ARE THE CHINESE DAMS TO BE BLAMED FOR THE LOWER WATER LEVELS IN THE LOWER MEKONG?

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The Lower Mekong has recently experienced lower water levels in the dry seasons. Many people believe that this phenomenon is a consequence of the construction and operation of the Chinese dams in the upper part of the Mekong main stream, the Lancang River. This chapter examines the low flows of the Lower Mekong with aims of revealing truths, myths, and uncertainties of the water levels alterations related to the Chinese dams.

1 Introduction

China has proposed a cascade of eight dams, and two of them have been completed, Manwan in 1993 and Dachaoshan in 2003, to meet its need for electricity in the Upper Mekong River (or Lancang Jiang). The entire hydropower cascade involves over 23 km^3 of active reservoir storage (Mogg, 1997). Apart from providing renewable energy, the Mekong cascades are supposed to provide better flood control during the wet season and increased water supply in downstream areas during the dry season. Chapman and He (1996) estimated that impact of Manwan and Dachaoshan dams on the water discharge are insignificant due to their small capacity and significant changes will only be noted after the operation of Xiaowan dam. When Xiaowan dam is completed, dry season flows can be increased up to 70% as far as 1,000 km downstream in Vientiane, Laos, due to the impoundment of discharge during the wet season (He & Chen, 2002; IRN, 2002). This would be beneficial downstream in terms of irrigation and navigation development, hydropower transmission and possible flood control through flow regulation by the cascade reservoirs.

Yet the reality is that the Mekong River has recently been hit by the lower water levels. This has been perceived by many NGOs and local

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communities as a result of the two upper stream dams in China. However, a report released by Mekong River Commission (MRC) suggests that the recent droughts of the Mekong River were mainly due to the dry weather in combination with forest clearing rather than the Chinese dams (MRC, 2004; Phouthonesy, 2003). Apparently, these reports about the impacts of the Chinese dams are not consistent. In fact, most of them are contradictory (Appendix 1). This paper aims to examine the water flow at Chiang Saen and Chiang Khong, nearest gauging sites to the Chinese dams, with special reference to the low flows in the dry seasons.

The questions we want to address are:

- Were the water levels really lower in the recent years at the study sites?
- In which degree did the first dam (i.e. the Manwan Dam) alternate the water discharge?
- What are the uncertainties related to the hydrological alteration as a result of the Dam?

Figure 1 The Mekong River showing the study gauging sites.

2 The Mekong River

The Mekong River, which originates in the Tibet-Qinghai plateau, flows through a distance of approximately 4500 km, before it enters the South China Sea at the Vietnam Delta (Figure 1). The first 2,000 km, the upper basin, flows through the Chinese territory while the lower basin covers an area of 600,000 km^2 in Myanmar, Thailand, Laos, Cambodia and Vietnam. Though abundant in biodiversity, the Mekong River is one of the most undeveloped rivers in the world, hence providing these countries a great asset for harnessing the river for hydropower development, irrigation project, flood control and domestic uses, which is crucial and beneficial for economic development, regionally and locally.

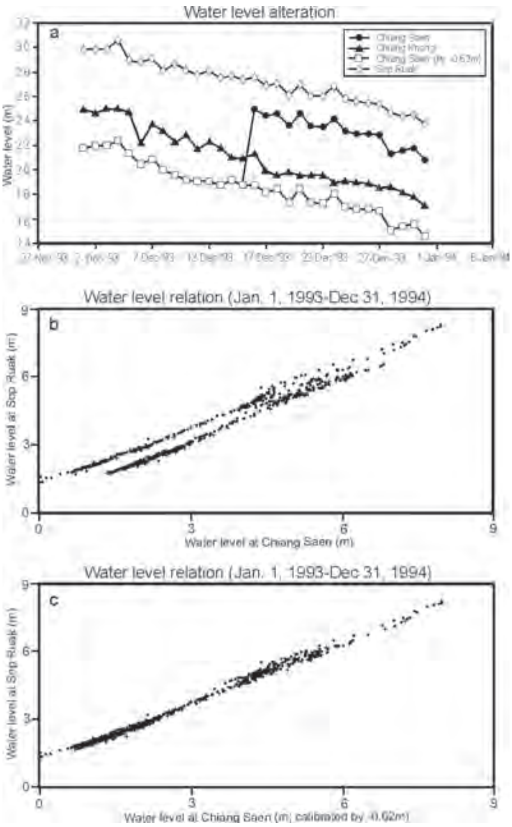

Figure 2 Water level values at Chiang Saen. (a) shows an abrupt jump of water level between Dec 15 and Dec 16, 1993 caused by the move of Chiang Saen gauging station to 500 m downstream from 4 April 1992 to 15 December 1993. Therefore, the water level values after Dec 15, 1993 should be subtracted by 0.62m in order to compare with the water level before the date. This calibration can be validated by the strong linear relationship between the water level of Chiang Saen and Sop Ruak who are near to each other (b and c).

