Mekong River Commission
For Sustainable Development

Understanding the Mekong River's hydrological conditions:

A brief commentary note on the "Monitoring the Quantity of Water Flowing Through the Upper Mekong Basin Under Natural (Unimpeded) Conditions" study by Alan Basist and Claude Williams (2020)

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Mekong River Commission
Documentation and Learning Centre
184 Fa Ngoum Road, Unit 18, Ban Sithane Neua, Sikhottabong District, Vientiane 01000, Lao PDR
Telephone: +856-21 263 263 | E-mail: mrcs@mrcmekong.org | www.mrcmekong.org

Table of Contents

Figures

1 Summary

About this note

The MRC Secretariat received the report of Alan Basist and Claude Williams of the consulting company Eyes on Earth on 13 April 2020 and was asked to comment on it by several media outlets and stakeholders. The Secretariat provided data based on requests by the authors in accordance with normal procedures, but was not requested to review the work in its draft or final versions. As one of the MRC's core functions is to monitor and report on the basin's conditions, in which the Basist and Williams report deals with, it is our responsibility to provide some commentaries based on existing MRC's data and knowledge.

We hope that this will aid in fostering further work and cooperation among our Member Countries, our Dialogue Partners China and Myanmar, and our stakeholders.

Overall hydrological picture

The annual flow regimes at Chaing Saen, where the Mekong enters the Lower Mekong Basin (LMB), have been altered by hydropower projects in China. These projects reduce wet season flows and increase dry season flows. This situation brings both opportunities and challenges.

The impact of these changes becomes less evident further downstream due to the inflows from tributaries in the LMB and the operations of the tributary hydropower dams.

The Eyes on Earth Study draws its conclusions from *calculated* flows at Chaing Saen, the most upstream point in the LMB. These calculations do not reflect the *actual* dry season flows over the last two years. The actual flows recorded in the Mekong River Commission's Procedures for the Maintenance of Flows on the Mainstream (PMFM) in the 2019 and 2020 dry seasons showed that **inflows from China were higher than typical for the dry season**.

The record low flow at Vientiane in Lao PDR noted in the 2019 and 2020 dry seasons was most likely due to the change in rainfall volume and pattern.

The MRC's data also showed that these recorded low flows do not persist further downstream of Vientiane due to the operations of the tributary hydropower dams. The PMFM showed that dry season inflows into Cambodia were higher than typical during 2019 and 2020.

Summary of the commentary

- Dam development in the upper reaches of the Mekong has led to changes in seasonal flows, with increased dry season flows and decreased wet season flows. Both phenomena are observed in the LMB, with the impact on the flow regime becoming progressively less noticeable further downstream.

- The findings of the Eyes on Earth study have not yet well taken into account the complexities of rainfall and runoff, thus not reflecting the actual hydrological conditions in the Basin. The conclusions drawn are based on calculated flows and not an analysis of the actual flows at Chaing Saen set against the long term trends.

- As the methods presented by the authors are highly empirical and calibrated on the period 1997-2001, various complex hydrological and physical processes that determine the runoff from the catchments and the river are not captured in the regression functions.

- Our preliminary analysis of hydrological and rainfall data showed that the 2019 drought in the basin was due largely to insufficient rainfall during the wet season with a delayed arrival and earlier departure of monsoon rains and an El Nino event that created an abnormally higher temperature and higher evapotranspiration.

- Inadequate information on water infrastructures in the Mekong River Basin and the way these infrastructures are operated have made it challenging to forecast short-term impacts.

- If the Member Countries and China are to share more information with the MRC, especially data and information on water use and infrastructure operation, the Commission will be in a better position to support seasonal water resource planning and management, and can correct misperceptions by the public and in the media.

2 General impression of the study

The study by Alan Basist and Claude Williams calculated water levels in the Upper Mekong River in China based on satellite data. This was used to determine how dams in China have altered the natural flow of the Mekong.

The authors' stated aim was to *"develop a reliable and simple model that predicted the natural flow of the Upper Mekong, then use this prediction to determine how the cascade of dams built on the Upper Mekong was altering the natural flow of the river*".

It analysed the flow regulation by the hydropower projects in China by comparing the predicted natural flow using the basin wetness index 'BWI' (Basist et al., 2001) of the catchment derived from satellite rainfall observations (SSMI/S, Special Sensor Microwave Imager and Sounder), against river height gauge data at Chiang Saen, Thailand (the most upstream point with monitoring data in the LMB).

The available data used in the study was based on satellite data from 1992 to 2019. The approach has been calibrated for data from 1997 to 2001 as the best representative (baseline average) of natural flow (before the larger storage reservoirs in the Lancang cascade started their operations). In addition, 1994 to 1996 data were used to validate the model. The main author of the study is recognised for his work on the SSMI/S data and the

development and application of the BWI. It is expected that the authors are well aware of the *approximate character of this approach* and its apparent limitations.

