MEKONG RIVER COMMISSION

THE COUNCIL STUDY

The Study on the Sustainable Management and Development of the Mekong River Basin, including Impacts of Mainstream Hydropower Projects

Thematic Report on the Positive and Negative Impacts of Hydropower Development on the Social, Environmental, and Economic Conditions of the Lower Mekong River Basin

(Unedited Version)

Prepared by: Hydropower Thematic Team and Multi-consult

29 December 2017

Disclaimer:

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The MRC is funded by contribution from its member countries and development partners of Australia, Belgium, European Union, Finland, France, Germany, Japan, Luxembourg, the Netherlands, Sweden, Switzerland, the United States and the World Bank

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Produced for	MRC Member Countries
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Document History				
Document	**Date**	**Authors**	**Status**	**Comment**
Final	29/12/2017	David A. Wright Jens Johan Laugen Leif B. Lillehammer	Final Report	Submitted
Draft	22/11/2017	David A. Wright Jens Johan Laugen Leif B. Lillehammer	Final Report	Submitted
Draft	08/11/2017	David A. Wright Jens Johan Laugen Leif B. Lillehammer	Draft Final Report	Submitted
Draft	30/10/2017	David A. Wright Jens Johan Laugen Leif B. Lillehammer	Draft Final Report	Submitted
Draft	15/06/2017	David A. Wright Jens Johan Laugen Leif B. Lillehammer	Draft Final Report	Submitted
Draft	15/05/2017	Jens Johan Laugen Leif B. Lillehammer David A. Wright	Draft Final Report	Submitted
Draft	30/03/2017	Jan Høiseth Bjørn Stenseth Jens Johan Laugen Leif B. Lillehammer Piseth Chea	Draft Final Report	Submitted

Abbreviations and Acronyms

ALU	Agric/Landuse Change
BDP	Basin Development Plan
CA	Concession Agreement
COD	Commercial Operation Date
CS	Council Study
DIW	Domestic and Industrial Water Use
DNF	Data Not Found
FPI	Flood protection infrastructure
FS	Feasibility Study
FSL	Full Supply Level
GWh	one million kWh
HPP	Hydropower
IQQM	Model
IRR	Irrigation
ISIS	Model
ISH	Initiative for Sustainable Hydropower
IWRM	Integrated Water Resources Management
kW	kilowatt = one thousand Watt
kWh	kilowatt hour
LMB	Lower Mekong Basin
m^3/s	cubic metres per second
mamsl	metres above mean sea level
mcm	million cubic metres
MOL	Minimum Operating Water Level
MOU	Memorandum of Understanding
MS	Mekong Main Stream
MW	megawatt = one thousand kW
NAV	Navigation.
OWL	Operating Water Level
PDA	Project Development Agreement
PDG	Preliminary Design Guidlines
PFS	Pre-Feasibility Study
ROW	Right Of Way
UMB	Upper Mekong Basin

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1 Summary

1.1 Introduction

This Thematic Report on the Positive and Negative Impacts of Hydropower Development in the Lower Mekong River presents an assessment of the cumulative positive and negative impacts of hydropower development in selected Lower Mekong River tributaries and the mainstream.

The focus is on how the dams can influence fisheries, river flow, sediment and nutrient flux in terms of quantity, quality, timing and the resulting transboundary positive and negative impacts on environmental, social and economic parameters in the mainstream corridor, floodplains and Delta as well as coastal processes.

The report estimates, as far as possible within the available data and knowledge base available to the Council Study, the disaggregated economic benefits and updated assessment of sediment transport and the effect of change on geomorphology, bank erosion and coastal processes and fisheries.

1.2 Main Results

Hydropower has both the positive and negative influence on macro-economic growth in the LMB:

Hydropower emerges as the sector with highest relevance to contribute to macro-economic growth for the lower Mekong basin. However, hydropower is also linked to the highest trade-offs: Nearly 25% of the hydropower gains would be lost in the fisheries sectors under development proposed by 2020 (scenario M2) and an additional 15% for developments proposed by 2040 (scenario M3). If effective mitigation measures are employed (Sub-scenario H3) analysis suggests that this could reduce the fisheries losses by up to 11%.

Transboundary Implications

The hydropower potential would benefit the four lower Mekong countries differently. Thailand emerges as the main beneficiary of Lao mainstream dams and Vietnam as a key beneficiary of mainstream dams in Cambodia. For instance, when compared to the base case[1], Thailand's power sector benefit would increase under M3 conditions by about $77 billion in net present value while Lao's sector would increase by about $32 billion in net present value. Similarly, the net present value of Vietnam's hydropower would increase by $24 billion for scenario M3 while the net present value for Cambodia's hydropower sector would increase by $14 billion. This benefit transfer is based on the power trading and cross-border investments in hydropower. It is important to emphasise that from a macro-economic perspective economic benefits related to mainstream hydropower would flow to non-Mekong countries (e.g. China, Malaysia, South Korea) as a result of their investments.

River Flows

Hydrological impacts of the considered run-of-the river schemes on the mainstream and tributaries have been found to be very limited. Except for peaking operations, the normal operation of these reservoirs does not lead to increased hydrological risks, as all 'natural' flows pass the dams without modification.

[1] Base case is the 2007 Scenario: Ref.: Council Study Macro Economic Assessment Report, 15. October 2017

The output and results of the IQQM modelling of the hydropower projects in the sub-scenarios is presented in table 4.24 with a comparison of flow results from Hydropower sub-scenarios (H1a, H1b, H2 and H3) comparing with M3cc from SWAT-IQQM Simul at 10 key stations on the Mekong mainstream. The results are shown in Figure 4.7 which shows the seasonal and transboundary effects of hydropower development in the sub-scenarios on flows. As can be seen from an examination of the figure, the percentage changes in flow in the different sub-scenarios are relatively small. For example less than 1% reduction in flow at all key stations during the May-October monsoon period and less than 1% increase in flow at all key stations during the November-April dry season. Transboundary effects on flow are therefore small in the modelling. Although hydropower is, apart from losses due to evaporation from reservoirs, a non-consumptive energy source, these results are still somewhat unexpected.

The main hydrological risk related to the downstream dams is related to the sub-daily hydropeaking. The peaking will cause rapid changes in the reservoirs and downstream reaches. The hydrological risks related to larger fluctuations in water-level are substantial. Mitigation of these effects is mostly done by fully eliminating the peaking procedures. If hydropeaking is still considered, it is useful to allow the fluctuations only in the impounded sections of the cascade, while operating the lower dam as a regulator to dampen the fluctuations from the upper reservoirs and prevent large fluctuations in the downstream (not impounded) river reach[2].

In the lower cascade the reservoirs of each dam will affect the tailwater of the upstream dam for a large range of discharges.

Sediments and Nutrients

The study results suggest that dams in the Mekong basin are likely to have very large reductions in sediment loads entering the delta, which may only partly be reduced if mitigation measures are implemented.

The "eWater Source Modelling for the Council Study Draft Report" dated September 2017 reported that sediment runoff from the Mekong catchments is forecast to increase from some 150,9 Million tonnes per annum under the Baseline 2007 scenario M1 to some 159.2 Million tonnes per annum (5.5% increase) under Development 2020 Main Scenario M2, to some 161.2 Million tonnes per annum (6.8% increase) under Development 2040 no climate change Main Scenario M3, and to some 178.2 Million Tonnes per annum (18.1% increase) under Development 2040 with climate change Main Scenario M3, due to land use change. However, there is a substantial reduction in the amount of sediment being transported downstream. For example, under the M1 () scenario, an estimated 143 Mt/annum of sediment reaches Kratie. Under the M3 scenario only 4 Mt/annum reaches Kratie, which is a reduction in sediment loads of 97%.

The hydropower scenario H3 implements mitigation measures for hydropower dams on the Mekong mainstream in the Lower Mekong Basin. The mitigation measures include the implementation of fish passage structures and sediment sluicing operations at the start of the wet season. The sluicing operations involve the coordinated drawn-down and refill of the dams in the upper and lower cascades. The H3 scenario mitigation measures have the effect of increasing the sediment load transmission to the Delta when comparing with M3CC or H2.

[2] Ref ISH0306 study report where more detailed analysis was done of this option.

There is also a change to seasonal variability of sediment load shown in the 2040 development scenario (M3CC), however, an increase in sediment in dry months of the year was observed and a reduction during wet season. However, the sediment (and nutrient) loads are still small compared to the H1a and H1b scenarios, which implement reduced levels of hydropower development. In other words the hydropower development has a major negative impact here.

Fisheries

The comparison of the thirteen sub-scenarios in the Council Study revealed which investments are likely to have the largest impacts on fish stocks and, thereby on sector income. Hydropower sub-scenario 1 has the largest positive impact and quantifies that the combined fisheries sectors in the lower Mekong basin could generate up to $70.6 billion without any hydropower in place. The fisheries sector in Lao PDR would increase by 124.2%. The fisheries sector in Thailand would nearly double its net present value.

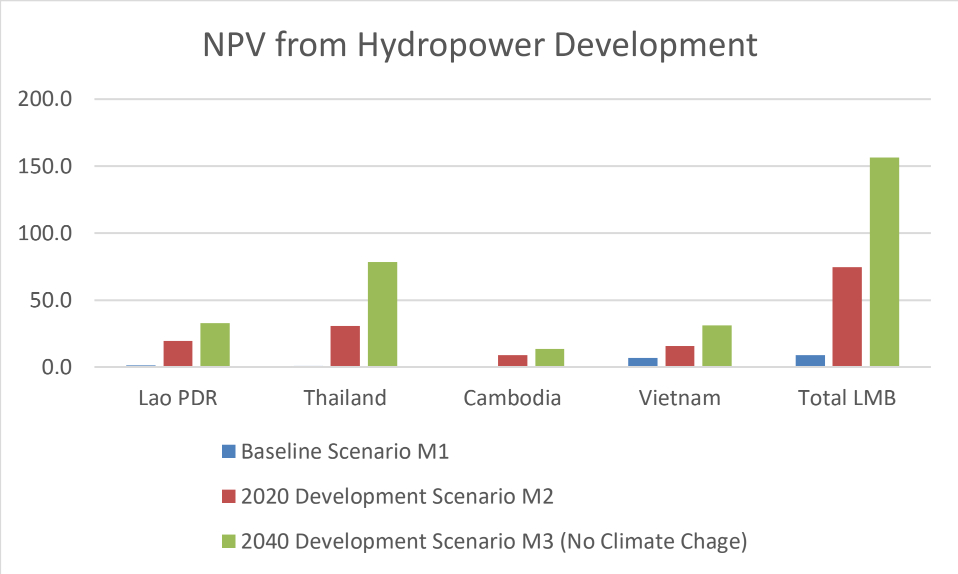
Socio-Economic Impacts – Transboundary Distribution of Net Present value under Hydropower Development

The hydropower sector is the primary focus of investments in all three main scenarios (M1, M2, M3). The hydropower development situation as described by the main scenario M2 is assessed as providing economic gains of about $66 billion as NPV across the basin over the 24 year period of this assessment. The third main scenario M3 would further increase the sector economic benefit by an additional $82 billion. The following table summarises the changes in NPV in the hydropower sector for the three main scenarios.

		M1	M2	M3
Lao PDR	B$	1.2	19.6	32.9
Thailand	B$	1.0	30.7	78.4
Cambodia	B$	0.0	8.8	13.8
Vietnam	B$	6.8	15.5	31.2
LMB	B$	9.0	74.6	156.3

The increase in net present value of hydropower in M2 benefits Thailand the most as 45% of the additional economic gains would realise in Thailand. This is largely due to the difference between the cost for importing electricity from Lao PDR and the domestic retail prices. Lao PDR would receive about 28% of the NPV gain in scenario M2. An equal share of 13% of the additional economic gains would go to Vietnam and Cambodia.

In a transboundary context, stepping hydropower investments further up, as defined by scenario M3, would double the economic benefit from hydropower. Comparing M1 and M3, in the bar chart of the figures below, shows that about half of the increase in economic benefits are received by Thailand while Lao PDR realises about a quarter of the overall increase. Vietnam would receive about 17% of the NPV increase in M3 and Cambodia about 9%.



The likely impact of sub-scenarios H1a and H1b on the economic performance of the hydropower sector is shown in the table below which is taken from the Council Studyt Macro-Economic Assessment Report. The removal of all hydropower under sub-scenario H1a leads to a 100% drop of income generated by the hydropower sector.

Net present value of the hydropower sector in billion US$ for sub-scenarios H1a and H1b

	M3CC	H1a-M3CC		H1b-M3CC		Tributary	Mainstream
Lao PDR	$35.1	-$35.1	-100.0%	-$7.5	-21.5%	$27.5	$7.5
Thailand	$80.3	-$80.3	-100.0%	-$21.1	-26.3%	$59.2	$21.1
Cambodia	$13.8	-$13.8	-100.0%	-$4.5	-32.8%	$9.3	$4.5
Vietnam	$31.2	-$31.2	-100.0%	-$15.2	-48.8%	$15.9	$15.2
LMB	$160.4	-$160.4	-100.0%	-$48.4	-30.2%	$112.0	$48.4

Sub-scenario H1b assumes that none of the proposed mainstream dams will be developed, including the ones that are already under construction. The table indicates that sector income would drop by 21.5% in Lao PDR, 26.3% in Thailand, 32.8% in Cambodia, and 48.8% in Vietnam. These disproportional effects emphasise the relevance of mainstream hydropower for each of the four countries and considers the trade of electricity in the transboundary context of the lower Mekong basin.

This picture becomes even clearer when isolating the net present value of economic benefits of tributary dams and mainstream dams. The results confirm an important point: Thailand's energy sector is a key beneficiary of mainstream dams in Lao PDR and Vietnam benefits substantially from mainstream dams in Cambodia. Within these two pairs the host countries Lao PDR and Cambodia would experience lower losses from a decision to refrain from mainstream dams than Thailand and Vietnam. Overall, the lower Mekong basin would lose 30.2% of economic benefits in the power generation sector if mainstream dams would not be realised. This situation would still imply an increase of economic benefits of $112 billion from tributary dams.

Sub-scenario H3 is focused on critical management changes, as described above. The assumed interventions, e.g. coordinated flushing and the installation of fish ladders, would reduce the power generation capacity. However, the hydropower team did not have sufficiently robust data to quantify the effects on generated power.

Effect of Hydropower Development on Employment and Income in the LMB

Socio-Economic and Macro-economic assessment reports include analyses of the effect of the different sectors on employment and income for the the various scenarios.

No significant basin-wide effect on employment and incomes due to variations in hydropower development scenarios were evident.

Main Macro-Economic Messages

1. The hydropower focused interventions considered by the selected scenarios M2 and M3 have the strongest influence on economic indicators.
2. Substantial trade-offs need to be expected in the fisheries sector, which is likely to increase food security risks for various areas in the lower Mekong basin. The socio-economic assessment report provides a deeper analysis of the food security risks and which areas are particularly at risk.
3. A few key transboundary effects impact on the economic performance of the hydropower and fisheries sector. Within the hydropower sector substantial benefits occur across the border as the import of cheap electricity generate large economic gains in Thailand and Vietnam. The economic benefits within Lao PDR and Cambodia as the host countries of mainstream and tributary dams are likely to receive the smaller fraction of economic returns. However, also the negative transboundary effect hydropower would have on the fisheries sector affects Thailand and Vietnam substantially and would not remain constrained to Lao PDR and Cambodia as the host countries of hydropower development. Mitigation investments in coordinated fishing programs or fish ladders would therefore also benefit mostly Thailand and Vietnam.

Main Ecological and Environmental Negative Impacts of Hydropower Development

- Bank erosion and the reduction of the availability of habitats
- Effects on riverine and wetland vegetation
- Effects on aquatic macroinvertebrates
- Efects on fish and fisheries
- Effects on Herpetofauna
- Effects on birds and mammals

Detaiuls of the results and conclusions are to be found in section 5.1.2. Further details are given in the report chapters and in full detail in the Council Study BioRa Report.

1.3 Council Study Key Messages – Hydropower Thematic

1. Mekong River Basin	**CS Hydropower Thematic Key Messages**
1.a Overall Key Policy Messages for the High political level	Hydropower emerges as the sector with highest relevance to contribute to macro-economic growth for the lower Mekong basin with a share of 43-49% of the sector growth potential. However, hydropower is also linked to the highest trade-offs: About 25% of the hydropower gains would be lost in the fisheries sectors under scenario M2 and about 15% for scenario M3. Sub-scenario H3 suggests that mitigation measures could reduce the fisheries losses by up to 11%.
1.b Key Messages on findings of the impacts (at technical level) under your thematic/discipline team	The mainstream schemes may not need so much active reservoir storage. The reservoirs on the mainstream schemes, as currently envisaged, are created to provide generating head, not storage. Reduction of reservoir size would be beneficial.
1.c Key messages on Major Transboundary issues	The lower Mekong basin would lose some 30% of economic benefits in the power generation sector if mainstream dams would not be realised, including the ones that are already under construction. The non-realisation of these dams would cause the hydropower sector income to drop by 21.5% in Lao PDR, 26.3% in Thailand, 32.8% in Cambodia, and 48.8% in Vietnam.
1.d Key messages on current status, future trends, potential risks and recommendations on mitigation options	An possible option to large dams in the mainstream could be the creation of a series of fully gated low head barrages which could provide a similar amount of energy if the cumulative head was the same.

2. Member Countries	**CS Hydropower Thematic Key Messages**
2.a Cambodia	
2.a.1 Overall Key Policy Messages for the High political and decision-making level	Hydropower emerges as the sector with highest relevance to contribute to macro-economic growth for the lower Mekong basin. However, hydropower is also linked to the highest trade-offs with respect to fisheries.
2.a.2 Key Messages on finding of the impact (at technical level) under your thematic/discipline team	The mainstream schemes do not need active reservoir storage. Analysis of peaking options indicates that storage provides very limited commercial benefit. The reservoirs on the mainstream schemes, as currently envisaged, are created to provide generating head, not storage. The creation of reservoirs obstructs downstream fish migration, traps sediment, reduces water quality and increases environmental footprint. Reduction of reservoir size would therefore be beneficial.
2.a.3 Key messages on Major Transboundary issues	The lower Mekong basin would lose 30% of economic benefits in the power generation sector if mainstream dams would not be realised, including the ones that are already under construction. The non-realisation of these dams would cause the hydropower sector income to drop by 32.8% in Cambodia.
2.a.4 Key messages on status and future trend, potential risk, and recommendations on mitigation options	An possible option to large dams in the mainstream could be the creation of a series of fully gated low head barrages which could provide a similar amount of energy if the cumulative head was the same.

2. Member Countries	**CS Hydropower Thematic Key Messages**
2.b Lao PDR	
2.b.1 Overall Key Policy Messages for the High political and decision-making level	Hydropower emerges as the sector with highest relevance to contribute to macro-economic growth for the lower Mekong basin. However, hydropower is also linked to the highest trade-offs with respect to fisheries.
2.b.2 Key Messages on finding of the impact (at technical level) under your thematic/discipline team	The mainstream schemes do not need active reservoir storage. Analysis of peaking options indicates that storage provides very limited commercial benefit. The reservoirs on the mainstream schemes, as currently envisaged, are created to provide generating head, not storage. The creation of reservoirs obstructs downstream fish migration, traps sediment, reduces water quality and increases environmental footprint. Reduction of reservoir size would therefore be beneficial. Thailand's energy sector is a key beneficiary of mainstream dams in Lao PDR. Lao PDR would experience lower losses from a decision to refrain from mainstream dams than Thailand and Vietnam.
2.b.3 Key messages on Major Transboundary issues	The lower Mekong basin would lose 30% of economic benefits in the power generation sector if mainstream dams would not be realised, including the ones that are already under construction. The non-realisation of these dams would cause the hydropower sector income to drop by 21.5% in Lao PDR.
2.b.4 Key messages on status and future trend, potential risk, and recommendations on mitigation options	An possible option to large dams in the mainstream could be the creation of a series of fully gated low head barrages which could provide a similar amount of energy if the cumulative head was the same.

2. Member Countries	**CS Hydropower Thematic Key Messages**
2.b Thailand	
2.b.1 Overall Key Policy Messages for the High political and decision-making level	Hydropower emerges as the sector with highest relevance to contribute to macro-economic growth for the lower Mekong basin. However, hydropower is also linked to the highest trade-offs with respect to fisheries.
2.b.2 Key Messages on finding of the impact (at technical level) under your thematic/discipline team	The mainstream schemes do not need active reservoir storage. Analysis of peaking options indicates that storage provides very limited commercial benefit. The reservoirs on the mainstream schemes, as currently envisaged, are created to provide generating head, not storage. The creation of reservoirs obstructs downstream fish migration, traps sediment, reduces water quality and increases environmental footprint. Reduction of reservoir size would therefore be beneficial. Thailand's energy sector is a key beneficiary of mainstream dams in Lao PDR. Thailand would experience higher losses from a decision to refrain from mainstream dams.
2.b.3 Key messages on Major Transboundary issues	The lower Mekong basin would lose 30% of economic benefits in the power generation sector if mainstream dams would not be realised, including the ones that are already under construction. The non-realisation of these dams would cause the hydropower sector income to drop by 26.3% in Thailand.
2.b.4 Key messages on status and future trend, potential risk, and recommendations on mitigation options	An possible option to large dams in the mainstream could be the creation of a series of fully gated low head barrages which could provide a similar amount of energy if the cumulative head was the same..

2. Member Countries	**CS Hydropower Thematic Key Messages**
2.b Vietnam	
2.b.1 Overall Key Policy Messages for the High political and decision-making level	Hydropower emerges as the sector with highest relevance to contribute to macro-economic growth for the lower Mekong basin. However, hydropower is also linked to the highest trade-offs with respect to fisheries.
2.b.2 Key Messages on finding of the impact (at technical level) under your thematic/discipline team	The mainstream schemes do not need active reservoir storage. Analysis of peaking options indicates that storage provides very limited commercial benefit. The reservoirs on the mainstream schemes, as currently envisaged, are created to provide generating head, not storage. The creation of reservoirs obstructs downstream fish migration, traps sediment, reduces water quality and increases environmental footprint. Reduction of reservoir size in these mainstream projects would therefore be beneficial to fisheries and the food security situation in the lower Mekong Delta in Vietnam.
2.b.3 Key messages on Major Transboundary issues	The lower Mekong basin would lose 30% of economic benefits in the power generation sector if mainstream dams would not be realised, including the ones that are already under construction. The non-realisation of these dams would cause the hydropower sector income to drop by 48.8% in Vietnam. Extensive hydropower development upstream will increase food security risks in the lower Mekong Delta in Vietnam.
2.b.4 Key messages on status and future trend, potential risk, and recommendations on mitigation options	An possible option to large dams in the mainstream could be the creation of a series of fully gated low head barrages which could provide a similar amount of energy if the cumulative head was the same.

2 Background and Scope of the Study

2.1 General

Hydropower is recognized as an important development opportunity for the Mekong River Basin and the people living within it. As set out in the Mekong River Commission's Strategic Plan (2011 to 2015) and the Basin Development Plan (BDP, approved January 2011), the development of LMB should follow Integrated Water Resource Management (IWRM) principles. Within the IWRM context the need to improve the sustainability of the basin's hydropower developments is a key Strategic Priority. With the significantly increasing scale and prevalence of this energy option, all MRC member countries are taking steps to understand and employ sustainable hydropower considerations. The MRC Strategic Plan as well as the BDP has now been updated for the period 2016-2020 (MRC, 2016a and b). The new MRC Strategic Plan also includes a detailed roadmap for organisational reform of MRC and its functions currently under implementation.

Hydropower in the Mekong is embedded in a closely woven social and environmental fabric. The region's people derive a substantial proportion of their livelihood and nutrition from the tributaries and mainstream Mekong. Ecosystem services support the livelihood as well as a rich globally unique biodiversity. The planning and implementation of hydropower should aim to ensure that the livelihoods are preserved, enhanced and made resilient to adapt to changes, and that the supporting biodiversity is maintained wherever possible. Chapter 3 introduces an overview of the current existing and planned hydropower development in both the Upper and Lower Mekong.

2.2 Objectives of the Council Study

The overall objective of the Council Study (CS) as set out in the Inception Report is to:

"*further enhance the ability of the MRC to advise Member Countries on the positive and negative impacts of water resources development on people, economies and the environment of the Mekong River Basin*".

The specific objectives are to:

- Further develop/establish a reliable scientific evidence base on the environment, social and economic consequences (positive and negative) of development in the Mekong River Basin
- Results of the study are integrated into the MRC knowledge base to enhance the BDP process providing support to the Member Countries in the sustainable management and development of the Mekong River Basin.
- Promote capacity and ensure technology transfer to Member Countries in the process of designing and conducting of the study.

The Council Study will provide insights on transboundary issues, including the regional distribution of benefits, costs, impacts and risks of basin developments. This will require the assessment of past, ongoing and planned water resource development, recognizing that in some countries most water resource development has already taken place, while in other countries much more is underway or planned.

The main scope and outcome of the Hydropower Thematic Report is to assess the environmental and social risks, impacts and benefits of existing and planned hydropower developments and also its impact on other sectors

3 Hydropower Developments in the Mekong River Basin

3.1 Mainstream Hydropower Projects on the Upper Mekong

A summary of the hydropower projects that are planned, under construction or in operation is presented in Table 3.1. (Ref: Major Dams in China, International Rivers, November 2014, combined with information from the same document dated 2012; 2013 Update: Dams on the Drichu (Yangtze), Zachu (Mekong) and Gyalmo Ngulchu (Salween) rivers on the Tibetan Plateau; and Dams and Development in China: The Moral Economy of Water and Power).

Table 3.1. Planned or constructed hydropower schemes on Lancang River, China and Tibet Autonomous Region.

Name of Project	Province, Country	Status	Installed Capacity (MW)
Ganlanba	Yunnan, China	Operational	155
Jinghong	Yunnan, China	Operational	1750
Nuozhadu	Yunnan, China	Operational	5850
Dachaoshan	Yunnan, China	Operational	1350
Manwan	Yunnan, China	Operational	1500
Xiaowan	Yunnan, China	Operational	4200
Gongguoqiao	Yunnan, China	Operational	900
Miaowei	Yunnan, China	Under Construction	1400
Dahuaqiao	Yunnan, China	Under Construction	920
Huangdeng	Yunnan, China	Under Construction	1900
Tuoba	Yunnan, China	Planned	1400
Lidi	Yunnan, China	Under Construction	420
Wunonglong	Yunnan, China	Under Construction	990
Gushui	Yunnan, China	Planned	1800
Baita	Tibet Autonomous Region	Planned	Unknown
Guxue	Tibet Autonomous Region	Site Preparation	2400
Bangduo	Tibet Autonomous Region	Under Active Consideration	Unknown
Rumei	Tibet Autonomous Region	Site Preparation	2400
Banda	Tibet Autonomous Region	Site Preparation	1000
Kagong	Tibet Autonomous Region	Site Preparation	240
Yuelong	Tibet Autonomous Region	Planned	100
Cege	Tibet Autonomous Region	Planned	160
Linchang	Tibet Autonomous Region	Planned	72

Name of Project	Province, Country	Status	Installed Capacity (MW)
Ruyi	Tibet Autonomous Region	Planned	114
Xiangda	Tibet Autonomous Region	Planned	66
Guoduo	Tibet Autonomous Region	Under Construction	165
Dongzhong	Tibet Autonomous Region	Planned	108
Niangla	Qinghai, China	Unknown	Unknown
Zhaqu	Qinghai, China	Operational	Unknown
Gongdou	Qinghai, China	Unknown	Unknown
Dariaka	Qinghai, China	Unknown	Unknown
Atong	Qinghai, China	Unknown	Unknown
Angsai	Qinghai, China	Planned	55
Saiqing	Qinghai, China	Unknown	Unknown
Longqingxia	Qinghai, China	Operational	2.5
Aduo	Qinghai, China	Unknown	Unknown
Shuiasai	Qinghai, China	Unknown	Unknown
		Total	**31467.5**

The scale and pace of the exploitation of Lancang River for its hydropower potential has gained momentum since the 1980's. There are nine operational schemes with combined installed capacity of 15,757.5 MW, and a further six schemes with a combined installed capacity of 5,795 MW under construction. In addition there are four schemes where site preparation has commenced with a combined installed capacity of 6,040 MW.

There are approximately eight hydropower projects in the Qinghai province of China currently planned. Two further hydropower projects, Zhaqu and Longqingxia, are operational. In Tibet Autonomous Region, there are approximately 13 identified hydropower projects, of which one is currently under construction. Construction of the 165 MW Guoduo hydropower project is planned to be completed in 2015. The 240 MW Kagong hydropower project is reported to be commencing site preparation.

Reliable information concerning hydropower development in the upstream reach of the Lancang River, both in Tibet Autonomous Region, and in the Qinghai province of China, is difficult to obtain. There are approximately seven projects with an unknown status and installed capacity.

In China, hydropower is promoted as the best possible alternative to coal-fired power stations. It is intended that hydropower development will significantly contribute to the target of 15 % of renewable energy by 2020.

The information on the main hydropower schemes in operation on the Lancang River below are based on various different sources. Due to the scarcity of avaialable data on these dams to the Council Study we summarize the main known details in Appendix 3.

3.2 Hydropower Projects on the Lower Mekong and Tributaries

3.2.1 Introduction

The lower Mekong Basin downstream of the Chinese border comprises the majority of the land area of Lao PDR and Cambodia, the northern and northeast regions of Thailand and the Mekong Delta and Central Highland regions of Viet Nam. Figure 3.1 identifies the majority of locations of existing and planned hydropower projects on the mainstream of the lower Mekong Basin and its tributaries. It is evident from Table 3.2 and 3.3 that the majority of hydropower projects in the lower Mekong Basin are located in Lao PDR.

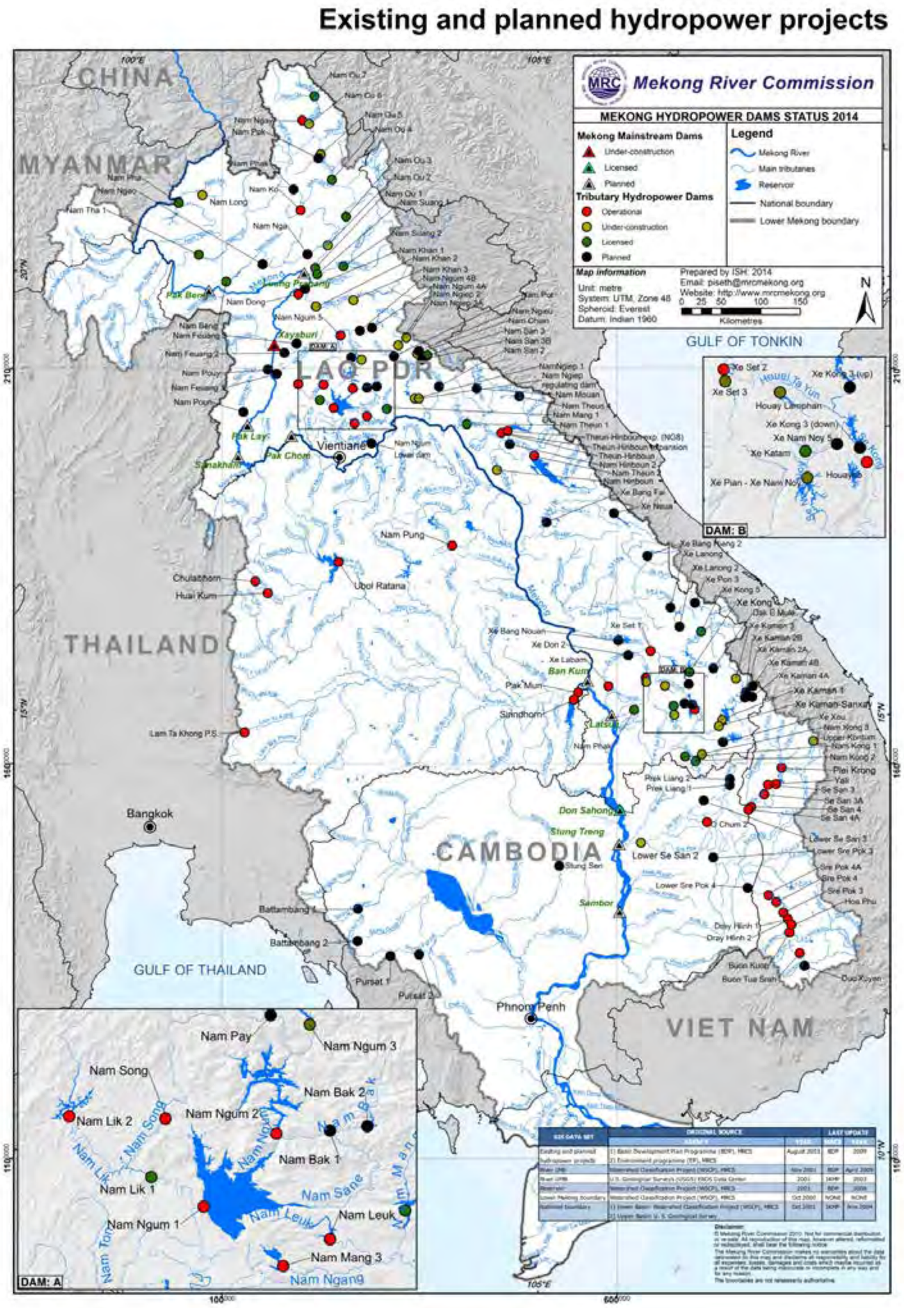


Figure 3.1 Hydropower Dams (operational, under construction, licensed and planned) on the Lower Mekong mainstream and tributaries (Source: Mekong River Commission).

3.2.2 Lower Mekong Basin – Mainstream

Proposed dams on the lower mainstream Mekong are listed in Table 3.2. Of these, ten would involve construction of dams across the entire river channel, eight within Lao PDR and two in Cambodia. The Don Sahong project within Lao PDR will involve commanding only the Hou Sahong Channel leaving the other channels of the Mekong at Kone Falls uninterrupted. The Sambor project included in the table is the smaller alternative dam that will include a natural sediment and bypass channel.

Table 3.2 Mainstream Hydropower Schemes.

Name of Project	Country	Status	Installed Capacity (MW)
Pak Beng	Lao PDR	Planned	1,230
Luang Prabang	Lao PDR	Planned	1,410
Xayaburi	Lao PDR	Under construction	1,285
Pak Lay	Lao PDR	Planned	1,320
Sanakham	Lao PDR	Planned	660
Pak Chom	Lao PDR	Planned	1,079
Ban Khoum	Lao PDR	Planned	2,000
Pou Ngoy (Lat Sua)	Lao PDR	Planned	651
Don Sahong	Lao PDR	Licensed	260
Stung Treng	Cambodia	Planned	980
Sambor[3]	Cambodia	Planned	1,703
		Total	**12,578**

(Ref DEB July 2015)

PNPCA PBHPP 912 MW Installed Capacity (MW)

The Lao Cascade

The Lao Cascade comprises five run-of-river dams with hydroelectric powerplants: Pak Beng, Luang Prabang, Xayaburi, Pak Lay and Sanakham. Xayaburi hydropower plant is currently under construction, planned to be operational in 2019, but the other hydropower plants are at less advanced stages of development.

The Lao Cascade Case Study assessment comprised the reach from the Burmese/Lao/Thai border and gauging station Chiang Saen down to short upstream of Vientiane. The modelled reach starts however 50 km short of the Chiang Saen and has a total length of 732 km. Until the Sanakham dam site, the Mekong runs entirely within Laos. From Sanakham dam site, the Mekong divides Thailand and Laos.

Over the modelled reach, the present total head is from 342 masl to 166 masl, i.e. a fall of 176 meters. Thus, the average slope on this reach is 0.24 m/km, which is gentle, but still steeper (around double) than further downstream from Vientiane.

[3] Alternative to the original Sambor that was 2600 MW (Wild and Loucks, 2015).

Apart from Vientiane, the only major town located along the river is Luang Prabang. The Xayabury dam construction site is 100 km downstream of Luang Prabang town.

The table below gives an overview on the planned dam locations within the Cascade reach. As indicated in the table, the reservoirs have lengths ranging from around 60 to 100 km. From the upstream end down to Sanakham, around two-thirds of the distance will be reservoirs and one-third free flowing river sections. It should however be noted that these figures are highly approximate since there is not a sharp transition from river to reservoir. Furthermore, the distribution between the two groups is based on the dry season situation. During the wet season, the gradient through the upper reaches of the reservoirs will be larger and the transition between reservoir and river will be even more difficult to identify.

Two gauging stations are located within the modelled Lao Cascade reach, providing data for calibrating the model (Luang Prabang and Chiang Khan). The Luang Prabang station is located at the town of the same name, i.e. close to the tail end of the Xayaburi reservoir. The Chiang Khan gauging station is located around 22 km downstream of the Sanakham dam site, i.e. downstream of the Lao Cascade.

Table 3.3 Length of reservoirs and river reaches in the Lao Cascade.