Administratively, the Mekong River basin is divided into two sub-basins: the Upper Mekong Basin (24% of total drainage area) and the Lower Mekong Basin (76% of total drainage area). The lower Mekong basin currently supports a population of about 60 million people, and is expected to increase to 90 million people in 2025. Correspondingly, electric power demand in the whole Mekong region is estimated to increase by 7% annually to 2022, requiring a fourfold increase in current electric generating capacity (MRC, 2003). In view of the future demand and economic viability of hydropower for the Mekong region, numerous projects to tap the hydroelectric potential of the Mekong River have been planned by individual countries; in tandem, research examining the potential environmental and social ramifications of these hydropower projects is also growing steadily.

The lower Mekong study area is characterized by a largely tropical climate, with two distinct seasons – a wet season from June to October and a generally dry season for the rest of the year. In the lower basin, mean annual precipitation varies from over 3000 mm in Lao PDR, and Cambodia to 1000mm in the semi-arid Korat Plateau in Northeast Thailand (MRC, 2003). The river usually begins rising in May and peaks in September or October, with the average peak flow at 45,000 m^{3}s-^{1}. Between June and November, discharge from the Mekong would have amounted to about 80% of its total annual discharge. Around November, flows start receding and reach the lowest levels in March and April, at approximately 1,500 m^3 s-^{1} (Kite, 2001).

3 Data and Methods

The study uses the historical data archived in Lower Mekong Hydrologic Yearbook by MRC. The time series of this study ranges from 1962 to 2003. The gauging stations of Chiang Saen (both

Table 1

Parameters	Hydrologic Alteration (%)	Degree of Hydrologic Alteration
Parameter Group 1		
January	0	low
February	-32	low
March	-77	high
April	-75	high
May	14	low
June	25	low
July	25	low
August	50	medium
September	25	low
October	-25	low
November	14	low
December	14	low
Parameter Group 2		
1-day minimum	-75	high
3-day minimum	-75	high
7-day minimum	-50	medium
30-day minimum	-50	medium
90-day minimum	-50	medium
Parameter Group 3		
1-day maximum	14	low
3-day maximum	25	low
7-day maximum	25	low
30-day maximum	-50	medium
90-day maximum	-25	low
Parameter Group 4		
Base flow	25	low

water levels and discharge) and Chiang Khong (only water levels data available) were selected on the basis of their close location to the Chinese Dam.

The model of Indicator of Hydrological Alteration (IHA) was employed to examine both water levels and discharge datasets. The IHA model was developed to evaluate the hydrologic alteration of stream flows caused by constructions like dams (Richter *et al.*, 1997; 1998). The IHA model is powerful for the study of changes in hydrologic regime due to the construction and operation of dams. For example, applying the IHA model, Magilligan & Nislowb (2005) found that Dams had significantly modified hydrologic regimes on a nationwide scale, for large and small rivers during the previous century in USA. In the non-parametric RVA (Range of Variability Approach) analysis, the full range of pre-impact data for each parameter is divided into three different categories based on either percentile values (The Nature Conservancy, 2005): the lowest category contains all values less than or equal to the 33rd percentile from the median; the middle category contains all values falling in the range of the 34th to 67th percentiles; and the highest category contains all values greater than the 67th percentile. In order to assess the degree of hydrologic alteration, Richter *et al.* (1998) introduced a factor of hydrologic alteration calculated for each of the three categories as:

Hydrologic Alteration factor = (observed frequency – expected frequency) / expected frequency

Richter *et al.* (1998) divided the range of hydrologic alteration factor into three classes: 0-33% representing low degree of hydrologic alteration; 34-67% representing medium degree of hydrologic alteration; and 67-100% representing high degree of hydrologic alteration. A positive hydrologic alteration value represents that the frequency of values in the category has increased from the pre-impact to the post-impact period while a negative value represents that the frequency of values has decreased.

