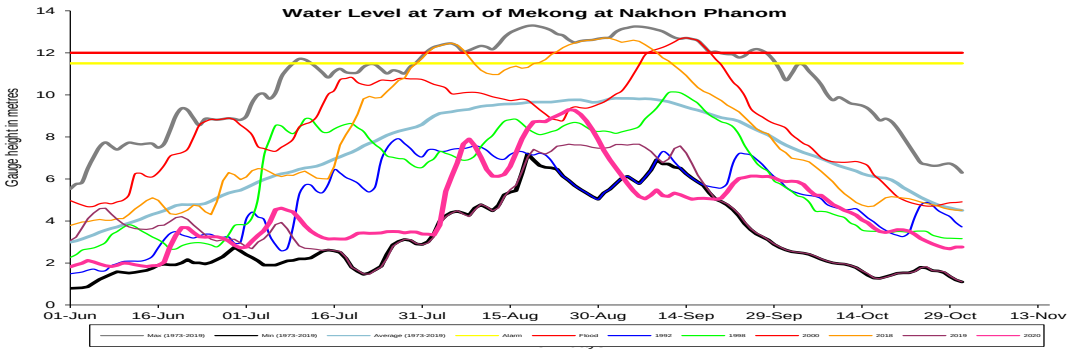


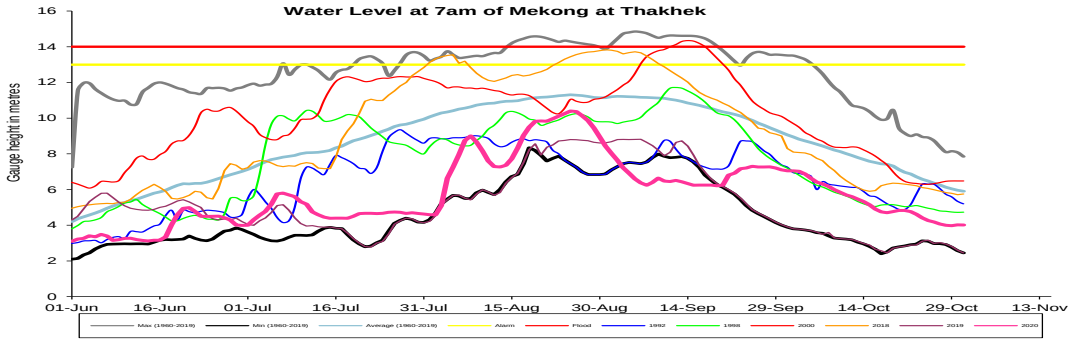

Water Level at 7am of Mekong at Chiang Khan
Gauge height in metres
20
18
16
14
12
10
8
6
4
2
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Max (1967-2019)
Min (1967-2019)
Average (1967-2019)
Alarm
Flood
1992
1998
2000
2018
2019
2020

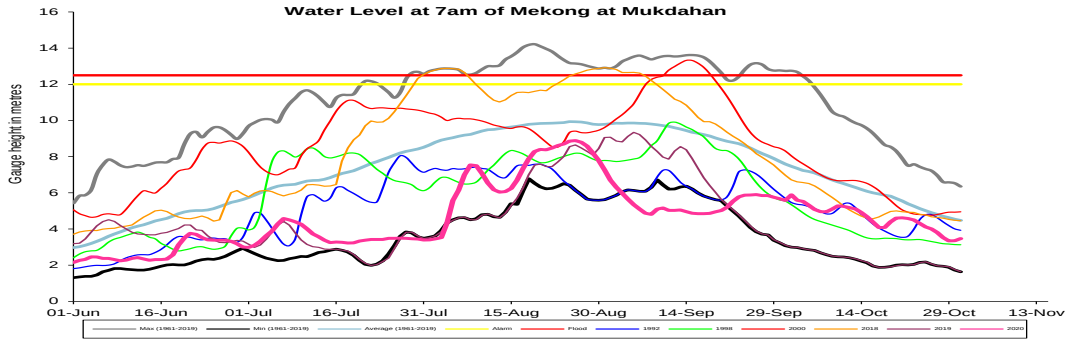

Water Level at 7am of Mekong at Vientiane
Gauge height in metres
14
12
10
8
6
4
2
0
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Max (1961-2019)
Min (1961-2019)
Average (1961-2019)
Alarm
Flood
1992
1998
2000
2018
2019
2020