Reach from:	Reach to:	Cumulative distance from u/s boundary km	Reach length km	Reservoir length km	River reach km
Model Boundary	Pak Beng	0	127	73	54
Pak Beng	Luang Prabang	127	143	100	43
Luang Prabang	Xayaburi	270	129.5	80	49.5
Xayaburi	Pak Lai	399.5	121.5	80	41.5
Pak Lai	Sanakham	521	81	58	23
Sanakham	Model Boundary	602	130		

Figure 3.2 portrays a longitudinal profile of the Lao Cascade. The lower outline of the blue polygon illustrates the thalweg in the Mekong (i.e. the lowest elevation in each cross-section), which clearly varies quite a lot along the longitudinal scale, and frequently some 20 m over a few km. The upper outline of the blue polygon illustrates the water surface after construction of all five dams. The black lines visible above the water illustrate the elevation of the extreme ends of each cross-section.

Due to the scale, it is difficult to discern in this figure the river reaches below each reservoir, except for upstream the Xayaburi reservoir. With a finer scale it, however, it would be possible to discern that there is a gradient of roughly 0.5 - 2 m before the transition into the reservoirs (largest upstream Xayaburi, smallest upstream Sanakham). The mentioned magnitude of gradients occurs in the dry season; in the wet season, the gradients are much larger.

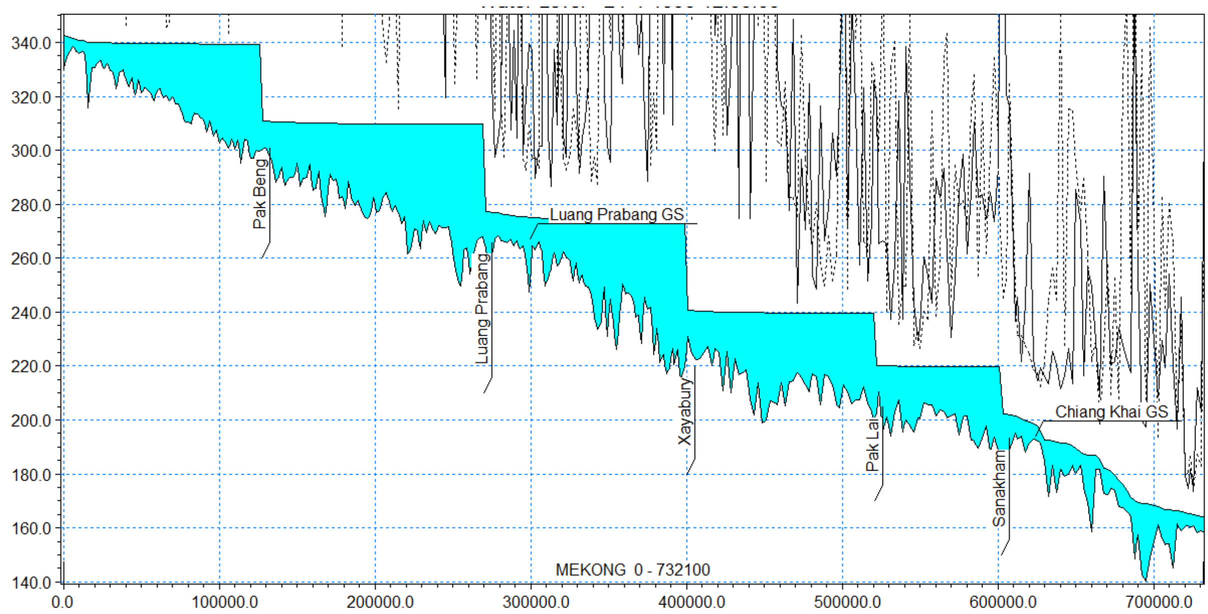


Figure 3.2 Longitudinal profile of the Lao Cascade.

Design flow and reservoir water level

The technical details of the Xayaburi hydropower plant are finalized, although not for the other four dams. As the information available is incomplete, we have chose to use the Xayaburi design as a “template” for the other hydropower plants when it comes to design flow, fish passage design and gate capacity. The design flow is scaled relative to the median flow at the different sites, while the fish passage and gate capacity was copied from Xayaburi.

The key hydropower data for the cascade is presented in Table 3.4.

Table 3.4 Key numbers for the dams in the Lao Cascade.

	Design flow	Full supply level	Capacity	Annual generation	Status
Pak Beng	4110 m³/s (5771 m³/s)	340/335 masl	912 MW	4 800 GWh	Prior Consultation concluded. Expected 2023
Luang Prabang	4110 m³/s	310 masl	1200 MW	6 100 GWh	Expected 2030
Xayaburi	5140 m³/s	275 masl	1285 MW	7 200 GWh	Under construction Expected finished in 2019
Pak Lay	5140 m³/s	240 masl	1000 MW	4 500 GWh	Expected 2030
Sanakham	5140 m³/s	220 masl	700 MW	3 600 GWh	Expected 2025

The Mainstream Dams below Pakse

There are six mainstream dams planned downstream of the case study cascade, four in Lao and two in Cambodia. The dams are plotted in the map below (Figure 3.2.2), and key numbers are presented in the following table.

Figure 3.3 Mainstream dams downstream of the Lao cascade.

Table 3.5 Key numbers of the mainstream dams downstream of the Lao Cascade.

	Design flow	Full supply level	Capacity	Annual generation	Status
Pakchom	5 720 m³/s	192 masl	1 080 MW	5 300 GWh	Expected 2025
Ban Kum	11 700 m³/s	115 masl	1 800 MW	8 400 GWh	Expected 2030
Latsua	9 600 m³/s	97.5 masl	600 MW	1 700 GWh	Expected 2025
Don Sahong	1 600 m³/s	73 masl	260 MW	2 000 GWh	Under construction. Expected finished in 2019.
Stung Treng	9 834 m³/s	52 masl	980 MW	5 000 GWh	Planned
Sambor	17 668 m³/s	40/35 masl	1 700/ 2500 MW	12 000/ 5 500 GWh	Planned

Hydropower dam from SCN EDS 2007_M1

As most of these hydropower plants are at an early stage of development, it is likely that some of the key numbers may change during the optimization of the plants. While most of the dams are expected to have similar design as in the Lao Cascade, there are some exceptions. Don Sahong, currently under construction, is located in within the 4000 Islands just upstream Khone Falls, and only occupies one branch of the braided river. For the Sambor dam, at least two different designs have been suggested. The original design consists of a dam, with a crest length of 18 km covering the whole river width, while the alternative design is a smaller dam that only occupies a part of the river. Both alternatives are included in the table above and the smaller alternative is illustrated in the Figure 3.2.3.

Figure 3.4 Google Earth illustration of the smaller alternative of Sambor (P.Loucks, 2017).

3.2.3 Lower Mekong Basin - Tributaries

The first hydropower plant Ubol Ratana in Thailand had start-up of turbine no. 1 on in 1966. By late 2015 38 hydropower plants with installed power larger than 15 MW have been completed and in operation. Laos has the highest number of hydropower projects with 18 in Laos, followed by Vietnam, while there are 5 in Thailand. The total installed effect of the hydropower projects is 7 150 MW while the calculated annual energy production is close to 29 450 GWh.

In the table below the hydropower projects in the LMB tributary schemes that had been commissioned up till the end of 2015 is listed. Only hydropower projects with an installed effect of 15 MW or above have been included. Energy density for the projects have been calculated where figures for reservoir area at full supply level have been available. Energy density is a measure of the footprint of project in terms of installed effect per area of land inundated (megawatt divided by reservoir area). High energy density values indicate that the project has a good yield in relation to the area footprint of the reservoir. Run-of river (ROR) projects which normally have limited intake ponds, and not storage reservoirs, have the highest energy densities and thereby the lowest impacts in terms of land loss in relation to energy production.

Table 3.6 Commissioned Hydropower Projects in LMB by the End of 2015.

	Project Name	COD	MW	Annual Energy GWh	Reservoir km^2	Energy Density MW/km^2
	Thailand					
1	Chulabhorn	1972	40	59	31	1.29
2	Pak Mun	1994	136	280	117	1.16
3	Sirindhorn	1971	36	90	288	0.13
4	Ubol Ratana	1966	25,2	56	410	0.06
5	Lam Ta Khong P.S.	2001	500	400	1430	0.35
	Laos					
6	Nam Ngum 1	1971	155	1002	370	0.42
7	Se Xet 1	1990	45	133,9	ROR	-
8	Theun- Hinboun	1998/2012	500	1251	105	4.76
9	Houay Ho	1999	152	450	37	4.11

	Project Name	COD	MW	Annual Energy GWh	Reservoir km^2	Energy Density MW/km^2
10	Nam Leuk	2000	60	218	12.8	4.69
11	Nam Mang 3	2005	40	150	ROR	-
12	Se Xet 2	2009	76	309	20	3.8
13	Nam Lik 1-2	2010	100	435	24.4	4,10
14	Nam Theun 2	2010	1075	6000	450	2.39
15	Nam Ngum 2	2012	615	2300	122.2	5.32
16	Nam Ngum 5	2012	120	507	15	8.00
17	Xekaman 3	2013	250	1000,3	5.25	47.61
18	Nam Ngiep 3A	2014	44	152,3	ROR	-
19	Nam Ngiep 2	2015	180	732	-	-
20	Nam Khan 2	2015	130	558	-	
21	Houay Lamphan Gnai	2015	88	500	6.8	12.9
22	Nam Sun 3A	2015	69	278,4	-	-
23	Nam Sun 3B	2015	45	173,5	-	-
	Vietnam					
24	Dray Hlinh 1	1990	45	100		
25	Yali	2002	720	3868	64.5	11.16
26	Se San 3	2006	260	1325	-	
27	Se San 3A	2007	96	479	-	
28	Dray Hlinh 2	2007	16	94	-	
29	Buon Tua Srah	2009	86	358	-	
30	Buon Kuop	2009	280	1459	37	7.57
31	Plei Krong	2009	100	501	80	1.25
32	Se San 4	2010	360	1649	54	6.67
33	Sre Pok 3	2010	220	1002	-	
34	Sre Pok 4	2010	80	360	-	
35	Se San 4A	2011	63	297	-	
36	Sre Pok 4A	2013	64	302	-	
37	Upper Kontum	2014	250	1056	-	
38	Hoa Phu	2014	29	113	-	
Total			**7 150**	**29 491**		

Hydropower dam from SCN DEV_ 2020_M2

4. Hydropower Modelling

4.1 Hydropower data in year 2007 for setting up IQQM Baseline model

The existing and proposed Hydropower dams data in the lower Mekong basin that prepared by BDP (see Hydropower Sector Review for joint basin planning process report 2009) were used for improving the Mekong IQQM model.

This database has 135 hydropower projects which consists of all in operation, under construction, under license and planned projects. The location of hydropower projects in lower Mekong basin as well as in Chinese part shown in Figure2-6 and the number of hydropower project and capacity are summary in Table 4.1.

Data requirement for setup of the Hydropower dams in the IQQM model included:

- Dam characteristics (Dam type, Length, Height, Spillway elevation, Design head and Design discharge)
- Operation data (Rated head, Plant design discharge, Installed capacity, Full storage level, Live storage, and Low supply level (see detail in Annex B).

Table 4.1: Existing and planned Hydropower dam projects in Lower Mekong Basin status year 2008

Country	Description	Status (Year 2008)				Total
		In Operation	Under Construction	Under License	Planned	
Cambodia	Projects	1	0	0	13	14
	Capacity (MW)	1	0	0	5,589	5,590
Laos	Projects	10	8	22	60	100
	Capacity (MW)	662	2,558	4,126	13,561	20,907
Thailand	Projects	7	0	0	0	7
	Capacity (MW)	745	0	0	0	745
Vietnam	Projects	7	5	1	1	14
	Capacity (MW)	1,204	1,016	250	49	2,519
Total	**Projects**	**25**	**13**	**23**	**74**	**135**
	Capacity (MW)	**2,612**	**3,574**	**4,376**	**19,199**	**29,760**

Source: BDP phase 2: 2010 (see Hydropower Sector Review for joint basin planning process report 2009)

In the upper part of Mekong basin (Upper Chinese border), there are 21 potential hydropower, of which 6 dams are in operation, 4 dams are under construction, 5 dams are in site preparation, 5 dam is planned, and 1 dam is cancelled as listed in Table 4.2.

The year 2007 was selected as the baseline for the study and therefore dams which operated before year 2007 were turned on in the model set-up.

4.2 Council Study Scenarios and Model Inputs and Gaps

4.2.1 Main Scenarios

The three development scenarios of the Council Study comprise:

(i) Early development scenario (M1)
(ii) Definite future scenario (M2)
(iii) Planned development scenario 2020 (M3)

The Early Development Scenario (M1) includes the infrastructure and the land cover in the 6 IWRM sectors as of 2007. The M1 scenario represents the baseline conditions of the Council Study and the reference conditions and attributes by which the other development scenarios are compared.

The Council Study scenarios are based on recorded hydrological data from 1985-2008. The predictions of change estimated for the scenarios therefore rely on the same 24-year period, or prediction horizon, independent of the level of development imposed on the Mekong River system.

The Definite Future Scenario (M2) includes all existing, under-construction, and firmly committed development in the six thematic sectors considered which are expected to be in place by 2020. The Planned Development Scenario (M3) includes in addition to contents of M2 water resource development that is planned in the six sectors in the Mekong Basin and that would be in place in 2040 if fully implemented.

Table 4.2 Basin-wide development scenarios

	Development scenario	Time horizon	Primary interventions	Climate	Flood Plain Settlement
M1	Baseline development scenario	Up to 2007	Water resources infrastructure developed in the Lower Mekong Basin up to 2007	1985-2008	2007
M2	Definite future scenario	Definite future up to 2020	Early scenario plus water resources infrastructure developed, under construction and planned in the Lower Mekong Basin between 2007 and 2020	1985-2008	2020
M3	Planned development scenarios	Planned future up to 2040	Definite Future plus infrastructure planned for implementation in the Lower Mekong Basin between 2020 and 2040	Mean warmer &wetter	2040
M3CC	Sub-scenarios	Planned future: 2040	FPF2, FPF3, IRR1, DIW1, DIW2, and ALU3 (as defined in the Implementation Plan of the Council Study and the CIA 2017 report)	Mean warmer and wetter	Applied in specific years

ALU = Agric/Land use Change; DIW = Domestic and Industrial Water Use; FPF = flood protection infrastructure; HPP = hydropower; IRR = irrigation; and NAV = Navigation

The levels of development for each Thematic Area are highlighted in Table 4.6

Table 4.3 Parameters for the main development scenarios

Scenario			Level of Development for water-related sectors						Climate	Floodplain settlement
			ALU	DIW	FPI	HPP	IRR	NAV		
M1	2007	Baseline Scenario 2007	2007	2007	2007	2007	2007	2007	1985-2008	2007
M2	2020	Definite Future Scenario 2020	2020	2020	2020	2020	2020	2020	1985-2008	2020
M3	2040	Planned Development Scenario 2040	2040	2040	2040	2040	2040	2040	1985-2008	2040
M4	2040CC	Planned Development Scenario 2040	2040	2040	2040	2040	2040	2040	Mean warmer & wetter	2040

Comparison between M2 and M1 measures the effects of water resource development between 2007-2020, while comparisons between M3 and M2 estimate the effects of the planned developments between 2020 and 2040 in the context of a climate expected to be warmer and wetter and with expansion of human settlements in the flood plains. Flood protection infrastructure development is not included in the main scenarios for M2 and M3 so that the impacts of changes in flood regimes can be evaluated in the context of other expected changes, in particular expansion of human settlements into floodplains.

The assessments done in this Council Study aim to predict, to the extent possible with available knowledge, the likely condition of the river ecosystem with developments expected for 2020 and 2040 in place. All rivers are continuously changing, but much of this change is around a dynamic equilibrium so that although they may appear to differ from season to season or year to year, they remain much the same over many years.

Water-resource developments and in particular those with river barriers such as most hydropower projects can disturb this dynamic equilibrium, driving a new trajectory of change that can become apparent in days (e.g., new effluents changing water quality) to years (e.g., fish populations declining as migration routes disappear) to decades (e.g., capture of sediments in reservoirs changing downstream channels and habitats). The descriptions for the scenarios 2020 and 2040 should therefore be seen as points at which many short-term changes may have happened and some of the medium and longer-term changes could still be ongoing.

The hydrologic modelling assessment is the foundation for the subsequent analysis in the Council Study. To fulfill the Council Study the modelling team has employed 3 model packages (DSF, eWater and WUP-FIN) with four main scenarios involving Early Development 2007 (M1) , Development 2020 (M2) , Development 2040 with (M3CC)[4]* and without climate change (M3noCC) which had been implemented and finalized so far.

In order to see clear impacts from different sectors for basin wide assessment including the change of future climate, the selected sectors are considered to model under various condition so called "Sub

[4] M3CC is run with climate change (IPSL_RCP4 4.5 : warmer plus seasonal change)

scenarios". The sub-scenarios are sector modifications for the 2040 Main Cumulative Scenario (M3CC), for each sub-scenario only one thematic sector definitions will be changed.

The following thematic and discipline sectors are taken into account in the sub scenarios formulation:

(1) Hydropower

(2) Agriculture and land use Change

(3) Irrigation

(4) Flood protection,

(5) Climate Change scenarios (Wetter and Drier)

Note: M3CC is run with climate change (IPSL_RCP4 4.5: warmer plus seasonal change)

4.2.2 Council Study Hydropower Sub-Scenarios

Additional sub-scenarios have been developed by each of the Council Study Thematic Teams in response to key policy questions arising from the stated objectives and assessment requirements of the Inception Report. The most rigorous study design compares the main scenario M3 with all sectors developed, with a sub-scenario having all the sector developments minus those in the target sector.

Table 4.4 Sub-scenarios to test the effects of water resources development in the hydropower sector.

	Scenario and subscenarios	**Level of Development for water-related sectors**						Climate	Floodplain
		ALU	DIW	FPF	HPP	IRR	NAV		
M3	Planned Development Scenario 2040	2040	2040	2040	2040	2040	2040	Mean warmer & wetter	2040
H1	Planned Development 2040 without HPP	2040	2040	2040	**2007**	2040	2040	Mean warmer & wetter	2040
H2	Planned Development 2040 with HPS1	2040	2040	2040	**HPS1**	2040	2040	Mean warmer & wetter	2040
H3	Planned Development 2040 with HPS2	2040	2040	2040	**HPS2**	2040	2040	Mean warmer & wetter	2040

Thus, under the 4 thematic sectors and one discipline sector, there are totally 13 sub-scenarios which are being implemented and led by the modelling team to support the Council Study team for further assessment. This task is expected to be completed by end of August 2017.

The 4 sub-scenarios relevant to the Hydropower Thematic assessment are summarised in the Table below and explained in the following sections.

Table 4.5 Hydropower Development Sub-Scenarios

N^0	Description	Sub Scenarios Name	Detail information of sub-scenarios
1	Planned Development 2040 without HPP	**H1.a**	Dev2040_M3CC without any dams
2		**H1.b**	Dev2040_M3CC with Chinese dams and tributary dams *but without ALL LMB mainstream dams*
3	Planned Development 2040 with HPS1	**H2**	Dev2040_M3CC (with all dams in MB in 2040 and seasonal climate change)
4	Planned Development 2040 with HPS2	**H3**	Dev2040_M3CC with All tributary with its mitigation, operation..including Sambor

4.2.2.1 Planned Development 2040 without HPP

Assumptions

This sub-scenario is set to create a basiline for HPS1 and HPS2 in order to measure the relative impacts of those scenarios. In this sub-scenario all existing and planed hydropower developments have been removed from the model so that a baseline can be obtained with no hydropower in the basin:

Planned Development 2040 without HPP – E.g. 2 model runs without HPP dams (reference cases)

a) 2040 Without any dams as discussed below
b) 2040 Chinese dams and tributary dams *but without ALL LMB mainstream dams*

4.2.2.2 Planned Development 2040 with HPS1

Assumptions

Operation, mitigation and design parameters will be as for the Planned Development Scenario 2040. As before, all dams are expected at least to comply with the Preliminary Design Guidelins (PDG) requirements.
The intention of this scenario is to compare the influence on the Council Study assessments of the mainstream dams situated in the upper Laos area with those further downstream in southern Laos and Cambodia. This difference was evident in both the BDP2 Scenario Assessment and in the the Delta Study. These found the dams in the Cambodian floodplain to have the most impact on fisheries and on the fine-grained sediments. This scenario allows the Cumulative Impact Assessment to compare full and part mainstream and tributary dam development:

Planned Development 2040 with HPS1 - Operation, mitigation and design parameters will be as for the Planned Development Scenario 2040 (BDP 2040). All dams are expected at least to comply with the PDG requirements. Includes large/original version of Sambor Project.

This is the same as the M3noCC: Main Scenario M3 (Full Development 2040 without Climate change): So thereis no need for the Modelling Team to re-run this, since it is BDP 2040 without Climate Change and includes both tributary dams and mainstream dams.

Design Characteristics and Parameters of Mainstream Dams included in HPS1

The updated figures for the MS Dams in the LMB are provided in the following table. It should be noted that different sources give different figures for some parameters.

Table 4.6: Main characteristics for Mainstream Mekong Dams

Project Name	Full Supply Level	Max Head	Rated Head	Plant factor	Turbine Flow	Live Storage	Peaking Period [2]	Installed Power	Energy
	masl	M	M	%	m^3/s	Mcm	hours	MW	GWh/year
Pak Beng	340	20	16.0	45	7 250	780	30	1 230	4 846
Luang Prabang	320	Appr. 40	33.0	45	4 976	120	7	1 410	5 600
Xayaburi [1)]	275	35	28.5	65	5 110	212	12	1 285	7 370
Pak Lay	240	25	18.6	51	8 880	317	10	1 320	5 948
Sanakham	215	18-19	6.4	64	9 000	132	4	660	3 696
Pak Chom	192	DNF	22	56	Appr. 5 600	808	40	1 079	5 318
Ban Koum	115	DNF	18.6	48	11 700	DNF	DNF	2 000	8 433
Phou Ngoy	97.5	DNF	10.8	39	10 000	530	15	800	2 751
Don Sahong	DNF	25	DNF	89	1 600	115	32	260	2 000
Stung Treng	52	DNF	11.6	65	9 800	518	15	900	5 096
Sambor	40	22.9	16.5	52	17 668	465	12	2 600	11 740

1) Xayabouri is under construction, about 50% completed and scheduled for operation in 2019
2) Tail water level measured by the developer in low flow period in January 2009 at 210.65 masl

The plant factor expressed in percentage represents the ratio of the actual power output of the project over a period of time, to its theoretical power output if water was available to be diverted through the turbines at maximum turbine flow. It should be noted that Xayabouri has a plant factor of 65%. This is a reference project for the other MS Dams as it has had the most optimisation of production and plant scale. It is assumed that the final and optimized plant factor for the other MS Dams will come closer to Xayabouri's plant factor through further design optimisation. Given that peaking operation, maybe with the exception of Pak Beng, will either not be allowed for or not be beneficial, one should expect that the plant factors for Luang Prabang, Pak Lay, Pak Chom, Ban Koum and Phou Ngoy will be increased.

The assumption in this Scenario is that the remaining five MS Dams marked grey in the tables above will not be developed before 2040. Some serious constraints related to each of the projects are given below.

- Pak Chom; a transboundary project shared by Thailand and Lao, requires the resettlement of a large number of people, project development is in the early stage with little progress.

- Ban Koum; a transboundary project shared by Thailand and Lao, there are environmental and social conflicts (fishery, resettlement), project development is in an early stage with little progress.
- Phou Ngoy; solely within Lao, about same dam height as for Ban Koum but longer dam (1 300 m versus 800 m), capacity smaller than for Ban Koum because much lower rated head (800 MW versus 2 000 MW), energy smaller than for Ban Koum (2 751 GWh versus 8 433 GWh). FS has been going on for some years and is still not finalized, environmental and social conflicts are likely.
- Stung Treng; solely within Cambodia, requires a long dam for a limited head, inundation of about 212 km^2, the reservoir length about 50 km, environmental and social conflicts (fishery, resettlement), further development recommended to be delayed. In addition, the economics of the development seems marginal due to the large structure and based on investigations and information gathered during the BDP Scenarios assessment.
- Sambor; solely within Cambodia, requires a long dam for a limited head, capacity 2 600 MW requires 18 km long dam with more than 600 km^2 inundated area, capacity 1 703 MW requires more than 2 km long dam with more than 60 km^2 inundated area, environmental and social conflicts (fishery, resettlement) may also occur and development may be delayed to allow for re-design to be considered.

General Criteria for inclusion in HPS1

The list of hydropower projects in Planned Development Scenario 2040 has been examined with regard to the following aspects (where relevant data is available):

1. Transboundary tributary projects will need to be reviewed and potentially excluded due to high likelihood of not proceeding (e.g. with reservoir in one country and dam & power station in another country).
2. Projects with high costs are unlikely to proceed with current proposed scale and design (above 8 US cent per kWh) (depending on access to reasonably reliable investment and production figures)
3. Projects with Plant Factor less than 40% most often indicate high costs and poor economics; these are also less likely to proceed;
4. Social and environmental red flags such as large inundation of land or ecologically sensitive areas and/or significant resettlement consequences
5. Projects 15MW or less are excluded from direct assessment.
6. The potential of unidentified projects to be discovered and developed, i.e. projects that have not been identified to date but will be identified and realized in the period 2016 – 2040

4.2.2.3. Planned Development 2040 with HPS2

Assumptions

HPS2 has been described by the Council Study as follows: Level of Development as for HPS1 with Joint Reservoir Operation and good coordination among all mainstream dams and by taking into account operation for navigation lock, fish passages, sediment flushing as well as measures to maintain acceptable water quality during and after flushing. HPS2 corresponds to "5 Project Cascade + Hydro Peaking…….. *but with sediment management by reservoir drawdown during frequent (2 year) floods at all 5 projects following the Xayaburi strategy and incorporating hydro peaking to transfer limited flow to high tariff times of day and days of the week when river flows drops below installed capacity."*

Design Characteristics and Parameters under Planned Development 2040 with HPS2 - HPS2 have been described by the Council Study as follows: Level of Development as for HPS1 with Joint Reservoir

Operation and good coordination among all mainstream dams and by taking into account operation for navigation locks, fish passages, sediment flushing as well as measures to maintain acceptable water quality during and after flushing. HPS2 is for all proposed mainstream dams.

4.3 Gap-filling for Hydropower Development Data and Scenario Modelling

The scenarios encompass a series of potential mainstream and tributary dams and their impoundments for hydropower generation. In the 2007 Baseline, most of the existing dams are located outside the study area, in China with 14 tributary dams in the LMB (Table 4.7)

For Scenario 2020 there are 63 possible tributary barriers (Table 4.7), and two possible barriers on the mainstream Mekong River in the LMB

The developments associated with Scenario 2040 would alter water levels along the Lower Mekong so that for most river reaches these no longer reflect bed topography but rather a step-drop sequence of dam reservoir levels.

Table 4.7 The number of tributary HPPs included in 2007 Baseline, Scenarios 2020 and 2040

<table>
<tr><th>No</th><th>Country</th><th colspan="2">Number of HPPs in tributaries</th></tr>
<tr><td rowspan="4">2007, 2020 and 2040</td><td>Lao PDR</td><td>5</td><td rowspan="4">14</td></tr>
<tr><td>Thailand</td><td>4</td></tr>
<tr><td>Cambodia</td><td>0</td></tr>
<tr><td>Vietnam</td><td>5</td></tr>
<tr><td rowspan="4">2020 and 2040</td><td>Lao PDR</td><td>39</td><td rowspan="4">49</td></tr>
<tr><td>Thailand</td><td>0</td></tr>
<tr><td>Cambodia</td><td>0</td></tr>
<tr><td>Vietnam</td><td>10</td></tr>
<tr><td rowspan="4">2040</td><td>Lao PDR</td><td>54</td><td rowspan="4">57</td></tr>
<tr><td>Thailand</td><td>0</td></tr>
<tr><td>Cambodia</td><td>0</td></tr>
<tr><td>Vietnam</td><td>1</td></tr>
<tr><td colspan="3">Total</td><td>120</td></tr>
</table>

Not all data for the hydropower developments is available and the following strategy was followed for gap-filling procedures for hydropower dams:

Inputs from Thematic Team

- Basis characteristic of Hydropower Dams in China
- Basis characteristic of Hydropower Dams in LMB countries

Methods to fill data gaps:

- Reservoir Sureface area estimated for some projects
- Reservoir Volume estimated for some projects
- Tailwater level estimated for some projects
- Operation rule curve estimated for some projects
- Spillway discharge estimated for some projects

Model Outputs:

- Flow (quantity and timing) on Mainstream (daily basis)

• Sediment (quantity and timing) on Mainstream (daily basis)

• Nitrogen (quantity and timing) on Mainstream (daily basis)

• Phosphorus (quantity and timing) on Mainstream (daily basis)

Limitations

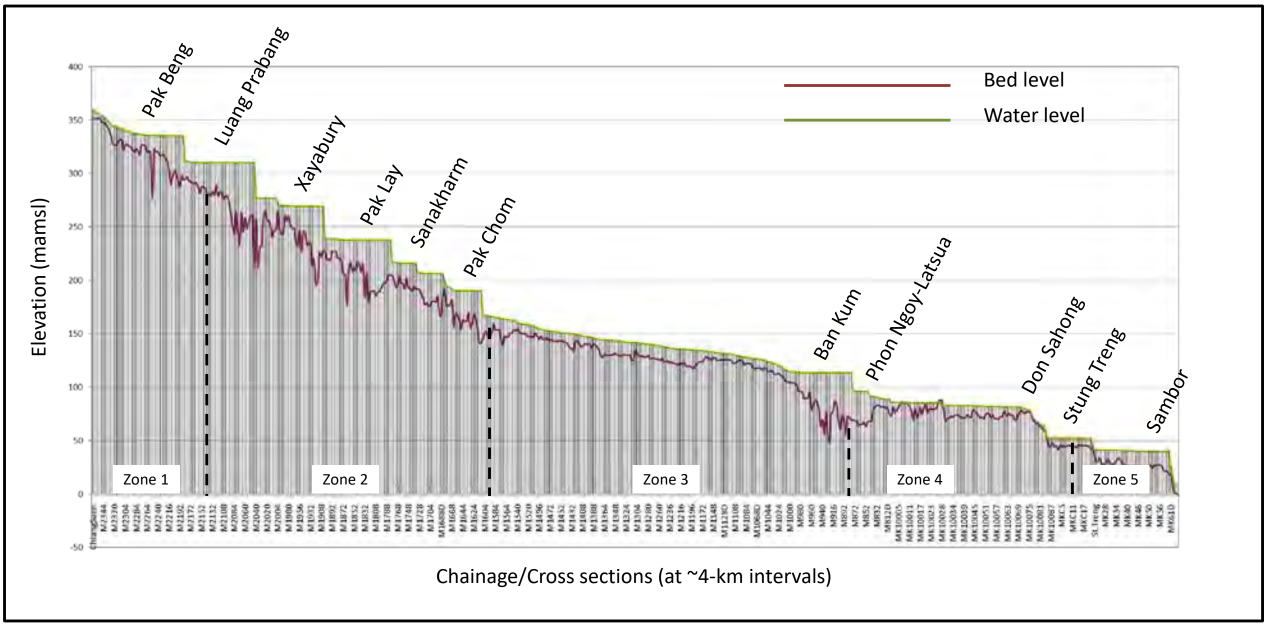
• Lacking the Relationship of Volume-Surface Area-Elevation of reservoirs.

• Lacking the Operation rule curve, therefore some output (the detailed rule curves are not available or not accurate for some projects.)

Table 4.8 Mainstream HPPs included in each main development scenario

HPP	2007 Baseline	2020	2040
Langcang Cascade	Yes	Yes	Yes
Pak Beng			Yes
Luang Prabang			Yes
Xayabury		Yes	Yes
Pak Lay			Yes
Sanakharm			Yes
Pak Chom			Yes
Ban Kum			Yes
Phon Ngoy-Latsua			Yes
Don Sahong		Yes	Yes
Stung Treng			Yes
Sambor			Yes

Figure 4.1 Long profile of the Mekong River from Chiang Saen to Kratie showing predicted water levels associated with potential HPP reservoirs included in the 2040 scenarios.



Further details of the gap-filling procedures are to be found in Annex 4 and in the Council Study Modelling Team Reports.

4.4 Mitigation Options

4.4.1 Mitigation Options for Council Study Hydropower Sub-Scenarios

Mitigation options consider all mainstream dams and have been modelled under the Council Study Hydropower sub-scenarios. Focus has been on assessing the difference between, no mitigation (Council Study hydropower sub-scenario H2) and with mitigation (Council Study hydropower sub-scenario H3), as it concentrates on mitigation, and the effectiveness of those introduced in H3 contrary to the "no-mitigation". A summary of the H3 mitigation measures imposed on the LMB mainstream dams is summarized in Table 4.9.

Table 4.9 Mitigation measures imposed on mainstream dams (in the H3 sub-scenario).

Site/Mitigation Option	Minimum Flow	Fish Pass	Flushing	Comments
Pakbeng	Yes. (>Q95)	Yes. (1% of mean flow)	Yes. Down-ramp 0.1 m/hr; Up-ramp 0.2 m/hr	
Luangprabang	Yes. (>Q95)	Yes. (1% of mean flow)	Yes. Down-ramp 0.1 m/hr; Up-ramp 0.2 m/hr	
Xayaburi	Yes. (>Q95)	Yes. (1% of mean flow)	Yes. Down-ramp 0.1 m/hr; Up-ramp 0.2 m/hr	
Paklay	Yes. (>Q95)	Yes. (1% of mean flow)	Yes. Down-ramp 0.1 m/hr; Up-ramp 0.2 m/hr	

Site/Mitigation Option	Minimum Flow	Fish Pass	Flushing	Comments
Sanakham	Yes. (>Q95)	Yes. (1% of mean flow)	Yes. Down-ramp 0.1 m/hr; Up-ramp 0.2 m/hr	
Pakchom	Yes. (>Q95)	Yes. (1% of mean flow)	Yes. Down-ramp 0.1 m/hr; Up-ramp 0.2 m/hr	
Ban Kum	Yes. (>Q95)	Yes. (1% of mean flow)	Yes. Down-ramp 0.1 m/hr; Up-ramp 0.2 m/hr	
Latsua	Yes. (>Q95)	Yes. (1% of mean flow)	Yes. Down-ramp 0.1 m/hr; Up-ramp 0.2 m/hr	
Don Sahong	Yes. (>Q95 and minimum flow for Khone Falls)	No	No flushing	Dams one side channel of Mekong
Sambor	Yes. (>Q95 in side channel)	Yes. 1% of design flow	No	The small version of Sambor (1700 MW) is the mitigation measure imposed in H3
Stung Treng	Yes. (>Q95)	Yes. (1% of mean flow)	Yes. Down-ramp 0.1 m/hr; Up-ramp 0.2 m/hr	

4.4.1 Description of Mitigation options

4.4.1.1 Minimum Flow, Ramping Rates and Fish Pass

Minimum flow for all dams: Q_{95} of the annual discharges (for historic conditions, before the Chinese and tributary dams were implemented) sustained to support ecosystem functioning. For the small version of Sambor, the side channel has to be provided with sufficient flow but at least Q95% of the Mekong.

Ramping rates for all dams: In general, downstream water level changes has been limited to 5cm/hour. For exceptional (i.e. annual, multi-annual) flushing events, draw down operations should has been limited to a rate of 0.1 m/hour and filling operations to 0.2 m/hour.

Fish pass for all dams (excl. Don Sahong and Sambor): It is assumed, that the fish pass causes a loss of 1% of the mean annual flow at the dam site.

Fish pass for Sambor: For Sambor (where only a certain proportion of the flow is used for hydropower production), 1% of the design flow should be considered as "lost" for energy production.

Fish pass for Don Sahong: The side channel acts as natural fish pass. Assuming that the performed excavations improved the passability no additional structure is required.

4.4.1.2 Sediment Mitigation Options and Strategy

- Draw down all reservoirs to a minimum level at the **beginning of the wet season** (so not a full shut down), and maintain the low level for a **month**. This operation is used to maximize movement of sediment and minimise deposition in the onset of the wet season (when concentrations are usually somewhat higher than later in the season). The latter is not justified in the first decades as there is only little sediment accumulating close enough to the dam to be able to make it worthwhile effort (findings from case study).

- Note that these procedures allow a significant drop of reservoir level, but do not necessarily mean that the power stations have to be shut off. For instance in Pak Beng the power units can continue to produce energy until the head drop below 7.3 m (according to the developer). Only if all (low-level if any) gates are open, and we reach such low levels with high tailwater (which is the case during flood), the energy generation will stop.
- The ramping rates used for lowering the water-level are following the constraints as suggested in the ramping rates above to minimise impacts on fish and river banks. Note that with this rate, some artificial high flow may occur downstream (as all the releases start to count up, and we do not propose a sub-sequential lowering of all the reservoirs.
- For filling after the period of minimum water level, we propose a downstream to upstream filling per cascade, to prevent the river to 'dry-up' at the end of the cascade. It is probably easier and more controllable to fill each lake till normal operation level using a normal ramping rate, starting with the lower reservoir first (Pakchom), and then moving up to the top (Pak Beng) if we consider the upstream cascade. The downstream and upstream cascade can be considered independent (start filling at the same time). The up-ramping rate is 0.2 m/hr as described previously.
- The period of 1 month for keeping the levels low is based on an arbitrary choice, in order to see how much sediment can be sluiced with such a period. The length of such a period would of course be a subject of negotiations between countries and developers, on how much mitigation can cost and so on.

