– Short Technical Note –

Mekong Sediment from the Mekong River Commission Study

Summary

The Mekong River flows through China, Myanmar, Lao PDR, Thailand, Cambodia and Viet Nam. The assessment of various water resources development impacts on the water quality and quantity is currently a main concern for environmental, social and economic policy analysts in the Mekong Region. However, the quantitative assessment of such impacts is a complex task. The four Mekong prime ministers commissioned the study to assess the positive and negative impacts of water resources developments on the people, the economy and the environment. The study implements a range of alternative development scenarios, including historical conditions and future development situations.

This paper presents the results of modelling changes in sediment loads in the Mekong basin by employing water resource modelling to support the impact assessment, which is part of the study. The MRC Decision Support Framework (DSF) was integrated with the eWater Source model to formulate different scenarios. The results discussed herein indicate that existing and proposed dams in the Mekong basin are expected cumulatively to have significant impacts on sediment loads entering the Mekong delta. Sediment reduction has been estimated at 67% and 97% in the 2020 and 2040 development scenarios, respectively. The loss of sediment is expected to have damaging consequences on the productivity of the river, geomorphology and persistence of the Delta landform itself. Mitigation measures to pass sediment through dams on the mainstream could reduce the consequences of downstream sediment starvation, though proposed tributary dams and those in the Upper Lancang area would still have significant impact.

1. Introduction

The Mekong River, one of the largest rivers in Southeast Asia, flows southward from the Tibetan Plateau to the South China Sea through the Indochina Peninsula, forming a Delta at its mouth. The Mekong River Commission Member Countries – Cambodia, Lao PDR, Thailand and Viet Nam – have plans for development, and significant water-related infrastructure has already been built or under construction in major tributaries and the upper reaches of the mainstream. The development of water-related infrastructure is in response to rapidly growing populations and economic development, with associated increases in demand for, and the development of water resources. As a result of this development, economic growth would follow and bring significant benefits to the region. However, if development is not properly planned and designed, it could have serious consequences for the downstream reaches.

The Mekong River serves as the heart and circulatory system for all the nutrients and building blocks of life; the pure water is the lifeblood that carries the fine sediment that conveys the nutrients. Water resources development in the basin is bringing significant changes to the river, including deteriorating water quality, the trapping of sediments, and the creation of barriers for migrating fish.

The MRC Council Study (Study on Sustainable Management and Development of the Mekong River with Impacts of Hydropower Projects in the Mainstream) aims to enhance the ability of the MRC to advise Member Countries on the positive and negative impacts of water resources development on the people, the economy and the environment of the Mekong Basin[1]. Six selected developments are modelled in the study, such as hydropower, irrigation, agriculture and land-use changes, domestic and industrial water use, navigation, and flood protection. Substantial changes in sediment can be expected in the Mekong River due to the cumulative effect of dams in the Basin (see Figure 1).

[1] MRC. (2014). *Study on the sustainable management and development of the Mekong River, including impacts of mainstream hydropower projects (Council Study): Inception report*. Mekong River Commission Secretariat, Vientiane.