Based on requests by the lead author through normal procedures, the MRC Secretariat provided water level data recorded at Chiang Saen from 1960 to 2019. The MRC's river monitoring data, including water level and rainfall data, are available to the public at https://portal.mrcmekong.org/home.

The study provides a useful perspective on the use of satellite data to determine stream flow. It also supports some of the findings of various earlier studies by the MRC. The effects of hydropower dams in the Lancang River (the Mekong River in China) on the flow regime in the Lower Mekong Basin (LMB) are well known. The MRC's latest *State of the Basin Report* (SOBR) and the *Council Study* (*Study on Sustainable Management and Development of the Mekong River including Impacts of Mainstream Hydropower Projects*) have extensively documented the histrocial and expected changes in flows from China. These two major reports on the basin's conditions and trends are not referenced in the Eyes on Earth study. The changes have been built into the MRC's Decision Support Framework and have been considered in the MRC's Basin Development Strategy.

The SOBR notes that dam development in the upper reaches of the Mekong has led to changes in seasonal flows, with increased dry season flows and decreased wet season flows (MRC, 2019). Both phenomena are observed in the LMB, with the impact on the flow regime becoming progressively less noticeable further downstream. At Chiang Saen, the average dry season flows from 2010-2017 increased by 35% compared to the 2000-2009 flows, while flood season flows were reduced by 31%.

3 Specific conclusions from the study

The Eyes on Earth study concludes that the "severe lack of water in the Lower Mekong during the wet season of 2019 was largely influenced by the restriction of water flowing from the Upper Mekong during that time" (Basist & Williams, 2020, p. 18). The study further notes that "cooperation between China and the Lower Mekong countries to simulate the natural flow cycle of the Mekong could have improved the low flow conditions experienced downstream between May and September of 2019" (ibid., p. 18).

However, this conclusion should note the major contribution of rainfall in the Northern and Eastern catchments to the Mekong flows. By far the major contribution comes from the two major left-bank (eastern) tributaries between Vientiane and Nakhon Phanom, and Pakse and Steung Treng. Together they contribute more than 40% to the flow (see Figure 1). This means water infrastructures in the Lower Mekong tributaries – where some 73 out of 150 planned dams have been installed over the last 55 years – could have various degrees of impact on the flow.