<u>Some comments on the levels</u>:

- We assume that turbines can operate down to 1/3 of the design head. The minimum water-levels are chosen such that the power stations can operate during sluicing.
- **Pak Beng**: In the PNCPA for Pak Beng the absence of low-level gates only allows a decrease until 332 m at discharge approaching 15000 m3/s. For the time-being it may be useful to go for a 17 m lowering similar as was proposed in Xayaburi, i.e. minimum level would be 323 m (and still produce some power).
- **Luang Prabang**: We have not achieved much information as per date, except that LP will have an operation level between 310 and 315 m. This gives about 35 m of water-level difference over the dam, hence we would expect a lower 'sluicing' level of 295 m if we lower similar as Xayaburi and other dams to a 15 m decrease (from 310 to 295 m).
- **Xayaburi**: Lowered from 275 to 256 m, so 19 m lowering.
- **Pak Lay**: Operation level is 240 to 245 m, so we can apply the lowering from 240 to 229 m to reproduce the sluicing operation.
- **Sanakham**: Lowered from 220 to 213 m (so only 7 m from full operation level, because of tailwater).
- **Sangthong-Pakchom**: We consider a level of 192 m, and we propose the lowering to 182 m, which means a 10 m lowering (realistically based on the dam height, as there are not much data).
- **Ban Kum**: We consider the level 115 m, and propose lowering to 105 m (again 10 m).
- **Latsua**: We consider the level 97 m, and propose lowering to 90 m which is the lowest supply level.
- **Don Sahong**: There will be no sluicing operations as far as we know (due to the nature and design of this dam)

- **Strung Treng**: We consider a level of 52 m, and it can be lowered to 50 m (the dam is only 10 m high). At present we do not have more information.
- **Sambor**: the mitigation is in the choice of a smaller dam. This does not involve the sluicing operation.
- In all dams, the tailwater (and remaining headloss over the structure) remains the limiting factor for the minimal water depth. The numbers mentioned above will probably not be met when tailwaters are high during high flow conditions.

Table 4.10 summarizes the sediment mitigation options and strategy for the mainstream dams.

Table 4.10 Summary *of sediment mitigation options and strategy for the mainstream dams.*

	OL	TWL at design flow	Min L	Down-ramp	Up-ramp
	m+MSL	m+MSL	m+MSL	m/hr	m/hr
Pak Beng	340	313	323	0.1	0.2
Luang Prabang	310	280	295	0.1	0.2
Xayaburi	275	244	256	0.1	0.2
Pak Lay	240	222	229	0.1	0.2
Sanakham	220	206	213	0.1	0.2
Pakchom	192		182	0.1	0.2
Ban Kum	115		105	0.1	0.2
Latsua	97		90	0.1	0.2
Don Sahong	-		-	-	-
Stung Treng	55		50	0.1	0.2
Sambor	-		-	-	-

4.4.1.3 Minimum Flow, Ramping Rates and Fish Pass

Minimum flow for all dams: Q_{95} of the annual discharges (for historic conditions, before the Chinese and tributary dams were implemented) sustained to support ecosystem functioning. For the small version of Sambor, the side channel has to be provided with sufficient flow but at least Q95% of the Mekong.

Raping rates for all dams: In general, downstream water level changes has been limited to 5cm/hour. For exceptional (i.e. annual, multi-annual) flushing events, draw down operations should has been limited to a rate of 0.1 m/hour and filling operations to 0.2 m/hour.

Fish pass for all dams (excl. Don Sahong and Sambor): It is assumed, that the fish pass causes a loss of 1% of the mean annual flow at the dam site.

Fish pass for Sambor: For Sambor (where only a certain proportion of the flow is used for hydropower production), 1% of the design flow should be considered as "lost" for energy production.

Fish pass for Don Sahong: The side channel acts as natural fish pass. Assuming that the performed excavations improved the passability no additional structure is required.

4.5 Model Results and Outputs

Extracts from the results from the different modelling exercises are given in Annex 5 and in full in the reports of the Council Study Modelling Team. Here we focus on some of the key results.

4.5.1 Flow Levels

The output and results of the IQQM modelling of the hydropower projects in the sub-scenarios is presented in Appendix 5 with a comparison of flow results from Hydropower sub-scenarios (H1a, H1b, H2 and H3) comparing with M3cc from SWAT-IQQM Simul at 10 key stations on the Mekong mainstream.

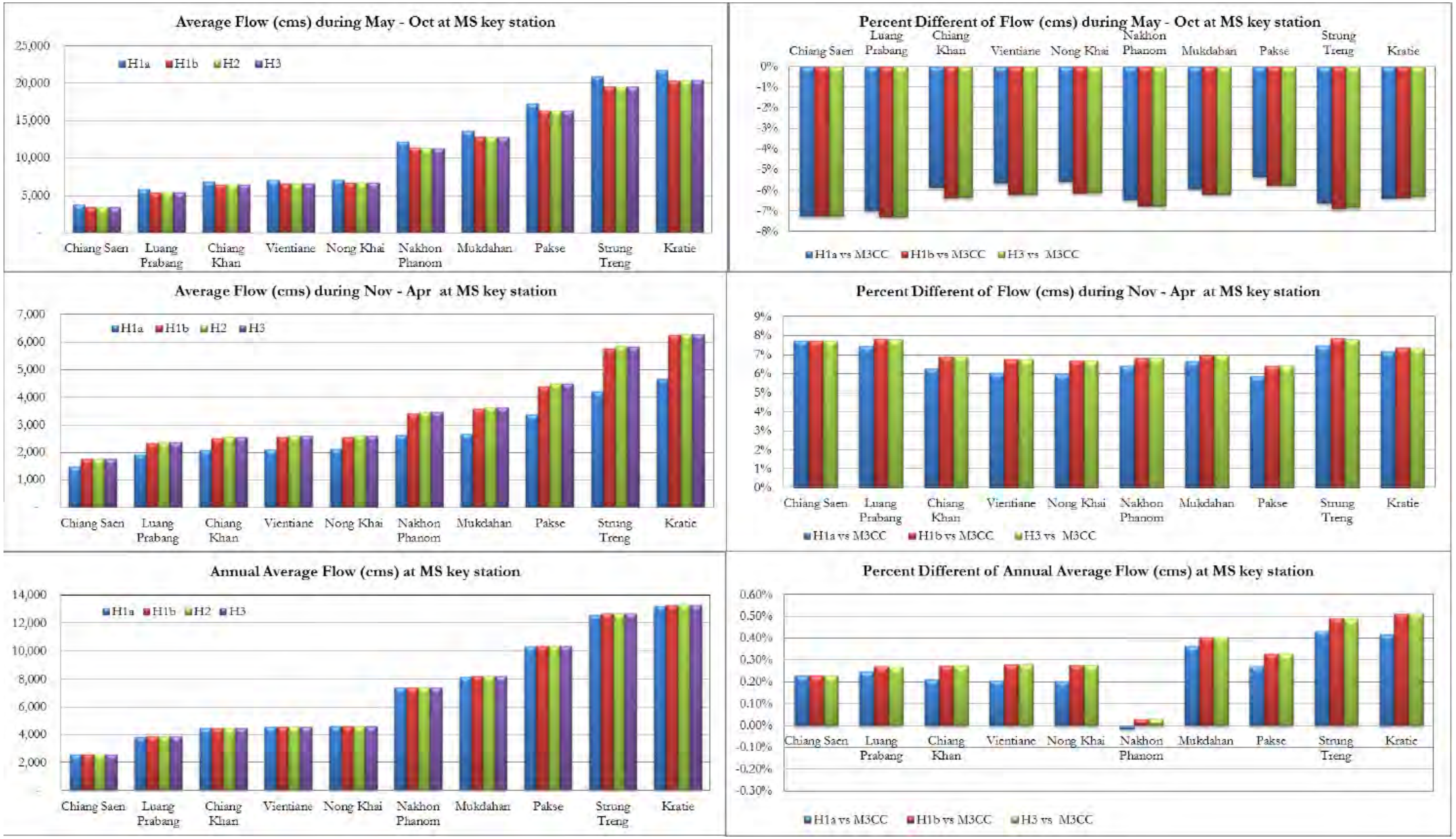
The results are shown in Figure 4.2 which shows the seasonal and transboundary effects of hydropower development in the sub-scenarios on flows.

As can be seen from an examination of the figure, the percentage changes in flow in the different sub-scenarios are relatively small.

For example less than 1% reduction in flow at all key stations during the May-October monsoon period and less than 1% increase in flow at all key stations during the November-April dry season. Transboundary effects on flow are therefore small in the modelling.

Although hydropower is, apart from losses due to evaporation from reservoirs, a non-consumptive energy source, these results are still somewhat unexpected.

Figure 4.2 The average flow (m^3/s) and percentage change from sub-scenarios H1a, H1b, H3 and M3cc from SWAT-IQQM Simulation at Key stations



4.5.2 Sediments

The study results suggest that dams in the Mekong basin are likely to have very large reductions in sediment loads entering the delta, which may only partly be reduced if mitigation measures are implemented. Figure 4.3 and Figure 4.4 illustrate the changes in sediment loads along the length of the Mekong River for each of the main scenarios. Figure 4.5 compares the sediment mass trapped by dams in each region

The "eWater Source Modelling for the Council Study Draft Report" dated September 2017 reported that sediment runoff from the Mekong catchments is forecast to increase from some 150,9 Million Tonnes per annum under the Baseline 2007 scenario M1 to some 159.2 Million Tonnes per annum (5.5% increase) under Development 2020 Main Scenario M2, to some 161.2 Million Tonnes per annum (6.8% increase) under Development 2040 no climate change Main Scenario M3, and to some 178.2 Million Tonnes per annum (18.1% increase) under Development 2040 with climate change Main Scenario M3, due to land use change. However, there is a substantial reduction in the amount of sediment being transported downstream. For example, under the M1 () scenario, an estimated 143 Mt/annum of sediment reaches Kratie. Under the M3 scenario only 4 Mt/annum reaches Kratie, which is a reduction in sediment loads of 97% (see Figure 4.5).

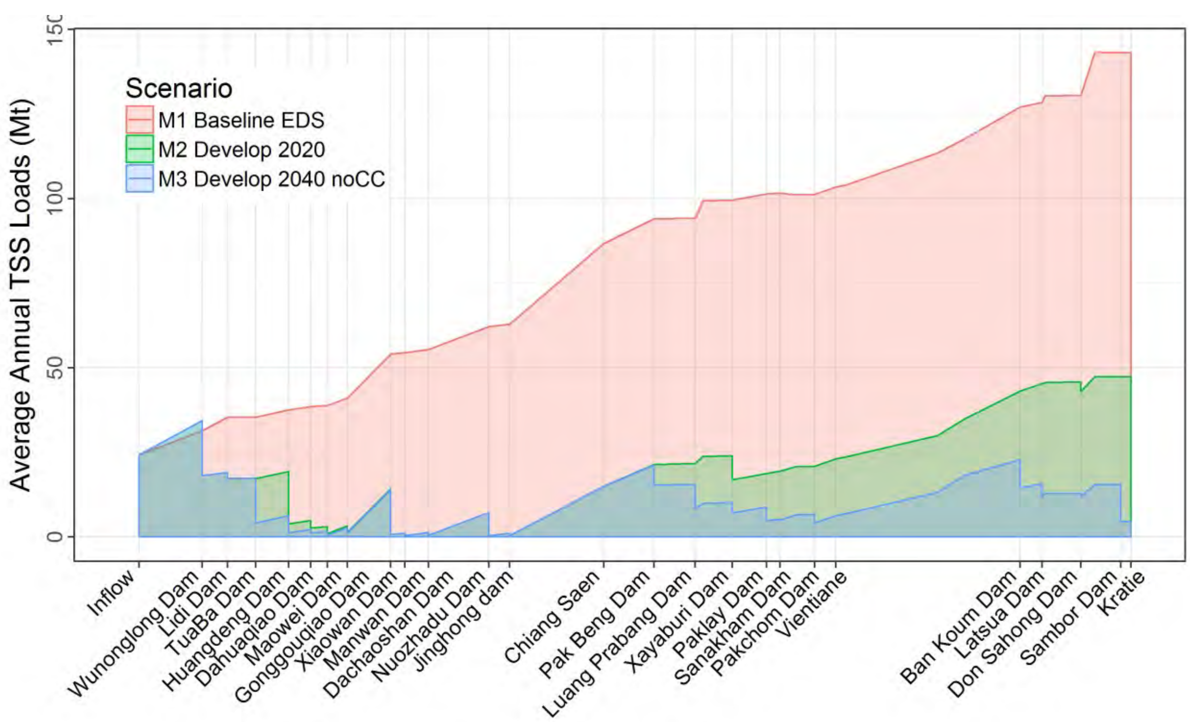


Figure 4.3 Comparison of average annual TSS loads on the Mekong (and Lancang) River under the three main scenarios without climate change.

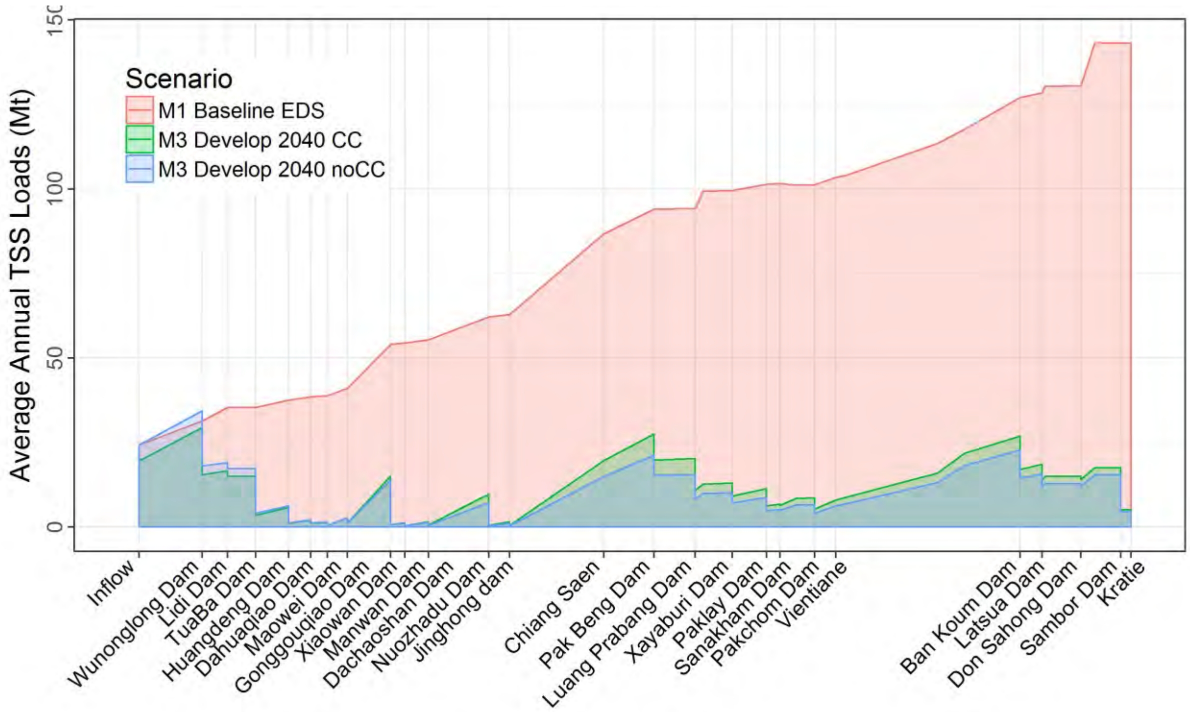


Figure 4.4 Comparison of average annual TSS loads on the Mekong (and Lancang) River for the Development 2040 scenario with and without climate change. The Baseline scenario results are included for reference.

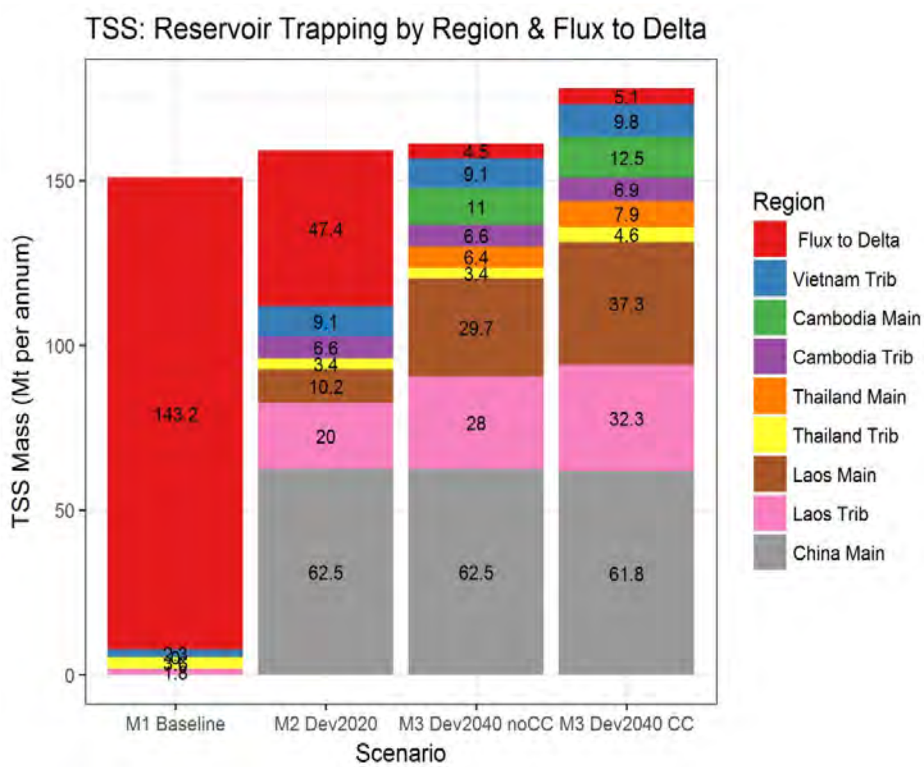


Figure 4.5 Comparison of the mass of sediment trapped by reservoirs within each region and the load entering the delta for each of the main scenarios.

4.5.4 Main Results from Council Study Socio-Economic Assessment

The Socio-Economic Impact Assessment and the Macro-Economic Assessment of the Council Study have different areas of interest. The Social Impact Assessment was focussed along the corridors, whilst the Macro-Economic Assessment was basin scale. Here we attempt to preset the summary results from both assessments. For full details of the results, however, reference is made to the detailed reports of the respective economic studies.

4.5.4.1 Changes in the Monetary Value of Agriculture and Fisheries

In the Socio-Economic Impact Assessment monetary value of agricultural and fisheries production was calculated from the production/surplus estimates derived from the social and economic assessment as described in the Council Study Social and Economic Assessment report. The relative mean values (US$ year 1-24) of fish and rice for the corridor zones and the four main development scenarios are reported in Figure 4. and Figure 4.7 respectively.

The reported fish values represent the aggregate of the white fish, grey, black, non-native and marine/estuarine guilds summarised by the BioRA team.

The comparative percent changes in the mean US$ value of fish and rice production across the four main development scenarios and corridor zones are reported in Table 4.111 and 4.12 respectively.

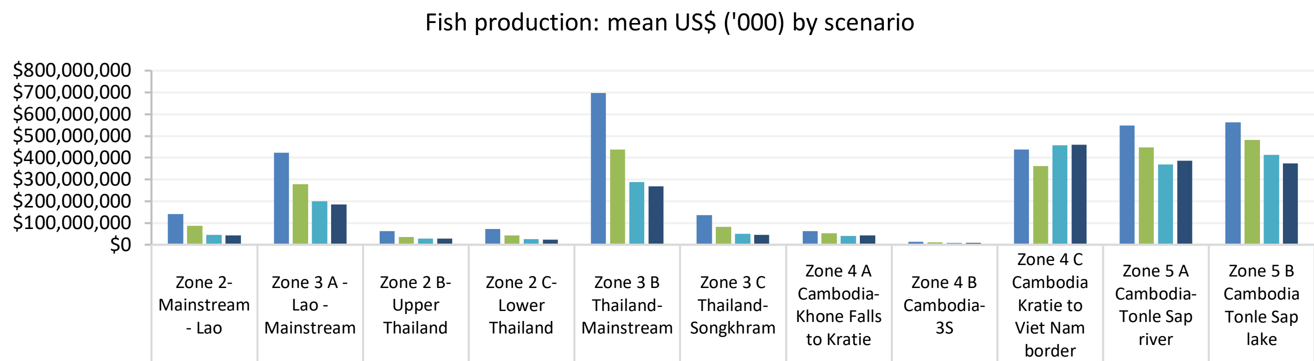
The main results for Fisheries were:

- The total mean fisheries value of the M2 and M3 scenario (year 1-24) for all zones modelled in the LMB declines by US$ 1.04 and US$1.57 billion (-25% and -38% respectively) compared to the M1 baseline.
- The highest proportion of the decline in value occurs between the M1 and M2 scenarios (US$ 1.05 billion); the additional decline from M2-M3 equals US$0.52 billion or a further decline of 21%.
- TheM1-M2 percent changes range from -3% (Vietnam zone 6A) to -39% (Lao PDR zone 2).
- TheM1-M3 percent changes range from -3% (Vietnam zone 6A) to -68% (Lao PDR zone 2 and Thailand zone 3C).
- The predicted effects of climate change introduce a further 2% reduction of the M3 scenario or US$ 0.134 billion.

The main results for Rice Production were:

- The mean rice value of the M2 and M3 scenario (year 1-24) increases by US$ .34 and US$ 0.95 billion compared to the M1 baseline.
- The highest proportion of the increase in value occurs between the M2 and M3 scenarios (US$ 0.61 billion) or an additional mean increase of 10%.
- The M1-M2 percent changes range from 0% (Vietnam zone 6A and 6B; Cambodia 4B and 5B) to 66% (Thailand zone 3C).
- TheM1-M3 percent changes range from -5% (Thailand zone 3C) to 96% (Thailand zone 2C).
- The predicted effect of climate change introduces a -6% decline in value of the M3 scenario or US$135 billion.

Figure 4.6 Estimated monetary value (mean US$) of fish production: by corridor zone across development scenarios



	Zone 2-Mainstream - Lao	Zone 3 A - Lao - Mainstream	Zone 2 B-Upper Thailand	Zone 2 C-Lower Thailand	Zone 3 B Thailand-Mainstream	Zone 3 C Thailand-Songkhram	Zone 4 A Cambodia-Khone Falls to Kratie	Zone 4 B Cambodia-3S	Zone 4 C Cambodia Kratie to Viet Nam border	Zone 5 A Cambodia-Tonle Sap river	Zone 5 B Cambodia Tonle Sap lake
M1	$141,216,2	$422,518,7	$62,108,34	$71,218,78	$696,654,1	$137,024,3	$62,288,23	$13,836,48	$438,255,7	$546,744,8	$562,541,3
M2	$86,838,09	$278,808,9	$36,341,48	$43,387,36	$437,225,3	$81,883,11	$53,162,75	$11,710,44	$361,254,1	$446,684,4	$480,759,0
M3	$45,904,16	$200,256,1	$28,219,88	$25,244,05	$289,163,8	$50,412,86	$41,591,87	$9,014,682	$457,478,4	$369,619,8	$412,794,9
CC	$42,614,47	$186,200,5	$27,834,43	$24,285,34	$269,092,5	$46,146,73	$41,805,71	$9,064,503	$459,762,7	$385,125,6	$375,012,2

Table 4.11 Relative changes in the value (US$) of M1, M2, M3 and M3CC corridor fish production

Fish production	M1-M2		M1-M3		M3-M3CC		M2-M3	
SIMVA Zone	$'000	%	$'000	%	$'000	%	$'000	%
Zone 2-Mainstream - Lao	-54,378	-39%	-95,312	-67%	-3,290	-7%	-40,934	-47%
Zone 3 A - Lao - Mainstream	-143,710	-34%	-222,263	-53%	-14,056	-7%	-78,553	-28%
Zone 2 B-Upper Thailand	-25,767	-41%	-33,888	-55%	-385	-1%	-8,122	-22%
Zone 2 C-Lower Thailand	-27,831	-39%	-45,975	-65%	-959	-4%	-18,143	-42%
Zone 3 B Thailand-Mainstream	-259,429	-37%	-407,490	-58%	-20,071	-7%	-148,062	-34%
Zone 3 C Thailand-Songkhram	-55,141	-40%	-86,611	-63%	-4,266	-8%	-31,470	-38%
Zone 4 A Cambodia-Khone Falls	-9,125	-15%	-20,696	-33%	214	1%	-11,571	-22%
Zone 4 B Cambodia-3S	-2,126	-15%	-4,822	-35%	50	1%	-2,696	-23%
Zone 4 C Cambodia Kratie to	-77,002	-18%	19,223	4%	2,284	0%	96,224	27%
Zone 5 A Cambodia-Tonle Sap	-100,060	-18%	-177,125	-32%	15,506	4%	-77,065	-17%
Zone 5 B Cambodia Tonle Sap	-81,782	-15%	-149,746	-27%	-37,783	-9%	-67,964	-14%
Zone 6 A VietNam Delta -	-102,828	-2%	-170,567	-3%	97,470	2%	-67,739	-1%
Zone 6 B VietNam Delta - saline	-108,712	-8%	-176,644	-13%	99,795	8%	-67,933	-5%
Total	-1,047,892	-25%	-1,571,918	-38%	134,509	-2%	-524,026	-21%

Figure 4.7 Estimated monetary NPV (mean US$) of rice production: by corridor zone across scenarios

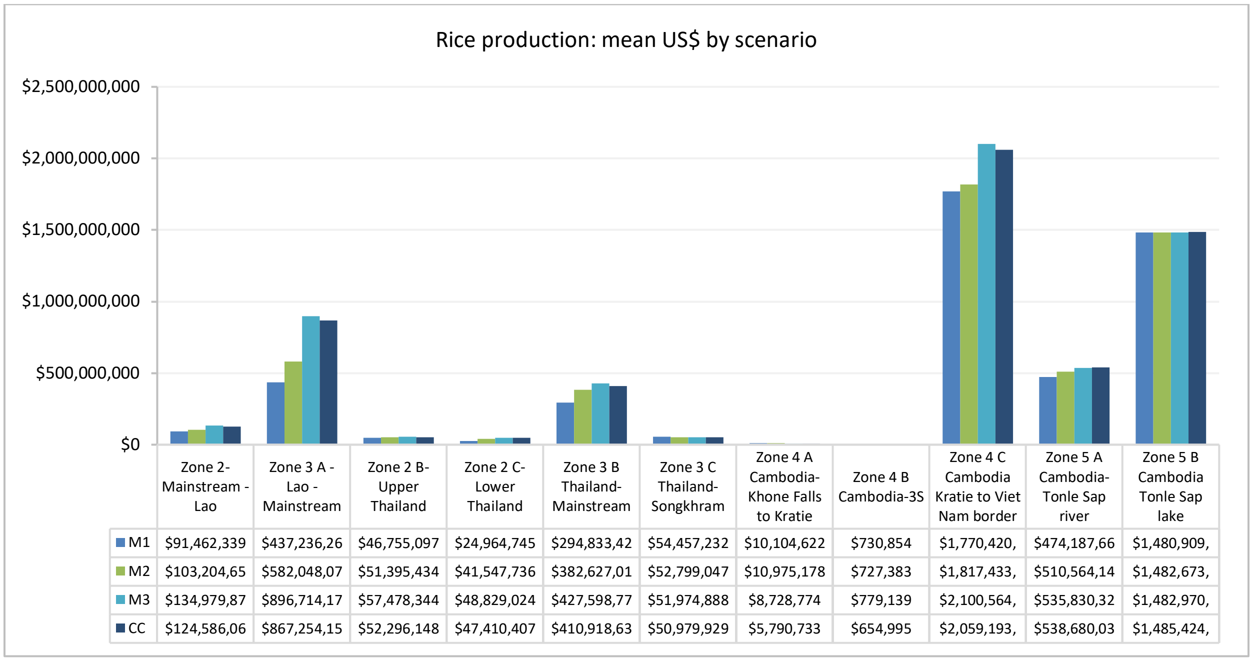


Table 4-12 Relative changes in the value (US$) of M1, M2, M3 and M3CC corridor rice production

Rice production	M1-M2		M1-M3		M3-M3CC		M2-M3	
SIMVA Zone	$'000	%	$'000	%	$'000	%	$'000	%
Zone 2-Mainstream - Lao	11,742	13%	43,518	48%	-10,394	-8%	31,775	31%
Zone 3 A - Lao - Mainstream	144,812	33%	459,478	105%	-29,460	-3%	314,666	54%
Zone 2 B-Upper Thailand	4,640	10%	10,723	23%	-5,182	-9%	6,083	12%
Zone 2 C-Lower Thailand	16,583	66%	23,864	96%	-1,419	-3%	7,281	18%
Zone 3 B Thailand-Mainstream	87,794	30%	132,765	45%	-16,680	-4%	44,972	12%
Zone 3 C Thailand-Songkhram	-1,658	-3%	-2,482	-5%	-995	-2%	-824	-2%
Zone 4 A Cambodia-Khone Falls to	871	9%	-1,376	-14%	-2,938	-34%	-2,246	-20%
Zone 4 B Cambodia-3S	-3	0%	48	7%	-124	-16%	52	7%
Zone 4 C Cambodia Kratie to Viet	47,013	3%	330,144	19%	-41,371	-2%	283,130	16%
Zone 5 A Cambodia-Tonle Sap river	36,376	8%	61,643	13%	2,850	1%	25,266	5%
Zone 5 B Cambodia Tonle Sap lake	1,764	0%	2,061	0%	2,454	0%	297	0%
Zone 6 A VietNam Delta -	-12,357	0%	-108,056	-3%	-15,324	0%	-95,699	-2%
Zone 6 B VietNam Delta - saline	-262	0%	-344	0%	-16,394	-2%	-82	0%
Total	337,314	13%	951,986	26%	-134,977	-6%	614,672	10%

4.5.5 Main Results from Council Study Macro-Economic Assessment

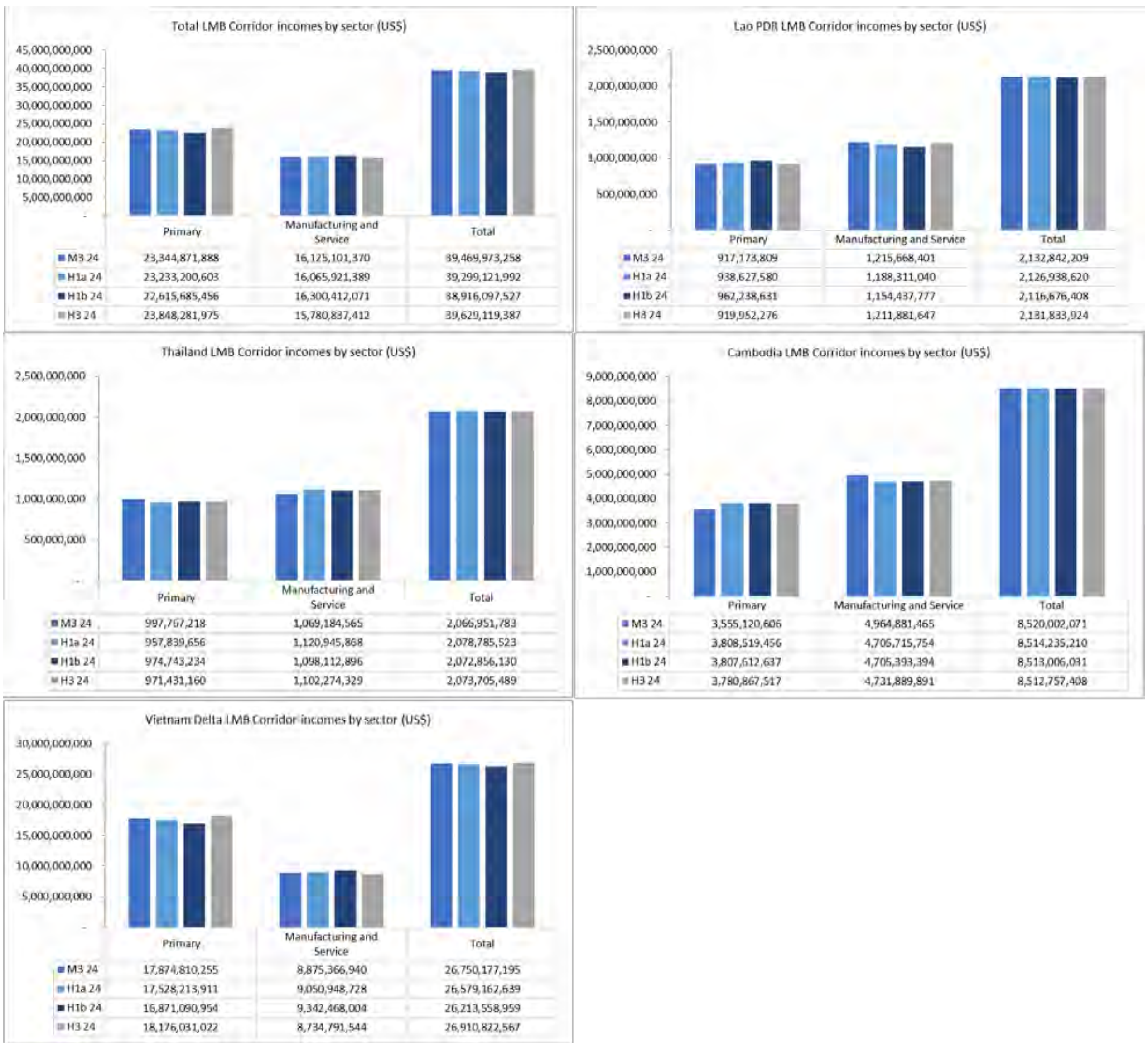
The Socio-Economic Impact Assessment and the Macro-Economic Assessment of the Council Study have different areas of interest. The Social Impact Assessment was focussed along the corridors, whilst the Macro-Economic Assessment was basin scale. Here we attempt to preset the summary results from both assessments. For full details of the results, however, reference is made to the detailed reports of the respective economic studies.

4.5.5.1 Effect of Hydropower Development on Employment and Income in the LMB

The Council Study Macro-economic assessment reports include analyses of the effect of the different sectors on employment and income for the the various scenarios.

No significant basin-wide effect on employment and incomes due to variations in hydropower development scenarios were evident.

Figure 4.8 Sector incomes by zone across the M3 and the H1a, H1b and H3 hydropower sub scenarios (year 24)



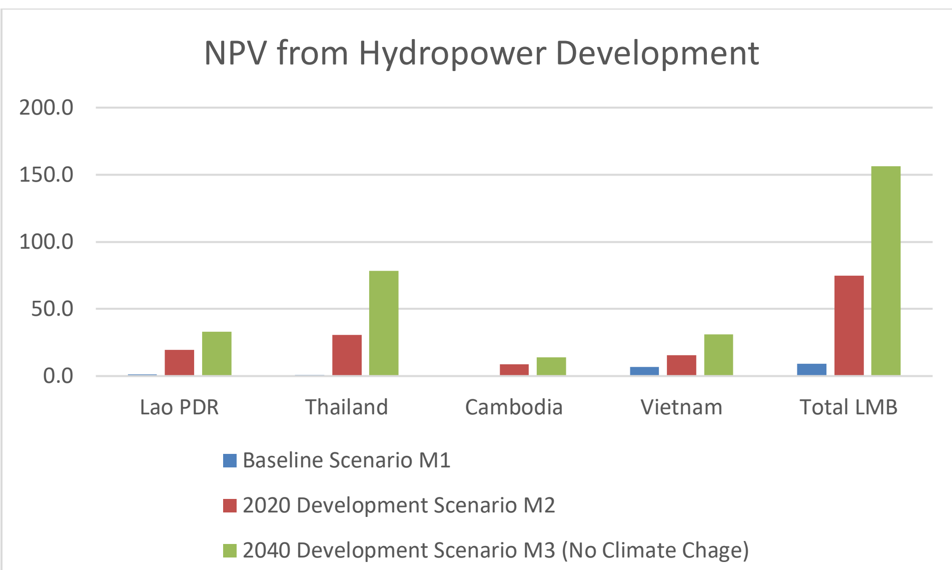
The incomes associated with the Hydropower development sub scenarios were generally less than the M1 (year 24) income estimates. Aggregate incomes were reduced by up to US$1.18 billion for the H1b scenario and US$0.47 billion for the H3 scenario.