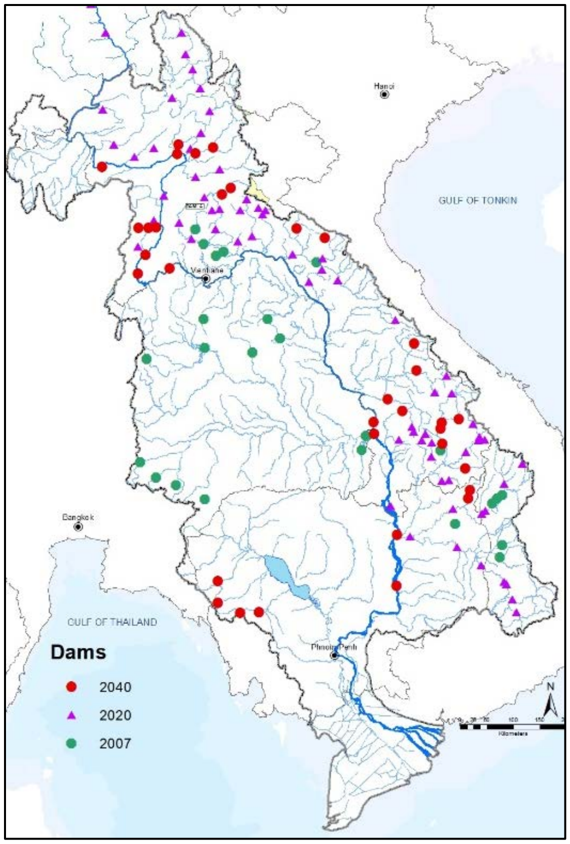

Figure 1. Hydropower dams in 2007, 2020 and 2040

A scenario-based approach is being used to consider various future conditions: the near future (2020), a longer-term planning horizon (2040) and an early development condition (2007) are compared as seen in Table 1.

Table 1. Summary of the baseline and main development scenarios for the study

Short Tiltle	Description	Detail Information
M1	Baseline 2007	Infrastructures of six related sectors in 2007
M2	Development 2020	Infrastructures of six related sectors in 2007, currently under construction and planned for 2020
M3	Development 2040	Infrastructures of six related sectors in 2007, currently under construction and planned for 2020 and 2040

2. Objectives

The general objective of this paper is to provide key findings on sediment reduction in the Mekong River emerging from the study results. Three specific goals include:

- *Sediment contribution by mainstream and tributaries*
- *Sediment trapped by hydropower cascade on the Mekong Basin*
- *Trends in sediment reduction from scenario comparison analysis*

3. Materials and Methods

This section describes the approaches used in the sediment reduction calculations.

3.1 Model and Data

The MRC Modelling system has been used extensively to support the CS together with additional modelling tools for agriculture and floodplain sedimentation. The MRC Decision Support Framework (DSF) was considered as a state-of-the-art computer-based system in 2001, which has been developed through a thorough consultation process involving the four MRC member Countries. The DSF includes a suite of models that performs the water quantity and quality simulations required to support the impact assessments.

Due to current limitations of the MRC DSF, it is integrated with the eWater Source to efficiently carry out sediment transport and trapping for scenario modelling structural change. The methodology used in the Council Study integrates the results of the IQQM and SWAT models and produces outputs which are required by the ISIS model.

All data transfers between models are facilitated by the Data Transfer Tool (DTT), which passes data between models via a central database called the Knowledge Base (KB) (see Figure 2).

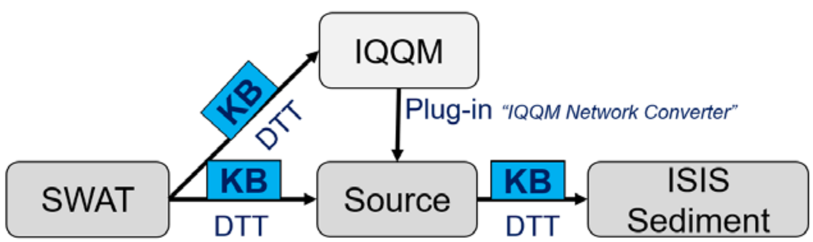

Figure 2. Relationship between the SWAT, IQQM, Source and ISIS models. Arrows show the direction of information flows

The available sediment data comes from three sources within the MRCS[2]:

- ✓ Mean suspended sediment concentration (SSC) from the Hymos Database
- ✓ Total suspended solids (TSS) from the EP Database

[2] MRC. (2015). *Strategic Plan 2011-2015*. Vientiane: Mekong River Commission Secretariat.

- ✓ Mean suspended sediment concentration (SSC) from the Discharge and Sediment Monitoring Project (DSMP)

Table 2 summarises the data availability. There are numerous issues with the data, including limited spatial and temporal range, discontinuous records, low sample numbers, and unreliable and inappropriate sampling methods.

Table2. Summary of sediment data availability

Data Source	Station Locations	Temporal Range	Comments
Hymos	Middle and theLower Mekong mainstream	1960 to the present	Data is discontinuous and there are limited sample numbers.
EP	17 on the Mekong 6 on the Bassac 23 on the tributaries 9 in the Delta	1985 to the present	Not all stations are available for the entire period. Data is likely to underestimate the true mean suspended sediment concentration due to the sampling method2009 to 2013
DSMP	15 on the Mekong 2 on the Bassac 1 on the Tonle Sap	2009 to 2013	The most reliable of the three datasets due to sampling methods and frequency. Refer to Koehnken (2015) for details. The data reflects the impacts of sediment trapping in the Upper Mekong due to the Manwan, Dachaoshan, Jinghong and Xiaowan Dams.

