Luangprabang hydropower and its downstream accumulative impact on sediment flux

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Abstract. With the aim to develop hydropower potential of the Lower Mekong Basin (LMB) and not to cause substantial impacts to natural environment, in 1980s and early 1990s of the last century, the then Interim Mekong Committee had studied a cascade of run-of-river hydropower projects in the Mekong mainstream. In 2008, Hydropower Development Programme of the Mekong River Committee (MRC) proposed a scenario consisting of 11 run-of-river hydropower projects. Luangprabang hydropower (LHP) is the second cascade in Laos and the tenth cascade from upstream of Lancang- Mekong river. The Environmental Impact Assessment report of LHP was carried out by Vietnam Association for Conservation of Nature and Environment (VACNE).

The accumulative impacts of hydropower cascades in mainstream of Lancang-Mekong river to downstream are significant negative in terms of sediment flux in downstream in which, contribution of the LHP is small or may be insignificant . Sediment impounded in LHP reservoir is estimated to be 10.1 tons/year or 17% sediment flow decreasement at Luangprabang Hydrological Station (LHS). The sediment impounded in LHP reservoir decreases about 6.95% total sediment volume flowing into the Mekong delta in Vietnam.

Keywords: Sediment index; Sediment flux, Accumulative impact, Hydropower, Mekong river.

1. Mekong river and hydropower potential

Rising in the glaciers of Tibet and flowing through territories of six countries namely China, Myanmar, Laos, Thailand, Cambodia and Viet Nam before entering the South China Sea, with total length of 4,400 km, catchment area of 795,000 km^2, average annual flows of 15,000 m^3/s, the Mekong River lends itself to romantic metaphors and impressive statistics, both of which are frequently invoked in the current dam-building debate. The river is ranked as 12th in the longest river in the world, 21st in terms of area and 8th in flows [1, 2]. The basin is divided into two parts as upper part (in China), and lower part (Lower Mekong Basin/LMB). The LMB is defined as the watershed area downstream of China and Myanmar, which covers an area of over 77% of basin area, including almost territories of Laos and Cambodia, 1/3 of Thailand and 1/5 of Viet Nam. In the LMB, many river reaches are border between Laos and Thailand and also many reaches run in entire territories of Laos, Cambodia and Viet Nam [1].

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In addition to abundant resources on forests, fisheries, lands etc., water resources in general and hydropower potential in particular are important resources of the basin that can meet energy demands in the region, contribute to poverty alleviation. In accordance with studied results of the MRC, hydropower potential of the river basin is estimated to 53,200 MW, of which 23,000 MW is in the upper part of China, and 30,000 MW in the lower part. Total existed, under construction, and planned installed capacity in the Lancang - Mekong River is 42,076 MW, accounting for 79.1 % exploitable potential in the region of which total planned capacity in the upper part in China is 14,800 MW, accounting for 64.4% hydropower potential of Lancang River. The lower part of basin has 27,276 MW potential capacity or 90.3% hydropower potential of the LMB (Table 1) [3].

Table 1. Installed capacity of existing, under-construction and planned projects in whole Lancang-Mekong river basin

Country/part		Under commission	Under construction	Planned	Total
China		2,850	11,950	750	14,800
LMB	Laos	669	2,558	14,773	18,000
	Thailand	779	-	-	779
	Cambodia	1	-	6,010	6,011
	Viet Nam	1,786	651	49	2,486
Total LMB		3,235	3,209	28,832	27,276
Total China + LMB		7,085	15,159	29,582	42,076

Lancang river basin (from source down to China's border) covers an area of 168,000 km^2, or 21.1% total area of Lancang-Mekong basin. Annual run-off volume is 74 km^3, or 16.2% total run-of of the basin but hydropower potential is 23,000 MW, accounting for 43.2% total potential of whole Lancang-Mekong basin. Out of 8 hydropower cascade in Lancang river, 2 projects have been put into commission, 4 projects are under construction and 2 remaining ones have been planned (Fig.1) [3].