4.5.5.2 Changes in NPV in Hydropower Sector for the Three Main Scenarios

The hydropower sector is the primary focus of investments in all three main scenarios. The hydropower development situation as described by the main scenario M2 come with substantial economic gains of about $66 billion as NPV over the 24 year period this assessment prescribes (approximating 2017 to 2040). The third main scenario would further increase the sector benefit by an additional $82 billion. Table 4.13 summarises the changes in NPV in the hydropower sector for the three main scenarios.

Table 4-13: Impacts on Net Present Value (NPV) of the hydropower sector for the three main scenarios

		M1	M2	M3
Lao PDR	B$	1.2	19.6	32.9
Thailand	B$	1.0	30.7	78.4
Cambodia	B$	0.0	8.8	13.8
Vietnam	B$	6.8	15.5	31.2
LMB	B$	9.0	74.6	156.3



The increase in net present value of hydropower in M2 benefits Thailand the most as 45% of the additional economic gains would realise in Thailand. This is largely due to the difference between the cost for importing electricity from Lao PDR and the domestic retail prices. Lao PDR would receive about 28% of the NPV gain in scenario M2. An equal share of 13% of the additional economic gains would go to Vietnam and Cambodia.

4.5.5.2 Cross-Sector Comparisons for Main Scenarios

The comparison of all four MRC related sectors suggests a rather positive assessment of economic benefits derived from scenarios M2 and M3. The main beneficiary for scenario M2 would be Cambodia because of its substantial expansion of agricultural production. The combined benefit of all four sectors (including subsistence production values) would increase by 81.3% for M2 and 96.1% for M3. These economic benefits provide a seemingly convincing economic argument. However, these results are only representing a narrow sector perspective. The macro-economic assessment below assesses the national economy and provides a discussion of how realistic these potential sector benefits are. Considering the labour force required for realising these agricultural gains, the Cambodian economy might experience only a small part of this agricultural potential to be realised, which means that Cambodia would be left with large losses in the fisheries sector and small gains in hydropower and navigation. The macro-economic assessment below will revisit this important issue in more detail.

Vietnam would also expand economic benefits in these four sectors under both scenarios, particularly in M3. Substantial gains in Vietnam's economy would eventuate through the import and domestic retail of Cambodian hydropower. The Navigation sector would provide the largest benefits to Vietnam under the assumptions of scenario M3. The fisheries sector would substantially decline, particularly when stepping from M1 to M2.

Lao PDR and Thailand would also experience a gain across the four sectors assessed above. Hydropower gains have the largest share with the trade-based benefit shift explained above. These gains are partially lost by the fisheries related side losses M2 and M3 entail. Both countries' protein dependency is likely to increase substantially, leaving both more exposed to food price increases. The socio-economic assessment analyses these effects in more detail.

Table 4-14 Cross-sector comparison for Net Present Value (NPV) of hydropower, fisheries, agriculture, and navigation for the three main scenarios

Differences to M1		Hydropower B$	Fisheries B$	Agriculture B$	Navigation B$	SUM B$	%
M2	Cambodia	8.8	-4.7	65.3	1.3	70.6	81.3%
	Lao PDR	20.5	-3.7	3.2	0.1	20.2	42.7%
	Thailand	31.6	-6.4	2.2	0.4	27.8	17.1%
	Vietnam	8.7	-1.7	21.0	8.2	36.1	28.0%
M3	Cambodia	13.8	-6.3	67.3	8.5	83.4	96.1%
	Lao PDR	33.8	-5.0	5.8	1.9	36.6	77.5%
	Thailand	79.3	-8.2	4.1	2.9	78.2	48.0%
	Vietnam	24.4	-3.2	26.3	55.5	103.1	80.0%

4.5.5.3 Hydropower Assessment for Sub-Scenarios

General

The main scenarios are defined as composites of various investments that combine changes in hydropower, irrigation, flood prevention, agricultural extension and climate change. Such composite scenarios make it difficult to attribute effects to particular investments in individual sectors. From a planning perspective, a more disaggregated definition of scenarios is more useful because assessment results can indicate which sectors to focus on. This analysis is provided by the sub-scenarios.

Sub-scenarios are based on the main scenario M3CC, which assumes the development status assumed for 2040 including a moderately wetter and warmer climate. The multi-sector changes M3CC entails are now being varied one by one, to reveal the impact of individual sectors.

For instance, sub-scenarios H1a and H1b modify the assumed investment in hydropower expansion and shows how indicators such as GDP are affected. It is important to emphasise that the variations the sub-scenarios assume below do not go down to the project level. From a planning perspective, it would be most useful to understand which individual project has the highest benefit and which is likely to be most damaging.

The sub-scenarios do not disaggregate scenarios to such a project level. Rather, they continue to assume larger bundles within sectors (e.g. multiple dams for the hydropower sector) and compare situations with and without such bundles of projects. As such, this approach allows attributing impacts to individual sectors but not to individual projects within each sector.

Hydropower

The Council Study design assumes three sub-scenarios for the hydropower sector to allow for a sector-specific impact assessment:

- H1a assumes a situation without any hydropower in the lower Mekong basin;
- H1b assumes a situation in which all tributary dams would exist as defined in scenario M3CC (the 2040 development situation) but no mainstream dam would be build;
- H3 defines a situation in which the operation and management of all mainstream dams is coordinated with all features of sustainable hydropower development, including regular coordinated flushing programs and effective fish ladders.

Table 4-14: Net present value of the hydropower sector in billion US$ for sub-scenarios H1a and H1b

	M3CC	H1a-M3CC		H1b-M3CC		Tributary	Mainstream
Lao PDR	$35.1	-$35.1	-100.0%	-$7.5	-21.5%	$27.5	$7.5
Thailand	$80.3	-$80.3	-100.0%	-$21.1	-26.3%	$59.2	$21.1
Cambodia	$13.8	-$13.8	-100.0%	-$4.5	-32.8%	$9.3	$4.5
Vietnam	$31.2	-$31.2	-100.0%	-$15.2	-48.8%	$15.9	$15.2
LMB	$160.4	-$160.4	-100.0%	-$48.4	-30.2%	$112.0	$48.4

Table 4.14 shows the likely impact of sub-scenarios H1a and H1b on the economic performance of the hydropower sector. Unsurprisingly, the removal of all hydropower under sub-scenario H1a leads to a 100% drop of income generated by the hydropower sector.

Sub-scenario H1b assumes that none of the proposed mainstream dams will be developed, including the ones that are already under construction. Table 4.14 indicates that sector income would drop by 21.5% in Lao PDR, 26.3% in Thailand, 32.8% in Cambodia, and 48.8% in Vietnam.

These disproportional effects emphasise the relevance of mainstream hydropower for each of the four countries and considers the trade of electricity in the transboundary context of the lower Mekong basin. This picture becomes even clearer when isolating the net present value of economic benefits of tributary dams and mainstream dams.

The results confirm that Thailand's energy sector is a key beneficiary of mainstream dams in Lao PDR and Vietnam benefits substantially from mainstream dams in Cambodia. Within these two pairs the host countries Lao PDR and Cambodia would experience lower losses from a decision to refrain from mainstream dams than Thailand and Vietnam.

Overall, the lower Mekong basin would lose 30.2% of economic benefits in the power generation sector if mainstream dams would not be realised. This situation would still imply an increase of economic benefits of $112 billion from tributary dams.

Sub-scenario H3 is focused on critical management changes, as described above. The assumed interventions, e.g. coordinated flushing and the installation of fish ladders, would reduce the power generation capacity. However, the hydropower team did not have sufficiently robust data to quantify the effects on generated power.

Fisheries

The impacts on the fisheries sector have been assessed for all 13 sub-scenario. The following ten sub-scenarios were assessed in addition to the three hydropower scenarios described above:

- A1: This sub-scenario assumes that the agricultural sector remains in the development state of 2007 while all other sectors are being expanded as assumed under M3CC
- A2: For this scenario it is assumed that the agricultural sector is being expanded even further than assumed for M3CC while all other sectors are being developed to the planned development state of 2040.
- I1: This sub-scenario assumes that irrigation investments are not being made and that irrigation areas remain at the state of 2007 while all other sectors change to the state of 2040.
- I2: Similar to A2, this sub-scenario assumes additional expansion of irrigation areas beyond what is assumed for M3CC, while all other sectors change to the state assumed for M3CC.
- C2: For this sub-scenario it is assumed that the period until 2040 will turn out to be wetter than assumed for M3CC.
- C3: For this sub-scenario we assume a dryer climate than for M3CC.
- F1: For this sub-scenario it is assumed that no investments in flood protection are being carried out if compared to M1 (2007 situation) while all other sectors are being developed according to M3CC assumptions.

- F2: For this sub-scenario we assume additional urban flood protection and flood plain management.
- F3: This sub-scenario assumes in addition to urban protection and floodplain management also joint operation of mainstream dams and selected tributary dams.

Table 4-14: Economic benefit of fisheries sector under the 13 sub-scenarios as NPV for the 24-year period in B$

in B$	**A1**	**A2**	**C2**	**C3**	**I1**	**I2**	**F1**	**F2**	**F3**	**H1a**	**H1b**	**H3**
	no ALU	2020	Wet	Dry	no IRR	high IRR	no FPI	FPI	FPI	no HPP	no Main	HPP
Cambodia	23.6	23.8	24.4	20.2	24.6	23.9	24.7	24.6	25.5	**30.1**	25.9	25.9
Lao PDR	3.2	3.2	3.2	3.0	3.2	3.2	3.3	3.2	3.2	**7.2**	5.3	3.3
Thailand	6.6	6.7	6.7	6.2	6.7	6.7	6.7	6.6	6.6	**13.1**	9.7	6.7
Vietnam	17.8	17.2	17.6	16.9	17.4	17.3	17.3	16.9	17.1	**20.2**	18.9	17.7
LMB	51.3	50.9	51.9	46.2	51.9	51.1	52.1	51.4	52.4	**70.6**	59.8	53.6

The comparison of the thirteen sub-scenarios above allowed for a sensitivity analysis and revealed which investments are likely to have the largest impacts on fish stocks and, thereby on sector income. Hydropower sub-scenario 1 has the largest positive impact and quantifies that the combined fisheries sectors in the lower Mekong basin could generate up to $70.6 billion without any hydropower in place. Table 4-14 emphasises this positive effect and shows that the fisheries sector in Lao PDR would increase by 124.2%. The fisheries sector in Thailand would nearly double its net present value.

Table 4-14 shows that without any mainstream dams but all tributary dams developed as planned for 2040 (H1b) the net present value is likely to range around $59.8 billion, which means that mainstream dams will cost the fisheries sector about $11 billion in net present value. Under the same scenario without any mainstream dams the net present value of the fisheries sector in Lao PDR would increase by about 63.9% and in Thailand by 46.2%.

The assumption of joint operation of mainstream dams, including regular flushing programs and effective fish passages, would mitigate some of the losses triggered by M3CC. This analysis quantifies the net present value of the mitigation effect at about $2.4 billion, which leaves the fisheries sector with a total net present value of about $53.6 billion, about 4.7% more than under M3CC.

Two interesting observations are worthwhile pointing out. First, of measures assumed under H3 have the same effect on Cambodia's fisheries sector as not building any mainstream dams. The BioRA report explains that while the population of white and black fish drops substantially with the construction of mainstream dams (even with improved management assumptions under H3) the biomass of non-natives and grey fish increases even further, especially with the improved dam management of sub-scenario H3. The second surprising effect is that sub-scenario H3 adds to the negative impact of M3CC on Vietnam's fisheries sector. The BioRA report clarifies for this comparison that H3 would allow for a larger population of white fish but grey and black fish, marine and estuary fish and non-natives would experience a further drop in biomass under H3 if compared with M3CC.

Table 4-15: Economic benefit changes in % of fisheries sector income compared to M3CC

% →M3CC	**A1**	**A2**	**C2**	**C3**	**I1**	**I2**	**F1**	**F2**	**F3**	**H1a**	**H1b**	**H3**
	no ALU	2020	Wet	Dry	no IRR	high IRR	no FPI	FPI	FPI	no HPP	no Main	HPP
Cambodia	+0.1%	+0.7%	+3.3%	-14.6%	+4.2%	+1.3%	+4.8%	+4.4%	+8.2%	**+27.5%**	+9.6%	+9.6%
Lao PDR	+0.5%	+0.5%	+0.7%	-7.9%	+0.6%	+0.5%	+1.3%	0.0%	-0.3%	**+124.2%**	+63.9%	+2.5%
Thailand	-0.2%	+0.6%	+0.6%	-7.2%	+0.2%	+0.5%	+1.4%	0.0%	-0.3%	**+97.3%**	+46.2%	+1.6%
Vietnam	+0.3%	-2.6%	-0.9%	-4.4%	-1.5%	-2.2%	-2.2%	-4.4%	-3.7%	**+13.8%**	+7.0%	-0.2%
LMB	+0.7%	-0.5%	+1.4%	-9.7%	+1.5%	-0.1%	+1.7%	+0.5%	+2.4%	**+37.9%**	+16.9%	+4.7%

The sub-scenarios reveal that climate change is the second most important scenario dimension. The assumption of dryer climates for the period until 2040 can have a substantial effect on the fisheries sector as Tables 4-51 and 4-52 show in column C3. The largest losses are likely to occur in Cambodia, where the fisheries sector could experience losses of up to14.6%. This risk aspect is important for any resilience analysis (see report on the cumulative impact assessment). Considering the uncertainty of climate projections, the assumptions made in M3CC on future rainfall patterns might be too optimistic and the climate in the lower Mekong basin could become drier.

The fisheries sectors of the lower Mekong basin are likely to experience gains if the climate turns out to be wetter than assumed under M3CC as quantified in Tables 4-14 and 4-15. Again, Cambodia would see the largest impact with 3.3% increase of its sectoral net present value. Vietnam would experience a decline of 0.9% if compared with M3CC. This decline is largely due to a loss in marine fish and non-natives as explained by the BioRA report.

Impacts of other sector investments on fisheries are small if compared with hydropower and climate change. Worth mentioning are positive impacts of changes in flood protection and changes in irritation investments on the net present value of fisheries in Cambodia.

Cross sector comparison

The comparison of the four sectors helps putting the sector impacts in perspective. This is of particular relevance for the design of more focussed assessment that are concerned with the disaggregated project level. The sector comparison shows which investments have the largest economic effects. Focussing on these sectors and assessing individual projects would help identifying the most beneficial or the most harmful or risky investments.

Error! Reference source not found.4-16 shows on top the net present value for hydropower, fisheries, agriculture and navigation under main scenario M3CC in billion dollars. Below these shaded rows results are listed for all sub-scenarios as absolute difference to M3CC in billion dollars. The bold numbers are based on actual modelling of the respective sub-scenario. All other numbers are assumed to be identical or very similar to main scenario M3 in absence of specific modelling. For example, climate change is likely to have an impact on power generation capacity under the various scenarios. However, these sub-scenarios have not been modelled.

Table 4-16: Economic benefit changes in % of fisheries sector income compared to M3CC

		Hydropower	Fisheries	Agriculture	Navigation	SUM	Difference
M3CC	Cambodia	13.8	**23.6**	129.5	8.5	175.5	
	Lao PDR	35.1	**3.2**	48.2	1.9	88.5	
	Thailand	80.3	**6.6**	158.9	2.9	248.8	
	Vietnam	31.2	**17.7**	125.0	55.5	229.4	
A1	Cambodia	0.0	**0.0**	0.0	0.0	0.0	0.0%
	Lao PDR	0.0	**0.0**	0.0	0.0	0.0	0.0%
	Thailand	0.0	**0.0**	0.0	0.0	0.0	0.0%
	Vietnam	0.0	**0.1**	0.0	0.0	0.1	0.0%
A2	Cambodia	0.0	**0.2**	**10.1**	0.0	10.3	5.9%
	Lao PDR	0.0	**0.0**	**15.3**	0.0	15.3	17.3%
	Thailand	0.0	**0.0**	**0.0**	0.0	0.0	0.0%
	Vietnam	0.0	**-0.5**	**0.0**	0.0	-0.5	-0.2%
C2	Cambodia	0.0	**0.8**	0.0	0.0	0.8	0.4%
	Lao PDR	0.0	**0.0**	0.0	0.0	0.0	0.0%
	Thailand	0.0	**0.0**	0.0	0.0	0.0	0.0%
	Vietnam	0.0	**-0.2**	0.0	0.0	-0.2	-0.1%
C3	Cambodia	0.0	**-3.4**	0.0	0.0	-3.4	-2.0%
	Lao PDR	0.0	**-0.3**	0.0	0.0	-0.3	-0.3%
	Thailand	0.0	**-0.5**	0.0	0.0	-0.5	-0.2%
	Vietnam	0.0	**-0.8**	0.0	0.0	-0.8	-0.3%
I1	Cambodia	0.0	**1.0**	0.0	0.0	1.0	0.6%
	Lao PDR	0.0	**0.0**	0.0	0.0	0.0	0.0%
	Thailand	0.0	**0.0**	0.0	0.0	0.0	0.0%
	Vietnam	0.0	**-0.3**	0.0	0.0	-0.3	-0.1%
I2	Cambodia	0.0	**0.3**	**0.0**	0.0	0.3	0.2%
	Lao PDR	0.0	**0.0**	**0.2**	0.0	0.3	0.3%
	Thailand	0.0	**0.0**	**2.4**	0.0	2.5	1.0%
	Vietnam	0.0	**-0.4**	**0.0**	0.0	-0.4	-0.2%

F1	Cambodia	0.0	**1.1**	0.0	0.0	1.1	0.6%
	Lao PDR	0.0	**0.0**	0.0	0.0	0.0	0.0%
	Thailand	0.0	**0.1**	0.0	0.0	0.1	0.0%
	Vietnam	0.0	**-0.4**	0.0	0.0	-0.4	-0.2%
F2	Cambodia	0.0	**1.0**	0.0	0.0	1.0	0.6%
	Lao PDR	0.0	**0.0**	0.0	0.0	0.0	0.0%
	Thailand	0.0	**0.0**	0.0	0.0	0.0	0.0%
	Vietnam	0.0	**-0.8**	0.0	0.0	-0.8	-0.3%
F3	Cambodia	0.0	**1.9**	0.0	0.0	1.9	1.1%
	Lao PDR	0.0	**0.0**	0.0	0.0	0.0	0.0%
	Thailand	0.0	**0.0**	0.0	0.0	0.0	0.0%
	Vietnam	0.0	**-0.7**	0.0	0.0	-0.7	-0.3%
H1a	Cambodia	**-13.8**	**6.5**	0.0	0.0	-7.4	-4.2%
	Lao PDR	**-35.1**	**4.0**	0.0	0.0	-31.1	-35.1%
	Thailand	**-80.3**	**6.5**	0.0	0.0	-73.9	-29.7%
	Vietnam	**-31.2**	**2.5**	0.0	0.0	-28.7	-12.5%
H1b	Cambodia	**-4.5**	**2.3**	0.0	0.0	-2.3	-1.3%
	Lao PDR	**-7.5**	**2.1**	0.0	0.0	-5.5	-6.2%
	Thailand	**-21.1**	**3.1**	0.0	0.0	-18.0	-7.3%
	Vietnam	**-15.2**	**1.2**	0.0	0.0	-14.0	-6.1%
H3	Cambodia	0.0	**2.3**	0.0	0.0	2.3	1.3%
	Lao PDR	0.0	**0.1**	0.0	0.0	0.1	0.1%
	Thailand	0.0	**0.1**	0.0	0.0	0.1	0.0%
	Vietnam	0.0	**0.0**	0.0	0.0	0.0	0.0%

The results shown in Table 4-16 confirm that the hydropower sector is likely to have the largest economic effect on the lower Mekong region.

4.5.5.4 Macro-economic benefits and consequences of Hydropower Development

The assessment of main scenarios considered three tiers, which explained that some investments seem positive at the level of individual sectors while macro-economic effects are likely to be negative or overall outcomes (involving also non-market criteria) are likely to be negative. This section applies the macro-economic perspective as the second assessment perspective to sub-scenarios.

Table 4-17: GDP range projections for the 13 sub-scenarios

GDP in B$ (constant 2017 $US)	Cambodia		Lao PDR		Thailand		Vietnam	
	Ag Max	Ag Min	Ag Max	Ag Min	Ag Max	Ag Min	Ag Max	Ag Min
M3CC	33.3	39.4	21.2	38.2	41.5	92.9	73.4	87.5
ALU1	32.5	**40.6**	20.5	**37.4**	39.4	87.2	72.1	86.3
ALU2	33.1	39.5	21.1	36.9	39.4	86.6	72	86.1
C2 (Wet)	32.5	39.2	20.5	36.8	39.5	86.8	72	86.3
C3 (Dry)	31.4	37.8	19.8	35.3	39.4	86.8	72	86.3
IRR 1	32.5	39.1	20.5	36.8	39.4	86.6	71.9	86
IRR 2	32.6	39.4	20.5	36.8	39.5	86.7	72	86.3
FPI 1	32.5	38.7	20.5	36.8	39.5	86.8	72	86
FPI 2	32.5	38.5	20.5	36.7	39.4	86.4	72	85.8
FPI 3	32.5	38.7	20.5	36.8	39.4	86.8	72	86
H1a	31.6	37.6	18.2	34.5	34.1	81.5	70.1	84.1
H1b	32.1	38.1	20	36.2	38	85.2	71.1	85
H3	33	39.2	21.1	38.1	40.4	**89.6**	73.5	**87.6**

Table 4-17 shows GDP projections for all 13 sub-scenarios based on the same approach applied to the main scenarios. Considering the relevance of workforce projections and the availability of labour to secondary and tertiary sectors Table 4-17 provides for all four countries and all sub-scenarios a value for a situation where labour is allocated to satisfy the demands by the agricultural sector. This situation is referred to as “Ag max”, which implies that less labour is available for secondary and tertiary sectors. The second situation is labelled “Ag min” and assumes that labour is likely to follow higher income opportunities in secondary and tertiary sectors. In this situation only the amount of labour is allocated to agricultural activities to secure food security needs. As explained in earlier sections, the reality is likely to be between these two values. This simplistic methodology was applied in absence of appropriate economic modelling that would more derive GDP projections more effectively and more robustly.

Table 4-17 provides a few insights. First, the ranges of projected GDP in 2040 are very different between the four countries. For Cambodia, GDP ranges between $31.4 billion and $40.6 billion, which is much narrower than the range of Lao PDR.

The GDP of Lao PDR would range between 18.2 billion and 38.2 billion. This implies from a resilience perspective that the investments considered in this study have a much more transformative effect on the economy of Lao PDR than what is likely to unfold in Cambodia. Similarly, the economy of Vietnam's Mekong delta is likely to grow up to $71.1 billion to 87.8 billion. In comparison, Thailand's northeast is likely to face a much wider range of $34.1 billion to 92.9 billion.

Second, the highest GDP projection emerges as A1 for Cambodia and Lao PDR and H3 for Thailand and Vietnam. These two pairs help focussing the development discussion. Re-considering agricultural expansion is likely to be highly beneficial for Lao PDR and Cambodia despite the seemingly positive potential within the narrow sector perspective. The economy-wide side effects are likely to be negative and outweigh the benefits within the agricultural sector. Hydropower benefits are likely to be substantial for Thailand and Vietnam because of the aforementioned trade-effects. However, mitigation investments assumed for H3 are likely to facilitate the highest macro-economic benefit for these two countries. Clearly, unfolding these two sets of scenarios and conducting a disaggregated macro-economic assessment of individual investment components would help fine-tuning the development strategies and is likely to reveal even higher GDP growth potential.

4.5.5.5 Implications of Hydropower Development on Economic Development

The following conclusions are extracted from the Council Study Macro-Economic Assessmenr Report.

- **First,** the hydropower focused interventions considered by the selected scenarios have the strongest influence on economic indicators. From a narrow sector perspective growth potential seems substantial and substantially larger than any other investment considered in the list of development strategies considered in the council study. However, realising this economic potential comes at a cost as the following points explain. The main conclusion with respect to hydropower development is that hydropower development with adequate mitigation measures ensuring sustainability of other sectors is overall the most economically positive approach for the region and, in a transboundary sense, for the individual countries.
- **Second,** substantial trade-offs need to be expected in the fisheries sector, which is likely to increase food security risks for various areas in the lower Mekong basin. The socio-economic assessment report provides a deeper analysis of the food security risks and which areas are particularly at risk.
- **Third,** a few key transboundary effects impact on the economic performance of the hydropower and fisheries sector. Within the hydropower sector substantial benefits occur across the border as the import of cheap electricity generate large economic gains in Thailand and Vietnam. The economic benefits within Lao PDR and Cambodia as the host countries of mainstream and tributary dams are likely to receive the smaller fraction of economic returns. However, also the negative transboundary effect hydropower would have on the fisheries sector affects Thailand and Vietnam substantially and would not remain constrained to Lao PDR and Cambodia as the host countries of hydropower development. Mitigation investments in coordinated fishing programs or fish ladders would therefore also benefit mostly Thailand and Vietnam. However, the remaining economic effects would still be substantial and a narrow economic perspective is likely to distract from critical losses in food security for some areas along the Mekong, especially in Lao PDR and Cambodia as the socio-economic report explains. Those areas that depend on fisheries and will not benefit from the development changes would be hit hardest as their income would not replace the subsidence basis of their food security. This distributional effect entails the shift of economic benefits between

different population segments, away from rural subsistence based income receivers to those that are employed. Typically, the secondary effect is livelihood driven and would involve many moving from rural areas into urban and peri-urban areas; a phenomenon that has been observed for more than three decades across Asia. Clearly, these ripple effects cannot be captured in the limited methodology employed during this study. However, migration, livelihoods and poverty are key dimensions for the design of sustainable development programs.

5 Assessment of General Impacts of Hydropower Development on Mekong

5.1 Impact Assessment - Upper Mekong Basin

The development of hydropower projects on the Lancang River has implications for the Mekong River downstream. However, the impact on average flow diminishes gradually downstream as the overall contribution of the Lancang to the Mekong at the delta is only approximately 16%, albeit flow impacts of the Lancang major storage dams is noticeable in the upper parts of LMB, and especialy during extreme events.

Changes in flow due to the Lancang cascade may include:

- Peak flows decreased and lower annual flood volumes,
- Early flood season flows lower and later flood season flows higher,
- Later start and end of flood season conditions, and
- Increased dry season flows.

As an example, estimates for the change of flows for Chiang Saen (Northern Thailand), downstream of Lancang cascade, are 17-22% decrease in flow in June – November, and 60 – 90% increase in flow in December – May. The estimates for Kratie (Cambodia) are 8 – 11% decrease in flow in June – November, and 28 – 71 % increase in flow in December – May (Source: Mekong River Commission).

Although the annual average flows may not vary substantially, at least further downstream LMB, monthly and shorter time-frame changes in flow have an impact on fisheries and sediment transport. There are concerns about sediment transport and possible impacts of the dams due to sediment trapping for the Lower Mekong Basin, and a decrease has actually been reported in the ISH0306 case study assessment (MRC, 2016c). The river channel is responding to reduced sediment input, altered timing of flows and altered timing of sediment delivery, including increased bank erosion or channel incision, loss of riparian vegetation, increased exposure of bedrock or armouring of riverbed.

Furthermore, the water quality risks due to hydropower development on the Lancang River include nutrient growth in impoundments due to increased nutrients and light, low dissolved oxygen in impoundments and increased water temperature downstream. Water quality in Lancang reservoirs is further affected by land use as run off from rubber plantations, mining and possible increase of agricultural opportunities due to the access to water for irrigation purposes.

As an example of sedimentation on Lancang cascade, a bathymetric survey was conducted for the Manwan dam in 1996 (3 years after the closure of the dam), which showed that the elevation of the bottom of the reservoir was 30 m higher than when the dam was constructed. Since then, the Xiaowan dam, impounding a large reservoir upstream of Manwan, has been constructed, and the sediment load incoming to the Manwan reservoir has been greatly reduced. It is noted, however, that water quality has improved through co-operative operation of Manwan and Dachaoshan Dams.

The reduction in sediment load, altered timing of sediment delivery and delayed onset of flood are representing challenges for mitigation in the Lower Mekong Basin (see also MRC, 2016c). The flow regime and sediment timing of mainstream are going to be further altered by tributary hydropower developments.

The impacts of Lancang development on fisheries and aquatic ecology are mainly due to connectivity interruptions, impoundments, sedimentation, hydrological and water quality alterations and possible cumulative impacts.

5.2 Impact Assessment - Lower Mekong Basin

An assessment of the impact of the hydropower development on the environmental, social and economic parameters in the basin hads been extracted from the results of the Thematic Reports from other disclipine teams and the main results are presented and assessed here.

The main key messages are:

1. The connectivity-related impacts, such as trapping of sediment, disruption of migration paths and alteration of flow regimes, related to mainstream hydropower dams are substantial and far-reaching, and overshadow those of all other planned water-resource developments in the LMB.
2. The sediment flushing measures included in H3_HPP yielded slight improvements in predicted river condition relative to Scenario 2040CC in the lower reaches of the LMB.
3. The effectiveness of fish passages in preserving upstream and downstream migration of fish and other organisms past dam walls and through reservoirs is fundamental in determining the influence hydropower development on ecosystem integrity. In the Council Study, the effectiveness of fish passages in the main channel dams were assessed at 50%.
4. The most significant change anticipated is the reduction in sediment flux to the delta under both of the 2040 Scenarios with or without climate change impact. A large part of this reduction is the trapping of sediments in dams of the Upper Basin and in tributary dams of the LMB. Proposed Mainstream dams especially Sambor in Cambodia reduce the total amount of sediment that is free to pass downstream even more.
5. The effect on Total nitrogen and phosphorus from upstream will also be severe.
6. The Reversal of the Tonle Sap will be significantly reduced due to refilling of upstream dams early in the dry season.
7. Flooding in both the upper and lower parts of the basin will increase noticeably in the more extreme cases. Some decrease in average flood peaks may cause the channel to adjust morphologically.
8. Bank Erosion Issues will increase significantly especially downstream of Sambor.
9. Irrigated Area increases are expected primarily in Lao PDR and Cambodia but these have a limited impact on the flow in the mainstream.
10. Mainstream dams simulations are still showing significant trapping of sediments proportionally although the total amount of finer sediment reaching the mainstream is significantly reduced. This offers some potential that working with ISH a mitigation solution can be identified.

11. Operation of dams to mitigate the adverse effect of upstream storage and climate change on the Tonle Sap reversal should be considered.

The connectivity-related impacts, such as trapping of sediment, disruption of migration paths and alteration of flow regimes, related to mainstream hydropower dams are expected to be substantial and far-reaching, and to overshadow those of all other planned water-resource developments in the LMB. Chief among these impacts are substantial increases in channel erosion with severe impacts on the availability of river and floodplain habitats; a drop in floodplain productivity, and fundamental changes to the fish communities, resulting in an approximately 40% decline in fish biomass across the basin, partly as a result of interference with migration patterns which increases the more downstream that barrier is located.

The predictions for the H3_HPP hydropower sub-scenario suggest that sediment flushing may offer some relief from the effects of sediment starvation, but that this is insufficient to eliminate the issue and periodic flushing of sediments could result in slugs of anoxic sediments moving downstream, smothering habitats, increasing localised embeddedness of riffles and detrimentally affecting the river's aquatic life.

Similarly, the efficacy of fish passages intended to facilitate up- and downstream migration of fishes past in-channel HPP weirs and impoundments is a matter of considerable debate, with the prevailing view among specialists that existing types and sizes of fish ladders will have difficulty accommodating the intensity and diversity of fish attempting to migrate up the mainstream Mekong River, and provide little or no assistance with downstream migration (and larval drift).

While it is clear that tributary dams also have the potential to substantially prejudice river ecosystem functioning, the prospects for mitigation thereof through their careful siting, design and/or operation are far greater than for their mainstream counterparts. Experience from other basins suggests that avoiding important migration routes or securing protection of alternative tributary migration routes and spawning grounds will also reduce the impacts of in-channel dams on basin-wide fish migration.

5.3 Predictions of change for impounded reaches under main development scenarios

The reservoirs associated with the mainstream dams will change much of the channel habitat that is present in Scenarios 2007 and 2020 into deeper, lake-like habitat under the conditions modelled for Scenarios 2040 and 2040CC.

For instance, 19% of the river in BioRA Zone 2 would be converted to lake-like habitat by Scenario 2020, but this would increase to 88% in Scenario 2040 (thus, only 12% of the river in Zone 2 would remain); and those river lengths would be subjected to significantly altered water and sediment flows because of the dams

The following sections outline the expected implications for the river ecosystem.

Table 5.1 River length in each BioRA zone that would be inundated by mainstream reservoirs in each scenario

BioRA Zone	Length of river represented by zone	2007		2020		2040	
		Length inundated by reservoirs					
	m	m	%	m	%	m	%
Zone 1	167 903	0	0	0	0	68 000	41%
Zone 2	555 800	0	0	104 000	19%	384 000	88%
Zone 3	762 500	0	0	0	0	0[5]	0
Zone 4	521 000	0	0	0	0[6]	230 000	32%
Zone 5	476 000	0	0	0	0	238 000	50%
Zones 6-8	n/a	0	0	0	0	0	0
Total	2 483 203	0	0	104 000	4%	920 000	37%

5.4 Effect of Hydropower Development on Hydrology and Peaking Flows

Hydrological impacts of the considered run-of-the river schemes have been found to be very limited. Except for peaking operations, the normal operation of these reservoirs does not lead to increased hydrological risks, as all 'natural' flows pass the dams without modification.

For the choice of smaller reservoirs, any remaining operational influence on the water-level and discharge, will be even smaller than the regular sized reservoirs. Particularly during hydropeaking operations, the amplitude of water-level fluctuations will be less severe than for the original active storage.

More technical solutions for mitigation of sediment-risks or fish connectivity, such as low head turbines and fish friendly spillways, will have only relevance for the local conditions around the dam, but not for the hydrological risks upstream of downstream.

Temporary shutdown of the cascade for environmental purposed means that during this period all flows can pass without noticeable modifications by the operation of the scheme. Only temporary, if the reservoir is lowered before, or refilled after shutdown, the discharges in the downstream reach will be affected, and reservoir levels may drop or rise quickly. For these periods, it is relevant to define appropriate ramping rates. Note that these conditions are only occurring once a year, and may therefore allow a slightly higher ramping rate than more frequent water-level fluctuations.

The main hydrological risk related to the downstream dams is related to the sub-daily hydropeaking. The peaking will cause rapid changes in the reservoirs and downstream reaches. The hydrological risks related to larger fluctuations in water-level are substantial. Mitigation of these effects is mostly done by fully eliminating the peaking procedures. If hydropeaking is still considered, it is useful to allow the fluctuations only in the impounded sections of the cascade, while operating the lower dam as a regulator to dampen the fluctuations from the upper reservoirs and prevent large fluctuations in the downstream (not impounded) river reach.

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[5] Ban Kum and Latsu are situated in Zone 4, close to the upstream boundary with Zone 3. The models effectively indicate little or no flooding in FA3.Should the designs of Ban Kum and Latsu HPPs be such that some parts of Zone 3 are flooded, they are not accounted for here.

[6] Don Sahong reservoir is excluded because it does not flood across the whole channel.

In the lower cascade the reservoirs of each dam will affect the tailwater of the upstream dam for a large range of discharges. The backwater of Latsua dam will reach the Mun River mouth, although this has already been reduced significantly by moving the dam location downstream of Pakse. The remaining backwater effect still requires careful analysis. In analogy with Pak Beng dam, to prevent backwater problems during low-flow periods, and flooding during high flow, it may be necessary to lower the operation level during certain periods of the year.

5.5 Effect of Hydropower Development on Erosion and the Availability of Habitats

Once a river is impounded, rocky and sandy habitats along its channel are flooded by the reservoir and the bottom of the reservoirs are likely to be covered with fine sediments. The riparian zone of vegetation will be largely drowned, eliminating any refuge that that provides to wildlife. It is unlikely that similar vegetation and habitats will establish around the reservoir because of the unnatural fluctuations of water levels and the greatly reduced deposition of sediments and nutrients; instead there could be a barren zone around the high water mark of the reservoirs, vegetated by whatever plants can cope with the fluctuations of water levels. Natural riverine habitats would be mostly lost in both the aquatic area and the riparian zone, and some new habitat would become available in the still waters of the reservoir, which could be exploited by some fish and other aquatic species. The reservoirs could become major barriers to the movement of people and terrestrial wildlife, especially if they fill valleys floors and have steep terrain at their edges.

Sediment deltas will develop at the upstream ends of the reservoirs, with the composition and extent dependant on the sediment content of the inflowing water. Reservoirs such as Pak Beng, which is scheduled to be the first mainstream dam in the LMB under Scenario 2040, will likely have higher rates of sediment accretion that reservoirs lower in the cascade. The lower, larger impoundments, such that associated with Sambor HPP, will trap sediments that are transported through the smaller, upstream impoundments.