4 Were the water levels really lower in the dry season in recent years at Chiang Sean and Chiang Khong?

The reports on the water levels changes are contradictive (Appendix 1). For example, while the media reported that the lower Mekong had experienced lower water levels (e.g. Asia Times, 2002), Quang & Nguyen (2003) concluded that the average monthly-high, monthly-low and monthly-average dry-season water levels have increased by 0.68 m, 0.57 m and 0.62 m,

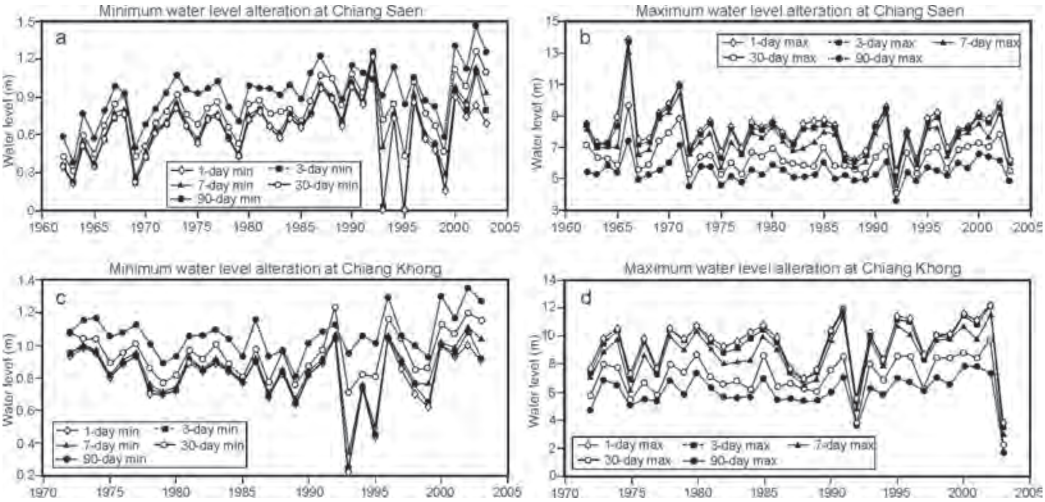

Figure 3 Minimum and maximum water levels at Chiang Saen and Chiang Khong.