With the aim to develop hydropower potential of the Mekong mainstream and not to cause substantial impacts to natural environment, in 1980s and early 1990s of the last century, the Interim Mekong Committee had studied a cascade of run-of-river hydropower projects (no regulation) in the Mekong mainstream. These projects would operate in an isolate regime so that the selection could be actively undertaken basing on proposed criteria as economic energy effectiveness, extent of socio-environment impacts etc. After all hydropower cascades in China part are put into operation, energy effectiveness of these projects would be significantly increased. However scenarios of hydropower development in the Mekong mainstream had also been changed a lot. In 2008, Hydropower Development Programme of the MRC proposed a scenario consisting of 11 run-of-river hydropower projects in the lower part (Fig.1) [3].

2. Summary of LHP

2.1. Location

LHP, invested by Petro Vietnam Power Corporation (PV Power) is located at km of 2,036 from the sea and the tenth hydropower cascade in the mainstream of Lancang-Mekong river. As a run-of-river hydropower project, LHP dam site is about 3.5 km upstream of the confluence of Nam Ou and Mekong rivers and about 30 km far from Luangprabang City. Location and main parameters of LHP are shown in Fig. 2.

No.	Cascade	Status	Type	Installed capacity (MW)	Completion time
1	Gongguoquiao	Under Construction	Run-of-River	750	2012
2	Xiaowan	Under Construction	Storage	4,200	2010-2014
3	Manwan	Under operation	Run-of-River	1,500	1993-1996
4	Dachaoshan	Under operation	Run-of-River	1,350	2001-2004
5	Nuozhadu	Under Construction	Storage	5,500	2014
6	Jinghong	Under Construction	Run-of-River	1,500	2013
7	Ganlanba	Planned	Run-of-River	150	before 2025
8	Mengsong	Planned	Run-of-River	600	before2025
Total:				14,800	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	Pak Beng	Laos	Run-of-River	1,230	-
2	Luangprabang	Laos	Run-of-River	1,410 (1,500)	-
3	Xayabury	Laos	Run-of-River	1,260	-
4	Pak Lay	Laos	Run-of-River	1,320	-
5	Sanakham	Laos	Run-of-River	570	-
6	Pak Chom	Laos – Thailand	Run-of-River	1,079	-
7	Ban Koum	Laos - Thailand	Run-of-River	2,330	-
8	Lat Sua	Laos	Run-of-River	800	-
9	Don Sahong	Laos	Run-of-River	360	2015
10	Stung Treng	Cambodia	Run-of-River	980	-
11	Sambor	Cambodia	Run-of-River	3,300	-
Total:				14,639	
				Source: MRC, 2008	

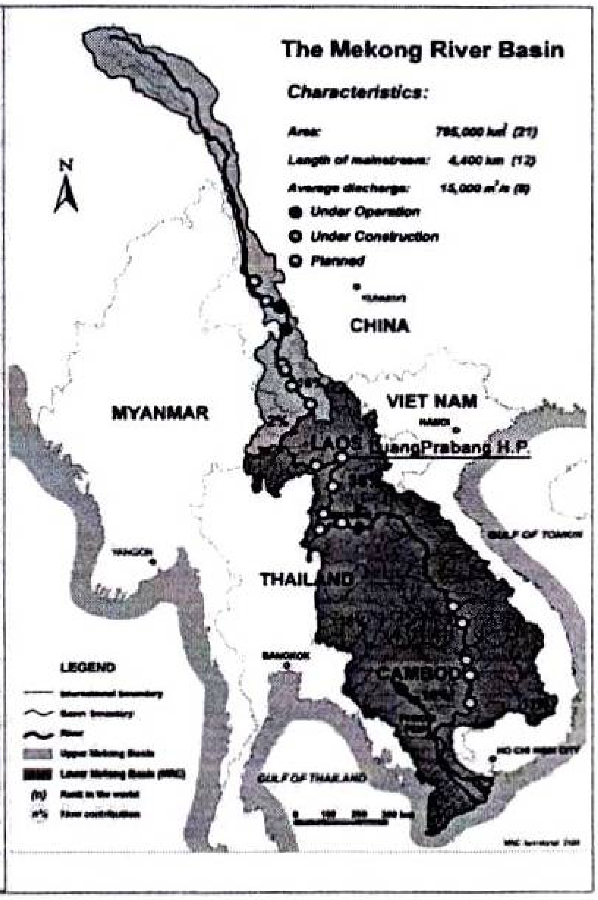

Fig. 1. Hydropower cascades in the Lancang-Mekong River.