5.6 Effect of Hydropower Development on Riverine and Wetland Vegetation

Much of the natural riparian vegetation will be destroyed because it is under water or in newly water-logged soils, which become anoxic and kill the roots. Inundation also prevents the dispersal of seeds or accumulation of organic matter, and so recruitment in the riparian communities is halted. According to the findings presented in the BioRa report the herbaceous marsh and upper and lower bank riparian vegetation are expected to be reduced by 90-100% except in steep-sided reached of the River.

Predicting how algal biomass would change within a reservoir constructed on the river is difficult, and may not be uniform over the length of the water body. The river turbulence is undoubtedly important in ensuring that water adjacent to algal cells does not become depleted of nutrients, thus stimulating algal growth, but it also ensures that cells spend some of their time deep in the water below the photic zone thus inhibiting growth. Concentrations of chlorophyll in the Mekong are high (although data are limited) indicating that primary production in upstream impoundments is unlikely to be dramatically higher than production in the river.

In the shallow Tonle Sap Lake, algal biomass is lowest in the flood season (3.4 µg/L in 2005) when the lake is filled with turbid Mekong water and highest in the dry season (54 µg/L in 2005) when water levels are low, temperatures relatively high and the water relatively clear. In general, algal measurements in the Lake exceed the highest river measurements, which suggests that algal biomass in a shallow reservoir is likely to be higher than in the river, but possibly not by very much. However, in localized protected areas of impoundments where sediment deposition rates are high and light penetration is high, algal blooms may persist for the dry season. Algal blooms, should they occur, can be harmful to animals and people, however, as the can lead to foul odours and tastes, deoxygenation of bottom waters, toxicity and fish kills.

5.7 Effect of Hydropower Development on Aquatic Macroinvertebrates

Groups of macroinvertebrates are expected to respond differently to impoundment depending on the morphology of the impoundment, which is partially dictated by its location within the basin. For instance, the insects that are mostly important as food for fish and birds live on stones or sand and most will not survive in the reservoirs because the bottom will be covered in fine silt. On the other hand, some of the groups that contribute directly towards the OAA harvest, such as snails, bivalves, shrimps and crabs are expected to be more abundant in the reservoirs than in the river.

The standing waters of reservoirs also provides excellent habitats for zooplankton, which is a critical food item for some fish and thus an important link in the food chain from algae to people. Based on chlorophyll data from Tonle Sap Lake, algal biomass in shallow impoundments will be appreciably higher those that in the river during the dry season. Overall, benthic invertebrate biomass will probably be increased in some zones, although the composition will be quite different. Similarly, the amount of insect emergence from the reservoir may be similar to that from the river, but is expected to be comprised of different species, which may affect its value as a food source, and to occur at different times of the year to that in the river, depending on how the impoundment is managed. Neotricula aperta, the snail host for Schistosomiasis, requires stony substrates and flowing water, and so will not survive in a reservoir.

Invertebrates such as mosquitoes will be unaffected by impoundments. They are rare in the river, or impoundments, or any large water bodies that contain fish. Mosquito-transmitted disease in the lower Mekong occurs primarily in forested and urban areas where there are temporary aquatic habitats such as phytotelmata, and puddles of water in roof gutterings, old tyres and the like which are fish free and where mosquito larvae grow rapidly.

Blackfly larvae (Simuliidae) may be abundant downstream of impoundments if there is suitable substrate, such as stones or concrete, for attachment and a current for feeding. They benefit from the algae and seston in the water, which may be at higher concentrations in the outflow from an impoundment than in the free flowing river. However, blackflies do not appear to be a substantial pest to humans or stock in the LMB as they are in Africa (where they transmit Onchocerciasis) or northern North America (where they savagely attack humans and large animals). In the Mekong, as in Australia, the blackflies seem to largely ignore humans, and do not seem to be associated with transmission of any important diseases. They are, however, eaten by people in some parts of the basin.

Full details are to be found in the Councilø study BioRa Report.

5.8 Effect of Hydropower Development on Fish and Fisheries

None of the white fish species will be able to survive in the reservoirs associated with Scenarios 2020 and 2040, and so rhithron resident species, main channel resident (long distant white) species and main channel spawner (short distance white) species are expected to be essentially eliminated from impounded areas.

On the other hand, it is expected that the generalist and non-native fish species will benefit from the impounded conditions and thus will increase in abundance, and dominate catches in the reservoirs. However, since these species tend to be smaller than the migratory white species, the overall fish biomass will probably be lower in the impoundments than in the river in 2007 Baseline.

The exception to this is possibly the reservoir associated with the Sambor HPP. Sambor is likely to result in a massive shallow reservoir that would significantly increase habitat for, and hence the production of, eurytopic (generalist) species, which are the dominant guild here. This large increase in a dominant fish group should result in an increase in fish biomass in the reservoir.

The potential success of Impoundment fisheries in the Lower Mekong Basin is addressed in the Council Study BioRA report. Estimated capture-fishery yields from impoundments in the LMB have been by some estimated to some 200 kg/hectare/year, but these data need to be disaggregated. There is a strong negative correlation between productivity and lake area, with a yield of some 200 kg/ha only applying for very small reservoirs, and a mean yield for all reservoirs of only some 21.9 kg/ha. Lower production figures are consistent with 'run of the river' HPP reservoirs, where the reservoirs are largely confined to the natural river channel, and do not create the lentic or stillwater environments that favour fish production. The species composition of fisheries in reservoirs is likely to be dominated by lower-value species, and fishermen will need to adapt their gears and operation.

One of the main mitigation strategies against reduced fisheries as a result of water-resource development in the LMB is cage culture and culture-based fisheries in the impoundments. While these measures may provide some mitigation, they are unlikely to substitute lost production. Furthermore, former wild-capture fishermen may be unable to exploit the new fish source because of the high capital cost for setup, high recurrent costs of feeding the fish, and the skills needed to manage aquaculture businesses.

Full details are to be found in the Council Study BioRa Report.

5.9 Effect of Hydropower Development on Herpetofauna

When a section of a river changes to reservoir each group of amphibians and reptiles may respond differently. In general, only the semi-aquatic snakes and turtles, which will be prejudiced by the absence of seasonal flooding, are expected to decline in impounded areas. Other groups are predicted to increase by between 5 and 20%. This is because the shallow waters around the margin of the impoundment, particularly in the lower, flatter reaches of the LMB, should be suitable for many of them .

The evidence is not conclusive, however, and other studies have suggested that the complex habitat structure of rivers and floodplains, and the greater amount of leaf litter present in unaltered systems, supports greater species richness than does the habitat made available in reservoirs. The prediction also assumes that there will be no major drawdowns in the water level of the reservoirs. Apart from their negative effects on vegetation, drawdowns may also expose and harm hibernating reptiles and amphibians that are buried in lake sediments.

Full details are to be found in the Council Study BioRa Report.

5.10 Effect of Hydropower Development on Birds and Mammals

The expected responses of the birds to a change from river to reservoir are provided in Table 5.6. None of the groups of birds that are dependent on riverine habitats are expected to fare well at reservoirs, mainly because the combination of inundation and lack of seasonal flooding will eliminate habitats such as sandy banks, reeds and grasses, large riverside trees, rocky crevices and vertical river banks that can be used for nesting, but also because of the change in food available in reservoirs.

The expected responses of the mammals to the change from river to reservoir are provided in the Council Study BioRA REport. Neither hog deer nor dolphins are expected to survive in or around impounded areas. The hog deer depend on riparian and floodplain vegetation, which would be severely reduced in the absence of flooding. The habitat usage and feeding patterns of dolphins are thought to be strongly influenced by the long-distance movement of small cyprinid fish, and thus their predicted decline is attributed to the predicted decline in migratory white fish.

Finally, although otters can and will inhabit reservoir edge habitats, their numbers are expected to be lower than in the river because of increased susceptibility to predation along reservoir edges as a result of, for instance, fewer holting areas.

5.11 Effect of Hydropower Development on Sediments and Water Quality

- ***The amount of sediment discharged during a flushing event at the bottom of the cascade (Sanakham) is small compared to the annual load of sediment entering the cascade***. In most scenarios, the volume of sediment entering the impoundment exceeds the volume discharged during the flushing event. This is especially relevant to gravels and medium and coarse sand. The low sediment discharge from the impoundments is attributable to the overall low sediment loads entering the impoundments, combined with the short duration of the model runs; the flushing scenarios were completed using the sediment accumulation in the reservoirs after 7-years of cascade operation. The overall volume of sediment deposited in the impoundments during the 7-year period is very small compared to the volume of the impoundments, and sediment 'deltas' have not reached anywhere near the toe of the dam. It is expected that sediment accumulation will increase after a period of several decades that will lead to a larger volume of sediment being mobilised during an individual flushing event.
- ***The reservoir geometry affects sediment movement during flushing***. The cascade is characterised by long, narrow impoundments, punctuated by sharp bends within each of the reservoirs. These 'choke' points reduce the transport of sediment due to reductions and changes in velocities caused by the channel morphology. These features affect sediment transport during 'normal' operations as well as during flushing;
- ***Silt and clay are relatively insensitive to sediment flushing***. Silt and clay are generally transported through the impoundments under the non-flushing flow regime, so only limited volumes of this grain-size accumulate in impoundments. During flushing, the quantity of silt and clay tends to be uniform throughout the event, and similar to the magnitude of the load entering the impoundment. An exception occurred at Pak Lay when draw down rates during flushing were 'unconstrained', and water levels decreased at rates greater than 1 m/hr. During this event large quantities of silt and clay were mobilised. This is consistent with silt and clay accumulating in quiet areas of the reservoir that require a large change in the flow dynamics to re-mobilise;
- ***The timing and initial conditions of flushing affect the efficiency of flushing. In general, the higher the sediment loads entering the impoundment at the initiation of flushing, the more successful the results***. This is due to a larger proportion of the sediment remaining in suspension and being transported through the impoundment under the higher shear stress conditions created by flushing.
- Flushing during periods of high flows will promote the movement of sediment delivered by tributaries through the reservoir. ***Sediment flushing coinciding with the end of the dry season will remove a larger silt and clay load as compared to at other times of year, due to the accumulation of fine-sediment during the dry season.*** This is a minor consideration when planning sediment flushing as most of this material would be re-mobilised during the wet season, with or without flushing.
- The rate of reservoir drawdown is important. ***In general, the faster the drawdown rate, the higher the resulting shear stress and the higher the sediment load entrained and discharged***

from the impoundment. 'Slow' drawdown maintains low discharge volumes and sediment concentrations, but moves less material as compared to the 'fast' drawdown;

- Based on this, ***the coordinated flushing of the cascade, involving the coordinated timing of water level decrease in successive reservoirs to promote movement of a sediment 'plug' through multiple impoundment, is a possibility and likely to improve the overall success rate as compared to the flushing of individual impoundments*** independently.
- The duration that low water levels are maintained affect sediment flushing. In almost all of the flushing model runs, water levels were decreased to the targeted minimum level and held at the minimum for 1-day before increasing at the rate of 0.2 m/hr up to the minimum operating level. In one of the Pak Beng runs, the water level was maintained at the lowest point for 2-days. The longer 'hold' period increased the quantity of sediment discharged in all size fractions, with the largest increase occurring in the fine sand fraction. The quantity of fine-sand mobilised during the1 m/hr flush with the extended 'hold' at low water exceeded the quantity of fine-sand mobilised using a higher flushing rate of 2 m/hr;
- The maximum volume of water discharged during sediment flushing is controlled by the rate of drawdown and the rate of water entering from upstream. High drawdown rates provide the greatest 'return' with respect to sediment discharge, but also produce large flood peaks. The size of these peaks needs to be considered with respect to human safety and downstream impacts. This finding is consistent with previous investigations into flushing that found approximately twice the annual average flow is required to promote successful flushing.

5.12 Effect of Climate Change

The key messages from the climate change sub-scenarios are:

- A wetter climate future will mitigate some of the ecological impacts associated with Scenario 2040, but only slightly because flood protection measures are expected to limit the increase in flooding.
- A drier climate future will exacerbate the ecological impacts associated with Scenario 2040, especially in the lower parts of the LMB.
- For Tonle Sap Great Lake, the Cambodian floodplains and the Viet Nam Delta, the effects of a drier climate on ecosystem condition are greater than the positive effects of a wetter climate. This is partly because the inflows from the Lake's tributaries and direct rainfall into the Lake that provide a buffer against changes in the mainstream Mekong River are reduced in the drier climate, but also because these systems are so dependent on flooding extent and duration, both of which are expected to be reduced under a drier climate.
- It is possible that the developments in Scenario 2040, would provide the downstream ecosystem with some level of protection against extreme flood events, but this could not be evaluated using the selected array of scenarios.
- The resilience of the LMB aquatic ecosystems, particularly Tonle Sap Great Lake, to a drier climate will be compromised by the developments in Scenario 2040.

6.0 Main Challenges and Recommendations

6.1 Fish Migration

The creation of reservoirs effectively prevents downstream drift of eggs and larvae and so the reproduction cycle for migratory species is severely affected. Downstream migration of adult fish will be associated with high injury and mortality rates through the turbines. Certain larger migratory species may become extinct and a 60% reduction in biomass within the cascade reach may occur.

There is a considerable body of knowledge relating to the requirements for attraction flows and the design of fish passage systems. Physical and numerical model studies can be undertaken to refine the necessary geometry to create the required conditions for an upstream fish passage system. However fish passages at the scale of the mainstream cascade are still essentially unproven, and the cumulative efficiency of the upstream fish passages on all five projects is predicted to be low, as indicated in Section 5.5 of this report.

Solutions for assisting downstream migration on the cascade, as currently envisaged, are not available. The creation of reservoirs results in a negligible flow velocity. The passive downstream drift of eggs and larvae is not supported at velocities below 0.2 m/s and at lower velocities they will sink and die. Adult species have the capacity to swim downstream but will eventually encounter the power intake screens of the next hydropower scheme. The trash rack bar spacing on hydropower plants is typically selected to exclude trash that might otherwise damage or become jammed in the turbine and so smaller fish species will be drawn into the turbine. Trash rack flow velocities of approximately 1 m/s are commonly adopted from trash exclusion. Fish that pass through the screens are unlikely to survive the pressure gradients and blade strike from conventional turbines. Fish can be prevented from entering the turbine if the trash rack bar spacing and flow velocity are reduced. A maximum velocity of approximately 0.12 m/s is commonly recommended to avoid damaging the fish when they encounter the screens. On this basis the power intake screens would need to be increased in area by a factor of ten, which is not realistic for a large project. If downstream migration is not feasible then the value of providing upstream fish passages is questionable.

6.2 Sediment

Under the possible main scenarios development scenarios (M2, M3, M3CC) result in large reductions to the mass of sediments and nutrients reaching the Mekong delta. For the Development 2040 scenarios (M3, M3CC), the reduction in sediment loads is revealed. The modelling of sediment transport through the mainstream cascade indicates that fine silts and nutrients will generally pass, but sand and gravel will be trapped in the reservoirs. Fine sand can be mobilised by reservoir flushing, but only minimal quantities of coarse sand and gravel can be mobilised. Modelling indicates that, with flushing and other mitigation, approximately 30 Mt of sediment enters the cascade each year but only 5 Mt exits. The flushing process severely impacts the ecology of the cascade.

The implementation of sediment passage structures for mainstream dams in the Lower Mekong Basin could significantly improve sediment loads reaching the Mekong Delta. However, mitigation measures are only likely to be effective if they are implemented in a coordinated way for all dams in the cascade as illustrated in H3.

A more fundamental change in scheme design will be required if these impacts are to be further reduced.

6.3 Some Potential Engineering Solutions from the ISH0306 Study

6.3.1 Smaller Reservoirs

The mainstream schemes do not require active reservoir storage. Analysis of peaking options indicates that storage provides very limited commercial benefit. The reservoirs on the mainstream schemes, as currently envisaged, are created to provide generating head, not storage. The creation of reservoirs obstructs downstream fish migration, traps sediment, reduces water quality and increases environmental footprint. Reduction of reservoir size would therefore be beneficial.

The creation of a series of fully gated low head barrages could replace a single mainstream dam and would capture a similar amount of energy if the cumulative head was the same. These structures would impound smaller volumes of water and keep the river closer to its natural regime. At critical times of year (or on a regular basis such as weekends) the gates could be opened and the river returned to entirely natural conditions to allow sediment transport and fish migration in either direction. This form of structure is adopted for tidal barrages.

6.3.2 Low Head Turbines

There are various forms of low head turbine commercially available. Conventional low head horizontal axis bulb turbines can function efficiently at differential heads as low as 5 m. This type of machine currently provides the only practical alternative to pass the high volumetric flow rates required for the Mekong.

Low speed machines with a low number of blades present a reduced hazard to downstream fish passage. This hazard can be removed almost entirely by shutting down generation and placing the turbines in sluicing mode. Under this sluicing condition there is almost no pressure gradient and the blades will rotate slowly.

The hazard created by horizontal axis bulb turbines can be further reduced by increasing the submergence of the centre line. There are two requirements for the submergence of a horizontal axis turbine:

- ***Intake submergence:*** The centre line at the intake must be sufficiently submerged to prevent the formation of detrimental vortices. Minor circulation can usually be accepted but air or trash entraining vortices must be avoided.

- ***Draft Tube submergence:*** The centre line of the draft tube must be sufficiently submerged to provide a back pressure on the turbine runner to prevent the formation of vapour pressures and damaging cavitation.

The turbine centre line elevation must be selected to satisfy both these criteria. However, the proportional pressure gradient through the machine can be reduced by setting the centreline lower than the minimum requirement. The concept is shown in Figure 6.1.

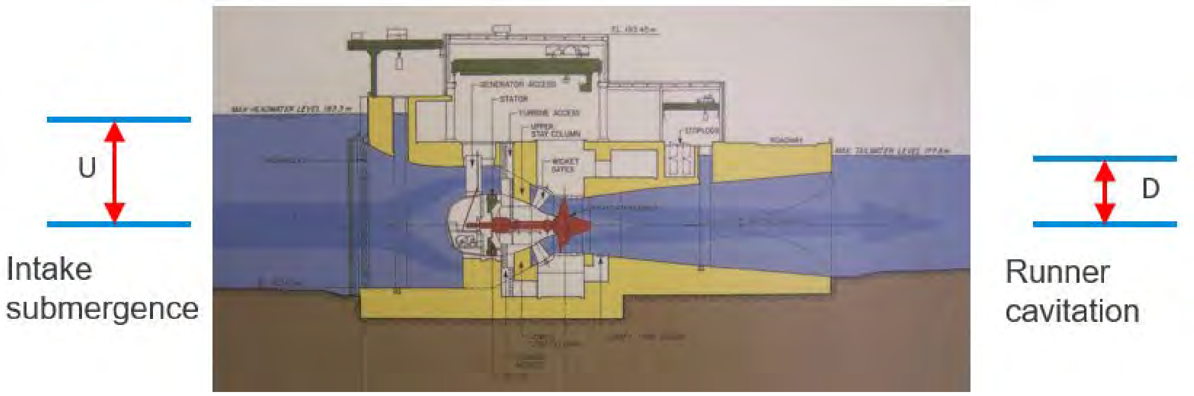

Figure 6.1. *Bulb Turbine Submergence.*

Lowering the turbine centre line results in additional cost for the structure and the excavation. A lower centre line does not alter the generating head (U-D) or the energy delivered, but the relative pressure gradient (U/D) for fish passing through the machine is reduced and a lower centre line improves the opportunity to return the river to its natural regime by sluicing.

6.3.3 Low Impact Spillways

Gated spillways will be required for the mainstream Mekong projects because of the high flow rates that must be discharged. The most economic form of gated spillway is likely to be a gated crest as shown in Figure 6.2.

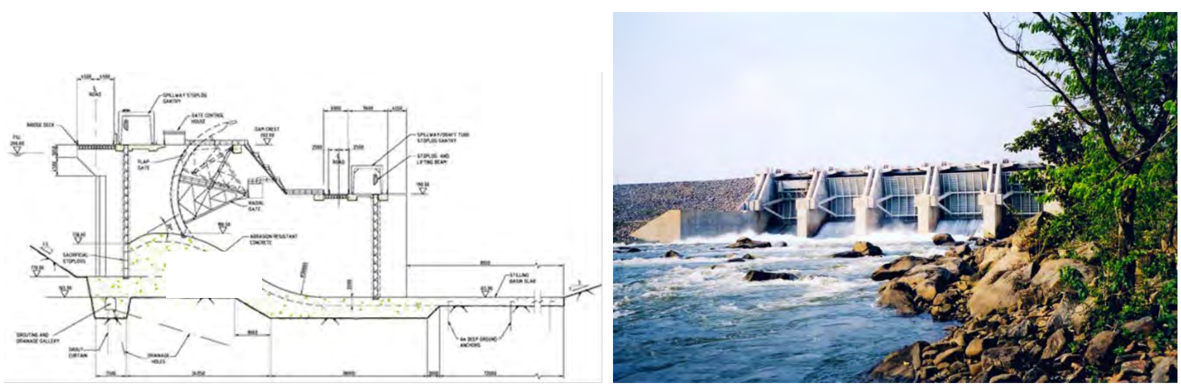

Figure 6.2. *Gated Crest Spillway.*

The gated crest spillway shown in Figure 6.2 is a barrier to upstream fish migration because the water velocity flowing down the weir face will be too high when the gates are fully open. The gated crest is also unsuitable for downstream migration when the gate is partially open (as shown) because of the rapid pressure drop when the water passes under the gate seal. The weir is also a fixed barrier to downstream sediment transport until material has accumulated to the level of the crest.

When the gate is in the fully open position downstream fish migration may be feasible but a hydraulic jump may form on the apron downstream that may cause injury to fish through impact or high pressure gradients. For this reason, end sills and baffle blocks should be avoided on the downstream apron if fish migration is required.

Lower head barrages will relieve some of these issues and undershot gates may provide a satisfactory arrangement if the gate sill is set at riverbed level. The Nam Ou 2 project in Laos shown in Figure 6.3

comprises three horizontal axis bulb turbines and seven vertical lift gates. Once all seven gates are fully open the river returns to its natural regime and the project is not a barrier to fish migration or sediment transport. However when the gates are partially open the scheme remains a complete barrier to fish migration in either direction, and coarse sands and gravels are deposited in the reservoir upstream.

Figure 6.3. *Nam Ou 2.*

An alternative approach is to avoid undershot gates where possible and adopt overshot gates. These could be either flap gates or sector gates. Figure 6.4 shows the Nakdong Dalseong and Yeoju rising sector gate barrages in South Korea. These structures can generate a differential head of approximately 10 m and comprise rising sector gates 45 m long. The gates can be lowered to allow the river to be returned to a fully natural condition to allow fish migration, sediment transport and navigation. The gates can be operated in an undershot or overshot condition and can be fully withdrawn from the water for maintenance.

Figure 6.4. *Rising Sector Gate Barrages (South Korea).*

6.3.4 Bottom Outlet Gates

If bottom outlet gates are adopted for draw down or sediment management it may still be possible to use these facilities for downstream fish migration if the pressure gradient can be made sufficiently gradual.

One option to create a gentler gradient would be to provide a submerged conduit downstream of the gate so that the pressure drop is distributed along the entire length of the conduit.

6.3.5 Temporary Shut Down

The option of temporary shut down of the plant could be considered.

This will have implications due to stopping of generation and drawing the reservoirs down at critical times of year. This strategy could facilitate fish migration and sediment transport at selected periods when natural river conditions would be most beneficial. The value of energy lost during these shut down periods could be assessed against the improved environmental performance of the cascade.

However the adopted spillway geometry at Xayaburi will not support this mode of operation. Flow velocities through the spillway gates in the range 7 – 10 m/s make upstream fish migration impossible and downstream migration hazardous.

The concept of shut down can therefore only be contemplated for projects downstream of Xayaburi.

The adoption of a shut down mode of operation has been studied on other projects in the region. For example, the Xe Bang Fai 1 Hydroelectric Project (Lamson Geotechnical Co Ltd & Viet Ha Consultant – June 2016) is planned to be shut down for approximately 3 months each year when high tail water levels reduce the generating head to less than 2 m. Under these conditions the spillway gates will be opened and the river will return to its natural condition. This strategy restores the connectivity of the river and has the additional benefit of reducing the risk of flooding upstream.

6.3.6 Alternative Layouts

Alternative layouts could be considered for mainstream projects such as replacing a typical 30 m gross head mainstream project, with two 15 m gross head projects. The overall river reach of the two lower head projects would be the same as the full height scheme. In this manner, the extent of river reach concessions would remain unchanged.

The lower head projects would provide the following environmental advantages:

- Substantial reduction in impounded water volume, potentially resulting in improved water quality, reduced temperature change and lower sediment retention;
- Lower head dams, making fish passage in either direction more feasible and survivable;
- Lower gross heads suitable for fully gated barrages;
- Lower gross heads suitable for horizontal axis low speed bulb turbines;
- Creation of impounded depths much closer to natural flood surcharge levels; and
- Making it feasible to draw down reservoirs to natural river conditions during flood periods without large changes in water level and corresponding ecological stress.

The reduced gross heads would permit the adoption of rising sector gates designed for gross head differences of up to 15 m. Figure 6.5 shows the operating positions for these gates.

All river flow is diverted through the turbines when the gates are in the fully raised position. This configuration would be adopted throughout the dry season when the river discharge is lower than the capacity of the generating plant.

When the river discharge exceeds the generating plant capacity, spilling will commence. This will typically occur for at least 4 months each year. Spill flows will pass over the crest of the gates and down the downstream face. This configuration avoids rapid pressure gradients and fish can pass without injury. The correct discharge can be achieved by adjusting the angle of the gate. The head pond level can be permitted to rise, thereby maintaining the generating head.

Local accumulation of sediment can scoured by rotating the gate in the opposite direction to release an undershot flow. Continued rotation in this direction will raise the gate out of the water for maintenance.

At critical times of the year, the generating plant can be shut down and the gates lowered so that the river is returned to entirely natural conditions. This configuration will facilitate unimpeded fish migration in either direction and sediment transport in a downstream direction.

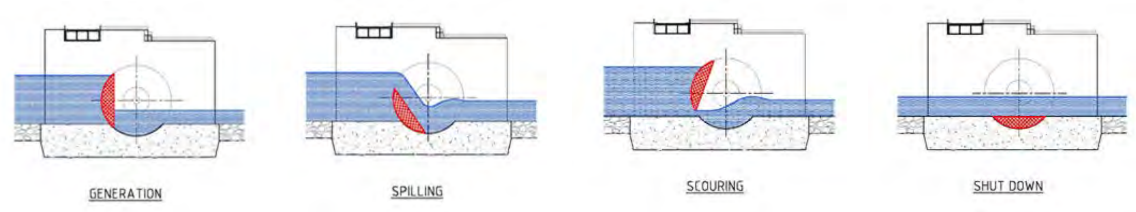

Figure 6.5. *Rising Sector Gate – Operating Positions.*

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ANNEXES

Annex 1: Hydropower projects in Lower Mekong Basin-Operation Data

Annex 2: Hydropower projects in Lower Mekong Basin-Characteristic Data

Annex 3: Further Information on Hydropower Projects on the Upper Mekong Mainstream

Annex 4: Gap-filling for Hydropower Development Data and Scenario Modelling

Annex 5: Model Outputs

Annex 1: Hydropower projects in Lower Mekong Basin-Operation Data

Project	Project Name	River	Commission	Operation Data								
				Rated Head	Plant Design Discharge	Installed Capacity	Peaking Capability	Mean Annual Energy	Firm Annual Energy	Full Supply Level	Low Supply Level	Live Storage
			year	m	m3/s	MW	MW	GWh	GWh	m.amsl	m.amsl	mcm
L001	Nam Ngum 1	Nam Ngum	1971	38.5	414.4	148.7	148.7	1,006.0	846.0	212.0	196.0	4,700.00
L002	Nam Dong	Nam Dong	1970	136.5	1.0	1.0	0.9	4.8	4.0	605.0	603.3	0.02
L003	Xelabam	Xedon	1969	17.0	38.0	5.0	4.5	23.5	20.0	119.3	118.0	0.80
L004	Xeset 1	Xeset	1994	153.4	33.0	45.0	45.0	154.3	82.3	482.0	479.0	0.30
L005	Theun-Hinboun	Nam Theun, hinboun	1998	225.5	106.0	210.0	186.0	1,327.0	1,300.0	400.0	395.0	15.00
L006	Houayho	Houayho, Xekong	1999	748.3	23.0	150.0	144.0	487.0	397.0	883.0	860.0	649.00
L007	Nam Leuk	Nam Leuk, Nam Ngum	2000	174.2	39.5	60.0	53.4	207.0	149.0	405.0	388.0	228.20
L008	Nam Mang 3	Nam Mang, Nam Ngum	2004	513.2	9.1	40.0	39.3	138.0	113.0	750.0	742.0	45.00
L009	Nam Ko	Nam Ko	1996	34.5	5.4	1.5	1.3	5.0	3.0	525.0	523.0	0.00
L010	Nam Ngay	Nam Ngay	2002	17.0	8.5	1.2	1.2	3.5	2.8	455.5	452.5	0.67
L011	Nam Theun 2	Nam Theun, Xe Bangfai	2009	356.6	334.0	1,075.0	1,080.0	5,936.0	5,339.0	538.0	525.5	3,378.40
L012	Xekaman 3	Houayho, Xekong	2009	477.7	62.5	250.0	237.0	982.8	485.7	960.0	925.0	108.54
L013	Xeset 2	Xe Set	2009	246.0	35.2	76.0	75.0	309.0	134.0	813.0	803.5	9.30
L014	Nam Ngum 2	Nam Ngum	2010	146.5	448.0	615.0	554.0	1,976.0	1,387.0	375.0	345.0	2,994.00
L015	Nam Lik 2	Nam Lik	2010	74.5	187.0	100.0	71.0	460.0	334.0	305.0	270.0	826.00
L016	Nam Ngum 5	Nam Ngum	2011	337.0	42.9	120.0	107.0	507.0	307.0	1,100.0	1,060.0	251.00
L017	Xekaman 1	Xe Kaman	2011	99.0	336.6	290.0		1,096.0		230.0	218.0	1,683.00
L018	Xekaman-Sanxay	Xe Kaman	2011	12.2	378.0	32.0	32.0	123.0	122.0	122.0	122.0	0.00
L019	Theun-Hinboun expansion	Nam Theun	2012	225.5	110.0	222.0	195.0	1,395.0	1,300.0	400.0	395.0	15.00
L020	Theun-Hinboun exp. (NG8)	Nam Theun	2012	47.0	134.0	60.0	20.0	294.0	161.0	455.0	420.0	2,262.00
L021	Nam Ngum 3	Nam Ngum	2014	298.7	169.0	440.0	440.0	2,077.0	1,659.0	720.0	660.0	979.00
L022	Nam Theun1	Nam Theun	2014	140.0	404.0	523.0	388.0	1,840.0	1,424.0	292.0	260.0	2,549.20
L023	NamNgiep 1	Nam Ngiep	2015	136.2	230.0	260.0	252.0	1,327.0	1,300.0	320.0	296.0	1,191.80
L024	Nam Ngiep-regulating dam	Nam Ngiep	2015	12.0	160.0	16.8	16.0	108.0	100.0	181.0	176.0	4.70
L025	Nam Tha 1	Nam Tha	2013	65.5	289.5	168.0	168.0	759.4	530.0	455.0	442.5	675.50
L026	Nam Long	Nam Ma	2013	245.0	2.6	5.0	5.0	37.0	33.7	1,016.0	1,013.5	0.13
L027	Xepian-Xenamnoy	Xepian/Xenamnoy	2013	642.0	70.0	390.0	390.0	1,748.0	1,730.0	786.5	760.0	885.00
L028	Xe Katam	Xenamnoy	2013	450.0	16.0	60.8	60.8	380.0	284.0	910.0	890.0	115.00
L029	Xekong 4	Xekong	2014	140.0	240.0	300.0	300.0	1,901.0	1,760.0	290.0	270.0	3,100.00

Project	Project Name	River	Commission	Operation Data								
				Rated Head	Plant Design Discharge	Installed Capacity	Peaking Capability	Mean Annual Energy	Firm Annual Energy	Full Supply Level	Low Supply Level	Live Storage
			year	m	m3/s	MW	MW	GWh	GWh	m.amsl	m.amsl	mcm
L030	Nam Kong 1	Nam kong	2014	186.0	44.5	75.0	75.0	469.0	408.0	320.0	287.0	505.00
L031	Xe Kong 3up	Xekong	2012	33.7	460.0	144.6	144.6	598.7	50.1	160.0	155.0	95.09
L032	Xe Kong 3d	Xekong	2012	17.2	568.0	91.1	91.1	375.7	25.9	117.0	111.0	168.38
L033	Xe Kong 5	Xekong	2016	188.1	146.0	248.0	248.0	1,201.0	1,017.0	500.0	470.0	1,355.50
L034	Don sahong	Mekong	2013	17.0	2,400.0	360.0	359.7	2,375.0	1,988.7	74.5	72.0	115.00
L035	Nam Ou 1	Nam Ou	2013	20.5	1,045.0	180.0	180.0	829.0	500.2	305.0	300.0	10.00
L036	Nam Ou 2	Nam Ou	2014	11.0	932.0	90.0	90.0	413.0	254.9	320.0	316.0	8.40
L037	Nam Ou 3	Nam Ou	2013	43.0	831.0	300.0	300.0	1,337.0	838.3	375.0	370.0	13.50
L038	Nam Ou 4	Nam Ou	2014	16.0	558.0	75.0	75.0	337.0	237.4	400.0	395.0	9.20
L039	Nam Ou 5	Nam Ou	2013	25.0	514.0	108.0	108.0	496.0	358.3	430.0	425.0	11.20
L040	Nam Ou 6	Nam Ou	2014	68.0	368.0	210.0	210.0	840.0	717.4	510.0	490.0	363.00
L041	Nam Ou 7	Nam Ou	2015	90.0	238.0	180.0	180.0	725.0	702.6	630.0	600.0	1,134.00
L042	Nam Lik 1	Nam Lik	2014	19.5	300.0	54.0	54.0	255.0	219.0	195.0	191.0	6.80
L043	Nam San 3	Nam San	2014	877.0	6.7	48.0	48.0	366.0	274.0	1,470.0	1,445.0	121.70
L044	Nam Pha	Nam Pha	2016	111.0	142.3	147.2	147.2	577.0	444.0	550.0	515.0	2,738.00
L045	Nam suang 1	Nam Suang	2016	35.7	130.0	40.0	40.0	187.0	163.4	325.0	314.5	87.60
L046	Nam Suang 2	Nam Suang	2016	122.8	119.6	134.0	134.0	617.6	525.6	460.0	435.0	2,014.70
L047	Nam Nga	Nam Ou	2017	97.3	107.9	97.8	97.8	434.3	315.4	440.0	407.0	1,565.10
L048	Nam Beng	Nam Beng	2014	75.4	43.2	30.0	30.0	120.0	77.4	430.0	410.0	97.90
L049	Nam Feuang 1	Nam Feuang	2015	57.0	57.1	28.0	28.0	113.2	26.7	340.0	334.0	30.00
L050	Nam Feuang 2	Nam Feuang	2015	130.0	22.9	25.0	25.0	110.6	27.8	570.0	565.0	5.00
L051	Nam Feuang 3	Nam Feuang	2015	211.0	11.3	20.0	20.0	88.5	21.8	820.0	815.0	4.80
L052	Mekong at Pakbeng	Mekong	2016	31.4	4,362.0	1,230.0	1,230.0	5,268.1	4,073.0	345.0	340.0	442.40
L053	Mekong at Luangprabang	Mekong	2016	40.0	3,812.0	1,410.0	1,412.0	5,437.3	4,205.0	310.0	300.0	734.00
L054	Mekong at Xayabuly	Mekong	2016	24.4	6,018.0	1,260.0	1,260.0	6,035.3	5,139.4	275.0	270.0	224.70
L055	Mekong at Paklay	Mekong	2016	25.7	5,782.0	1,320.0	1,320.0	5,420.7	4,251.7	240.0	235.0	383.50
L056	Mekong at Sanakham	Mekong	2016	25.0	5,918.0	1,200.0	1,200.0	5,015.0	3,978.2	215.0	210.0	106.10
L057	Mekong at Sangthong-Pakchom	Mekong	2017	22.0	5,720.0	1,079.0	1,079.0	5,318.0	5,052.0	192.0	190.0	11.80
L058	Mekong at Ban Kum	Mekong	2017	18.6	11,700.0	1,872.0	1,872.0	8,434.0	8,012.0	115.0	115.0	0.00
L059	Mekong at Latsua	Mekong	2018	10.0	9,600.0	800.0	800.0	3,504.0	2,452.0	100.0	100.0	0.00