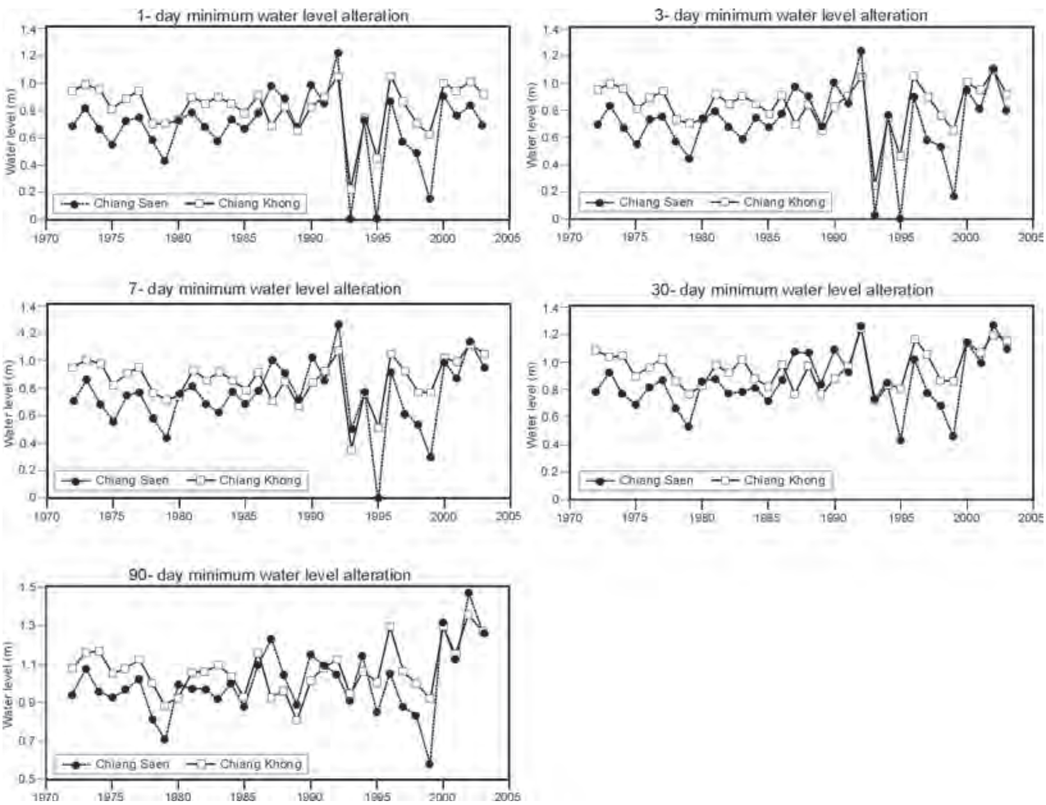

Figure 4 Comparison of minimum water levels between Chiang Saen and Chiang Khong.

respectively, at Chiang Saen from pre-impact period to post-impact period, due to the Manwan Dam. Apparently, there is a need to conduct a systematical analysis of water levels to find out whether it's true in the first that the water levels were lower.

We examined the daily water levels (or gauging heights) at the study sites recorded in the MRC Hydrological Archives, and found that the water levels records require calibration due to the move of the gauging station in 1992, same year as the Manwan Dam started to store water (Appendix 2). The zero elevation of gauging was 0.2 m difference, but we found that the discrepancy of the old and new gauging sites is around 0.62 m (Figure 2). The relation between the calibrated water levels at the new site and the water levels at the Sop Ruak station, upstream Chiang Saen is closer (Figure 2).

After the calibration, the model of Indicators of Hydrologic Alteration (IHA) developed by The Nature Conservancy (Richter *et al*., 1996) has been employed to examine the alteration of the water levels. Here we apply the model to the water levels at both Chiang Saen and Chiang Khong sites to find out a series of the magnitudes of the water levels or minima/maxima in the dry/wet seasons (Figure 3).

At Chiang Saen, the 1-day, 3-day and 7-day minima water levels decreased significantly after the Manwan Dam operation, while the decrease in the 30-day and 90-day minimum water levels was insignificant (Figure 3). The maximum water levels (the 1-day, 3-day, 7-day, 30-day and 90-day maxima) had an increasing trend, but the increasing was in insignificant after the dam operation (Figure 3). At Chiang Saen, the 1-day minimum water level in 1993 and 1995 was 0.20 m and 0.22 m lower, respectively, than that in 1963 (the lowest year at Chiang Saen from 1962 to 1991 before the dam-operation); the 3-day minimum water levels in 1993 and 1995 are 0.20 m and 0.23 m lower than that in 1963 (Figure 3).

The consistency of the minimum water level alteration between at Chiang Saen and Chiang Khong can also clearly be seen from Figure 4.

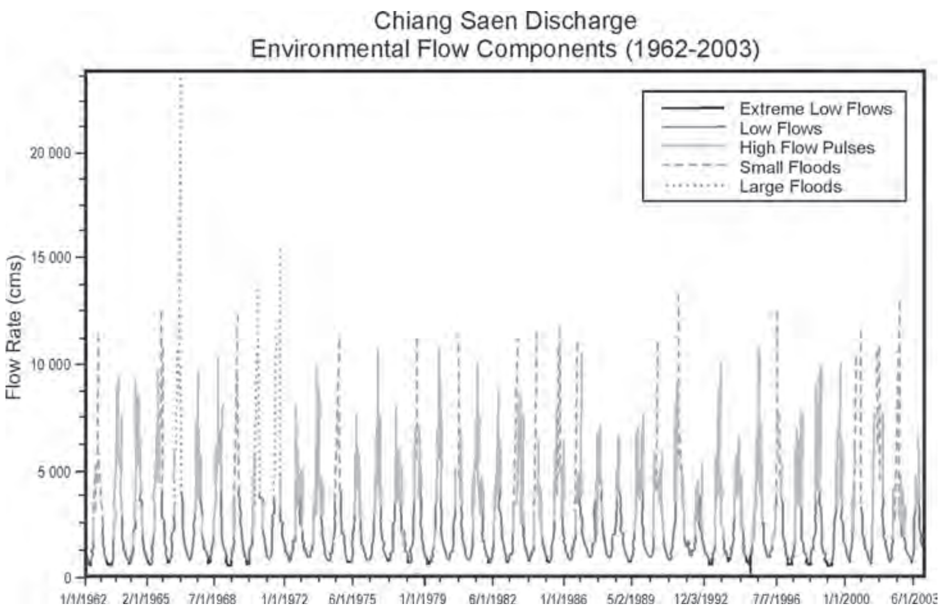

Figure 5 The daily water discharge from 1962-2003 in Chiang Saen showing environmental flow components.