No.	Parameters	Unit	Value
I	Reservoir (Run-of-river)		
	Full supply water level (FSL)	m	320
	Death water level	m	318
	Total storage	10^6m^3	1,589.8
	Active storage	10^6m^3	136.1
	Death storage	10^6m^3	1,453.7
	Reservoir area (at FSL)	km^2	72.39
II	Barrage dam		
	Type		Gravity
	Maximum height	m	57.5
III	Spillway		
	Number of spillway gates		10
	Gate dimension (B x H)		18 x 22
IV	Lock		
	Throughput capacity	t/year	1,210,000
	Number of chambers		2
	Chamber dimension	m	12 x 120 x 3
V	Powerhouse		
	Installed capacity	MW	1,500
	Number of units	n	10
	Energy generation	10^6kWh	7,102.7
VI	Economic factors		
	Total investment costs	10^9VND	58,973.34
	NPV	10^9VND	5,314.88
	EIRR	%	14.84
	B/C	-	1.2

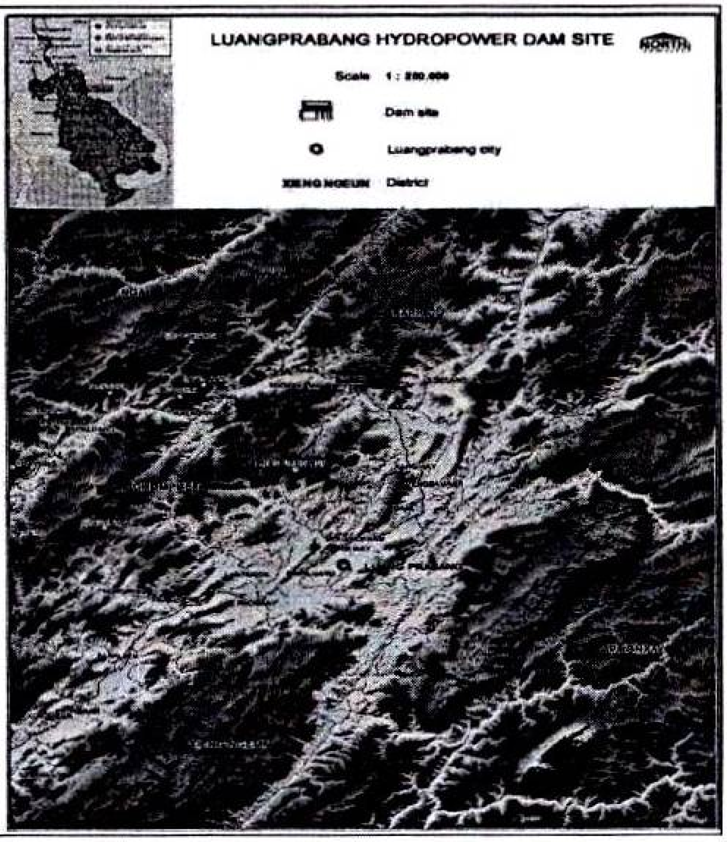

Fig. 2. Location and main parameters of LHP.

3. Accumulative impact assessments of LHP to sediment flux in downstream

3.1. Impact assessment to sediment flux in downstream

LHP may significantly cause negative impacts on downstream such as: change in hydrological regimes, productivity of fisheries, sedimentation and etc. A decreasement in sedimentation due to trap efficiency (sediment index) of reservoir would negatively affect fisheries and agriculture. According to PECC1, total sedimentation (W_{TS}) in LHS is of 82.7 million ton annually [4]. The W_{TS} arrives to the reservoir (LHP) is of about 60.7 million ton annually. The flow of suspended load of sedimentation (W_{SL}) in LHS calculated by PECC1 is about 59.1 million tons/year. This value is suitable with the result in Kummu's research, which announced to 60 million tons/year [5]. The flow of W_{SL} to the site of LHP is calculated to be 46.7 million tons/year. The bed loads of annual sedimentation (W_{BL}) in LHS and LHP are 23.6 and14.0 million ton respectively. (Table 3) [4].