Project	Project Name	River	Commission	Operation Data								
				Rated Head	Plant Design Discharge	Installed Capacity	Peaking Capability	Mean Annual Energy	Firm Annual Energy	Full Supply Level	Low Supply Level	Live Storage
			year	m	m3/s	MW	MW	GWh	GWh	m.amsl	m.amsl	mcm
L060	Xe Pon 3	Xe Banghieng	2018	277.2	30.4	75.0	75.0	338.9	328.5	580.0	560.0	368.00
L061	Xe Kaman 2A	Xe Kaman	2018	48.6	155.0	64.0	64.0	241.6	175.0	280.0	275.0	3.70
L062	Xe Kaman 2B	Xe Kaman	2018	78.8	90.0	100.0	100.0	380.5	202.0	370.0	340.0	216.80
L063	Xe Kaman 4A	Xe Kaman	2018	423.6	26.0	96.0	96.0	375.0	262.5	860.0	840.0	16.50
L064	Xe Kaman 4B	Xe Kaman	2018	459.1	18.4	74.0	74.0	301.0	195.7	865.0	850.0	21.20
L065	Dak E Mule	Xe Kong	2018	433.8	27.4	105.0	105.0	506.0	415.0	780.0	756.0	154.00
L066	Nam Khan 1	Nam Khan	2019	56.0	195.0	101.8	101.8	458.5	422.0	340.0	320.0	805.00
L067	Nam Khan 2	Nam Khan	2018	138.7	109.5	140.0	136.3	578.6	493.0	470.0	450.0	528.00
L068	Nam Khan 3	Nam Khan	2018	79.2	70.1	47.0	32.5	222.4	205.8	560.0	532.0	860.50
L069	Nam Ngum 4A	Nam Ngum	2018	158.4	39.7	54.0	54.0	267.7	236.5	1,040.0	1,010.0	332.30
L070	Nam Ngum 4B	Nam ngum	2018	158.0	38.7	54.0	54.0	267.0	236.5	880.0	870.0	1.70
L071	Nam Ngum, Lower dam	Nam ngum	2018	13.6	776.4	90.0	90.0	526.0	498.0	160.0	155.0	243.00
L072	Nam Pay	Nam ngum	2019	714.7	10.0	62.0	62.0	242.6	168.3	1,120.0	1,100.0	52.30
L073	Nam Mang 1	Nam Mang	2019	115.8	50.8	51.0	51.0	235.3	182.9	360.0	330.0	551.40
L074	Nam Pouy	Nam Pouy	2019	78.2	60.0	43.7	43.7	172.0	143.0	340.0	320.0	498.60
L075	Nam Poun	Nam Poun	2019	61.2	148.8	84.9	84.9	342.0	281.0	300.0	280.0	339.00
L076	Nam Ngao	Nam Ou	2019	347.6	6.6	20.0	20.0	155.0	108.4	880.0	855.0	434.00
L077	Nam Chian	Nam Ngiep	2019	656.2	26.3	148.0	148.0	627.2	480.0	1,040.0	1,020.0	8.30
L078	Nam Ngieu	Nam Ngiep	2020	189.5	18.7	30.4	30.4	132.3	105.4	1,060.0	1,050.0	18.80
L079	Nam Pot	Nam Ngiep	2018	703.3	3.5	22.0	22.0	99.5	96.4	1,145.0	1,127.0	45.10
L080	Nam San 3B	Nam San	2020	257.4	16.7	38.0	38.0	141.0	141.0	520.0	500.0	11.70
L081	Nam San 2	Nam San	2020	74.3	94.3	60.0	60.0	290.7	262.8	240.0	220.0	1,946.40
L082	Nam Pok	Nam Ou	2020	59.4	4.9	2.6	2.6	14.4	11.1	460.0	455.0	5.10
L083	Nam Phak	Nam Ou	2018	99.0	5.8	5.1	5.1	28.3	21.7	700.0	693.0	1.90
L084	Nam Hinboun 1	Nam Hinboun	2020	17.1	311.0	45.0	45.0	173.0	140.0	160.0	150.0	1,224.00
L085	Nam Hinboun 2	Nam Hinboun	2019	848.0	1.7	13.0	13.0	58.5	56.9	1,093.0	1,081.0	25.60
L086	Xe Bang Fai	Xe Bang Fai	2019	16.0	756.8	107.0	103.8	564.2	486.0	155.0	150.0	
L087	Xe Neua	Xe Bang Fai	2020	94.0	40.8	34.0	34.0	230.0	196.0	370.0	330.0	624.00
L088	Nam Theun 4	Nam Theun	2020	157.2	20.5	30.0	30.0	130.5	125.1	720.0	680.0	806.50
L089	Nam Mouan	Nam Theun	2020	115.3	105.7	110.0	107.3	452.2	305.0	380.0	360.0	1,960.00

Project	Project Name	River	Commission	Operation Data								
			year	Rated Head m	Plant Design Discharge m3/s	Installed Capacity MW	Peaking Capability MW	Mean Annual Energy GWh	Firm Annual Energy GWh	Full Supply Level m.amsl	Low Supply Level m.amsl	Live Storage mcm
L090	Xe Bang Hieng 2	Xe Bang Hieng	2020	44.6	42.6	16.0	16.0	73.5	70.0	280.0	263.0	642.90
L091	Xedon 2	Xe Don	2021	39.6	152.5	54.0	54.0	319.0	221.0	170.0	159.0	1,743.00
L092	Xe Set 3	Xe Don	2020	164.1	13.6	20.0	20.0	74.0	50.0	1,022.0	1,018.0	3.54
L093	Xe Bang Nouan	Xe Bang Nouan	2021	118.8	19.0	18.0	18.0	79.1	78.8	260.0	230.0	1,477.00
L094	Xe Lanong 1	Xe Bang Hieng	2021	64.4	55.9	30.0	30.0	153.5	131.4	350.0	330.0	373.74
L095	Xe Lanong 2	Xe Bang Hieng	2018	178.2	12.9	20.0	20.0	103.5	87.6	580.0	560.0	79.20
L096	Nam Phak	Nam Phak	2018	669.5	13.0	75.0	75.0	307.0	279.0	920.0	910.0	34.97
L097	Xe Nam Noy 5	Xe Kong	2022	572.3	3.9	20.0	20.0	124.0	102.0	800.0	780.0	8.80
L098	Houay Lamphan	Xe Kong	2018	592.0	11.4	60.0	60.0	264.4	227.0	840.0	800.0	128.20
L099	Nam Kong 2	Xe Kong	2021	106.5	76.5	74.0	74.0	309.5	256.0	460.0	437.0	139.60
L100	Xe Xou	Xe Kong	2022	51.8	131.3	63.4	63.4	286.2	227.0	180.0	160.0	1,714.00
C001	O Chum 2	O Chum	1992	32.6	3.8	1.0	0.6	3.0	1.2	254.0	251.5	0.12
C002	Lower Se San2+Lower Sre Pok2	Se San	2016	26.2	2,119.2	480.0	120.5	2,311.8	611.0	75.0	74.0	379.40
C003	Battambang 1	Sangker	NA	34.0	104.0	24.0	13.9	123.2	105.7	76.0	58.0	1,040.00
C004	Battambang 2	Sangker	NA	450.0	6.0	22.0	22.0	114.4	114.0	670.0	658.0	110.00
C005	Sambor	Mekong	2020	32.9	19,163.0	3,300.0	2,030.0	14,870.0	9,150.0	40.0	38.0	2,000.00
C006	Stung Treng	Mekong	NA	15.2	18,493.0	980.0	591.0	4,870.0	2,937.0	55.0	50.0	70.00
C007	Pursat 1	Pursat	NA	115.0	99.2	100.0	95.0	442.9	321.4	200.0	185.0	690.00
C008	Pursat 2	Pursat	NA	23.0	57.0	10.0	10.0	42.1	42.1	50.0	41.0	295.00
C009	Lower Se San 3	Se San	NA	58.5	500.0	243.0	225.0	1,977.0	954.3	150.0	147.0	3,120.00
C010	Prek Liang 1	Prek Liang	NA	153.0	27.2	35.0	34.0	189.0	153.5	330.0	310.0	110.00
C011	Prek Liang 2	Prek Liang	NA	168.0	17.7	25.0	24.0	186.4	171.5	515.0	496.0	180.00
C012	Lower Sre Pok 3	Sre Pok	NA	31.5	775.0	204.0	200.0	1,101.6	781.0	125.0	118.0	5,310.00
C013	Lower Sre Pok 4	Sre Pok	NA	52.2	327.0	143.0	143.0	772.2	542.5	190.0	185.0	2,700.00
C014	Stung Sen	Stung Sen	NA	19.0	145.0	23.0	23.0	124.2	124.2	43.5	35.0	2,890.00
V001	Upper Kontum	Se San/ Dak Bla/Dak Nghe	2011	904.1	30.5	250.0	200.0	1,056.4	801.5	1,170.0	1,146.0	122.70
V002	Plei Krong	Se San/ Kroong Po Ko	2008	31.0	367.6	100.0	80.0	417.2	286.5	570.0	537.0	948.00
V003	Yali	Se San	2001	190.0	424.0	720.0	576.0	3,658.6	1,991.9	515.0	490.0	779.02
V004	Se San 3	Se San	2006	60.5	486.0	260.0	208.0	1,224.6	649.1	304.5	303.2	3.80
V005	Se San 3A	Se San	2007	21.5	500.0	96.0	76.8	475.0	236.5	239.0	238.5	4.00

Project	Project Name	River	Commission	Operation Data								
				Rated Head	Plant Design Discharge	Installed Capacity	Peaking Capability	Mean Annual Energy	Firm Annual Energy	Full Supply Level	Low Supply Level	Live Storage
			year	m	m3/s	MW	MW	GWh	GWh	m.amsl	m.amsl	mcm
V006	Se San 4	Se San	2009	56.0	719.0	360.0	288.0	1,420.1	932.1	215.0	210.0	264.16
V007	Se San 4A	Se San	2008	0.0	0.0	0.0	0.0	0.0	0.0	155.2	150.0	7.50
V008	Duc Xuyen	Sre Pok/Krong Kno		71.0	81.0	49.0	39.2	181.3	146.3	560.0	551.0	413.41
V009	Buon Tua Srah	Sre Pok/Krong Kno	2009	46.5	204.9	86.0	68.8	358.6	199.7	487.5	465.0	522.60
V010	Buon Kuop	Sre Pok	2009	98.5	316.0	280.0	224.0	1,455.2	613.2	412.0	409.0	14.74
V011	Dray Hlinh 2	Sre Pok	2007	18.5	101.0	16.0	12.8	85.0	78.1	302.0	299.0	1.50
V012	Sre Pok 3	Sre Pok	2009	60.0	412.8	220.0	176.0	1,060.2	440.6	272.0	268.0	62.58
V013	Sre Pok 4	Sre Pok	2009	17.1	468.9	70.0	56.0	329.3	142.4	207.0	204.0	10.11
V014	Dray Hlinh 1	Sre Pok	1990	15.0	94.9	12.0	9.6	94.0	78.1	302.0	299.0	1.50
T001	Chulabhorn	Nam Phrom	1972	366.0	13.3	40.0	33.6	93.0	27.9	759.0	739.0	0.14
T002	Huai Kum	Nam Phrom	1982	23.0	5.5	1.2	0.8	2.0	0.6	312.0	298.0	0.02
T003	Nam Pung	Nam Pung	1965	85.0	8.6	6.3	5.0	15.0	4.5	284.0	270.0	0.16
T004	Pak Mun	Mun	1994	11.6	1,320.0	136.0	113.3	280.0	84.0	108.0	105.5	0.13
T005	Sirindhorn	Lam Dom Noi	1971	30.3	141.0	36.0	33.6	86.0	25.8	142.2	137.2	1.14
T006	Ubol Ratana	Nam Pong	1966	16.0	176.6	25.2	21.1	56.0	16.8	182.0	175.5	1.70
T007	Lam Ta Khong P.S.	Lam Ta Khong	2001	360.0	165.0	500.0	416.0	0.0	0.0	277.0	261.0	0.29

Annex 2: Hydropower projects in Lower Mekong Basin-Characteristic Data

Project	Project Name	River	Characteristic Data					
			DAM			SPILLWAY		
			Type code	Length m	Height m	Spill Elevation Elevation m (msl)	Design Head m	Design Discharge m3/s
L001	Nam Ngum 1	Nam Ngum	G	468	75	202.5	9.5	4,100
L002	Nam Dong	Nam Dong	C	50	10	605/604.5	3/3.5	88
L003	Xelabam	Xedon	G	435	3.7	119.3	3	10,500
L004	Xeset 1	Xeset	G/E	124/304	18	482	4	986
L005	Theun-Hinboun	Nam Theun, hinboun	G	330	27	387.8	10	3,380
L006	Houayho	Houayho, Xekong	RCU	600	76.5	883	3.4	298
L007	Nam Leuk	Nam Leuk, Nam Ngum	C/RE	60/800	46.5	405	3.5	2,100
L008	Nam Mang 3	Nam Mang, Nam Ngum	C/E	150.9/435.8	28/19.9	750	3	778
L009	Nam Ko	Nam Ko	C	38	6	525	4.2	1,200
L010	Nam Ngay	Nam Ngay	C	81.9	26.93	525	5.5	1,502
L011	Nam Theun 2	Nam Theun, Xe Bangfai	C/E/E/E/E	314/543/515/789/490	45	523	15	8,262
L012	Xekaman 3	Houayho, Xekong	RCU	467.4	99	947.5	14.78	5,676
L013	Xeset 2	Xe Set	G/E/E	144/50/28.4	26	813	4	1,536
L014	Nam Ngum 2	Nam Ngum	RCU	485	181	360.5	16.5	8,900
L015	Nam Lik 2	Nam Lik	RCU	309.5	101.4	286	20	2,080
L016	Nam Ngum 5	Nam Ngum	C	258	104.5	1090	10	3,231
L017	Xekaman 1	Xe Kaman	C	186	110	219	17	6,789
L018	Xekaman-Sanxay	Xe Kaman	G	180	28	123	9.5	11,800
L019	Theun-Hinboun expansion	Nam Theun		330	27	387.8	10	3,380
L020	Theun-Hinboun exp. (NG8)	Nam Theun	C	485.6	67	434	16	17,200
L021	Nam Ngum 3	Nam Ngum	C	600	220	704	16	10,281
L022	Nam Theun1	Nam Theun	C	780	177	280	16	17,469
L023	NamNgiep 1	Nam Ngiep	C	513	151	300	20	4,839
L024	Nam Ngiep-regulating dam	Nam Ngiep	G	214	21	172	10	4,839
L025	Nam Tha 1	Nam Tha	RCU	349.2	93.65	441	18	8,830
L026	Nam Long	Nam Ma	G	64.98	12	1016	4.66	951
L027	Xepian-Xenamnoy	Xepian/Xenamnoy	R/E/E/E	1430/831/720/409	75/16.5/16/20.5	786.5	8	1,061
L028	Xe Katam	Xenamnoy	R/E/G/G	420.5/1340/115/26	41.4/13.7/7/11	910	2	640

Annex 3: Further Information on Hydropower Projects on the Upper Mekong Mainstream

Jinghong Hydropower Project

The Jinghong Dam Hydropower Project is located in the southern part of Yunnan Province, China. The project has mainly been designed for power generation but has also other functions such as providing better flood control and enhancing navigation. The construction of the scheme started in 2005, with the first unit entering commercial operation in 2008. The project was reportedly fully operational in 2009. The scheme has an installed capacity of 1,750 MW, and comprises the following main structures:

Figure A-3.1 Jinghong Dam (Source www.flickr.com)

- Main Dam (RCC gravity dam, 704.5 m long and 108 m high).
- Power house containing 5 x 350 MW Francis turbine generator units
- Spillway structure
- Ship lock

Nuozhadu Hydropower Project

The Nuozhadu Hydropower Project is located in the Yunnan Province of China. The project is designed mainly for power generation but also fulfils multifunctional purposes such as flood control and improvement of downstream navigation. The scheme has an installed capacity of 5,850 MW, which is reported to be the largest hydropower station along the Lancang River and in Yunnan Province. The project comprises the following main structures:

Figure A-3.2 Nuozhadu Hydropower Project (Source www.flickr.com)

- Main Dam (central core rockfill dam, 608 m long and 261.5 m high).
- Power house with 9 x 650 MW turbine generator units
- Gated side channel spillway.

The scheme has been operational since 2012, with the last unit commissioned in 2014. The reservoir created by the dam allows for major seasonal regulation.

Dachaoshan Hydropower Project

The Dachaoshan hydropower project, located on Lancang River, Yunnan province, is a single purpose project for power production. The project has an installed capacity of 1,350 MW and commenced commercial operation in 2003. The project comprises the following main structures:

- Main Dam (RCC gravity dam, 460 m long and 111 m high).
- Power house containing 6 x 225 MW Francis turbine generator units
- Crest overflow gated spillways

Figure A-3.3 Dachaoshan Hydropower Project (Source www.flickr.com)

Manwan Hydropower Project

The Manwan hydropower project, located on Lancang River, has an installed capacity of 1,500 MW and comprises the following main structures:

- Main Dam (concrete gravity dam, 418 m long and 132 m high).
- Power house containing 5 x 250 + 1 x 300 MW Francis turbine generator units
- Crest gated spillway and a tunnel spillway

The Manwan Hydropower Station began operation in 1996 and has been subject of extensive studies as the first large scale hydropower station on the Lancang River.

FigureA- 3.4 Manwan Hydropower Project. (Source: www.flickr.com)

Xiaowan Hydropower Project

The Xiaowan hydropower project is a significant component of the Lancang River cascade. Its main purpose is electricity generation. It is the world’s second highest arch dam at 292 m and it creates a large reservoir which is acting as a sediment retention buffer for the Manwan and Dachaoshan hydropower projects. The Xiaowan hydropower project has an installed capacity of 4,200 MW, and comprises the following main structures:

- Main Dam (double curvature arch dam, 902 m long and 292 m high).
- Power house containing 6 x 700 MW Francis turbine generator units
- Crest gated spillway and a tunnel spillway

The construction of the scheme commenced in 2002. The first unit entered commercial operation in 2009 and last unit was commissioned in 2010. The size of the reservoir created by the dam allows for major seasonal regulation.

Figure A-3.5 Xiaowan Hydropower Project. (Source: Mekong River Commission)

Gongguoqiao Dam

The 900 MW Gongguoqiao hydropower project comprises the following main structures:

- Main Dam (gravity, roller compacted concrete dam, 356 m long and 105 m high).
- Power house containing 4 x 225 MW Francis turbine generator units
- Crest gated spillway and a tunnel spillway

Figure A-3.6 Gongguoqiao Dam. (Source: www.flickr.com)

The construction of the project started in 2008 and the scheme commenced commercial operation in 2011. The last unit was commissioned in 2012.

Annex 4: Gap-filling for Hydropower Development Data and Scenario Modelling

Gaps and Weaknesses Addressed:

- Lacking some basic characteristic in some projects: Tailwater, Spillway discharge, Year of operation....
- Lacking the Relationship of Volume ~ Surface Area ~ Elevation of reservoir in almost projects.
- Lacking the Operation rule-curve, therefore some output (the detail rule-curve will not accuracy at all in some projects)
- Only the LMB dams (existing and proposed project) were update upto 2014, the Chinese Dam projects were not updated, which still use the information from BDP2 (year 2010)

Table A-4.1 Parameters of Hydropower Projects used in the Council Study Modeling

Parameter	Sub-Parametter	Unit
Project Name		
Year of Operation		
Location	Long	
	Lat	
Catchment	Catchment areas	km2
	Annual Inflow	m3/s
	Annual volume	mill.m3
Topographic	Detail of	Relationship of V~A~Z
Water Level in Reservoir	Flood Water Level	m.a.s.l
	Normal Water Level	m.a.s.l
	Dead Water Level	m.a.s.l
Reservoir Volume	Surface Area at FSL	Km2
	Active Volume	mill.m3
	Dead Volume	mill.m3
	Total Volume	mill.m3
	Rule Curve	
Flow and Water Level	Tailwater Level	m
	Qmin (each turbine)	m3/s
	Qmax (each turbine)	m3/s
	Total Qdesign	m3/s
	Qmaintain P90%	m3/s
Rate Head	Designed	m
	Maximum	m
	Minimum	m
Powerhouse	No. Turbine	
	Turbine Efficiency	%
	Elevation of turbine	m
Energy Generation	Install Capacity	MW
	Firm Energy	GWh
	Annual Energy	GWh
	Time on using the install capacity	Hours/year
Sluice (Sed, other purpose)	Width (BxH)	m x m
	Inlet crest	m
	Outlet crest	m
	Qdesign	m3/s
Spillway with Gate	Crest	m
	No. of Gate	
	Width (BxH)	
	Qdesign	m3/s
Overflow Spillway	Crest	m
	Width (BxH)	
	Qdesign	m3/s

Mainstream Hydropower Projects in the LanCang River in China

Data collected and analysis from China as presented in table below. The 6 new Chinese Dam projects (CN009-CN014) were updated by the Council Study Modelling Team based on data from Beijing Hydropower Institute.

Table A-4.2 shows the data for the Chinese Dams used in the Council Study Modelling.

The main gaps and weaknesses which needed to be addressed were as follows:

- Lacking some basic characteristic in some projects: Tail-water, Spillway discharge, Sand and Sediment Sluice
- Lacking the Relationship of Volume ~ Surface Area ~ Elevation of reservoir.
- Lacking the Operation rule-curve
- Only the 8 projects were update upto 2014 (6 existing projects, 2 proposed projects) which still use the information from BDP2 (year 2010)

Mainstream Hydropower Projects in the Lower Mekong Basin Mainstream

Data collected and analysis of the mainstream dams in the Lower Mekong Basin mainstream are presented in Table A-4.3 as used in the Council Study Modelling.

The main gaps and weaknesses which needed to be addressed were as follows:

- Lacking some basic characteristic in some projects: Tail-water, Spillway discharge, Sand and Sediment Sluice.
- Lacking the Relationship of Volume ~ Surface Area ~ Elevation of reservoir.
- Lacking the Operation rule-curve, Number of turbine, Discharge of each turbine, Turbine efficiency.

Hydropower Projects in Cambodia, Lao PDR, Thailand and Vietnam in the Council Study Modelling

The details of the hydropower projects in Cambodia, Lao PDR, Thailand and Vietnam used in the Council Study modelling are given in Tables A-4.4, A-4.5, A-4.6 and A-4.7 respectively.

Table A-4.2 Hydropower Projects in China on the Lancang River used in the Council Study modelling

ID	Project Name	Year of Operation	Location		Catchment			Topographic	Water Level in Reservoir			Reservoir Volume				
			Long	Lat	Catchment areas	Annual Inflow	Annual volume	Detail of	Flood Water Level	Normal Water Level	Dead Water Level	Surface Area at FSL	Active Volume	Dead Volume	Total Volume	Rule Curve
					km2	m3/s	mill.m3	Relationship of V~A~Z	m.a.s.l	m.a.s.l	m.a.s.l	Km2	mill.m3	mill.m3	mill.m3	
CN001	Gongguoqiao	2008	99.345	25.550	97,200	984.9	31060.0	BDP2	No data	1,319.0	1,311.0	343	120.0	390.0	510	BDP2
CN002	Xiaowan	2010	100.091	24.705	113,300	1219.9	38470.0	BDP2	No data	1,236.0	1,162.0	No data	9,900.0	4,750.0	14,650	BDP2
CN003	Manwan	1996	100.449	24.622	114,500	1230.0	38790.0	BDP2	No data	994.0	982.0	415	251.0	662.0	913	BDP2
CN004	Dachaoshan	2003	100.370	24.025	121,000	1340.1	42260.0	BDP2	No data	906.0	860.0	826	275.0	720.0	995	BDP2
CN005	Nuazhadu	2016	100.433	22.634	144,700	1731.4	54600.0	BDP2	No data	807.0	756.0	320	12,300.0	10,300.0	22,600	BDP2
CN006	Jinghong	2010	100.767	22.053	149,100	1840.1	58030.0	BDP2	No data	602.0	595.0	510	309.0	810.0	1,119	BDP2
CN007	Ganlanba	No data	100.914	21.861	151,800	1880.1	59290.0	No data	No data	533.0	533.0	No data	No data			No data
CN008	Mengsong	Cancelled	101.147	21.780	160,000	2019.9	63700.0	No data	No data	519.0	519.0					
CN009	Miao Wei	2020	99.174	25.855	93,900	960	30274.6	No data	No data	1,479.0	1,444.0		1,278.0	1,520.0	2,798	
CN010	Da Hua Qiao	2020	99.147	26.337	92,600	925	29170.8	No data	No data	1,479.0	1,373.0		41.0	252.0	293	
CN011	Huang Deng	2020	99.104	26.547	91,900	901	28413.9	No data	No data	1,622.0	1,607.0		411.0	1,096.0	1,507	
CN012	Tuo Ba	2020	99.104	27.193	88,700	810	25544.2	No data	No data	1,715.0	1,705.0		168.0	406.0	574	
CN013	Li Di	2020	99.020	27.502	86,400	750	23652.0	No data	No data	1,821.0	1,816.0		15.0	80.0	95	
CN014	Wu Nong Long	2020	98.917	27.926	85,900	743	23431.2	No data	No data	1,943.0	1,931.0		148.0	498.0	646	

ID	Project Name	Flow and Water Level					Rate Head			Powerhouse			Energy Generation			
		Tailwater Level	Qmin (each turbine)	Qmax (each turbine)	Total Qdesign	Qmaintain P90%	Designed	Maximum	Minimum	No. Turbine	Turbine Efficiency	Elevation of turbine	Install Capacity	Firm Energy	Annual Energy	Time on using the install capacity
		m	m3/s	m3/s	m3/s	m3/s	m	m	m		%	m	MW	GWh	GWh	Hours/year
CN001	Gongguoqiao	BDP2	No data	No data	1,170.0	No data	77.0	No data: 2st priority update	No data: 2st priority update	No data: 1st priority update	No data: 1st priority update	No data: 1st priority update	750.0	170.0	4,063.0	No data
CN002	Xiaowan	BDP2			1,877.0	No data	248.0						4,200.0	1,765.0	18,540.0	
CN003	Manwan	BDP2			1,880.0	No data	89.0						1,550.0	796.0	7,870.0	
CN004	Dachaoshan	BDP2			2,180.0	No data	80.0						1,350.0	680.0	7,090.0	
CN005	Nuazhadu	BDP2			3,490.0	No data	205.0						5,500.0	2,322.0	22,670.0	
CN006	Jinghong	BDP2			2,890.0	No data	67.0						1,500.0	765.0	8,470.0	
CN007	Ganlanba	No data			-	No data	10.0						250.0	75.0	777.0	
CN008	Mengsong				-	No data	28.0						600.0	337.0	3,383.0	
CN009	Miao Wei				960.0	No data	154.0						2,200.0	839.0	10,260.0	
CN010	Da Hua Qiao				925.0	No data	106.0						920.0	306.7	4,070.0	
CN011	Huang Deng				901.0	No data	131.0						1,600.0	628.0	8,080.0	
CN012	Tuo Ba				810.0	No data	84.0						900.0	358.0	4,625.0	
CN013	Li Di				750.0	No data	33.0						300.0	139.0	1,680.0	
CN014	Wu Nong Long				743.0	No data	112.0						1,200.0	439.0	5,750.0	

Table A-4.2 (contd.): Hydropower Projects in China on the Lancang River used in the Council Study modelling (contd.)

ID	Project Name	Sluice (Sed, other purpose)				Spillway with Gate				Overflow Spillway		
		Width (BxH)	Inlet crest	Outlet crest	Qdesign	Crest	No. of Gate	Width (BxH)	Qdesign	Crest	Width (BxH)	Qdesign
		m x m	m	m	m3/s	m			m3/s	m		m3/s
CN001	Gongguoqiao	No data: 2st priority update	No data: 2st priority update	No data: 2st priority update	No data: 2st priority update	No data: 2st priority update	No data: 3st priority update	No data: 3st priority update	No data: 2st priority update	No data: 2st priority update	No data: 3st priority update	No data: 2st priority update
CN002	Xiaowan											
CN003	Manwan											
CN004	Dachaoshan											
CN005	Nuazhadu											
CN006	Jinghong											
CN007	Ganlanba											
CN008	Mengsong											
CN009	Miao Wei											
CN010	Da Hua Qiao											
CN011	Huang Deng											
CN012	Tuo Ba											
CN013	Li Di											
CN014	Wu Nong Long											

Table A-4.3: Hydropower Projects in the Lower Mainstream Mekong River Basin used in the Council Study Modeling

ID	Project Name	Year of Operation	Location		Catchment			Topographic	Water Level in Reservoir			Reservoir Volume				
			Long	Lat	Catchment areas	Annual Inflow	Annual volume	Detail of	Flood Water Level	Normal Water Level	Dead Water Level	Surface Area at FSL	Active Volume	Dead Volume	Total Volume	Rule Curve
					km2	m3/s	mill.m3	Relationship of V~A~Z	m.a.s.l	m.a.s.l	m.a.s.l	Km2	mill.m3	mill.m3	mill.m3	
M052	Mekong at Pakbeng	2022	19.844	101.019	218000.0	3170.0	99969.1	BDP2	No data	340.0	339.0	21.8	780.0	957.4	1737.4	BDP2
M053	Mekong at Luangprabang	2025	20.066	102.192	230000.0	3810.0	120152.2	BDP2	No data	320.0	318.0	59.0	119.6	1469.9	1589.5	BDP2
M054	Mekong at Xayabuly	2019	19.247	101.819	272000.0	3990.0	125828.6	BDP2	No data	275.0	268.0	49.0	212.0	514.02	726.02	BDP2
M055	Mekong at Paklay	2025	18.401	101.584	283000.0	4030.0	127090.1	BDP2	No data	240.0	237.0	83.8	316.5	1034.78	1351.28	BDP2
M056	Mekong at Sanakham	2025	17.833	101.550	292000.0	4160.0	131189.8	BDP2	No data	220.0	215.0	94.0	131.6	150.29	281.89	BDP2
M057	Mekong at Sangthong-Pakchom	2025	18.202	102.050	295500.0	4385.0	138285.4	BDP2	No data	192.0	190.0	80.5	807.7	289.2	1096.9	BDP2
M058	Mekong at Ban Kum	2025	15.418	105.587	418400.0	9149.0	288522.9	BDP2	No data	115.0	115.0	132.5	No Data	Not consistance	2110	BDP2
M059	Mekong at Latsua (Phou Ngoy)	2025	15.025	105.868	550000.0	9600.0	302745.6	BDP2	No data	97.5	95.5	87.0	530.0	Not consistance	Not correct	BDP2
M034	Mekong at Don sahong	2019	13.944	105.956	553000.0	10310.0	325136.2	BDP2	No data	74.5	72.0	2.9	115.0	Not consistance	Not correct	BDP2
M005	Sambor	TBD	12.000	105.450	646000.0	13950.0	439927.2	BDP2	No data	40.0	39.0	620.5	465.0	3794	4259	BDP2
M006	Stung Treng	TBD	13.593	106.007	555900.0	13714.0	432484.7	BDP2	No data	52.0	51.0	211.0	518.0	150.78	668.73	BDP2

ID	Project Name	Energy Generation				Sluice (Sed, other purpose)				Spillway with Gate				Overflow Spillway		
		Install Capacity	Firm Energy	Annual Energy	Time on using the install capacity	Width (BxH)	Inlet crest	Outlet crest	Qdesign	Crest	No. of Gate	Width (BxH)	Qdesign	Crest	Width (BxH)	Qdesign
		MW	GWh	GWh	Hours/year	m x m	m	m	m3/s	m			m3/s	m		m3/s
M052	Mekong at Pakbeng	912	4073	4846	No Data	No data: 1st priority update	No data: 1st priority update	No data: 1st priority update	No data: 1st priority update		No Data	No Data		312.5	No Data	3160
M053	Mekong at Luangprabang	1200	4205	8258	4735									No Data		4500
M054	Mekong at Xayabuly	1260	4180.9	5990	No Data									No Data		4500
M055	Mekong at Paklay	1320	4251.7	6460	3240									No Data		4500
M056	Mekong at Sanakham	660	3978.2	3697	No Data									No Data		2700
M057	Mekong at Sangthong-Pakchom	1079	5052	5318	No Data									No Data		4500
M058	Mekong at Ban Kum	1872	8012	8434	No Data									No Data		6000
M059	Mekong at Latsua (Phou Ngoy)	651	2314.92	3278	5840									No Data		6000
M034	Mekong at Don sahong	260	1988.7	2044	No Data					Need re-check			Need re-check	Need re-check		Need re-check
M005	Sambor	2600	2684	11740.2	4515									No Data		No Data
M006	Stung Treng	900	2937	5096.53	5663									No Data		No Data

ID	Project Name	Flow and Water Level					Rate Head			Powerhouse		
		Tailwater Level	Qmin (each turbine)	Qmax (each turbine)	Total Qdesign	Qmaintain P90%	Designed	Maximum	Minimum	No. Turbine	Turbine Efficiency	Elevation of turbine
		m	m3/s	m3/s	m3/s	m3/s	m	m	m		%	m
M052	Mekong at Pakbeng	BDP2	No Data	No Data	7250.0	No Data	16	No data: 1st priority update	No data: 1st priority update	No data: 1st priority update	No data: 1st priority update	No data: 1st priority update
M053	Mekong at Luangprabang	BDP2			4976.0	No Data	33					
M054	Mekong at Xayabuly	BDP2			5000.0	No Data	29					
M055	Mekong at Paklay	BDP2			4500.0	No Data	35					
M056	Mekong at Sanakham	BDP2			5500.0	No Data	13.5					
M057	Mekong at Sangthong-Pakchom	BDP2			5720.0	No Data	22					
M058	Mekong at Ban Kum	BDP2			11700.0	No Data	18.6					
M059	Mekong at Latsua (Phou Ngoy)	BDP2			10000.0	No Data	10.8					
M034	Mekong at Don sahong	BDP2			2400.0	No Data	17					
M005	Sambor	BDP2			17668.0	No Data	16.5					
M006	Stung Treng	BDP2			9834.0	No Data	11.6					

Table A-4.4: Hydropower Projects in Cambodia used in the Council Study Modeling

ID	Project Name	Year of Operation	Location		Catchment			Topographic	Water Level in Reservoir			Reservoir Volume				
			Long	Lat	Catchment areas	Annual Inflow	Annual volume	Detail of	Flood Water Level	Normal Water Level	Dead Water Level	Surface Area at FSL	Active Volume	Dead Volume	Total Volume	Rule Curve
					km2	m3/s	mill.m3	Relationship of V~A~Z	m.a.s.l	m.a.s.l	m.a.s.l	Km2	mill.m3	mill.m3	mill.m3	
C001	O Chum 2	1992	13.792	106.967	44.7	2.2	67.8	BDP2	No data	254.0	251.5	No Data	0.1	Not consistance	Not correct	BDP2
C002	Lower Se San 2	2017	13.553	106.200	49200.0	1306.0	41186.0	BDP2	No data	75.0	74.0	334.4	333.2	1459.3	1792.5	BDP2
C003	Battambang 1	No Information	12.800	102.900	2135.0	78.6	2478.7	BDP2	No data	77.0	58.0	92.0	1040.0	Not consistance	Not correct	BDP2
C004	Battambang 2	No Information	11.250	102.900	120.0	5.9	186.1	BDP2	No data	670.0	658.0	16.0	110.0	Not consistance	Not correct	BDP2
C007	Stung Pursat 1	No Information	12.533	103.550	1263.0	41.1	1296.1	BDP2	No data	195.0	170.0	81.4	1014.0	306	1320	BDP2
C008	Stung Pursat 2	No Information	12.283	103.617	2080.0	32.0	1009.2	BDP2	No data	50.0	41.0	No Data	295.0	Not consistance	Not correct	BDP2
C009	Lower Se San 3	No Information	14.032	107.024	15435.0	330.0	10406.9	BDP2	No data	140.0	118.0	726.9	14528.0	2372	16900	BDP2
C010	Prek Liang 1	No Information	14.217	107.251	917.0	40.2	1267.7	BDP2	No data	275.0	260.0	1.7	19.3	Not consistance	Not correct	BDP2
C011	Prek Liang 2	No Information	14.283	107.267	580.0	25.4	801.0	BDP2	No data	495.0	480.0	2.1	19.5	Not consistance	Not correct	BDP2
C012	Lower Sre Pok 3 (3A)	No Information	13.388	107.050	25311.0	713.0	22485.2	BDP2	No data	120.0	112.0	721.0	3931.0	1932	5863	BDP2
C013	Lower Sre Pok 4	No Information	13.038	107.450	13727.0	378.0	11920.6	BDP2	No data	148.0	146.0	33.0	44.0	160	204	BDP2
C014	Stung Sen	No Information	13.300	105.250	10540.0	145.0	4572.7	BDP2	No data	43.5	35.0	No Data	2890.0	Not consistance	Not correct	BDP2
C015	Se Kong	No Information	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	51.0	530	581	No Data
C016	Prek Por 1	No Information	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	94.0	68	162	No Data
C017	Prek Liang 1A	No Information	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	Not consistance	No Data	No Data
C018	Prek Ter 2	No Information	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	290.0	377	667	No Data
C019	Prek ter 3	No Information	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	981.0	609	1590	No Data
C020	Prek Chhlong 2	No Information	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	128.0	365	493	No Data
C021	Se San 1	No Information	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	117.0	53	170	No Data

ID	Project Name	Energy Generation				Sluice (Sed, other purpose)				Spillway with Gate				Overflow Spillway		
		Install Capacity	Firm Energy	Annual Energy	Time on using the install capacity	Width (BxH)	Inlet crest	Outlet crest	Qdesign	Crest	No. of Gate	Width (BxH)	Qdesign	Crest	Width (BxH)	Qdesign
		MW	GWh	GWh	Hours/year	m x m	m	m	m3/s	m			m3/s	m		m3/s
C001	O Chum 2	1	1.2	3	No Data					3.65			278			
C002	Lower Se San 2	400	611	1953.9	4885									No Data		No Data
C003	Battambang 1	24	105.66	120	2832									50		1250
C004	Battambang 2	36	114	187	No Data					Need re-check			Need re-check	Need re-check		Need re-check
C007	Stung Pursat 1	40	321.4	335	8760					183			6370			
C008	Stung Pursat 2	10	42.1	42.1	No Data					Need re-check			Need re-check	Need re-check		Need re-check
C009	Lower Se San 3	260	954.3	1310.2	600									No Data		No Data
C010	Prek Liang 1	72	173.4	324.3	No Data					275			3811			
C011	Prek Liang 2	56	142.1	259.6	No Data					495			1742			
C012	Lower Sre Pok 3 (3A)	300	1141.4	1201.4	4005	No Data	No Data	No Data	No Data	Need re-check	No Data	No Data	Need re-check	Need re-check	No Data	Need re-check
C013	Lower Sre Pok 4	48	198.6	220.7	4598					Need re-check			Need re-check	Need re-check		Need re-check
C014	Stung Sen	23	124.2	124.2	No Data					Need re-check			Need re-check	Need re-check		Need re-check
C015	Se Kong	148	No Data	551	No Data					No Data			No Data	No Data		No Data
C016	Prek Por 1	5	No Data	32	No Data					No Data			No Data	No Data		No Data
C017	Prek Liang 1A	22	No Data	106	No Data					No Data			No Data	No Data		No Data
C018	Prek Ter 2	11	No Data	55	No Data					No Data			No Data	No Data		No Data
C019	Prek ter 3	15	No Data	92	No Data					No Data			No Data	No Data		No Data
C020	Prek Chhlong 2	12	No Data	51	No Data					No Data			No Data	No Data		No Data
C021	Se San 1	90	No Data	480	No Data					No Data			No Data	No Data		No Data

Table A-4.4 (contd.): Hydropower Projects in Cambodia used in the Council Study Modeling (contd.)