3.2 Approaches to estimate sediment trapping in reservoir and sediment contribution

Sediment trapping efficiency (TE) is the proportion of sediment deposited in a reservoir relative to the incoming load.

Two approaches are used in the Council Study; full modelling of the hydraulics of sediment movement for the mainstream using a 1D hydrodynamic model, and full basin-wide simulations of all tributaries, the upper Lancang and lower mainstream dams using Source. In ISIS, the movement of sediment is calculated using sediment transport formula according to grain size. In Source, trapping is estimated via Brune (1953)[3]. The Brune algorithm is a widely used, well-established empirical model, which requires two key inputs to calculate TE. These are the reservoir capacity and average total annual inflow.

The Brune method was checked for Mekong conditions for the Manwan and Dachaoshan Dams in China. The results were compared with other literature reviews such as Fu et al. (2007)[4] and Kummu et al. (2010)[5]. It was found that the implementation of the Brune TE methodology in eWater Source produced comparable results as those obtained by Fu et al. (2007)[6]. As a ressult, TE for Xiaowan and Nuozhadu Dams, and other dams in China and the Lower Mekong Basin (LMB) were estimated using the same approach. eWater Source routes the sediment through tributaries to the Mekong River, including trapping

[3] Brune, G. M. (1953). Trap efficiency of reservoirs. *Eos, Transactions American Geophysical Union, 34*(3), 407-418.
[4,6] Fu, K., & He, D. (2007). Analysis and prediction of sediment trapping efficiencies of the reservoirs in the mainstream of the Lancang River. *Chinese Science Bulletin, 52*(2), 134–140.
[5] Kummu, M., Lu, X. X., Wang, J. J., & Varis, O. (2010). Basin-wide sediment trapping efficiency of emerging reservoirs along the Mekong. *Geomorphology, 119*(3-4), 181-197.

in reservoirs. To validate the accuracy of the hydrodynamic model, modelling results are compared against monitoring data from MRC datasets, though as yet there is no data for mainstream reservoir trapping as the first dams at Xayaburi and DonSaHong are under construction.

4. Results & Discussion

4.1 Sediment Contribution from tributaries

Results of the calculations are presented in Figure 3, which depicts each scenario for 62 tributaries that have direct sediment into the Mekong mainstream and two associated areas in the Viet Nam Delta. The total catchment area of the Mekong is 822,206 km^2. The contributions of tributaries were represented as total sediment load yearly into the Mekong mainstream.

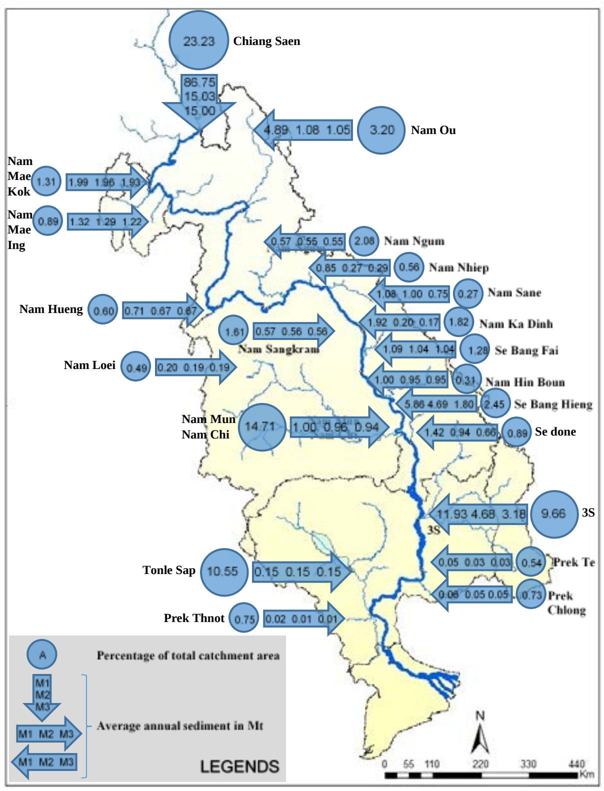

Figure 3. Annual sediment contribution by tributaries in Mt in each scenario

4.2 Trends in sediment reduction from scenario comparison analysis

Altering sediment transport and deposition in the Mekong River due to other infrastructure development is also provided in this paper. It was found that the primary effect is due to hydropower dam development in the basin. Figure 4 shows the changes in sediment loads along the course of the Mekong River for each of the main scenarios. We note a large reduction in the amount of sediment load transported downstream in the scenarios.