Table 3. Sediment inflows to LHP and LHS

Computing section	Flv (km^2)	Q_0 (m^3/s)	R_0 (kg/s)	Amount (10^6 ton/year)		
				W_{SL}	W_{BL}	W_{TS}
Luangprabang hydrological station (LHS)	268,000	3,810	1,874	59.1	23.6	82.7
Luangprabang hydropower (LHP)	230,000	3,008	1,480	46.7	14.0	60.7

The coefficient of suspended matter of LHP is calculated using the below formula of US Army Corps Engineer [6]:

$SI = f(\tau, Q, L, V\} = 21.5\%$

In which:

SI = Sediment Index (Trap Efficiency)

τ = Hydraulic residence time

Q= The discharge

L= Reservoir length

V= Reservoir volume

Thus, estimated sediment kept in LHP reservoir is 46.7 million tons/year * 21.5% = 10.1 tons/year. In other words, 10.1 million tons/year of W_{SL} in the lower section of LHP reservoir will be decreased as or 17% sediment flow at LHS will be reduced. According to results of previous researches, total amount of W_{SL} flow of LMB was estimated to be in the range from 150 to 170 million tons/year [5]. Total amount of average W_{SL} flow (in 3,000 years) to the Mekong River delta was calculated to be 144.74 million tons/year [7]. The impacts of sediment trapped in LHP reservoir is insignificant as only about 6.95% decreasement of total sediment flowing into the Mekong River delta (Fig. 3).

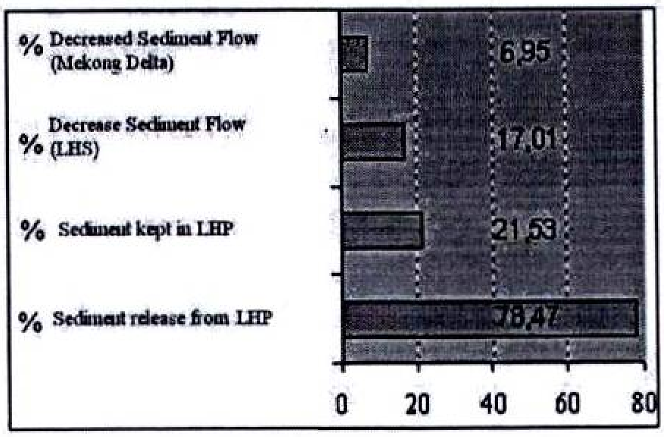

Fig. 3. Ratio of decreased sediment flows in downstream of the LHP.

3.2. Accumulative impact assessment to sediment flux in downstream

The first hydropower cascade on the mainstream in Lancang River (China) is

Manwan hydropower dam. In 1992, Manwan hydropower reservoir started filling in and most of the sediment volume are impounded in the reservoir. The productivity of keeping sediment of Manwan hydropower reservoir is 68% that decreases W_{SL} flow in Chiang Saen around 56%, from 71 million tons/year to 31 million tons/ year. In LHS, alternative value is 47% and W_{SL} flow decreased from 113 million tons/year to 60 million tons/ year [5].

The changes of TSS content in LHS in the period from 1985 to 2006 can be seen in figure 4 [5, 8]. TSS content in the water of Mekong River in LHS has a trend to decrease remarkably. Especially after Manwan hydropower reservoir has been fully filled (1992), TSS value dropped dramatically. After that, when Dachaosan hydropower reservoir stored water (2003), TSS value continued to reduce. However, the level is not so much compared to impacts caused by Manwan hydropower dam. Reason is that the sediment volume in the upstream has been kept in Manwan hydropower reservoir before flowing into Dachaosan hydropower reservoir. TSS value in 2005 and 2006 in LHS had trends to increase. That was caused mainly by floods taken place in the tributary (Nam Ou river) resulting in TSS content on Nam Ou River and increasement of TSS value in LHS.