ID	Project Name	Flow and Water Level					Rate Head			Powerhouse		
		Tailwater Level	Qmin (each turbine)	Qmax (each turbine)	Total Qdesign	Qmaintain P90%	Designed	Maximum	Minimum	No. Turbine	Turbine Efficiency	Elevation of turbine
		m	m3/s	m3/s	m3/s	m3/s	m	m	m		%	m
C001	O Chum 2	BDP2			3.8	No Data	32.6					
C002	Lower Se San 2	BDP2			2118.0	No Data	28.5					
C003	Battambang 1	BDP2			27.0	No Data	34					
C004	Battambang 2	BDP2			5.8	No Data	450					
C007	Stung Pursat 1	BDP2			38.8	No Data	122					
C008	Stung Pursat 2	BDP2			57.0	No Data	23					
C009	Lower Se San 3	BDP2			760.0	No Data	40.5					
C010	Prek Liang 1	BDP2			66.8	No Data	132.5					
C011	Prek Liang 2	BDP2			40.1	No Data	173					
C012	Lower Sre Pok 3 (3A)	BDP2	No Data	No Data	1699.2	No Data	20	No Data	No Data	No Data	No Data	No Data
C013	Lower Sre Pok 4	BDP2			736.8	No Data	7.5					
C014	Stung Sen	BDP2			145.0	No Data	19					
C015	Se Kong	No Data			No Data	No Data	No Data					
C016	Prek Por 1	No Data			No Data	No Data	No Data					
C017	Prek Liang 1A	No Data			No Data	No Data	No Data					
C018	Prek Ter 2	No Data			No Data	No Data	No Data					
C019	Prek ter 3	No Data			No Data	No Data	No Data					
C020	Prek Chhlong 2	No Data			No Data	No Data	No Data					
C021	Se San 1	No Data			No Data	No Data	No Data					

The main gaps and weaknesses which needed to be addressed were as follows:

- Lacking some basic characteristics in some projects: Tail-water, Spillway discharge, Sand and Sediment Sluice.
- Lacking the Relationship of Volume - Surface Area - Elevation of reservoir.
- Lacking the Operation rule curves, Number of turbines, Discharge of each turbine, Turbine efficiency, Rated head

Table A-4.5: Hydropower Projects in Lao PDR used in the Council Study Modeling

ID	Project Name	Year of Operation	Location		Catchment			Topographic	Water Level in Reservoir			Reservoir Volume				
			Long	Lat	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Rule Curve
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table A-4.5 (contd.): Hydropower Projects in Lao PDR used in the Council Study Modeling (contd.)

ID	Project Name	Energy Generation: Install Capacity MW	Firm Energy GWh	Annual Energy GWh	Time in using the install capacity Hour/year	Water used (other purposes): [illegible]	[illegible]	[illegible]	[illegible]	Spillway with Gate: Crest m	No. of Gate	Width (B*H)	Qdesign m3/s	Overflow Spillway: Crest m	Width (B*H)	Qdesign m3/s
L001	Nam Ngum 1	155	890	1,025.0	No Data									No Data		No Data
L002	Nam Dong	1	4	4.8	No Data					605/604.5			98			
L003	Xelabam	5	20	25.0	No Data					115.5			10500			
L004	Xeset 1	45	82.2	133.9	No Data					492			986			
L005	Theun-Hinboun	220	1300	1,560.0	No Data					397.6			1580			
L006	Houayho	150	397	450.0	No Data					885			298			
L007	Nam Leuk	60	149	218.0	No Data					405			2100			
L008	Nam Mang 3	40	113	150.0	No Data					750			770			
L009	Nam Ko	1.5	3	8.0	No Data					525			1297			
L010	Nam Ngay	1.2	2.8	5.2	No Data					525			1507			
L011	Nam Theun 2	1080	5270	6,000.0	No Data									No Data		No Data
L012	Xekaman 3	250	485.7	985.0	3812									No Data		No Data
L013	Xeset 2	76	234	309.8	4066					813			1536			
L014	Nam Ngum 2	615	1387	2,300.0	No Data									No Data		No Data
L015	Nam Lik 1-2	100	334	435.0	No Data									252		1940
L016	Nam Ngum 5	120	307	507.0	No Data									1015		1115
L017	Xekaman 1	290	Need re-check	1,096.6	No Data									170		190
L018	Xekaman-Sanxay	32	122	121.0	No Data					123			11800			
L019	Theun-Hinboun expansion	220	1300	1,460.0	No Data					397.6			1580			
L020	Theun-Hinboun exp. (NG8)	60	161	316.0	No Data									400		200
L021	Nam Ngum 3	480	1659	2,146.0	No Data									No Data		No Data
L022	Nam Theun 1	400	1424	2,371.0	No Data									No Data		No Data
L023	Nam Ngiep 1	272	1300	1,507.0	No Data									261		200
L024	Nam Ngiep regulating dam	18	100	100.0	No Data									No Data		No Data
L025	Nam Tha 1	168	530	756.0	No Data									No Data		No Data
L026	Nam Long	5	33.71	37.0	No Data					1055			971			
L027	Xepian Xenamnoy	410	1716	1,748.0	No Data					786.5			1361			
L028	Xekatam	60	284	381.0	No Data					910			840			
L030	Nam Kong 1	150	408	469.0	No Data									259.8		2.8
L031	Xe Kong 3up	105	50.11	455.6	No Data									131		2430
L032	Xe Kong 3d	100	25.93	375.7	No Data									107		4864
L033	Xe Kong 5	330	1017	1,613.5	No Data									No Data		No Data
L035	Nam Ou 1	180	500.096	719.0	No Data									327		8443
L036	Nam Ou 2	120	254.916	546.0	No Data									890		7546
L037	Nam Ou 3	210	608.332	836.0	No Data									343		8546
L038	Nam Ou 4	132	237.396	519.0	No Data									382		4058
L039	Nam Ou 5	240	758.284	1,049.0	No Data									396		4492
L040	Nam Ou 6	180	717.444	739.0	No Data									429		3501
L041	Nam Ou 7	210	702.553	838.0	No Data									524		2511
L042	Nam Lik 1	64	118	256.0	No Data									No Data		No Data
L043	Nam San 3A	69	274	278.4	No Data					1435			730			
L044	Nam Pha	180	444	730.0	No Data									No Data		No Data
L045	Nam Seuang 1	42	163.4	167.0	No Data									No Data		No Data
L046	Nam Seuang 2	134	525.6	621.0	No Data									No Data		No Data
L047	Nam Ngai 1	100	333.4	434.1	No Data									No Data		No Data
L048	Nam Beng	36	77.4	145.0	No Data									No Data		No Data
L049	Nam Feuang 1	28	28.7	113.2	No Data									299.5		1200
L050	Nam Feuang 2	23	27.7692	110.5	No Data	No Data	No Data	No Data	No Data	Need re-check	No Data	No Data	Need re-check	Need re-check	No Data	Need re-check
L051	Nam Feuang 3	26	21.8124	98.5	No Data					Need re-check			Need re-check	Need re-check		Need re-check
L060	Xe Kon 5	47.6	528.5	164.2	No Data									No Data		No Data
L061	Xe Kaman 2A	64	175	241.6	No Data									No Data		No Data
L062	Xe Kaman 2B	100	203	380.5	No Data									No Data		No Data
L063	Xe Kaman 4	54	262.5	267.7	No Data									No Data		No Data
L065	Dak E Mule	130	415	506.0	No Data					790			1917			
L067	Nam Khan 2	130	465	558.0	No Data									No Data		No Data
L068	Nam Khan 3 (Down)	60	255.83	240.6	No Data					560			1955			
L069	Nam Ngum 4	220	236.52	267.7	No Data					1040			1320			
L071	Nam Ngum 1 (down) Lower Nam ...	110	498	526.0	No Data									No Data		No Data
L072	Nam Pay	86	168.5	419.5	No Data					1120			180			
L073	Nam Mang 1	57	180.92	201.0	No Data									No Data		No Data
L074	Nam Pouy 1	60	143	294.0	No Data									No Data		No Data
L075	Nam Poun	56	281	243.8	No Data									No Data		No Data
L076	Nam Ngao	20	108.4	110.6	No Data					880			880			
L077	Nam Chian	104	480	444.5	No Data					1040			894.4			
L078	Nam Ngiep (Nam Ngiep 3A)	44	165.4	153.2	No Data									No Data		No Data
L079	Nam Pot	15	96.26	70.5	No Data					1145			251			
L080	Nam San 3B	45	141	177.5	No Data					520			1004			
L083	Nam Phak	5.1	21.7	28.1	No Data									No Data		No Data
L084	Nam Hinboun 1	45	140	173.6	No Data									No Data		No Data
L085	Nam Hinboun 2	13	56.9	58.5	No Data					1055			224			
L087	Xe Neua	53	196	230.0	No Data									No Data		No Data
L088	Nam Theun 4	80	125.1	190.0	No Data									No Data		No Data
L089	Nam Mouan	100	305	439.3	No Data									No Data		No Data
L090	Xe Bang Hieng 2	50	70	73.0	No Data									No Data		No Data
L092	Xe Set 3	23	50	82.0	No Data					1022			332.3			
L093	Xe Bang Nouan	35	76.84	79.1	No Data					280			856			
L094	Xe Lanong 1	70	131.4	256.8	No Data									No Data		No Data
L095	Xe Lanong 2	35	87.6	142.7	No Data									No Data		No Data
L096	Nam Phak (Houaylamphan)	150	279	498.0	No Data					820			287			
L097	Xe Nam Noy 5	20	103	124.0	No Data					890			416			
L098	Houay Lamphan Gnai	84.8	227	403.0	No Data									No Data		No Data
L099	Nam Kong 2	66	256	264.4	No Data									No Data		No Data
L100	Xenu	30	227	125.6	No Data									No Data		No Data
L102	Nam Mouw	1.2	Need re-check	67.0	No Data					Need re-check			Need re-check	Need re-check		Need re-check
L103	Nam Ngiep 2	180	Need re-check	723.0	No Data					Need re-check			Need re-check	Need re-check		Need re-check
L104	Xenamnoy 1	14.8	Need re-check	100.0	No Data					Need re-check			Need re-check	Need re-check		Need re-check
L105	Nam Sane	14	Need re-check	46.6	No Data					Need re-check			Need re-check	Need re-check		Need re-check
L106	Nam Hinboun	30	Need re-check	155.2	No Data					Need re-check			Need re-check	Need re-check		Need re-check
L108	Nam Bak	160	Need re-check	744.0	No Data					Need re-check			Need re-check	Need re-check		Need re-check
L112	Nam Phouan	52	Need re-check	229.0	No Data					Need re-check			Need re-check	Need re-check		Need re-check
L113	Sekong Downstream	75	Need re-check	367.8	No Data					Need re-check			Need re-check	Need re-check		Need re-check
L115	Nam Ang Tha Beng	40.95	Need re-check	181.3	No Data					Need re-check			Need re-check	Need re-check		Need re-check
L116	Xepian-Houaysoy	115	Need re-check	292.5	No Data					Need re-check			Need re-check	Need re-check		Need re-check
L117	Tad Salen	3.2	Need re-check	17.0	No Data					Need re-check			Need re-check	Need re-check		Need re-check
L118	Nam Kong 3	45	Need re-check	170.0	No Data					Need re-check			Need re-check	Need re-check		Need re-check

Table A-4.5 (contd.): Hydropower Projects in Lao PDR used in the Council Study Modeling (contd.)

ID	Project Name	Flow and Water Level					Rate Head			Powerhouse		
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Designed (m)	Maximum (m)	Minimum (m)	[illegible]	Turbine Efficiency (%)	[illegible] (%)
L001	Nam Ngum 1	BDP2			414.4	No Data	78.8					
L002	Nam Dong	BDP2			1.6	No Data	136.5					
L003	Xekaman	BDP2			38.0	No Data	17					
L004	Xeset 1	BDP2			33.0	No Data	153.4					
L005	Theun-Hinboun	BDP2			206.5	No Data	225.5					
L006	Houayho	BDP2			23.0	No Data	748.3					
L007	Nam Leuk	BDP2			78.5	No Data	174.2					
L008	Nam Mang 3	BDP2			8.3	No Data	513.2					
L009	Nam Ko	BDP2			5.4	No Data	34.5					
L010	Nam Ngay	BDP2			8.5	No Data	17					
L011	Nam Theun 2	BDP2			374.0	No Data	350.6					
L012	Xekaman 3	BDP2			62.2	No Data	102					
L013	Xeset 2	BDP2			79.5	No Data	246					
L014	Nam Ngum 2	BDP2			449.0	No Data	129.5					
L015	Nam Lik 1-2	BDP2			187.0	No Data	74.5					
L016	Nam Ngum 5	BDP2			42.9	No Data	377					
L017	Xekaman 1	BDP2			344.0	No Data	101.2					
L018	Xekaman-Sanxay	BDP2			378.0	No Data	12.2					
L019	Theun-Hinboun expansion	BDP2			110.0	No Data	225.5					
L020	Theun-Hinboun exp. (NG8)	BDP2			134.0	No Data	47					
L021	Nam Ngum 3	BDP2			103.0	No Data	351					
L022	Nam Theun 1	BDP2			519.9	No Data	138					
L023	Nam Ngiep 1	BDP2			230.0	No Data	137					
L024	Nam Ngiep-regulating dam	BDP2			380.0	No Data	10					
L025	Nam Tha 1	BDP2			289.5	No Data	60.5					
L026	Nam Long	BDP2			2.8	No Data	245					
L027	Xepian Xenamnoy	BDP2			80.0	No Data	630					
L028	Xekatam	BDP2			16.0	No Data	455					
L030	Nam Kong 1	BDP2			44.5	No Data	186					
L031	Xe Kong 3up	BDP2			460.0	No Data	33.7					
L032	Xe Kong 3d	BDP2			566.0	No Data	19.2					
L033	Xe Kong 5	BDP2			210.0	No Data	185					
L035	Nam Ou 1	BDP2			1,506.0	No Data	16					
L036	Nam Ou 2	BDP2			994.0	No Data	15					
L037	Nam Ou 3	BDP2			949.0	No Data	26.5					
L038	Nam Ou 4	BDP2			710.0	No Data	21					
L039	Nam Ou 5	BDP2			567.0	No Data	49					
L040	Nam Ou 6	BDP2			345.0	No Data	88					
L041	Nam Ou 7	BDP2			275.9	No Data	104					
L042	Nam Lik 1	BDP2			488.0	No Data	19.5					
L043	Nam San 3A	BDP2			13.0	No Data	676					
L044	Nam Pha	BDP2			282.3	No Data	126					
L045	Nam Seuang 1	BDP2			130.1	No Data	35.7					
L046	Nam Seuang 2	BDP2			119.8	No Data	122.7					
L047	Nam Ngiep 1	BDP2			107.9	No Data	97.5					
L048	Nam Beng	BDP2			43.2	No Data	70					
L049	Nam Feuang 1	BDP2			57.3	No Data	37					
L050	Nam Feuang 2	BDP2	No Data	No Data	27.5	No Data	130	No Data	No Data	No Data	No Data	No Data
L051	Nam Feuang 3	BDP2			11.3	No Data	211					
L060	Xe Pon 3	BDP2			25.0	No Data	210					
L061	Xe Kaman 2A	BDP2			155.0	No Data	68.6					
L062	Xe Kaman 2B	BDP2			90.0	No Data	78.8					
L063	Xe Kaman 4	BDP2			39.2	No Data	495					
L065	Dak E Mule	BDP2			27.4	No Data	433.8					
L067	Nam Khan 2	BDP2			209.5	No Data	138.7					
L068	Nam Khan 3 (Down)	BDP2			176.8	No Data	80					
L069	Nam Ngum 4	BDP2			103.5	No Data	235					
L071	Nam Ngum (down) Lower dam	BDP2			776.7	No Data	13.6					
L072	Nam Hey	BDP2			87.0	No Data	700					
L073	Nam Pheng 1	BDP2			77.8	No Data	90					
L074	Nam Poun 1	BDP2			60.0	No Data	80					
L075	Nam Poun	BDP2			148.8	No Data	76					
L076	Nam Ngao	BDP2			6.6	No Data	347.6					
L077	Nam Chian	BDP2			23.3	No Data	900					
L078	Nam Ngeu (Nam Ngiep 3A)	BDP2			34.0	No Data	189.5					
L079	Nam Pot	BDP2			3.3	No Data	701.3					
L080	Nam San 3B	BDP2			17.5	No Data	290					
L083	Nam Phak	BDP2			Need re-check	No Data	Need re-check					
L084	Nam Hinboun 1	BDP2			Need re-check	No Data	Need re-check					
L085	Nam Hinboun 2	BDP2			Need re-check	No Data	Need re-check					
L087	Xe Neua	BDP2			46.8	No Data	64					
L088	Nam Theun 4	BDP2			29.5	No Data	137					
L089	Nam Mouan	BDP2			205.7	No Data	701.2					
L090	Xe Bang Hieng 2	BDP2			42.6	No Data	44.5					
L092	Xe Set 3	BDP2			116.0	No Data	146					
L093	Xe Bang Nouan	BDP2			19.8	No Data	318.4					
L094	Xe Lanong 1	BDP2			99.0	No Data	218.5					
L095	Xe Lanong 2	BDP2			24.5	No Data	168					
L096	Nam Phak (Houykatam)	BDP2			13.0	No Data	674					
L097	Xe Nam Noy 5	BDP2			3.9	No Data	572					
L098	Houay Lamphan Gnai	BDP2			11.4	No Data	526.4					
L099	Nam Kong 2	BDP2			78.2	No Data	87.9					
L100	Xeset	BDP2			105.0	No Data	29					
L102	Nam Nhoua	BDP2			Need re-check	No Data	Need re-check					
L103	Nam Ngiep 2	BDP2			47.6	No Data	445					
L104	Xenamnoy 1	BDP2			Need re-check	No Data	73.6					
L105	Nam Sane	BDP2			Need re-check	No Data	78.4					
L106	Nam Hinboun	BDP2			445.7	No Data	17.1					
L108	Nam Bak	BDP2			44.4	No Data	709.4					
L112	Nam Phouan	BDP2			42.5	No Data	146.2					
L113	Sekong Downstream	BDP2			1,035.0	No Data	8.1					
L115	Nam Ang Tha Beng	BDP2			24.5	No Data	14.2					
L116	Xepian Houaysoy	BDP2			142.0	No Data	94.94					
L117	Tad Salen	BDP2			Need re-check	No Data	Need re-check					
L118	Nam Kong 3	BDP2			69.8	No Data	84.5					

Table A-4.6: Hydropower Projects in Thailand used in the Council Study Modeling

ID	Project Name	Year of Operation	Location		Catchment			Topographic	Water Level in Reservoir			Reservoir Volume				
			Long	Lat	Catchment areas	Annual Inflow	Annual volume	Detail of	Flood Water Level	Normal Water Level	Dead Water Level	Surface Area at FSL	Active Volume	Dead Volume	Total Volume	Rule Curve
					km2	m3/s	mill.m3	Relationship of V~A~Z	m.a.s.l	m.a.s.l	m.a.s.l	Km2	mill.m3	mill.m3	mill.m3	
T001	Chulabhorn	1972	16.533	101.650	545.0	164.0	5171.9	BDP2	No data	759.0	739.0	12.0	144.5	35.5	180	BDP2
T002	Huai Kum	1982	16.413	101.797	282.0	76.0	2396.7	BDP2	No data	312.0	298.0	2.4	20.0	0	20	BDP2
T003	Nam Pung	1965	16.972	103.981	296.0	125.0	3942.0	BDP2	No data	284.0	270.0	21.6	156.8	13.2	170	BDP2
T004	Pak Mun	1994	15.286	105.474	117000.0	24000.0	756864.0	BDP2	No data	108.0	105.5	60.0	125.0	100	225	BDP2
T005	Sirindhorn	1971	15.203	105.424	2097.0	1653.0	52129.0	BDP2	No data	142.2	137.2	289.0	1135.0	835	1970	BDP2
T006	Ubol Ratana	1966	16.767	102.633	12104.0	2309.0	72816.6	BDP2	No data	182.0	175.5	401.2	1695.0	555	2250	BDP2
T007	Lam Ta Khong P.S.	2001	14.803	101.551	1430.0	261.0	8230.9	BDP2	No data	277.0	261.0	No Data	299.6	20.3	319.9	BDP2

ID	Project Name	Energy Generation				Sluice (Sed, other purpose)				Spillway with Gate				Overflow Spillway		
		Install Capacity	Firm Energy	Annual Energy	Time on using the install capacity	Width (BxH)	Inlet crest	Outlet crest	Qdesign	Crest	No. of Gate	Width (BxH)	Qdesign	Crest	Width (BxH)	Qdesign
		MW	GWh	GWh	Hours/year	m x m	m	m	m3/s	m			m3/s	m		m3/s
T001	Chulabhorn	40	27.9	59										No Data		No Data
T002	Huai Kum	1.18	0.6	2										No Data		No Data
T003	Nam Pung	6.3	4.5	17						284			300			
T004	Pak Mun	136	84	280	No Data	No Data	No Data	No Data	No Data		No Data	No Data		No Data	No Data	No Data
T005	Sirindhorn	36	25.8	90										No Data		No Data
T006	Ubol Ratana	25.2	16.8	56										No Data		No Data
T007	Lam Ta Khong P.S.	500	Need re-check	400						Need re-check			Need re-check	Need re-check		Need re-check

ID	Project Name	Flow and Water Level					Rate Head			Powerhouse		
		Tailwater Level	Qmin (each turbine)	Qmax (each turbine)	Total Qdesign	Qmaintain P90%	Designed	Maximum	Minimum	No. Turbine	Turbine Efficiency	Elevation of turbine
		m	m3/s	m3/s	m3/s	m3/s	m	m	m		%	m
T001	Chulabhorn	BDP2			13.3	No Data	366					
T002	Huai Kum	BDP2			5.5	No Data	23					
T003	Nam Pung	BDP2			8.6	No Data	85					
T004	Pak Mun	BDP2	No Data	No Data	1320.0	No Data	11.6	No Data	No Data	No Data	No Data	No Data
T005	Sirindhorn	BDP2			141.0	No Data	30.3					
T006	Ubol Ratana	BDP2			176.6	No Data	16					
T007	Lam Ta Khong P.S.	BDP2			165.0	No Data	360					

The main gaps and weaknesses which needed to be addressed were as follows:

- Lacking some basic characteristic in some projects: Tail-water, Spillway discharge, Sand and Sediment Sluice
- Lacking the Relationship of Volume ~ Surface Area ~ Elevation of reservoir.
- Lacking the Operation rule-curve, Number of turbine, Discharge of each turbine, Turbine efficiency

Table A-4.7: Hydropower Projects in Vietnam used in the Council Study Modeling

ID	Project Name	Year of Operation	Location		Catchment			Topographic	Water Level in Reservoir			Reservoir Volume				
			Long	Lat	Catchment areas	Annual Inflow	Annual volume	Detail of	Flood Water Level	Normal Water Level	Dead Water Level	Surface Area at FSL	Active Volume	Dead Volume	Total Volume	Rule Curve
					km2	m3/s	mill.m3	Relationship of V~A~Z	m.a.s.l	m.a.s.l	m.a.s.l	Km2	mill.m3	mill.m3	mill.m3	
V001	Upper Kontum	2014	14.711	108.238	350.0	16.7	526.7	BDP2	No data	1170.0	1146.0	8.6	122.7	51	173.7	BDP2
V002	Plei Krong	2009	14.408	107.861	3216.0	128.0	4036.6	BDP2	No data	570.0	537.0	53.3	948.0	100.7	1048.7	BDP2
V003	Yali	2002	14.223	107.793	7455.0	262.0	8262.4	BDP2	No data	515.0	490.0	64.5	779.0	258.08	1037.1	BDP2
V004	Se San 3	2006	14.217	107.700	7788.0	274.0	8640.9	BDP2	No data	304.5	303.2	3.4	3.8	88.2	92	BDP2
V005	Se San 3A	2007	14.106	107.655	8084.0	283.0	8924.7	BDP2	No data	239.0	238.5	8.8	4.0	76.6	80.6	BDP2
V006	Se San 4	2010	13.967	107.500	9326.0	328.9	10372.2	BDP2	No data	215.0	210.0	58.4	264.2	629.14	893.3	BDP2
V007	Se San 4A	2011	13.933	107.466	9368.0	330.0	10406.9	BDP2	No data	155.2	150.0	1.8	7.5	5.6	13.1	BDP2
V008	Duc Xuyen	No Information	12.143	108.101	1100.0	35.7	1125.8	BDP2	No data	560.0	551.0	77.3	413.4	1336.37	1749.78	BDP2
V009	Buon Tua Srah	2009	12.285	108.048	2930.0	102.0	3216.7	BDP2	No data	487.5	467.5	37.1	522.6	264.4	787	BDP2
V010	Buon Kuop	2009	12.524	107.931	7980.0	217.0	6843.3	BDP2	No data	412.0	409.0	5.6	25.6	48.15	73.78	BDP2
V011	Dray Hlinh 2	2007	12.677	107.913	8880.0	241.0	7600.2	BDP2	No data	302.0	299.0	No Data	1.5	1.4	2.9	BDP2
V012	Sre Pok 3	2010	12.754	107.861	9410.0	250.6	7902.9	BDP2	No data	272.0	267.0	17.7	62.9	156.14	218.99	BDP2
V013	Sre Pok 4	2010	12.873	107.781	9568.0	273.0	8609.3	BDP2	No data	207.0	204.0	3.8	8.4	20.88	29.32	BDP2
V014	Dray Hlinh 1	1990	12.677	107.913	8880.0	241.0	7600.2	BDP2	No data	302.0	299.0	No Data	1.5	1.4	2.9	BDP2
V015	Sre Pok 4A	2013	12.894	198.313	9560.0	245.0	7726.3	BDP2	No data	186.2	185.6	No Data	0.1	1.51	1.6	BDP2

ID	Project Name	Energy Generation				Sluice (Sed, other purpose)				Spillway with Gate				Overflow Spillway		
		Install Capacity	Firm Energy	Annual Energy	Time on using the install capacity	Width (BxH)	Inlet crest	Outlet crest	Qdesign	Crest	No. of Gate	Width (BxH)	Qdesign	Crest	Width (BxH)	Qdesign
		MW	GWh	GWh	Hours/year	m x m	m	m	m3/s	m			m3/s	m		m3/s
V001	Upper Kontum	250	801.54	1056.4	4224									No Data		No Data
V002	Plei Krong	100	286.452	500.793	4172									No Data		No Data
V003	Yali	720	1991.85	3868.392	5081									No Data		No Data
V004	Se San 3	260	649.116	1325.354	4170									No Data		No Data
V005	Se San 3A	96	236.52	479.3	4438									No Data		No Data
V006	Se San 4	360	932.064	1649	3895									No Data		No Data
V007	Se San 4A	63	310.078	296.9	4731					155.2			No Data			
V008	Duc Xuyen	58	146.292	181.3	3380	No Data	No Data	No Data	No Data		No Data	No Data		No Data	No Data	No Data
V009	Buon Tua Srah	86	199.728	358.4	4170									No Data		No Data
V010	Buon Kuop	280	613.2	1459	5209									No Data		No Data
V011	Dray Hlinh 2	16	78.139	94	5312					302			7170			
V012	Sre Pok 3	220	440.628	1002	4819									No Data		No Data
V013	Sre Pok 4	80	142.437	360	4705									No Data		No Data
V014	Dray Hlinh 1	12	78.14	100	8060					302			7170			
V015	Sre Pok 4A	64	124.041	301.5	4711					Need re-check			Need re-check	Need re-check		Need re-check

Table A-4.7 (contd.): Hydropower Projects in Vietnam used in the Council Study Modeling (contd.)

ID	Project Name	Flow and Water Level					Rate Head			Powerhouse		
		Tailwater Level	Qmin (each turbine)	Qmax (each turbine)	Total Qdesign	Qmaintain P90%	Designed	Maximum	Minimum	No. Turbine	Turbine Efficiency	Elevation of turbine
		m	m3/s	m3/s	m3/s	m3/s	m	m	m		%	m
V001	Upper Kontum	BDP2	No Data	No Data	30.5	No Data	904.1	No Data	No Data	No Data	No Data	No Data
V002	Plei Krong	BDP2			367.6	No Data	31					
V003	Yali	BDP2			424.0	No Data	190					
V004	Se San 3	BDP2			486.0	No Data	60.5					
V005	Se San 3A	BDP2			500.0	No Data	21.5					
V006	Se San 4	BDP2			719.0	No Data	56					
V007	Se San 4A	BDP2			594.2	No Data	63					
V008	Duc Xuyen	BDP2			93.0	No Data	71					
V009	Buon Tua Srah	BDP2			204.9	No Data	46.5					
V010	Buon Kuop	BDP2			316.0	No Data	98.5					
V011	Dray Hlinh 2	BDP2			101.0	No Data	18.5					
V012	Sre Pok 3	BDP2			412.8	No Data	60					
V013	Sre Pok 4	BDP2			468.9	No Data	17.07					
V014	Dray Hlinh 1	BDP2			94.9	No Data	15.8					
V015	Sre Pok 4A	BDP2			498.0	No Data	14.8					

The main gaps and weaknesses which needed to be addressed were as follows:

- Lacking some basic characteristic in some projects: Tail-water, Spillway discharge, Sand and Sediment Sluice....
- Lacking the Relationship of Volume ~ Surface Area ~ Elevation of reservoir.
- Lacking the Operation rule-curve, Number of turbine, Discharge of each turbine, Turbine efficiency.

Hydropower Thematic Data Gap Filling Methodology for Council Study Modelling

After reviewing and checking available data for the hydropower developments for consistency and completeness, approaches for dat gap-filling were elaborated and implemented.

For unavailable ***turbine design discharge data***, the following equation was used:

$$P = Q * 9.81 * \gamma * H$$

In which:

P: Energy production (MW)

ɣ: Turbine efficiency

H: Head difference (m)

Q Turbine discharge

For unavailable ***maximum spillway discharge data***, the following equation was used and as shown in the diagram:

$$Q = 1.7 * L * H^{1.5}$$

In which:

L: Width of spillway (m)

H: Head (m)

Q: Volume of Spillway discharge

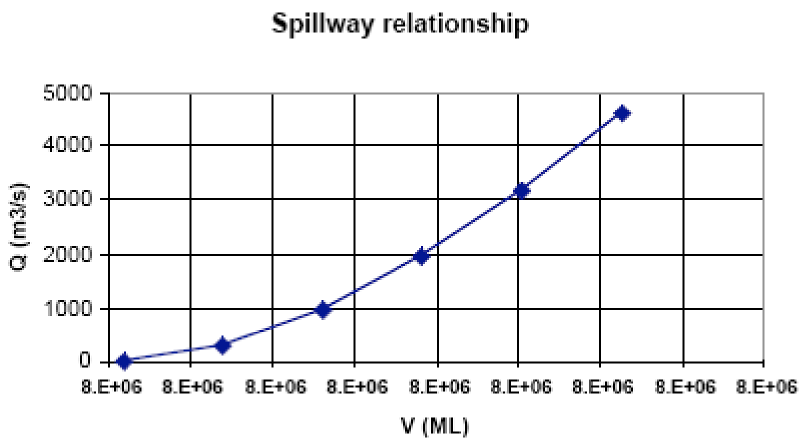

Figure A-4.1: Relationship of maximum spillway discharge

For the Relationship of Volume - Surface Area - Elevation, the following equation was used in the estimations and as shown in the diagram:

$$f = f(Z, L, \text{river slope}, \text{valley slope})$$

In which:

Z: Elevation of DEM where project is located (m)

L: Length of river corresponding with each Z level (m)

River slope: Slope of river (first point to dam located point)

Valley slope: Slope of DEM where project located (right and left river bank)

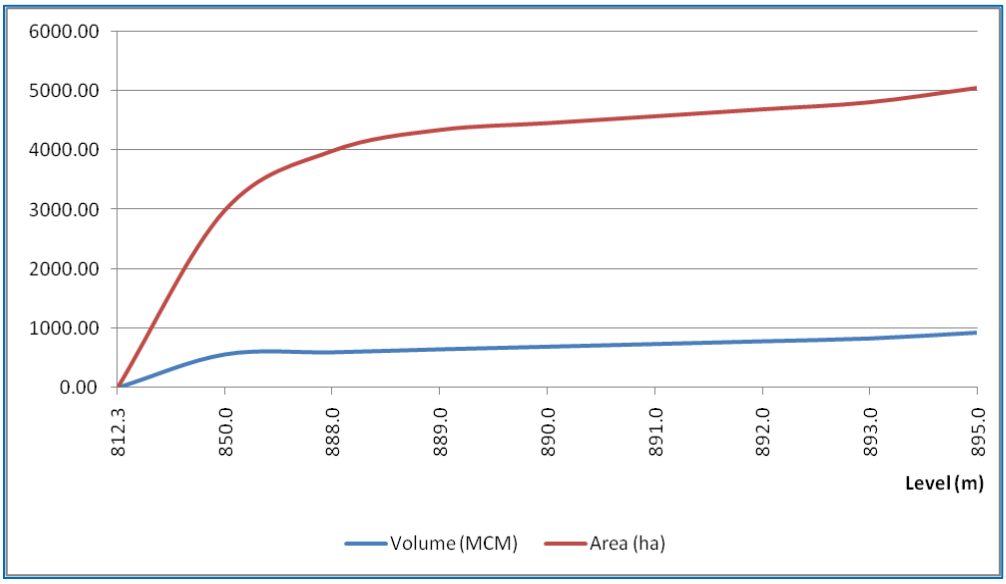

Figure A-4.2: Relationship of Volume - Surface Area - Elevation

Hydropower Plant Operation Rule Curves

Plant operational rule curves were designed for the hydropower plants as described in the Council Study Modelling reports. The following main considerations were included:

1. Prevent the reservoir from emptying until the end of the dryest season on record
2. Allow the reservoir to fill up by the end of the dryest wet season on record
3. Maximize annual energy generation

The first two objectives are met by designing a lower boundary to the fraction of live storage that must be maintained. This analysis only involves knowledge of inflow water volumes and the live storage of the reservoir.

The third objective is met by designing an upper boundary that balances the gains in energy production resulting from operating at high reservoir levels (higher head) and the losses of energy resulting from spilled water (lower turbine discharge). This analysis involves knowledge of the plant characteristics, specifically the reservoir volume-elevation relationship, the tail-water level of the plant and the installed capacity and design discharge of the plant.