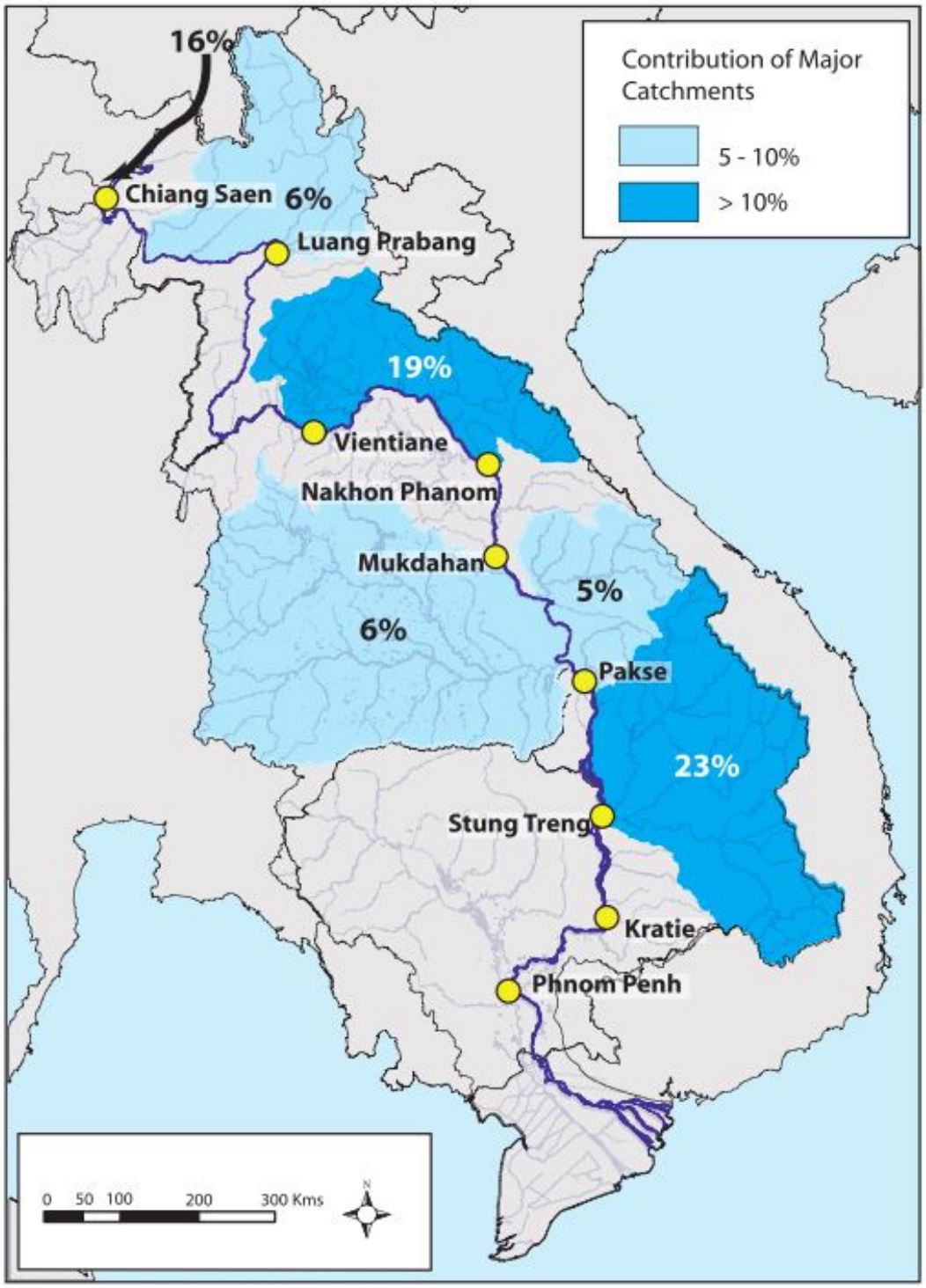

Figure 1. Major contributions of flows into the Mekong River

On average, the rainfall from the left bank contributes to almost 60% of the flood season discharge in the Mekong at the Lao-Cambodian border, while the contribution from China is in the order of 15%. Hence, the conclusion holds only up to Chiang Saen, which is the most upstream station in the LMB (see Figure 2). Satellite data of rainfall over the basin showing a wetter condition in China and drier in the rest of the basin appears to be correct. However, the approach does not provide robust scientific evidence that the storing of water in Chinese reservoirs *caused* the exceptionally low flows in the LMB at Vientiane in 2019 and 2020.

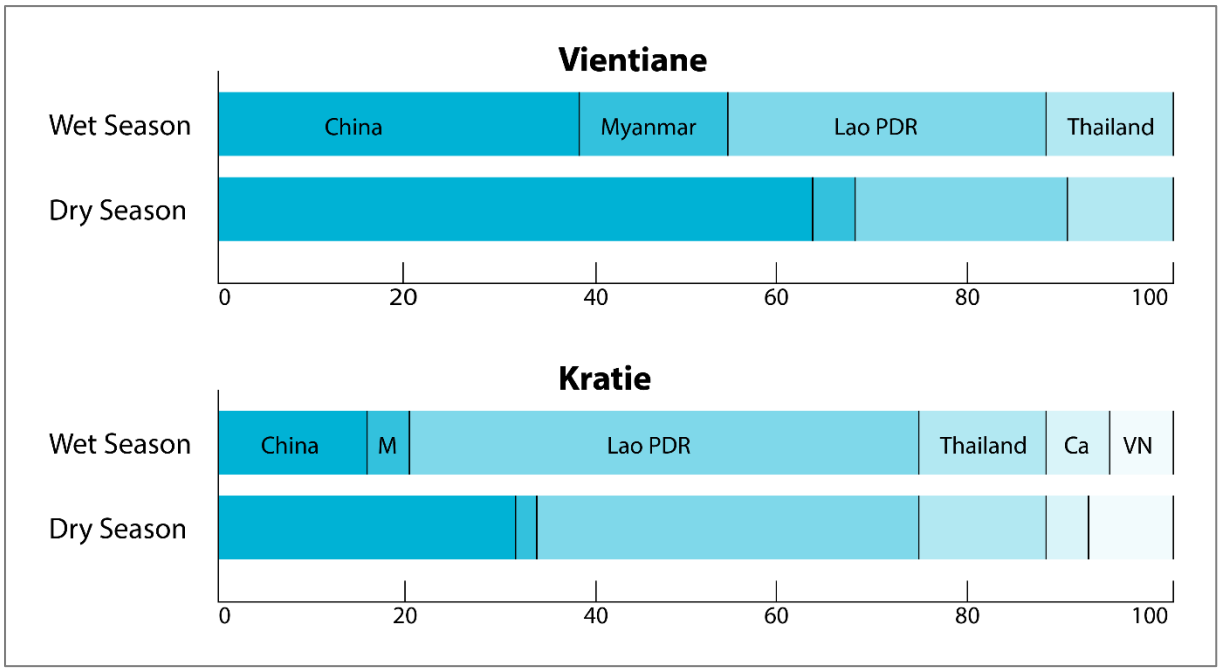

Figure 2. Contribution of the various tributaries on the mainstream flow at Vientiane and Kratie during the wet and dry seasons (MRC, 2009, p. 5)

In fact, the PMFM's data showed the inflow from China was higher than typical for these dry seasons. The record low flow was most likely the result of much lower than normal rainfall in the LMB, and the shift in rainfall patterns (see Figure 7). The operations of the hydropower projects in Lao PDR have also increased dry season flows in the Mekong downstream of Vientiane, and flows into Cambodia were also higher than typical for the 2019 and 2020 dry seasons.