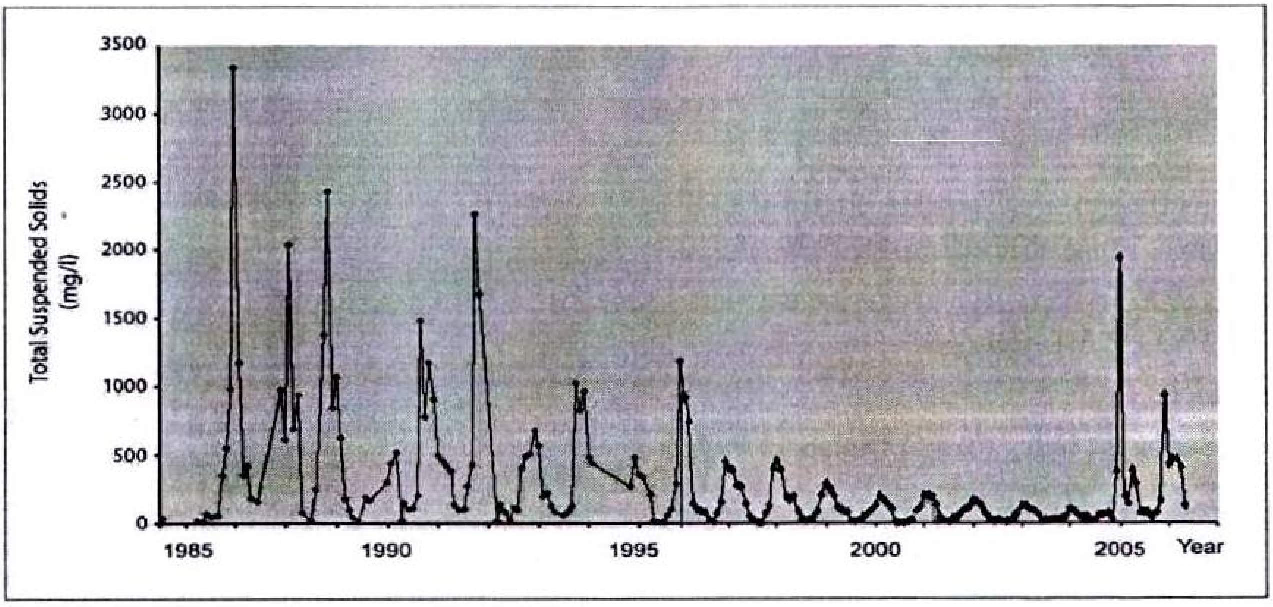

Fig. 4. Changes of TSS content at LHS, 1985-2006.

Relation between TSS content in the Mekong River in LHS and Nam Ou River is propitious, and has recurrent equation $y = 0.7104 X + 71.227$, with coefficient $r^2 = 0.7708$ (Fig. 5).

Thus, it can be primarily defined that TSS value in LHS after 1992 has decreased in comparison with the time before the fill - up of Manwan hydropower reservoir. After 2003 (Dachaoshan reservoir is filled in), TSS value continues to decrease at LHS. However, the rate is not much and has trend to be controlled by the flood regularity in the tributary (Nam Ou).