Data is prepared in sheet "RULE" of the excel project file. The sheet includes a means of estimating data that may not be available as follows:

- Design discharge and tailwater level can be derived automatically from data on installed capacity, head, efficiency and reservoir operating limits.
- The reservoir volume-elevation table can be automatically calculated from data on live storage and reservoir operating limits by means of a calculation table where the user can adjust river bed and valley slopes until the volume-elevation table matches the required live storage.

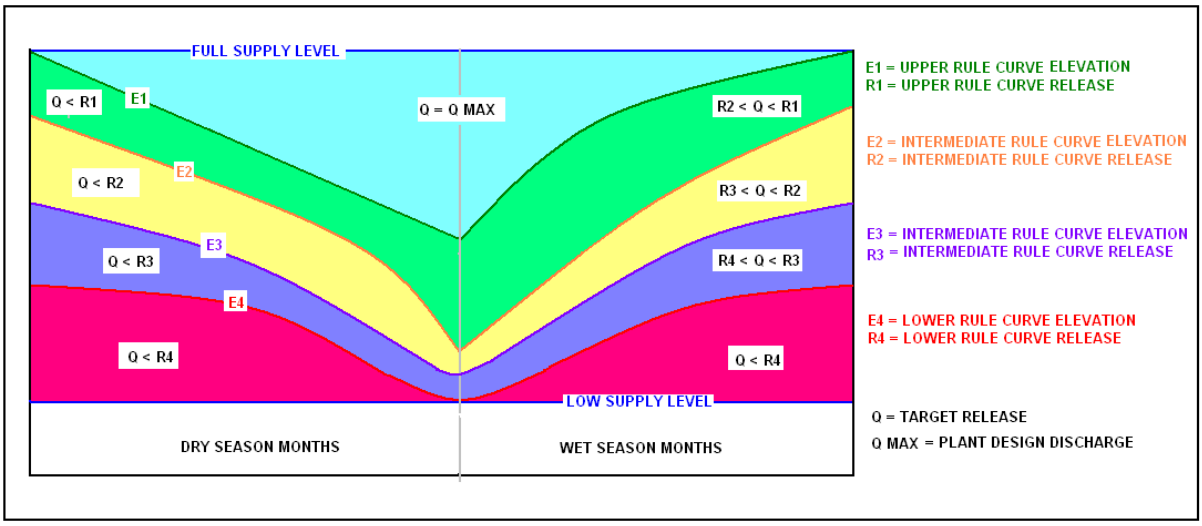

Figure A-4.3: Defining the zone for operation curve options

Annex 5: Model Outputs

A5.1 Results and Outputs for Main Scenarios from IQQM Modelling

The output and results of the IQQM modelling of the hydropower projects in the main scenarios is presented in terms of:

(1) Energy Production

(2) Evaporation from Reservoirs

(3) Releases & Spill

(4) Inflow to Dams

(5) Annual Current Volume

(6) Storage area of Reservoir

Table A-5.1: Summary of Results from Hydropower Projects in the Lower Mekong Tributaries

Country	Annual Energy Production- GWh				Country	Annual Inflow - m3/s			
	SCN M1	SCN M2	SCN M3	SCN M3 cc		SCN M1	SCN M2	SCN M3	SCN M3 cc
Cambodia	6	5,891	5,508	5,497	Cambodia	5	3,269	3,361	3,454
Laos	4,304	32,819	39,891	40,107	Laos	934	5,913	7,629	7,983
Thailand	906	849	899	919	Thailand	1,237	1,116	1,541	1,658
Vietnam	4,723	9,347	9,341	9,587	Vietnam	1,010	2,537	2,535	2,662
Country	**Annual Evap Volume - MCM**				**Country**	**Annual Current Volume -MCM**			
	SCN M1	SCN M2	SCN M3	SCN M3 cc		SCN M1	SCN M2	SCN M3	SCN M3 cc
Cambodia	(0)	(55)	(103)	(97)	Cambodia	1	11,861	12,065	12,123
Laos	(31)	(160)	(195)	(197)	Laos	6,203	47,068	77,723	78,604
Thailand	8	6	10	12	Thailand	4,686	4,277	5,444	5,704
Vietnam	(3)	(10)	(10)	(10)	Vietnam	863	3,111	3,109	3,173
Country	**Annual Release and Spill - MCM**				**Country**	**Annual Storage Area - Ha**			
	SCN M1	SCN M2	SCN M3	SCN M3 cc		SCN M1	SCN M2	SCN M3	SCN M3 cc
Cambodia	13	8,691	8,984	9,222	Cambodia	20	118,362	205,396	205,743
Laos	2,578	15,785	20,359	21,299	Laos	38,521	216,186	292,822	295,463
Thailand	3,249	2,930	4,046	4,353	Thailand	96,002	88,677	111,801	115,774
Vietnam	2,671	6,710	6,705	7,038	Vietnam	4,442	18,745	18,742	18,896

Table A-5.2: Summary Results from Hydropower dams in the Lower Mekong Mainstream

Dam name	Annual Energy Production- GWh				Dam name	Annual Inflow - m3/s			
	SCN M1	SCN M2	SCN M3	SCN M3 cc		SCN M1	SCN M2	SCN M3	SCN M3 cc
MS_Ban Kum	-	-	8,304	8,276	MS_Ban Kum	-	-	8,587	9,029
MS_Don sahong	-	-	964	964	MS_Don sahong	-	1,325	1,325	1,325
MS_Luangprabang	-	-	4,806	4,792	MS_Luangprabang	-	-	3,276	3,314
MS_Latsua (Phou Ngoy)	-	-	5,542	5,536	MS_Latsua (Phou Ngoy)	-	-	9,594	10,121
MS_Pakbeng	-	-	4,743	4,746	MS_Pakbeng	-	-	3,176	3,204
MS_Paklay	-	-	7,456	7,435	MS_Paklay	-	-	4,190	4,303
MS_Sambor	-	-	10,728	10,608	MS_Sambor	-	-	12,737	13,311
MS_Sanakham	-	-	4,028	3,332	MS_Sanakham	-	-	4,251	4,373
MS_Sangthong-Pakchom	-	-	5,135	5,108	MS_Sangthong-Pakchom	-	-	4,334	4,487
MS_Stung Treng	-	-	4,264	3,938	MS_Stung Treng	-	-	10,087	10,611
MS_Xayabuly	-	6,795	6,868	6,803	MS_Xayabuly	-	3,855	3,847	3,923
Dam name	Annual Evap Volume - MCM				Dam name	Annual Current Volume -MCM			
	SCN M1	SCN M2	SCN M3	SCN M3 cc		SCN M1	SCN M2	SCN M3	SCN M3 cc
MS_Ban Kum	-	-	(2)	(1)	MS_Ban Kum	-	-	1,945	1,958
MS_Don sahong	-	(2)	(2)	(1)	MS_Don sahong	-	591	591	591
MS_Luangprabang	-	-	(1)	(1)	MS_Luangprabang	-	-	1,028	1,028
MS_Latsua (Phou Ngoy)	-	-	(10)	(9)	MS_Latsua (Phou Ngoy)	-	-	1,427	1,440
MS_Pakbeng	-	-	(2)	(2)	MS_Pakbeng	-	-	517	519
MS_Paklay	-	-	(6)	(7)	MS_Paklay	-	-	1,248	1,247
MS_Sambor	-	-	(24)	(23)	MS_Sambor	-	-	11,790	11,773
MS_Sanakham	-	-	(0)	0	MS_Sanakham	-	-	245	279
MS_Sangthong-Pakchom	-	-	(1)	(2)	MS_Sangthong-Pakchom	-	-	927	928
MS_Stung Treng	-	-	(4)	(4)	MS_Stung Treng	-	-	384	395
MS_Xayabuly	-	(1)	(1)	(1)	MS_Xayabuly	-	633	635	635
Dam name	Annual Release and Spill - MCM				Dam name	Annual Storage Area - Ha			
	SCN M1	SCN M2	SCN M3	SCN M3 cc		SCN M1	SCN M2	SCN M3	SCN M3 cc
MS_Ban Kum	-	-	22,680	23,842	MS_Ban Kum	-	-	12,908	12,933
MS_Don sahong	-	3,499	3,499	3,499	MS_Don sahong	-	5,309	5,309	5,309
MS_Luangprabang	-	-	8,648	8,743	MS_Luangprabang	-	-	6,094	6,094
MS_Latsua (Phou Ngoy)	-	-	25,345	26,728	MS_Latsua (Phou Ngoy)	-	-	29,727	30,008
MS_Pakbeng	-	-	8,382	8,453	MS_Pakbeng	-	-	3,901	3,919
MS_Paklay	-	-	11,066	11,361	MS_Paklay	-	-	10,884	10,876
MS_Sambor	-	-	33,646	35,155	MS_Sambor	-	-	104,938	104,832
MS_Sanakham	-	-	11,220	11,540	MS_Sanakham	-	-	3,178	3,686
MS_Sangthong-Pakchom	-	-	11,439	11,842	MS_Sangthong-Pakchom	-	-	42,643	42,656
MS_Stung Treng	-	-	26,634	28,010	MS_Stung Treng	-	-	16,466	16,736
MS_Xayabuly	-	10,176	10,154	10,350	MS_Xayabuly	-	3,174	3,187	3,182

A.5.2 Results and Outputs for Sub-Scenarios from IQQM Modelling

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Table A-5.3 Comparison of flow results from Hydropower sub-scenarios (H1a, H1b, H2 and H3) comparing with M3cc from SWAT-IQQM Simul.

UNIT : cms

Station	Scenario Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Wet (May -Oct)	Dry (Nov - Apr)	Average	Compare with M3 cc (H2) Wet	Compare with M3 cc (H2) Dry	Compare with M3 cc (H2) Average
Chiang Saen	H1a	1,290	1,020	873	831	1,041	1,544	3,629	5,259	5,596	5,152	3,034	1,729	3,704	1,463	2,583	8%	-16%	0%
	H1b	1,602	1,292	1,172	1,093	1,316	1,699	2,797	4,618	5,264	4,915	3,190	2,143	3,435	1,749	2,592	0%	0%	0%
	H2 = M3CC	1,602	1,292	1,172	1,093	1,316	1,699	2,797	4,618	5,264	4,915	3,190	2,143	3,435	1,749	2,592			
	H3	1,602	1,292	1,172	1,093	1,316	1,699	2,797	4,618	5,264	4,915	3,190	2,143	3,435	1,749	2,592	0%	0%	0%
Luang Prabang	H1a	1,618	1,217	1,024	1,022	1,441	2,153	5,510	8,627	9,062	7,840	4,263	2,302	5,772	1,908	3,840	8%	-19%	0%
	H1b	2,079	1,686	1,537	1,471	1,806	2,292	4,403	7,674	8,561	7,477	4,453	2,811	5,369	2,339	3,854	0%	-1%	0%
	H2 = M3CC	2,135	1,684	1,534	1,469	1,803	2,284	4,309	7,666	8,588	7,458	4,494	2,844	5,351	2,360	3,856			
	H3	2,132	1,686	1,534	1,469	1,799	2,282	4,315	7,686	8,578	7,453	4,493	2,839	5,352	2,359	3,855	0%	0%	0%
Chiang Khan	H1a	1,693	1,239	1,040	1,067	1,781	2,670	6,105	9,752	11,029	9,614	4,929	2,479	6,825	2,075	4,450	7%	-18%	0%
	H1b	2,158	1,708	1,555	1,523	2,146	2,839	5,049	8,800	10,497	9,220	5,099	2,978	6,425	2,503	4,464	1%	-2%	0%
	H2 = M3CC	2,310	1,715	1,552	1,515	2,108	2,835	4,858	8,800	10,534	9,216	5,137	3,044	6,392	2,546	4,469			
	H3	2,286	1,717	1,553	1,515	2,100	2,837	4,874	8,809	10,522	9,211	5,169	3,030	6,392	2,545	4,469	0%	0%	0%
Vientiane	H1a	1,698	1,233	1,029	1,056	1,793	2,763	6,120	10,008	11,528	9,882	5,133	2,502	7,016	2,109	4,562	7%	-18%	0%
	H1b	2,168	1,703	1,545	1,514	2,167	2,951	5,101	9,036	10,975	9,488	5,281	2,991	6,620	2,534	4,577	1%	-2%	0%
	H2 = M3CC	2,382	1,705	1,532	1,492	2,103	2,957	4,830	9,044	11,044	9,502	5,318	3,073	6,580	2,584	4,582			
	H3	2,332	1,707	1,533	1,492	2,091	2,956	4,867	9,040	11,034	9,497	5,379	3,055	6,581	2,583	4,582	0%	0%	0%
Nong Khai	H1a	1,704	1,234	1,032	1,061	1,815	2,806	6,185	10,109	11,704	9,994	5,162	2,514	7,102	2,118	4,610	7%	-18%	0%
	H1b	2,174	1,704	1,548	1,519	2,188	2,995	5,166	9,137	11,152	9,599	5,309	3,004	6,706	2,543	4,624	1%	-2%	0%
	H2 = M3CC	2,387	1,706	1,534	1,497	2,124	3,001	4,896	9,145	11,220	9,614	5,346	3,086	6,667	2,593	4,630			
	H3	2,337	1,709	1,536	1,497	2,112	3,000	4,932	9,141	11,210	9,608	5,407	3,068	6,667	2,592	4,630	0%	0%	0%
Nakhon Phanom	H1a	1,961	1,290	1,115	1,211	2,582	6,264	12,192	18,041	19,726	14,072	7,046	3,069	12,146	2,615	7,381	7%	-24%	0%
	H1b	2,841	2,144	1,960	1,936	2,787	5,506	10,449	16,668	18,952	13,812	7,559	3,934	11,362	3,396	7,379	0%	-1%	0%
	H2 = M3CC	3,061	2,158	1,947	1,917	2,716	5,519	10,195	16,647	19,017	13,852	7,574	4,006	11,325	3,444	7,384			
	H3	3,007	2,161	1,948	1,917	2,705	5,516	10,245	16,632	19,006	13,848	7,613	4,012	11,325	3,443	7,384	0%	0%	0%
Mukdahan	H1a	1,944	1,273	1,124	1,259	2,763	6,872	14,133	20,812	22,091	15,081	7,246	3,092	13,626	2,656	8,141	7%	-26%	-1%
	H1b	2,969	2,238	2,074	2,073	2,976	6,039	12,324	19,395	21,314	14,866	7,891	4,130	12,819	3,562	8,191	0%	-1%	0%
	H2 = M3CC	3,189	2,252	2,061	2,054	2,905	6,053	12,070	19,373	21,379	14,907	7,906	4,202	12,781	3,611	8,196			
	H3	3,136	2,256	2,063	2,054	2,894	6,050	12,120	19,359	21,367	14,902	7,944	4,207	12,782	3,610	8,196	0%	0%	0%
Pakse	H1a	2,254	1,431	1,248	1,381	2,974	8,498	16,717	26,374	28,800	20,186	9,829	4,011	17,258	3,359	10,309	6%	-25%	-1%
	H1b	3,426	2,503	2,287	2,279	3,251	7,479	14,674	24,636	27,988	19,986	10,563	5,190	16,336	4,375	10,355	0%	-2%	0%
	H2 = M3CC	3,684	2,668	2,320	2,329	2,984	7,413	14,418	24,653	28,093	20,028	10,560	5,234	16,265	4,466	10,365			
	H3	3,684	2,668	2,320	2,329	2,984	7,413	14,418	24,653	28,093	20,028	10,560	5,234	16,265	4,466	10,365	0%	0%	0%
Strung Treng	H1a	2,977	1,911	1,601	1,782	3,677	10,013	19,860	32,374	34,899	24,999	11,896	4,991	20,970	4,193	12,582	7%	-28%	-1%
	H1b	4,858	3,558	3,004	2,942	3,712	8,248	16,783	29,729	33,947	25,077	13,194	7,018	19,583	5,762	12,673	0%	-1%	0%
	H2 = M3CC	5,083	3,722	3,041	2,981	3,488	8,176	16,553	29,734	34,073	25,127	13,188	7,051	19,525	5,844	12,685			
	H3	5,049	3,687	3,017	2,961	3,523	8,237	16,563	29,707	34,058	25,138	13,233	7,039	19,538	5,831	12,684	0%	0%	0%
Kratie	H1a	3,279	2,159	1,771	1,872	3,616	10,039	20,025	33,394	36,527	27,014	13,295	5,628	21,769	4,667	13,218	7%	-26%	-1%
	H1b	5,177	3,815	3,183	3,048	3,723	8,311	17,017	30,658	35,527	27,053	14,555	7,642	20,381	6,237	13,309	0%	-1%	0%
	H2 = M3CC	5,337	3,933	3,162	3,046	3,758	8,257	16,650	30,736	35,752	27,156	14,562	7,605	20,385	6,274	13,330			
	H3	5,259	3,902	3,136	3,022	3,787	8,321	16,665	30,707	35,739	27,161	14,730	7,525	20,397	6,262	13,330	0%	0%	0%

Figure A-5.1 The average flow (cms) and percentage change from sub-scenarios H1a, H1b, H3 and M3cc from SWAT-IQQM Simulation at Key stations

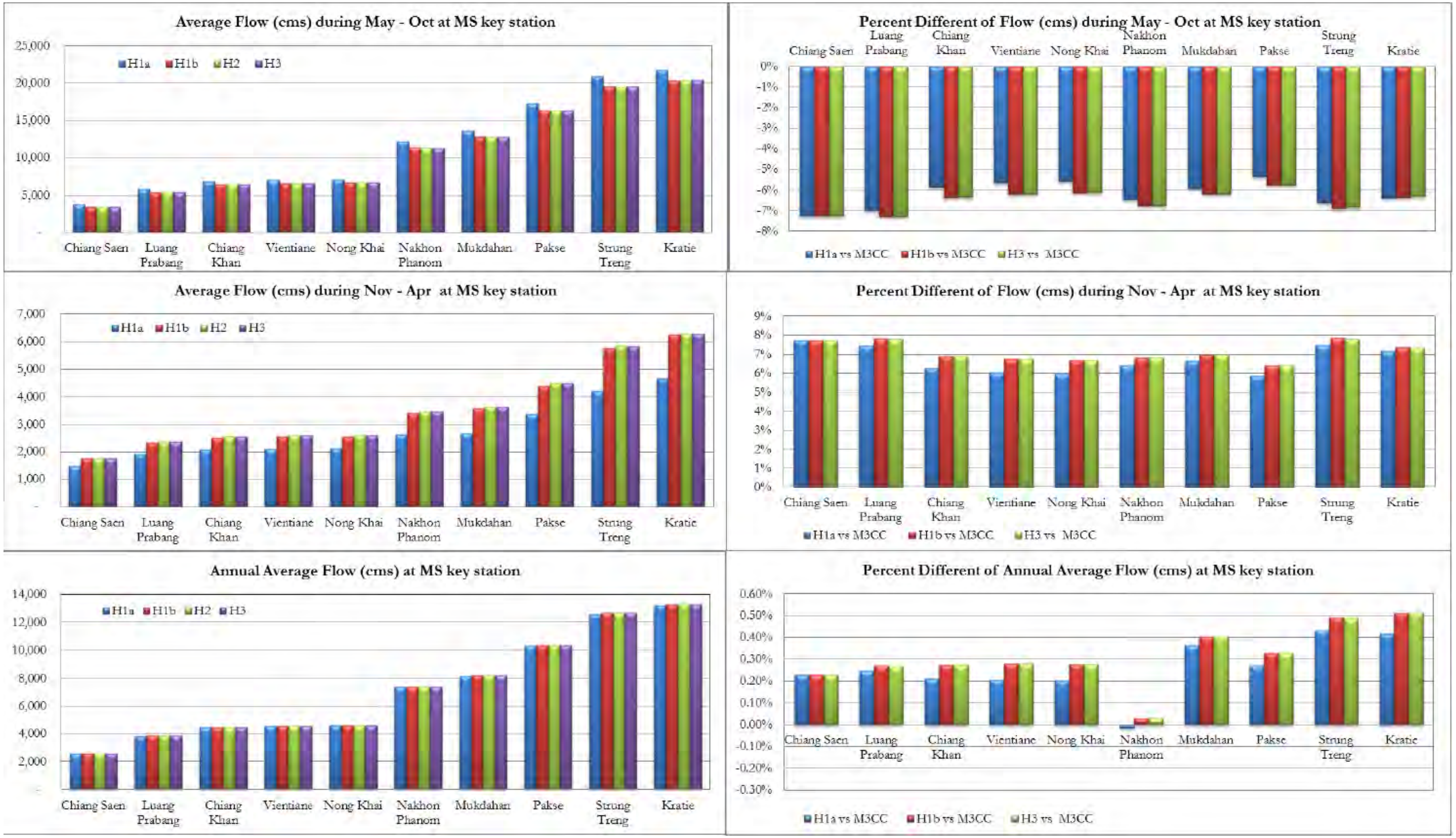

Table A-5.4: Summary Results from Impact of Climate Change on Hydropower Projects in Tributaries of the Lower Mekong Basin

Country	Annual Energy Production- GWh			Country	Annual Inflow - m3/s		
	SCN M3	Sub SCN C2	Sub SCN C3		SCN M3	Sub SCN C2	Sub SCN C3
Cambodia	5,508	5,529	5,384	Cambodia	3,361	3,400	3,282
Laos	39,891	40,348	38,764	Laos	7,629	7,931	7,063
Thailand	899	875	806	Thailand	1,541	1,497	1,297
Vietnam	9,341	9,443	9,497	Vietnam	2,535	2,569	2,592
Country	**Annual Evap Volume – MCM**			**Country**	**Annual Current Volume – MCM**		
	SCN M3	Sub SCN C2	Sub SCN C3		SCN M3	Sub SCN C2	Sub SCN C3
Cambodia	(103)	(90)	(97)	Cambodia	12,065	12,144	11,961
Laos	(195)	(177)	(185)	Laos	77,723	78,325	76,396
Thailand	10	21	12	Thailand	5,444	5,458	5,034
Vietnam	(10)	(9)	(11)	Vietnam	3,109	3,129	3,140
Country	**Annual Release and Spill – MCM**			**Country**	**Annual Storage Area - Ha**		
	SCN M3	Sub SCN C2	Sub SCN C3		Sub SCN A1	Sub SCN A1	Sub SCN A1
Cambodia	8,984	9,071	8,766	Cambodia	205,396	205,770	204,679
Laos	20,359	21,135	18,849	Laos	292,822	294,136	288,870
Thailand	4,046	3,915	3,400	Thailand	111,801	112,099	106,433
Vietnam	6,705	6,793	6,855	Vietnam	18,742	18,778	18,778

Table A-5.5: Summary Results from Impact of Land Use Change on Hydropower Projects in Tributaries of the Lower Mekong Basin

Country	Annual Energy Production- GWh			Country	Annual Inflow - m3/s		
	SCN M3cc	Sub SCN I1	Sub SCN I2		SCN M3cc	Sub SCN I1	Sub SCN I2
Cambodia	5,497	5,497	5,497	Cambodia	3,454	3,455	3,454
Laos	40,107	40,438	39,981	Laos	7,983	8,079	7,944
Thailand	919	922	921	Thailand	1,658	1,334	1,658
Vietnam	9,587	9,613	9,587	Vietnam	2,662	2,664	2,662

Country	Annual Evap Volume – MCM			Country	Annual Current Volume -MCM		
	SCN M3cc	Sub SCN I1	Sub SCN I2		SCN M3cc	Sub SCN I1	Sub SCN I2
Cambodia	(97)	(97)	(97)	Cambodia	12,123	12,121	12,123
Laos	(197)	(196)	(197)	Laos	78,604	78,929	78,496
Thailand	12	11	12	Thailand	5,704	4,926	5,666
Vietnam	(10)	(10)	(10)	Vietnam	3,173	3,180	3,173

Country	Annual Release and Spill – MCM			Country	Annual Storage Area - Ha		
	SCN M3cc	Sub SCN I1	Sub SCN I2		SCN M3cc	Sub SCN I1	Sub SCN I2
Cambodia	9,222	9,225	9,222	Cambodia	205,743	205,729	205,743
Laos	21,299	21,548	21,194	Laos	295,463	297,300	294,882
Thailand	4,353	3,505	4,352	Thailand	115,774	100,066	115,237
Vietnam	7,038	7,044	7,038	Vietnam	18,896	18,910	18,896

Table A-5.6: Summary Results from Impact of Irrigation Change on Hydropower Projects in Tributaries of the Lower Mekong Basin

Country	Annual Energy Production- GWh			Country	Annual Inflow - m3/s		
	SCN M3cc	Sub SCN I1	Sub SCN I2		SCN M3cc	Sub SCN I1	Sub SCN I2
Cambodia	5,497	5,497	5,497	Cambodia	3,454	3,455	3,454
Laos	40,107	40,438	39,981	Laos	7,983	8,079	7,944
Thailand	919	922	921	Thailand	1,658	1,334	1,658
Vietnam	9,587	9,613	9,587	Vietnam	2,662	2,664	2,662
Country	**Annual Evap Volume – MCM**			**Country**	**Annual Current Volume -MCM**		
	SCN M3cc	Sub SCN I1	Sub SCN I2		SCN M3cc	Sub SCN I1	Sub SCN I2
Cambodia	(97)	(97)	(97)	Cambodia	12,123	12,121	12,123
Laos	(197)	(196)	(197)	Laos	78,604	78,929	78,496
Thailand	12	11	12	Thailand	5,704	4,926	5,666
Vietnam	(10)	(10)	(10)	Vietnam	3,173	3,180	3,173
Country	**Annual Release and Spill – MCM**			**Country**	**Annual Storage Area - Ha**		
	SCN M3cc	Sub SCN I1	Sub SCN I2		SCN M3cc	Sub SCN I1	Sub SCN I2
Cambodia	9,222	9,225	9,222	Cambodia	205,743	205,729	205,743
Laos	21,299	21,548	21,194	Laos	295,463	297,300	294,882
Thailand	4,353	3,505	4,352	Thailand	115,774	100,066	115,237
Vietnam	7,038	7,044	7,038	Vietnam	18,896	18,910	18,896

Impact of Hydropower Dams

Country	Annual Energy Production- GWh					Country	Annual Inflow - m3/s				
	SCN M3cc	Sub SCN H1a	Sub SCN H1b	Sub SCN H2	Sub SCN H3		SCN M3cc	Sub SCN H1a	Sub SCN H1b	Sub SCN H2	Sub SCN H3
Cambodia	5,497	6	5,497	5,497	5,497	Cambodia	3,454	5	3,454	3,454	3,454
Laos	40,107	3,534	40,124	40,107	40,124	Laos	7,983	872	7,983	7,983	7,983
Thailand	919	919	919	919	919	Thailand	1,658	1,658	1,658	1,658	1,658
Vietnam	9,587	3,466	9,587	9,587	9,587	Vietnam	2,662	273	2,662	2,662	2,662
Country	**Annual Evap Volume – MCM**					**Country**	**Annual Current Volume -MCM**				
	SCN M3cc	Sub SCN H1a	Sub SCN H1b	Sub SCN H2	Sub SCN H3		SCN M3cc	Sub SCN H1a	Sub SCN H1b	Sub SCN H2	Sub SCN H3
Cambodia	(97)	(0)	(97)	(97)	(97)	Cambodia	12,123	1	12,123	12,123	12,123
Laos	(197)	(32)	(197)	(197)	(197)	Laos	78,604	6,297	78,642	78,604	78,642
Thailand	12	12	12	12	12	Thailand	5,704	5,704	5,704	5,704	5,704
Vietnam	(10)	(2)	(10)	(10)	(10)	Vietnam	3,173	665	3,173	3,173	3,173
Country	**Annual Release and Spill – MCM**					**Country**	**Annual Storage Area - Ha**				

	SCN M3cc	Sub SCN H1a	Sub SCN H1b	Sub SCN H2	Sub SCN H3		SCN M3cc	Sub SCN H1a	Sub SCN H1b	Sub SCN H2	Sub SCN H3
Cambodia	9,222	13	9,222	9,222	9,222	Cambodia	205,743	20	205,743	205,743	205,743
Laos	21,299	2,338	21,299	21,299	21,299	Laos	295,463	38,817	295,551	295,463	295,551
Thailand	4,353	4,353	4,353	4,353	4,353	Thailand	115,774	115,774	115,774	115,774	115,774
Vietnam	7,038	723	7,038	7,038	7,038	Vietnam	18,896	3,151	18,896	18,896	18,896

Table A-5.7: Summary Results from Hydropower dams in the Mekong Mainstream

Dam name	Annual Energy Production- GWh									
	Sub SCN A1	Sub SCN A2	Sub SCN C2	Sub SCN C3	Sub SCN I1	Sub SCN I2	Sub SCN H1a	Sub SCN H1b	Sub SCN H2	Sub SCN H3
MS_Ban Kum	8,268	8,276	8,361	8,152	8,533	8,212	-	-	8,276	10,391
MS_Don sahong	964	964	964	964	964	964	-	-	964	964
MS_Luangprabang	4,792	4,792	4,853	4,733	4,810	4,782	-	-	4,792	5,562
MS_Latsua (Phou Ngoy)	5,533	5,537	5,570	5,436	5,647	5,508	-	-	5,536	6,776
MS_Pakbeng	4,745	4,746	4,998	4,228	4,763	4,736	-	-	4,746	5,209
MS_Paklay	7,432	7,435	7,525	7,298	7,463	7,419	-	-	7,435	8,109
MS_Sambor	10,613	10,608	10,743	10,562	10,692	10,591	-	-	10,608	10,911
MS_Sanakham	3,331	3,332	3,348	3,302	3,334	3,330	-	-	3,332	3,312
MS_Sangthong-Pakchom	5,107	5,108	5,173	4,989	5,129	5,097	-	-	5,108	5,845
MS_Stung Treng	3,930	3,928	4,005	3,913	4,009	3,923	-	-	3,938	3,444
MS_Xayabuly	6,802	6,803	6,954	6,644	6,832	6,787	-	-	6,803	7,710
Dam name	Annual Evap Volume – MCM									
	Sub SCN A1	Sub SCN A2	Sub SCN C2	Sub SCN C3	Sub SCN I1	Sub SCN I2	Sub SCN H1a	Sub SCN H1b	Sub SCN H2	Sub SCN H3
MS_Ban Kum	(1)	(1)	(0)	(1)	(1)	(1)	-	-	(1)	(1)
MS_Don sahong	(1)	(1)	(1)	(1)	(1)	(1)	-	-	(1)	(1)
MS_Luangprabang	(1)	(1)	(1)	(1)	(1)	(1)	-	-	(1)	(1)
MS_Latsua (Phou Ngoy)	(9)	(9)	(7)	(10)	(8)	(9)	-	-	(9)	(8)
MS_Pakbeng	(2)	(2)	(2)	(2)	(2)	(2)	-	-	(2)	(2)
MS_Paklay	(7)	(7)	(6)	(6)	(7)	(7)	-	-	(7)	(7)
MS_Sambor	(23)	(23)	(19)	(15)	(23)	(23)	-	-	(23)	(23)
MS_Sanakham	0	0	0	(0)	0	0	-	-	0	0
MS_Sangthong-Pakchom	(2)	(2)	2	(3)	(2)	(2)	-	-	(2)	(2)
MS_Stung Treng	(4)	(4)	(3)	(2)	(4)	(4)	-	-	(4)	(4)
MS_Xayabuly	(1)	(1)	(1)	(1)	(1)	(1)	-	-	(1)	(1)
Dam name	Annual Release and Spill – MCM									
	Sub SCN A1	Sub SCN A2	Sub SCN C2	Sub SCN C3	Sub SCN I1	Sub SCN I2	Sub SCN H1a	Sub SCN H1b	Sub SCN H2	Sub SCN H3
MS_Ban Kum	23,749	23,848	23,891	20,215	24,827	23,649	-	-	23,842	23,842
MS_Don sahong	3,499	3,499	3,499	3,499	3,499	3,499	-	-	3,499	3,499
MS_Luangprabang	8,740	8,743	9,265	7,312	8,776	8,722	-	-	8,743	8,743
MS_Latsua (Phou Ngoy)	26,632	26,733	26,424	22,332	27,633	26,545	-	-	26,728	26,727
MS_Pakbeng	8,451	8,453	8,992	7,070	8,482	8,435	-	-	8,453	8,453
MS_Paklay	11,350	11,361	11,824	9,410	11,404	11,335	-	-	11,361	11,361
MS_Sambor	35,257	35,179	34,766	30,269	36,266	34,877	-	-	35,155	35,155
MS_Sanakham	11,527	11,540	11,990	9,565	11,584	11,514	-	-	11,540	11,540
MS_Sangthong-Pakchom	11,821	11,842	12,211	9,768	11,892	11,814	-	-	11,842	11,842
MS_Stung Treng	27,921	28,016	27,681	23,478	28,999	27,776	-	-	28,010	28,010
MS_Xayabuly	10,345	10,350	10,855	8,552	10,391	10,326	-	-	10,350	10,350

Dam name	Annual Inflow - m3/s									
	Sub SCN A1	Sub SCN A2	Sub SCN C2	Sub SCN C3	Sub SCN I1	Sub SCN I2	Sub SCN H1a	Sub SCN H1b	Sub SCN H2	Sub SCN H3
MS_Ban Kum	8,994	9,031	9,050	7,656	9,404	8,955	-	-	9,029	9,029
MS_Don sahong	1,325	1,325	1,325	1,325	1,325	1,325	-	-	1,325	1,325
MS_Luangprabang	3,312	3,314	3,510	2,771	3,326	3,306	-	-	3,314	3,313
MS_Latsua (Phou Ngoy)	10,084	10,123	10,008	8,456	10,465	10,051	-	-	10,121	10,121
MS_Pakbeng	3,203	3,204	3,406	2,680	3,215	3,197	-	-	3,204	3,204
MS_Paklay	4,298	4,303	4,477	3,564	4,319	4,293	-	-	4,303	4,303
MS_Sambor	13,349	13,320	13,167	11,463	13,733	13,205	-	-	13,311	13,310
MS_Sanakham	4,368	4,373	4,542	3,625	4,390	4,363	-	-	4,373	4,373
MS_Sangthong-Pakchom	4,479	4,487	4,628	3,702	4,506	4,476	-	-	4,487	4,487
MS_Stung Treng	10,577	10,613	10,488	8,895	10,986	10,522	-	-	10,611	10,610
MS_Xayabuly	3,921	3,923	4,112	3,242	3,938	3,913	-	-	3,923	3,923

Dam name	Annual Current Volume –MCM									
	Sub SCN A1	Sub SCN A2	Sub SCN C2	Sub SCN C3	Sub SCN I1	Sub SCN I2	Sub SCN H1a	Sub SCN H1b	Sub SCN H2	Sub SCN H3
MS_Ban Kum	1,956	1,958	1,961	1,906	2,052	1,937	-	-	1,958	1,956
MS_Don sahong	591	591	591	591	591	591	-	-	591	591
MS_Luangprabang	1,028	1,028	1,029	1,025	1,028	1,027	-	-	1,028	1,525
MS_Latsua (Phou Ngoy)	1,439	1,440	1,439	1,380	1,499	1,427	-	-	1,440	1,437
MS_Pakbeng	519	519	529	493	520	519	-	-	519	499
MS_Paklay	1,247	1,247	1,253	1,239	1,248	1,246	-	-	1,247	1,241
MS_Sambor	11,777	11,774	11,806	11,623	11,818	11,749	-	-	11,773	11,754
MS_Sanakham	279	279	280	270	279	279	-	-	279	279
MS_Sangthong-Pakchom	928	928	931	907	931	927	-	-	928	915
MS_Stung Treng	395	396	398	395	398	396	-	-	395	397
MS_Xayabuly	635	635	639	624	635	634	-	-	635	628

Dam name	Annual Storage Area – Ha									
	Sub SCN A1	Sub SCN A2	Sub SCN C2	Sub SCN C3	Sub SCN I1	Sub SCN I2	Sub SCN H1a	Sub SCN H1b	Sub SCN H2	Sub SCN H3
MS_Ban Kum	12,929	12,933	12,942	12,830	13,126	12,893	-	-	12,933	12,924
MS_Don sahong	5,309	5,309	5,309	5,309	5,309	5,309	-	-	5,309	5,309
MS_Luangprabang	6,094	6,094	6,104	6,076	6,096	6,093	-	-	6,094	5,955
MS_Latsua (Phou Ngoy)	29,984	30,008	29,990	28,786	31,130	29,749	-	-	30,008	29,963
MS_Pakbeng	3,919	3,919	4,008	3,690	3,927	3,915	-	-	3,919	3,736
MS_Paklay	10,875	10,876	10,910	10,829	10,885	10,871	-	-	10,876	10,845
MS_Sambor	104,855	104,835	105,035	103,920	105,107	104,686	-	-	104,832	104,719
MS_Sanakham	3,685	3,686	3,700	3,560	3,691	3,683	-	-	3,686	3,686
MS_Sangthong-Pakchom	42,653	42,656	42,682	42,467	42,680	42,642	-	-	42,656	42,539
MS_Stung Treng	16,737	16,738	16,801	16,717	16,797	16,738	-	-	16,736	16,776
MS_Xayabuly	3,182	3,182	3,213	3,111	3,188	3,179	-	-	3,182	3,138