Similarly, at Chiang Khong, the 1-day minimum water levels in 1993 and 1995 are 0.42 m and 0.28 m lower than that in 1989 (the lowest year at Chiang Khong from 1972 to 1991 before the dam-operation); the 3-day minimum water levels in 1993 and 1995 are 0.4 m and 0.27 m lower than that in1989 (Figure 4).

According to precipitation averaged over 16 sites from across the Basin (MRC, 2004), the 1992 was the driest year since 1960, but the water flow was not the lowest, suggesting the possible flow regulation by the Manwan Dam.

Completely different from Quang & Nguyen (2003), our results indeed show that the post-dam period (1992-2003) had lower water levels than the pre-dam period (1962-1991). It is also very obvious that the post-dam period had higher water level fluctuations as we found in a previous paper (Lu & Siew, 2006) or reported by others (e.g. Oxfam Hong Kong, 2002). However, such alteration in the low water level is significant only at a short range of time, i.e. over 1-7 days. When the time period got longer to 30 or 90 days, such change is no longer significant.

5 To what degree did the Manwan Dam modify the water discharge?

Though the water levels data show some alterations due to the Manwan Dam, the water discharge data are perhaps more appropriate for assessing hydrological alteration due to the dam operation. The daily water discharge at Chinag Saen fluctuated with the highest flood in 1966, 1970 and 1971, and the drought years in 1992 and 2003

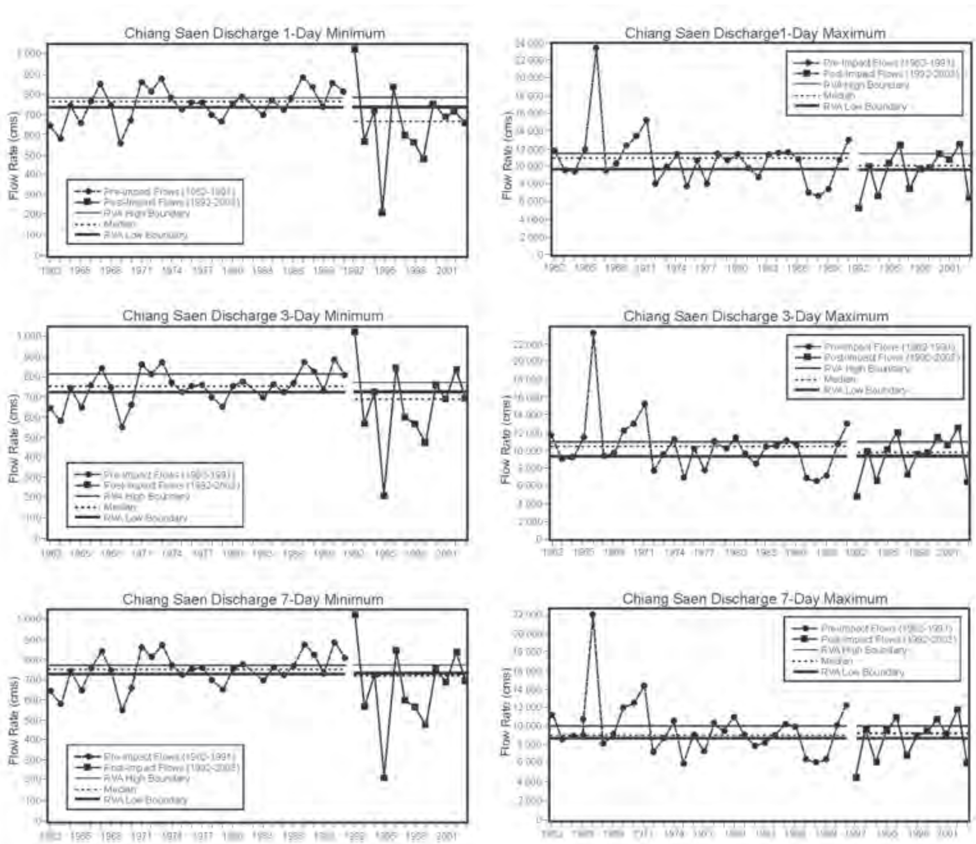

Figure 6 Daily minimum and maximum water flows at Chiang Saen.