While our data indicates that water levels at the Chiang Saen station were modified by the change in flows from China, including rainfall patterns, human activities and particularly hydropower operations upstream, the Jinghong dam in China contributed about 25% during the critical low flow of 2019 (the dry season flow).

The operation of hydropower projects in China is driven by two main factors: market demand for power and navigation between China and Myanmar/Thailand/Laos. Changes in the flow patterns over the last seven years, recorded in the MRC's PMFM, reflect the impacts of these operations on flows in the LMB.

In conclusion, the findings of the Eyes on Earth study do not align with the MRC's observations on the ground. While the study provides a point of reference for the MRC and the Lancang Mekong Cooperation Water Centre's ongoing *Joint Study on the 2019 Drought and Low Flows*, the conclusions drawn are based on calculated flows and not an analysis of the actual flows at Chaing Saen set against the long term trends.

4 Data and methodology

There is uncertainty in the use of satellite data to predict hydrological conditions in the river. The “simple regression model” used in the study could not take into account the complexities of rainfall and runoff, and may not reflect the actual hydrological conditions in the Basin.

The data is processed on a monthly average basis, which suits the relative coarse character of the methodology and the basin-wide character. However, averaging the daily water levels to represent the variable flow in the Mekong is not justified. Daily water levels in the Mekong show variations between 2 to 4 m relative to their monthly value. However, the rating curve for discharge is a non-linear (power) relation. A first error is made when comparing the monthly average of discharge to a discharge based on a monthly average water level. Furthermore, a 2-m water level variation at high flows represents much higher discharge variation than a 2-m water level variation at low flows. The various rating curves at Chaing Saen at different years illustrate this (Figure 3).

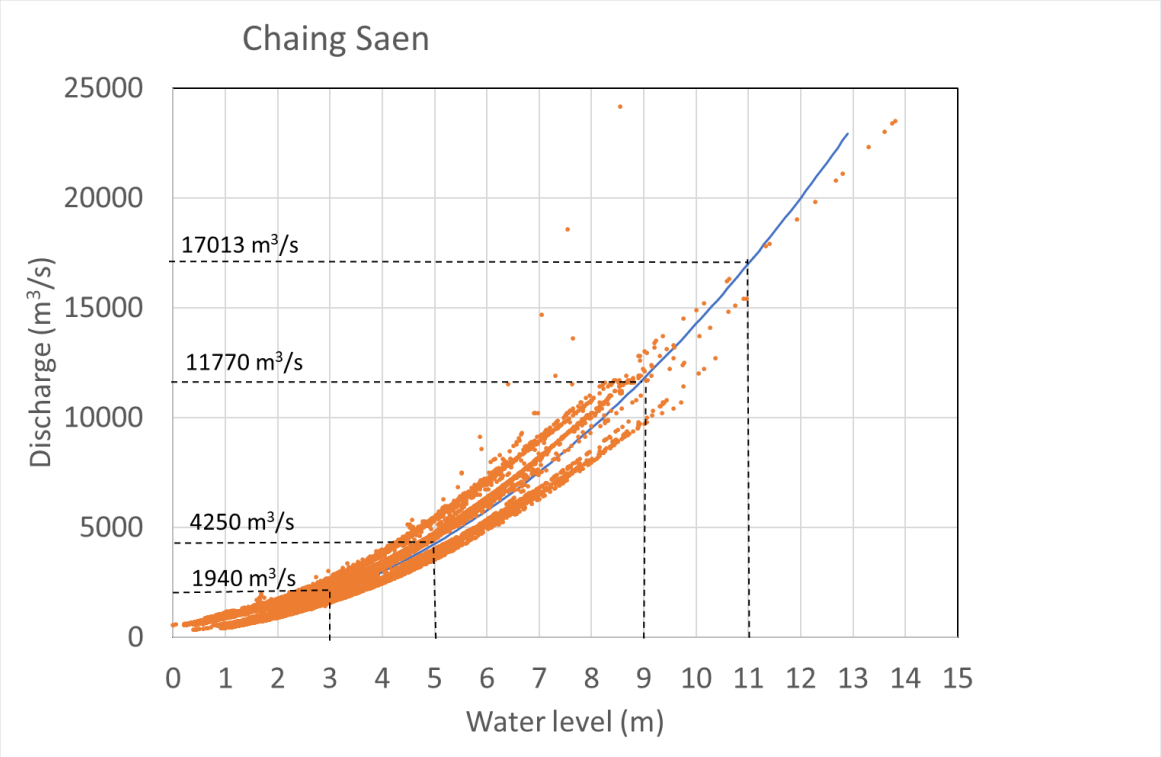

Figure 3. Chaing Saen's flow rating curves

Because of this limitation, the validity of the statements that impounded volumes translate to 126.44 m of river level over 28 years’ data can be disputed. The study would benefit greatly if the connection to the Chiang Saen gauge is based on discharges rather than water levels.