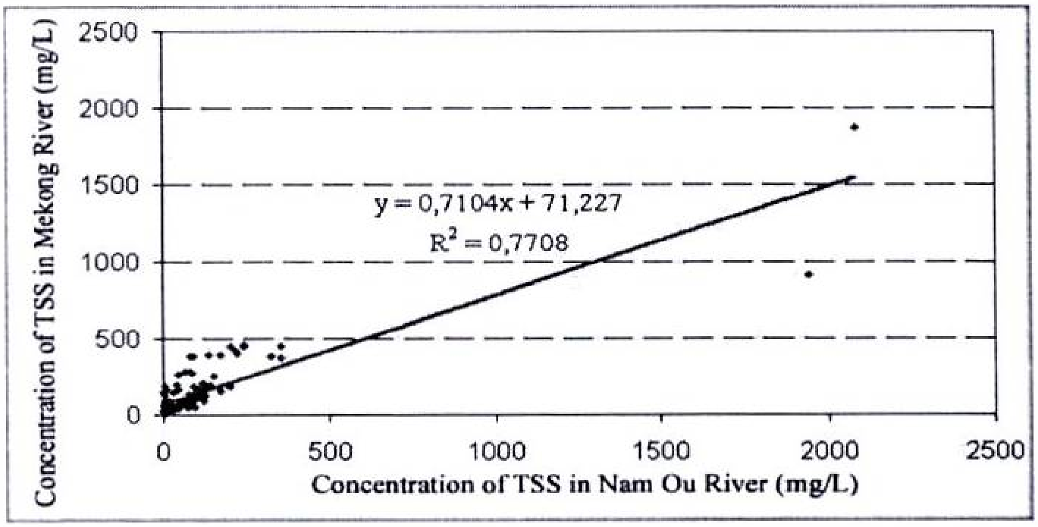

Fig. 5. Relation between TSS in the Mekong river and Nam Ou river.

The percentage between the active capacity of the hydropower reservoir and the annual flow to LHP is 0.14%, much lower than the cascade in the upstream. The percentage between total capacity of the hydropower reservoir and annual flow of LHP is also low, about 1.68% (Table 4) [4,5]. Thus, it can be said that the planning and operation of LHP will cause the smaller impacts to the hydrological regime in the downstream than other hydropower cascades in the upstream.

Regarding impacts to the hydrological regime in the downstream, accumulative impacts of hydropower cascades to the annual flow in Mekong River's intersection, especially large hydropower reservoirs in the upstream in China, must be counted. When LHP is completed (in 2017), 6 hydropower cascades in the upstream in China are expected to be finished 3 years earlier with total active storage of about 23.2 billion m^3, total storage up to 40.5 billion m^3, accounting for 54.7 % of the total annual flow of Lancang River in China. Mekong River's hydrological regime will be mainly controlled by the operation of the upstream reservoirs in the Mekong River. Thus, accumulative impacts of LHP to the downstream hydrology are not significant.

Table 4. Ratio of reservoir capacity and yearly inflows of hydropower dams

No	Reservoir	Annual average flow 10^6m^3 (A)	Total storage 10^6m^3 (B)	Active storage 10^6m^3 (C)	Percentage D=B/A*100 (D)	Percentage E=C/A*100 (E)
1	Gonguoquiao	31,060	510	120	1.64	0.39
2	Xiaowan	38,470	14,560	9,900	37.85	25.73
3	Manwan	38,790	920	257	2.37	0.66
4	Dachaoshan	42,260	890	367	2.11	0.87
5	Nuozhadu	55,190	22,400	12,300	40.59	22.29
6	Jinghong	58,303	1,233	249	2.11	0.43
7	Luangprabang	94,923	1,590	136	1.68	0.14

As about mentioned, the sediment flux in LHS was governed by the operation of hydropower cascades in upstream (Lancang river), and has trend to be more controlled by the flood regularity in the tributary (Nam Ou river). Furthermore, the impacts of LHP to the downstream hydrology are not remarkable. Thus, accumulative impacts of LHP to the downstream on sediment flux are unremarkable.

4. Conclusions

The sediment flux in LHS was governed by the operation of hydropower cascades in upstream (Lancang river), and has trend to be more controlled by the flood regularity in the tributary (Nam Ou river).

The impacts of LHP to the downstream on hydrology and sediment flux can be unremarkable. Sediment kept in LHP reservoir can be estimated to be 10.1 tons/year, and 17% decreasement of sediment flow in LHS. The sediment trapped in LHP reservoir would only decrease about 6.95% of total sediment flowing into the Mekong River delta. Thus, accumulative impacts of LHP to the downstream on sediment flux are unremarkable.

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