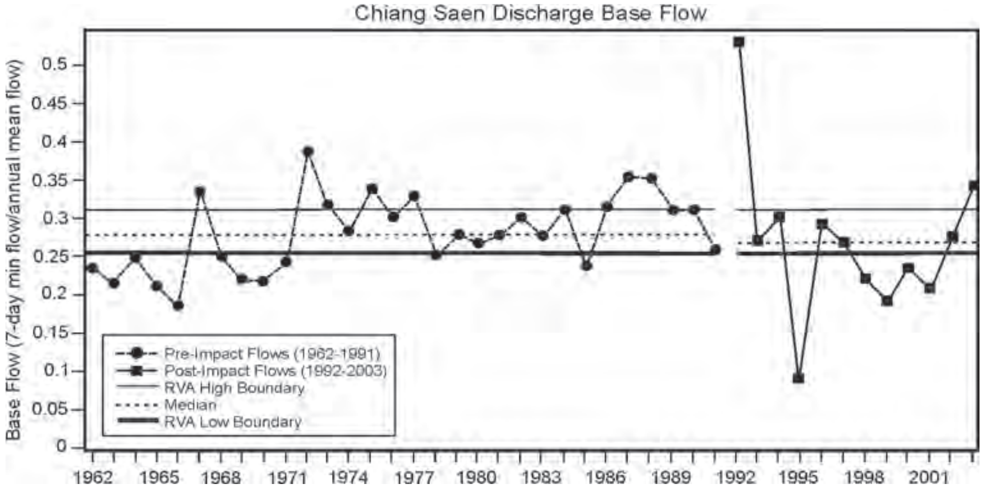

Figure 7 Base flows at Chiang Saen.

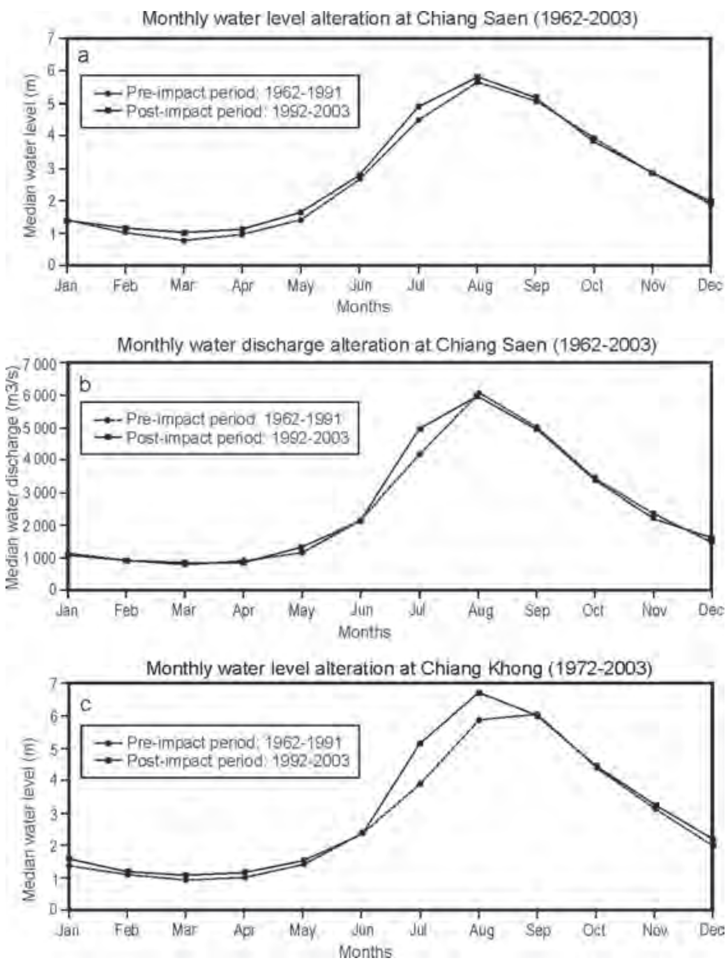

Figure 8 Monthly mean water level and discharge averaged over the entire pre- (1962-1991) and post-dam periods (1992-2003).

(Figure 5). The extreme flows indeed occurred in 5 years within 12 years since 1992.