It is possible to demonstrate the missing or underestimated flow volume from the monthly mean water level as shown in Figures 4 and 5 below. If daily records were used, the results

would be more convincing since the authors underestimated the original water level fluctuations and peaks by using monthly values.

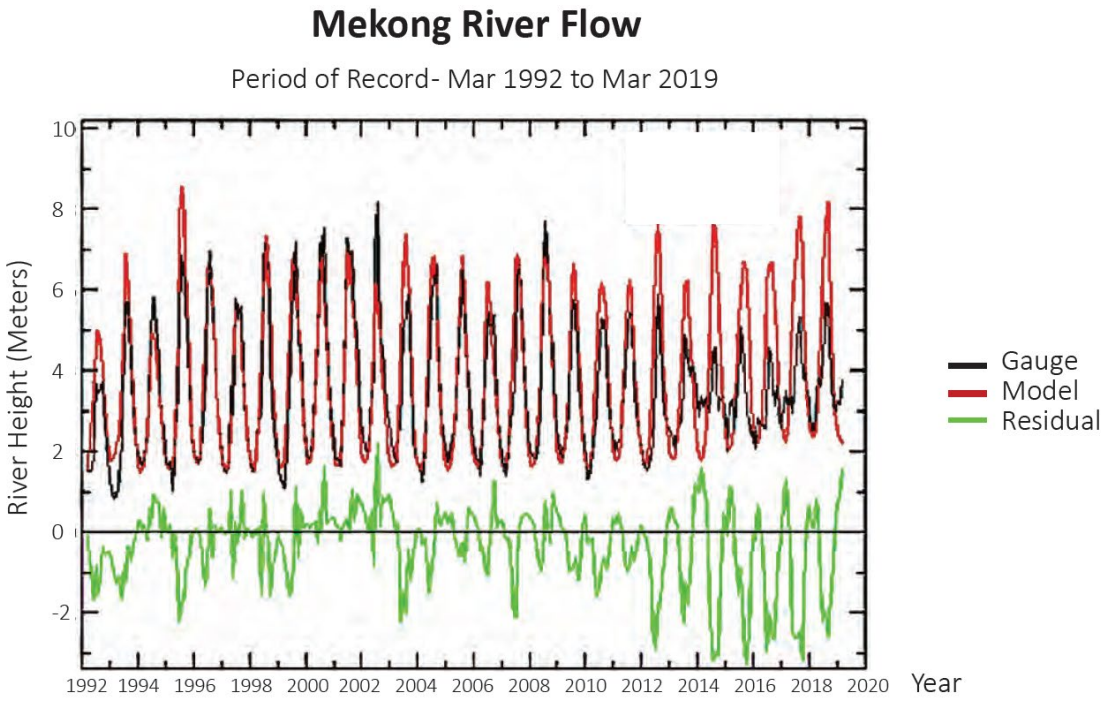

Figure 4. Monthly mean water level from the study (Basist & Williams, 2020, p. 15)

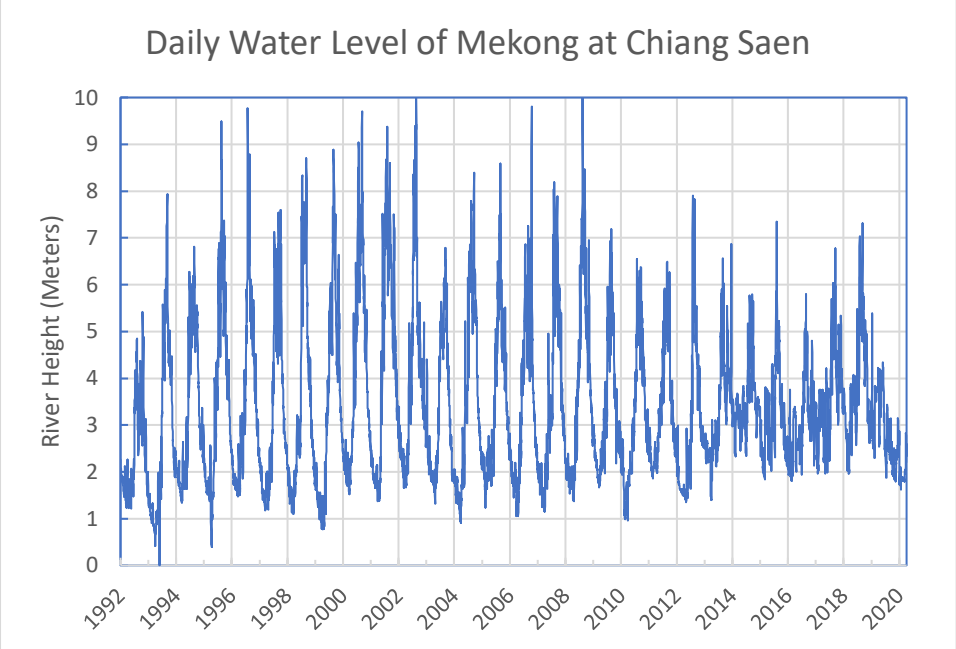

Figure 5. Daily water level recorded at Chiang Saen from the MRC Secretariat

Although the regression model provided a plausible result, with a standard error of about 0.67 m, *Figure 3* on page 16 of the report shows that the model could have overestimated the water level by as much as 2 m during the validation period (1994-1996) as well as some moments in the calibration period (1997 – 2001). Also, as the Manwan dam was commissioned in 1993, it would have already been affecting the flows at Chaing Saen during