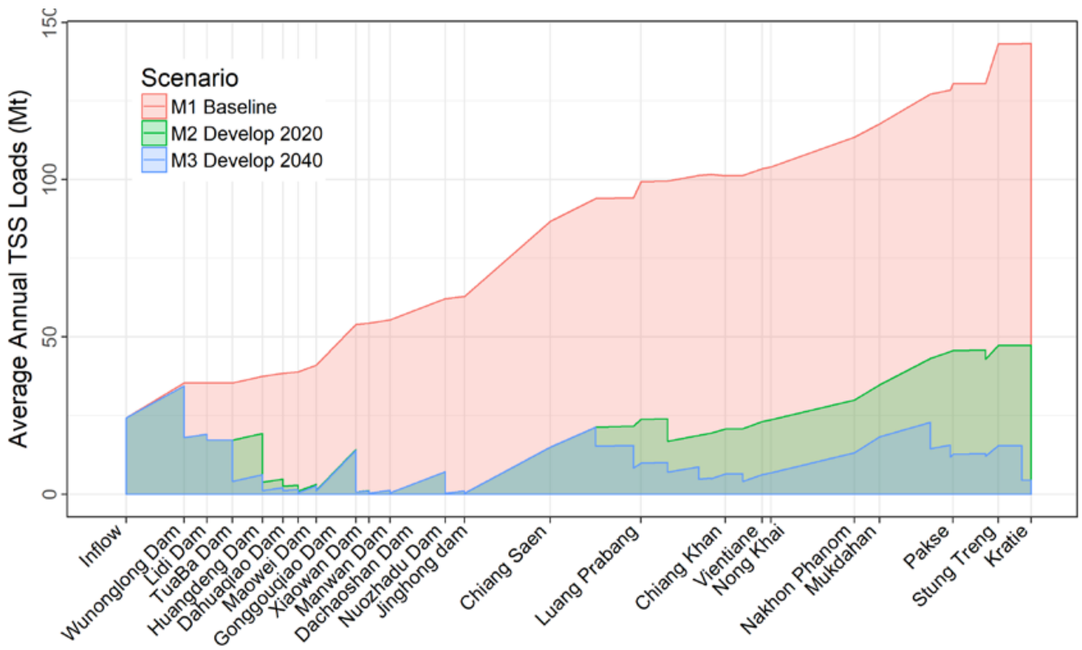

Figure 4. Longitudinal plot of sediment loads in the Mekong River from China (Lancang River to Kratie)

4.3 Sediment trapped by the LMB Mainstream hydropower cascade on the Mekong Basin

The Development 2020 and Development 2040 scenarios show sediment trapping by hydropower cascade on the Mekong as seen in Figure 5.