The analysis of the IHA shows that the degree of hydrologic alteration is high for March and April, medium for August, and low for other months (Table 1). The impact on daily minimum discharge is considerably significant. The degree of hydrologic alteration is high for 1-day minimum and 3-day minimum charge, and medium for 7-day minimum, 30-day minimum and even 90-day minimum discharge (Table 1; Figure 6). On the contrary, the impact on daily maximum discharge is much lower. For 1-day maximum and 3-day maximum, 7-day maximum, and 90-day maximum discharge, the degree of hydrologic alteration is low. Furthermore, except for August discharge, among the parameters whose degree of hydrologic alteration is high or medium, their hydrologic alteration factors are all negative, which means that the frequency of values in the middle category has significantly decreased from the pre-impact to the post-impact period. In addition, the base flow (i.e. 7-day minimum flow/annual mean flow) decreased after dam-operation (Figure 7).

Our results indicate that the post-dam period (1992-2003) indeed had a lower water flow than the pre-dam period (1962-1991). These changes, together with the changes in the low water level, are possible results of the Manwan Dam. If this is true, the changing is different from the conventional wisdom for a hydropower dam, i.e. the hydropower dam releases water in the dry season and store water in the wet season, which would increase monthly flows in the dry season, and decrease flows during the flooding season. Nevertheless, the monthly mean values of the water levels and discharge averaged across the entire pre- and post dam remain almost same (Figure 8). The possible reason may be attributed to the small scale of the Manwan Dam (He & Chen, 2002).

6 What are the uncertainties related to the hydrological alterations as a result of the dam?

Some uncertainties remain with our results of the hydrological alterations. First, the data series of the post-dam operation is only 12 years from 1992-2003. The data series for an appropriate analysis of the IHA is at least 20 years (The Nature Conservancy, 2005). Apparently we need to wait for more years to come to carry out similar sort of analysis.

Second, the move of the gauging site in Chiang Saen and its consequent change in the zero elevation have caused some problems for our analysis on the water levels changes. Though such change is not uncommon, it may not be noticed by later user. Any analysis without further calibration of the data could be misleading. For example, this may be the reason why Quang and Nguyen (2003) concluded that the dry season flow increased approximately 60% at Chiang Saen after operation of Manwan. Though we have calibrated the water levels data with certain confidence level, it is still necessary to further double check in the site.

Third uncertainty lies in the rating curve. We have found that the rating curve (stage and water discharge relation) developed in 1975 had been used till 1994. In other words there were no actual water discharge measurements over the almost 20 years from 1976-1994. The worst is that the 1975 rating curve was developed on the basis of 6 water discharge measurements with high water level only to 1.9 m (far away from the normal higher water levels around 10 m) (Appendix 2).

Fourth, the water flow is controlled by many other factors, apart from dam constructions. This is particularly true for large rivers and in the fast pace of environmental changes (Lu *et al.*, 2003). The upper Mekong River, like other Chinese rivers, has been experiencing dramatic changes over the past decade in the shrinkage of glacial covers in the Tibet-Qinghai Plateau, reforestation/afforestation, dam construction in the tributaries, highway constructions, sand mining, water diversion and consumption etc. For example, it was reported that climate in the valley of the upper Mekong has been getting hotter and drier. Apparently those factors and changes influencing water discharge need to be considered.

7 Conclusion

The present study on water discharge and water level alteration at Chiang Saen and Chiang Khong demonstrates that some of the hydrological regimes have been influenced by the operation of the Manwan Dam. Such influences are higher in the dry seasons than in the wet seasons. The dam-operation caused significant reduction in the low water levels and discharge, but the high water level alterations are insignificant at the two sites. The monthly mean values of the water levels and discharge averaged over the entire pre- and post dam remain almost same. The possible reason may be attributed to the small scale of the Manwan Dam (He & Chen, 2002). In addition, we are the first who noted and calibrated the effect of the move of the gauging site in Chiang Saen, such calibration is critical to draw a right conclusion on the impact of dam-operation.

If the reduction in the low water level and discharge was highly possibly attributed to the Manwan Dam, it is different from what was expected from a hydropower dam, i.e. the hydropower releases water in the dry season and store water in the wet season, which would increase monthly flows in the dry season, and decrease flows during the flooding season. In fact, it is common that Chinese rivers such as Yellow river and Yangtze River have recently experienced water decline (Lu, 2004). No doubt that this decline is partially due to the numerous dams constructed in various tributaries and main rivers, but other factors such as water consumption, land cover/land use change and climate variations play important role as well. It can be expected that the low water flow in the Lower Mekong River would be reduced further with the increasing demand of water in China and other riparian countries.