their “natural” flow period. The simulation should, therefore, have discounted the effect of the Manwan dam and should have attempted to minimise the error signal to ensure that the model provided more precise flow estimates.

Finally, as the methods presented by the authors are highly empirical and calibrated on the period 1997-2001, various complex hydrological and physical processes that determine the runoff from the catchments and the river are not captured in the regression functions. With this highly simplified regression approach, there is a chance that exceptional meteorological conditions and changes in the catchment in the past 20 years will also have contributed to a deviation in the observed hydrology and the simulated result. It is therefore not surprising that the findings of this study do not match the MRC’s analyses of the drought conditions. Based on a more thorough, yet preliminary, hydrological analysis, the MRC showed that drought problems in 2019 are diverse in space and time. This is further explained in Section 6.

5 Room for improvement

As a data-driven research piece, the study relied mainly on the understanding and consistency of the hydrological data. The study would be much improved if the followings are considered.

- **Natural condition:** The central question that influenced the results and findings of the study was the definition of baseline or a long-term average of the natural condition. This study adopted a 1997-2001 (5 years) water level at Chiang Saen. The MRC has data on water level and discharges at Chiang Saen from the 1960s (see MRC’s Data Portal). The MRC’s studies used the flow records from the 1960s – 2000s as a basis for the “natural” pre-development condition of the river. A longer record for the analysis should be considered.

- **Discharge and more robust model:** The Mekong River morphology is changing because of erosion/deposition. These change the water level and discharge/flow relationship. An analysis of these changes would have been more robust and enhanced the reliability of the study. For instance, in Figure 3 representing the Chiang Saen rating curves, the dots represent data for the period 1960s-2010s for which the band width partially reflects the changes in morphology over that period.

- To offer a more accurate and representative picture of how much water China may be storing, a simple model is not sufficient. A proper **hydrological model** representing a relationship between rainfall and runoff could be developed to verify the results derived from satellite data and wetness index in this study, as well as to reveal how much water China may be holding behind their dams. This is despite the fact that these hydrological models need calibration and estimates of the hydrological parameters (using rainfall data from satellites, evaporation estimates, snow, etc.).

- **Reservoir water surface from satellite imagery** helps understand how Upper Mekong dams are managed and operated. Future study should consider adding this factor. The technology is already available and proven; for instance, applied by Donchyts (2018) to develop the Aquamonitor (using freely available satellite data and the Google Earth Engine). Microwave Sentinel images with Synthetic Aperture Radar (SAR) have been applied to detect water surfaces using Normalised Difference Water Index (NDWI) to detect water bodies. However, this requires careful selection of thresholds to obtain sufficient accuracy.

- **Peer review to ensure quality assurance:** As stated earlier, the scientific basis for the study might not yet be sufficient to allow for conclusive findings. Information on review or quality assurance of the work should be provided. For data to be reliable, they need to be checked and taken through a quality assurance and quality control process. In other words, independent scientists should review the study.

- **A review of the literature on similar studies** should also be considered. The review would have enhanced readers' understanding by putting the work in perspective and providing evidence that could be used to support the findings. It would also help to demonstrate the authors' level of understanding of hydrological science, Mekong hydrology, the research field and the nature of the work.

6 What we know so far about the causes of the 2019 drought

Our preliminary analysis, using historical rainfall data (2008-2019) and observed water flows, showed that the 2019 drought in the basin was due largely to insufficient rainfall during the wet season with a delayed arrival and earlier departure of monsoon rains and an El Nino event that created an abnormally higher temperature and higher evapotranspiration.

During a normal year, Monsoon rains usually start in late May and end in October. Nevertheless in 2019, they began almost two weeks late and stopped about three weeks earlier than usual. The basin lost about five weeks of rain and only received about 75% of rainfall as compared to previous years (see Figure 6).