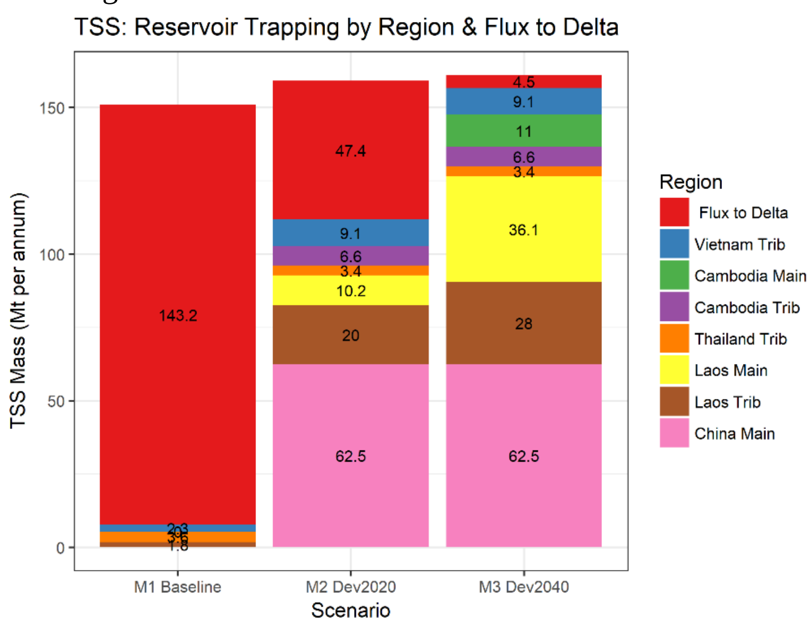

Figure 5. Mass of Sediment Trapped by mainstream LMB hydropower cascade on the Mekong

The sediment trapped by the Lao mainstream hydropower cascade in 2020 is 10.2 Mt/annum (million tons per annum). Figure 6a shows that sediment trapping by reservoirs will be 67%, implying that the sediment load reaching the Delta will be 33% of its 2007 level. The amount trapped by the Lao and Cambodian mainstream hydropower cascade in 2040 is 47.1 Mt/annum. Figure 6b illustrates that about 97% of the sediment load will be trapped, which indicates that the sediment load reaching the Delta will be 3% of its 2007 level after sediment stored in the channel is lost.

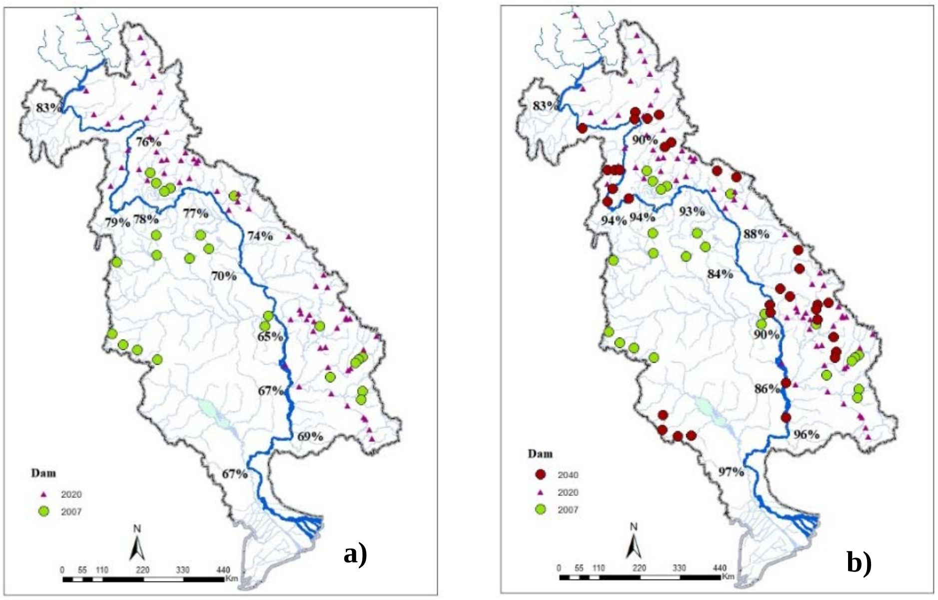

Figure 6. The average reduction of sediment of the M2 (a) and M3 (b)relative to the natural load

5. Conclusion

The temporal and spatial changes in the sediment load were investigated for the entire Mekong Basin. Due to the number of development projects in the Mekong Basin, results of the models demonstrate that without mitigation, hydropower development will have major impacts on the sediment balance in the Mekong Delta because the reduction in sediment loads is around 97% under the 2040 scenario. With this magnitude of potential sediment starvation on the Mekong River system, mitigation strategies of all planned dams should be implemented to improve sediment loads reaching the Mekong Delta.

If mitigation strategies involving the implementation of sediment passage structures for mainstream dams such as fish passage structures and sediment sluicing operations in the Lower Mekong Basin are implemented, it would be possible to reduce the serious impacts on the river channel and delta landforms, floodplain fertility, and productivity of the ecosystem, including the extraordinary Mekong River fisheries. However, mitigation measures are only likely to be effective if they are implemented in a coordinated way for all dams in the cascade.