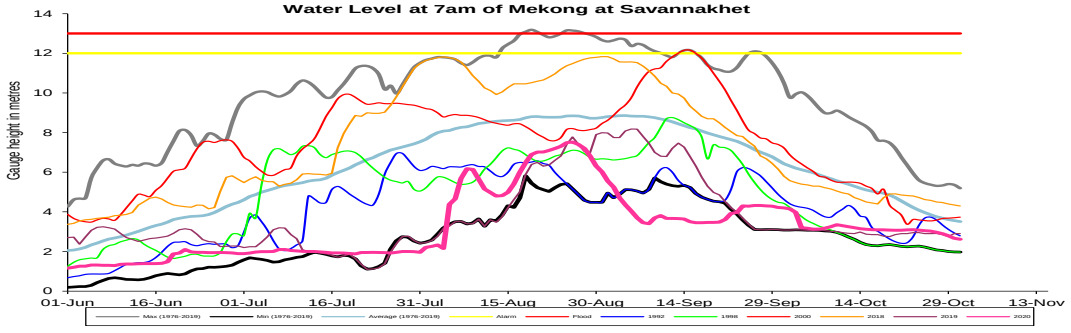

Water Level at 7am of Mekong at Nong Khai
Gauge height in metres
16
14
12
10
8
6
4
2
0
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Max (1965-2019)
Min (1965-2019)
Average (1965-2019)
Alarm
Flood
1992
1998
2000
2018
2019
2020

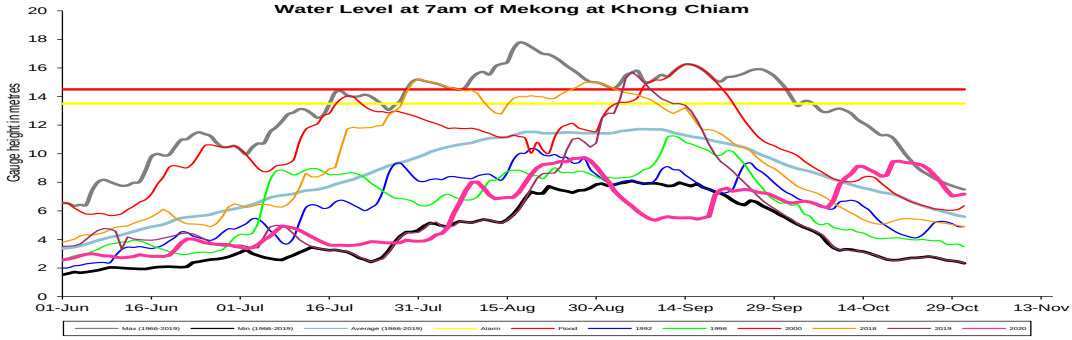

Water Level at 7am of Mekong at Paksane
Gauge height in metres
16
14
12
10
8
6
4
2
0
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Max (1985-2019)
Min (1985-2019)
Average (1985-2019)
Alarm
Flood
1992
1998
2000
2018
2019
2020

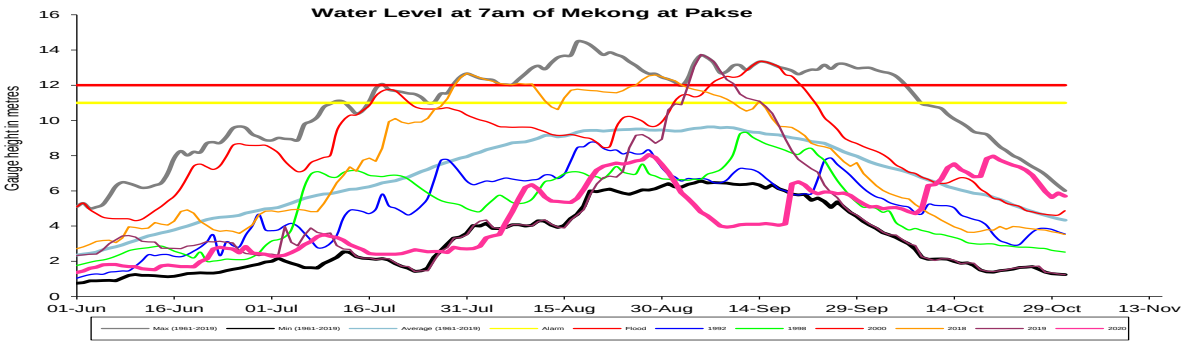

Water Level at 7am of Mekong at Nakhon Phanom
Gauge height in metres
0
2
4
6
8
10
12
14
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov

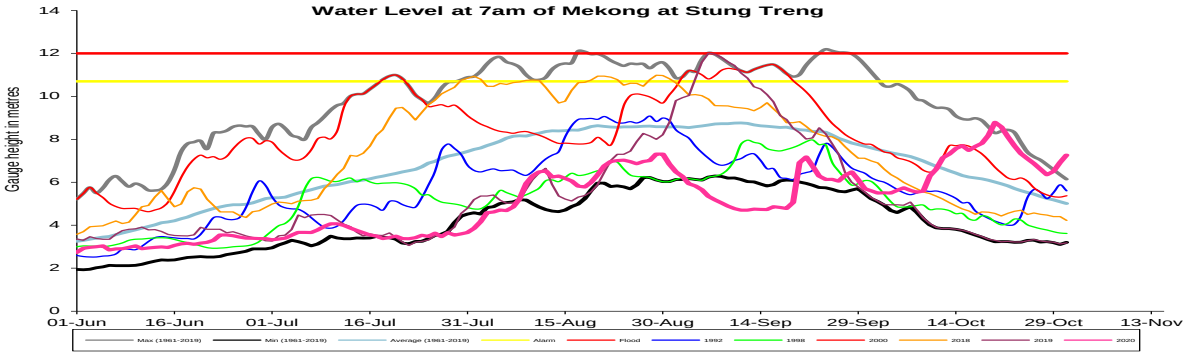

Water Level at 7am of Mekong at Thakhek
Gauge height in metres
0
2
4
6
8
10
12
14
16
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov

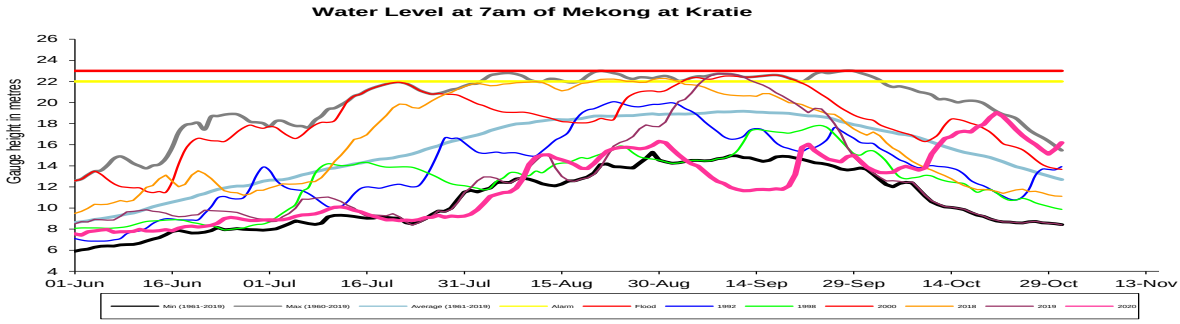

Water Level at 7am of Mekong at Mukdahan
Gauge height in metres
0
2
4
6
8
10
12
14
16
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov

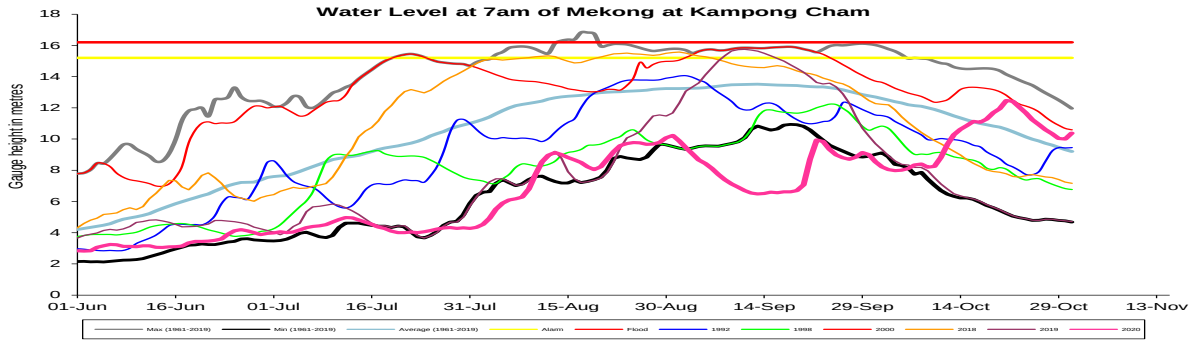

Water Level at 7am of Mekong at Savannakhet
Gauge height in metres
0
2
4
6
8
10
12
14
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov

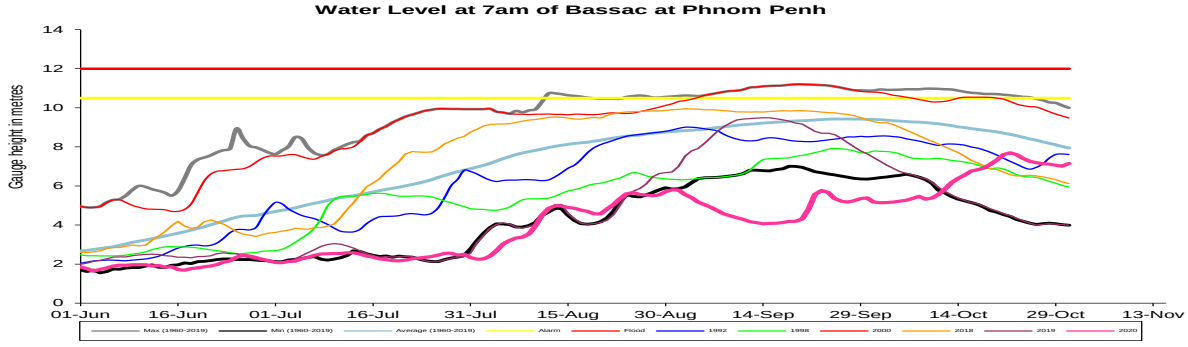

Water Level at 7am of Mekong at Khong Chiam
Gauge height in metres
0
2
4
6
8
10
12
14
16
18
20
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov

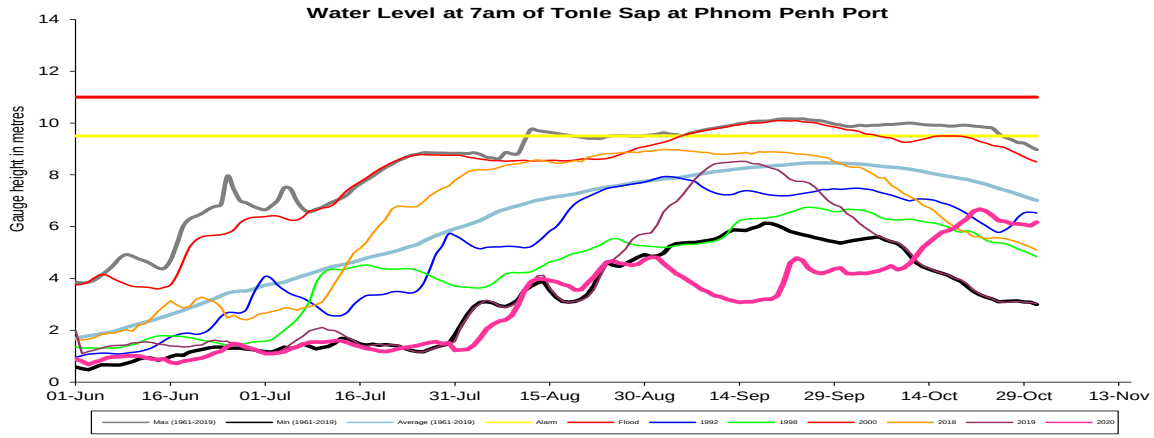

Water Level at 7am of Mekong at Pakse
Gauge height in metres
16
14
12
10
8
6
4
2
0
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov

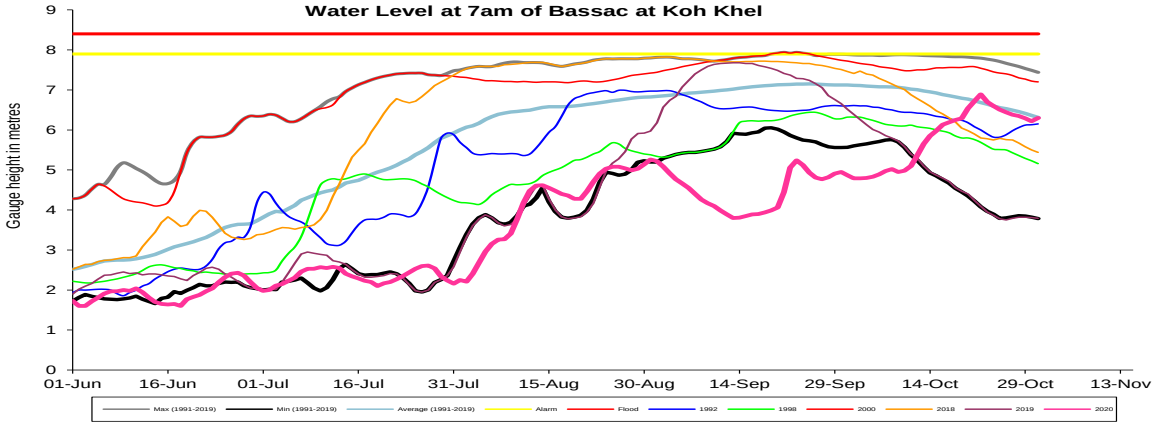

Water Level at 7am of Mekong at Stung Treng
Gauge height in metres
14
12
10
8
6
4
2
0
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov

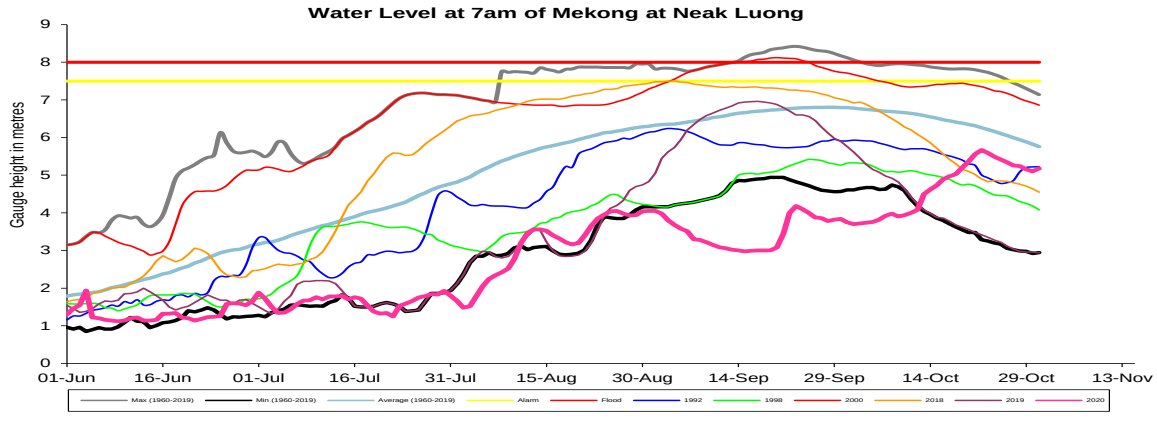

Water Level at 7am of Mekong at Kratie
Gauge height in metres
26
24
22
20
18
16
14
12
10
8
6
4
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov

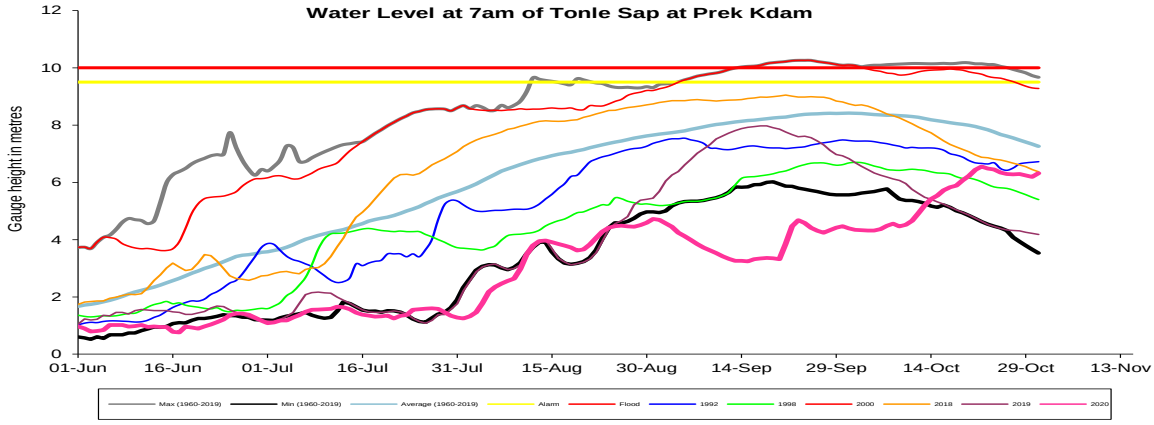

Water Level at 7am of Mekong at Kampong Cham
Gauge height in metres
18
16
14
12
10
8
6
4
2
0
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov

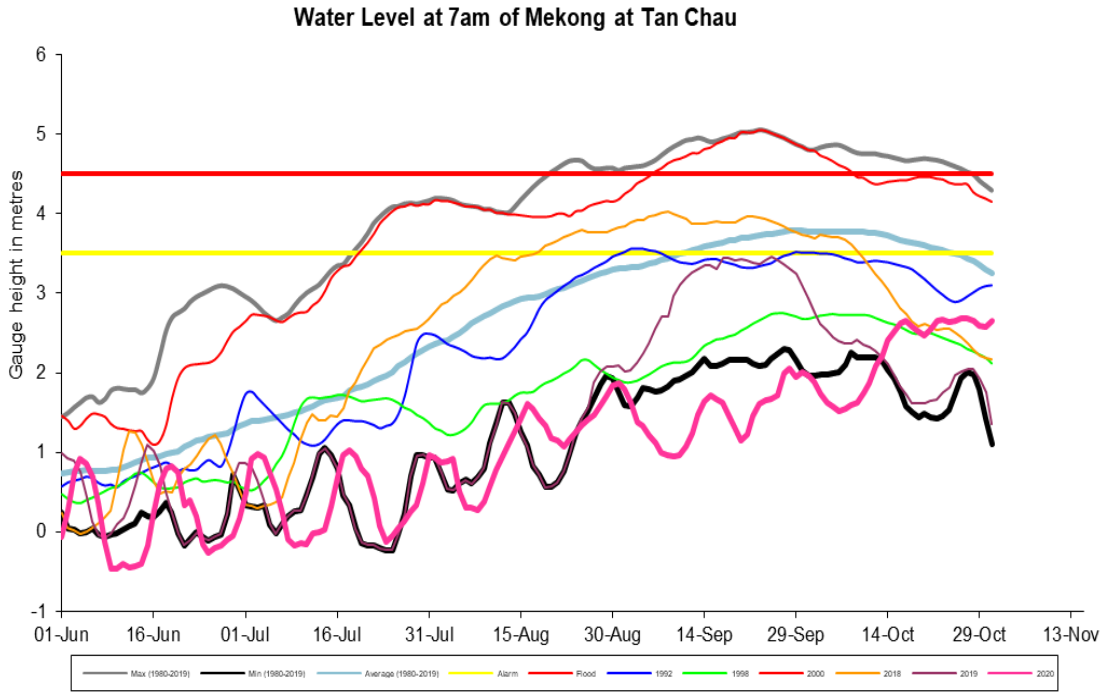

Water Level at 7am of Bassac at Phnom Penh
Gauge height in metres
14
12
10
8
6
4
2
0
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov

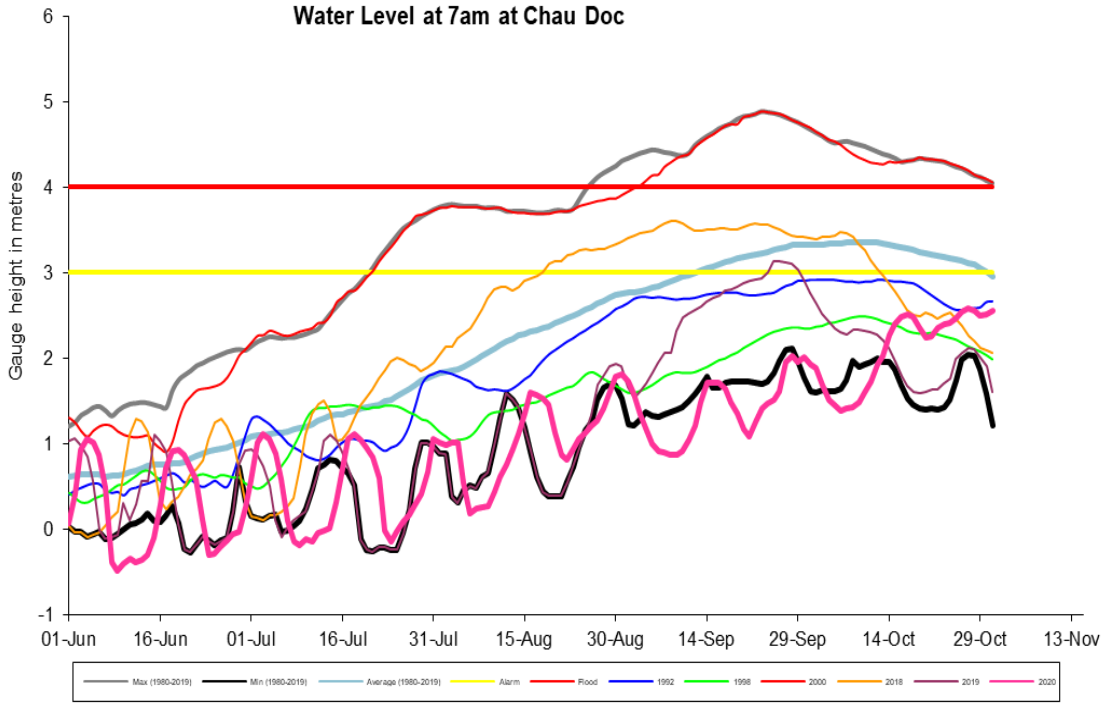

Water Level at 7am of Tonle Sap at Phnom Penh Port
Gauge height in metres
14
12
10
8
6
4
2
0
01-Jun
16-Jun
01-Jul
16-Jul
31-Jul
15-Aug
30-Aug
14-Sep
29-Sep
14-Oct
29-Oct
13-Nov
Max (1961-2019)
Min (1961-2019)
Average (1961-2019)
Alarm
Flood
1992
1998
2000
2018
2019
2020


Water Level at 7am of Bassac at Koh Khel
Gauge height in metres
9
8
7
6
5
4
3
2
1
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
Max (1991-2019)
Min (1991-2019)
Average (1991-2019)
Alarm
Flood
1992
1998
2000
2018
2019
2020


Water Level at 7am of Mekong at Neak Luong
Gauge height in metres
9
8
7
6
5
4
3
2
1
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
Max (1960-2019)
Min (1960-2019)
Average (1960-2019)
Alarm
Flood
1992
1998
2000
2018
2019
2020


Water Level at 7am of Tonle Sap at Prek Kdam
Gauge height in metres
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
Max (1960-2019)
Min (1960-2019)
Average (1960-2019)
Alarm
Flood
1992
1998
2000
2018
2019
2020


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
Max (1980-2019)
Min (1980-2019)
Average (1980-2019)
Alarm
Flood
1992
1998
2000
2018
2019
2020


Water Level at 7am 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
Max (1980-2019)
Min (1980-2019)
Average (1980-2019)
Alarm
Flood
1992
1998
2000
2018
2019
2020