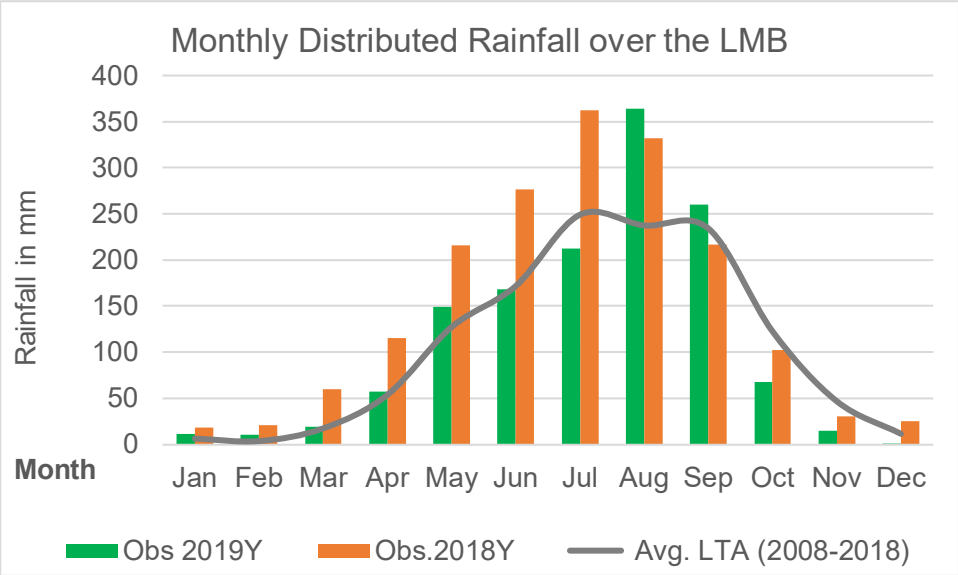

Figure 6. Monthly change of distributed rainfall over the Lower Mekong Basin.

In March this year, there were news reports in both Cambodia and Viet Nam on drought conditions in the Mekong Delta. However, while the mainstream flows at Vientiane were at record low flows, these record low flows did not persist downstream of Vientiane. Flows from China were higher than normal for the 2019 and 2020 dry seasons. From January 2020, flows at Kratie in Cambodia were also higher than typical for the dry season (see Figure 7).

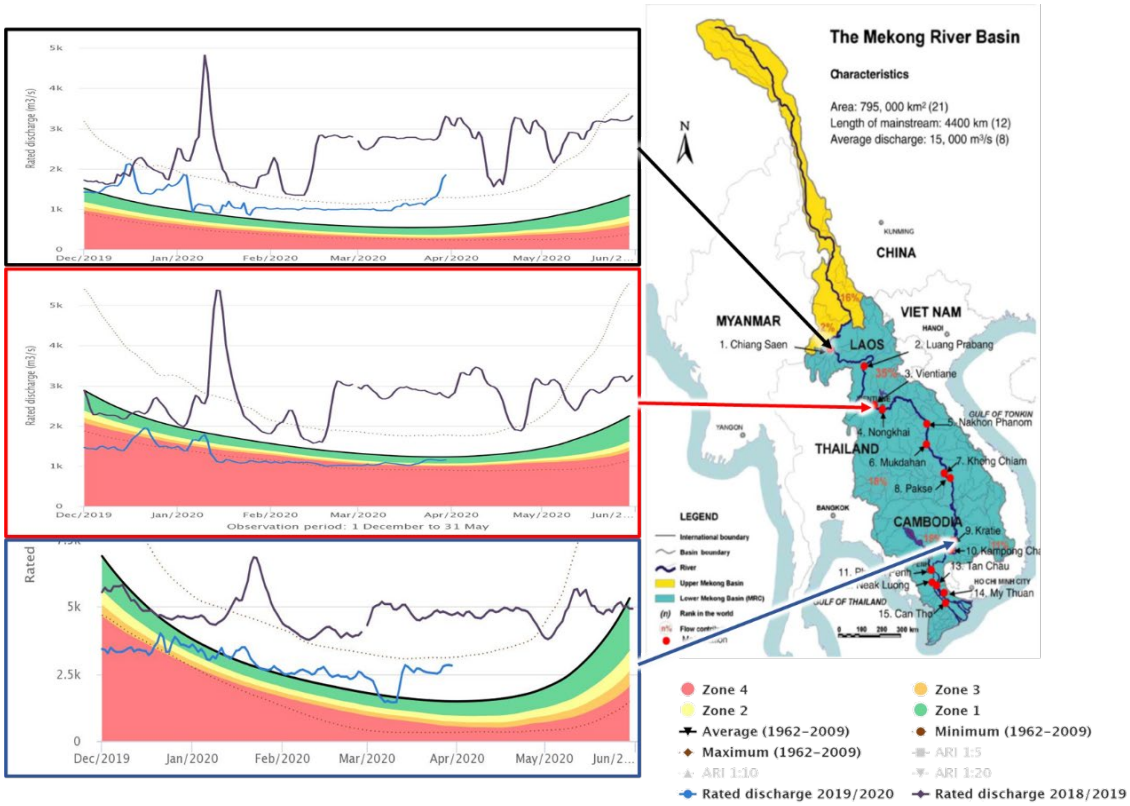

Figure 7. Information on the dry season flows from December 2019 to April 2020, set against historical records recorded in the MRC's PMFM

The higher than typical flows downstream of Vientiane could most likely be due to the tributary hydropower projects. The drought noted in the Mekong Delta was a meteorological not hydrological[1] phenomenon.