It is demonstrated that RVA and Hydrologic Alteration factor are useful for evaluating the hydrologic influences caused by dam-operation in the present study. Considering that at least twenty years of daily records be recommended to be used for each pre-impact and post-impact period (The Nature Conservancy, 2005), the twelve-year post-impact period becomes a limitation of the present study. In addition, the long-term series of climate records (e.g. precipitation and temperature) within the whole watershed upper the Chiang Saen gauging station should be employed in the future research in order to more precisely evaluate the hydrologic impacts of the dam-operation.

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Appendix 1

	Mean flow	Dry season flow	Wet season flow
Kummu & Varis, 2007	Increase in mean flow in post-dam period (1993-2000) at Luang Prabang and Pakse, compared to pre-dam period (1962-1992).	Flow regulation is expected to increase dry season flows	Flow regulation is expected to decrease wet season flows
Lu & Siew, 2006	No significant change in mean discharge after construction of Manwan, except a sharp decrease in 1992 (when Manwan Dam was closed for infilling).	Annual min discharge decreased at Chiang Saen and Luang Prabang, after Manwan began operations. Dry season fluctuations increased considerably in post-dam period; little change in wet season fluctuations.	Annual max discharge increased after operation of Manwan Dam but effect not noted in stations further downstream such as Khong Chiam and Pakse.
Osbourne, 2004			The dams may contribute to excessive flooding in the wet season, e.g. at Jinghong in 2003, from the sudden water release from one or both dams as their maximum holding capacity was reached.
Quang & Nguyen, 2003	Impact of Manwan significant at Chiang Saen, but decreases downstream and becomes negligible at stations near the estuary, like Chau Doc & Tan Chau.	Increased approx. 60% at Chiang Saen after operation of Manwan (654 m^3/s to 1055 m^3/s).	Increased approx. 28% at Chiang Saen after operation of Manwan. Probably due to increase in rainfall.
He & Chen, 2002 Plinston &He,1999 Chapman&He, 1996	Negligible impact from Manwan & Dachaoshan. Significant effects expected only after completion of Xiaowan. Mean discharge to LMB after completion of Xiaowan & Nuozhadu expected to increase 171%.	Substantial increase in flow expected after completion of Xiaowan, particularly in reaches down to Mukdahan.	Wet season discharge from Lancang could be reduced by as much as 25%. However, reduction in flow further downstream is expected to be insignificant as flow discharges from Lao tributaries are high.
Oxfam Study on the impacts of Lancang River Manwan Power Plant, 2002			Daily fluctuation at the base of Manwan Dam was 3-4 m (ave), peaking at 6.5 m in 1998. Since 1993, infilling and discharge of the reservoir resulted in >100 cave-ins and slides in areas below.
Roberts, 2001		Release of extra water from Manwan in wet season of Sep-Oct 2003 may have exacerbated the flooding downstream, though on a smaller scale.	

Appendix 2

Year	Measurements No.	Ranges of water levels	Rating curve	Note
1962	83	0.3-8.50		Zero of gage elevation 357.31 m above M.S.L. Ko Lake datum.
1963	73	0.2-7.40		
1964	70	0.5-7.40		
1965	88	0.3-9.00		
1966	No		Using 1965	
1967	119	0.77-7.37		
1968	113	0.48-7.37		
1969	111	0.22-9.02		
1970	90	0.48-9.78		
1971	86	0.64-9.59		
1972	87	0.66-6.55		
1973	67	0.65-7.46		
1974	55	0.57-8.60		
1975	8	0.59-1.90		
1976-1991	No		Using 1975	
1992	No		Using 1975	The staff gage has been moved to 500 m downstream since 4 April 1992.
1993	No		Using 1975	The staff gage has been moved to 500 m downstream from 4 April 1992 to 15 December 1993.
1994	Unknown		Using 1994 rating curve	Zero of gauging elevation 357.110 m above M.S.L. Ko Lake Datum.
1995	Unknown		Unknown	
1996	33	1.55-6.33		
1997	39	1.18-7.61		
1998	26	1.21-7.55		

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