While we know that the operation of dams in China causes impacts to the LMB (see MRC's State of the Basin Report), it is not true that the lack of water in the LMB during 2019 and 2020 was influenced mainly by these dams. The water flow contributions across the whole basin must be analysed.

7 What next for the MRC Member Countries and for MRC–China cooperation

MRC Member Countries

The MRC Member Countries are implementing their five-year Drought Management Strategy approved by the MRC Council late last year, including improving drought monitoring and forecasting systems, along with their capacities. If the Member Countries are to share more information with the MRC, especially data and information on water use and infrastructure, the Commission will be in a better position to support seasonal water resource planning and management, and can address misperceptions by the public and in the media.

Inadequate information on water infrastructures in the Mekong River Basin and the way these infrastructures are operated has made it challenging to forecast short-term impacts. For forecasting to be fast and accurate, year-round data from various sources are necessary.

As the Mekong River Basin develops, the Member Countries will need to further align national and regional interests. They need to recognise that cooperation in its own right has regional benefits and that growth and stability in neighbouring countries is in their own interest.

The line between the immediate benefits of development, social justice for those affected by that development, and environmental sustainability must be carefully navigated. This is the reason why the Member Countries need to strengthen efforts to work together in the common interest. They need to further practice due diligence in development planning and implementation in line with regional and national guidelines.

[1] *A meteorological drought refers to the situation when dry weather patterns dominate a certain area for a period of time. A hydrological drought occurs when low water supply becomes evident, usually after many months of a meteorological drought.*

Cooperation with China

While cooperation between the MRC and China – as an MRC Dialogue Partner – has been strengthened in recent times, more needs to be done to establish a more formal working relationship. A more institutionalised arrangement will enable the Commission to address risks that can only be managed through a 'whole of basin' approach.

For the past 16 years, China has provided its water level and rainfall data only during the flood season from two of its many stations on the Upper Mekong. This is useful for flood forecasting but not sufficient for other management purposes.

To increase the transparency of dam operations and to demonstrate cooperation in good faith, China should consider providing more data that covers more stations and includes the dry season data. Not only will this help the MRC Member Countries to better plan and manage their water resources and address potential short-term risks in a timely fashion, but will also help China to clear any misperceptions among the general public. Working with a neutral organisation like the MRC would be helpful to China in this regard.

How the MRC Secretariat is working with LMC Water Centre on the 2019 drought and low flows

The MRC Secretariat is working with the Lancang-Mekong Water Resources Cooperation Center to conduct a *Joint Study on the 2019 Drought and Low Flows*. The Joint Study aims to identify the causes and impacts of the drought and low flow conditions in 2019. This joint effort builds on past successful collaborations between the MRC and China, for example on the *Joint Observation and Evaluation of the Emergency Water Supplement from China to the Mekong River (JOE)* to alleviate the 2016 drought, and the *Joint Research on the Hydrological Impacts of the Lancang Hydropower Cascade on Downstream Extreme Events*.

It is anticipated that the findings of the Joint Study will provide practical recommendations leading to improved data and information sharing between the MRC Member Countries and China, the development of clear communication protocols, and coordinated operations of reservoirs in both China and MRC Member Countries. These actions will ensure a more effective response to current and future droughts and water flow issues.

What the MRC Secretariat is doing to improve flood and drought forecasting and to address emerging risks

At the MRC, we have begun to reinvigorate our data, information, modelling, forecasting, and communication systems.

This aims to upgrade the MRC's decision support framework (DSF) to become a more comprehensive decision support system (DSS) that includes operational models that provide more information on current conditions in the basin. The improved system will be able to offer faster reactions to address emerging changes, such as sudden water releases from

reservoirs in the Upper Basin, and to track the basin's state and development. This will enable the MRC to provide accurate up-to-date information to the public and decision-makers as quickly as possible.

The MRC has already engaged and expects to further its collaboration with all our international partners in pursuit of this initiative, including Australia, China, Japan, South Korea and the United States.

The MRC has also started advancing its flood and drought monitoring and forecasting functions. This aims to assist its Member Countries to effectively tackle flood and drought risks for vulnerable communities.

The work will also see the Commission transform its Regional Flood and Drought Management Centre (RFDMC) in Phnom Penh into a centre of excellence in providing faster and more accurate flood and drought forecasting and early warning to its four Member Countries.

The upgraded Centre will make available improved public information on flood and drought with the use of advanced technologies, so that local communities and governments are timely informed, and that damages can be reduced in time of danger. It will also help to facilitate an integration of flood and drought management functions to provide a longer lead-time and better accuracy of forecasting.

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Mekong River Commission Secretariat
P.O. Box 6101, 184 Fa Ngoum Road
Unit 18, Ban Sithane Neua, Sikhottabong District, Vientiane 01000, Lao PDR
Tel: +856 21 263 263. Fax: +856 21 263 264