STRATEGIC ENVIRONMENTAL ASSESSMENT OF HYDROPOWER ON THE MEKONG MAINSTREAM

FINAL REPORT

Prepared for the Mekong River Commission

by ICEM – International Centre for Environmental Management

October 2010

Disclaimer

This document was prepared for the Mekong River Commission Secretariat (MRCS) by ICEM – International Centre for Environmental Management engaged to facilitate preparation of a Strategic Environment Assessment (SEA) of proposals for mainstream dams in the Lower Mekong Basin.

While the SEA is undertaken in a collaborative process involving the MRC Secretariat, National Mekong Committees of the four countries as well as civil society, private sector and other stakeholders, this document was prepared by the SEA Consultant team to assist the Secretariat as part of the information gathering activity. The views, conclusions, and recommendations contained in the document are not to be taken to represent the views of the MRC. Any and all of the MRC views, conclusions, and recommendations will be set forth solely in the MRC reports.

For further information on the MRC initiative on Sustainable Hydropower (ISH) and the implementation of the SEA of proposed mainstream developments can be found on the MRC website:
http://www.mrcmekong.org/ish/ish.htm and http://www.mrcmekong.org/ish/SEA.htm

The MRC following position on mainstream dams is provided on the MRC website in 2009.

MRC position on the proposed mainstream hydropower dams in the Lower Mekong Basin

Twelve hydropower schemes are being studied by private sector developers for the mainstream of the Mekong River. The 1995 Mekong Agreement requires that such projects are discussed extensively among all four countries prior to any decision being taken. That discussion, facilitated by MRC, will consider the full range of social, environmental and cross-sector development impacts within the Lower Mekong Basin. So far, one proposed mainstream project has reached the stage of notification and prior consultation required under the Mekong Agreement. MRC has already carried out extensive studies on the consequences for fisheries and peoples' livelihoods and this information is widely available, see for example report of an expert group meeting on dams and fisheries. MRC is undertaking the Strategic Environmental Assessment (SEA) of the proposed mainstream dams to provide a broader understanding of the opportunities and risks of such development. Dialogue on these planned projects with governments, civil society and the private sector is being facilitated by MRC and all comments received are being considered.

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More information: www.icem.com.au | http://www.mrcmekong.org/ish/SEA.htm

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Cover images: Mekong River Commission, 2010; Zeb Hogan, 2009; Peter-John Meynell, 2010, Peter Ward, 2003

About the SEA of Hydropower on the Mekong mainstream

The Mekong River Commission (MRC) is an inter-governmental river basin organization that provides the institutional framework to implement the 1995 Mekong Agreement for regional cooperation in the Mekong Basin. The Governments of Cambodia, Lao PDR, Thailand and Viet Nam signed the Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin. They agreed on joint management of their shared water resources by cooperating in a constructive and mutually beneficial manner for sustainable development, utilization, conservation and management of the Mekong River Basin water and related resources.

Poverty alleviation as a contribution to the UN Millennium Development Goals is also a priority. The two upper states of the Mekong River Basin, the People's Republic of China and the Union of Myanmar, are dialogue partners to the MRC.

In a region undergoing rapid change and economic growth, the MRC considers the development of hydropower on the Mekong mainstream as one of the most important strategic issues facing the Lower Mekong region. Through the knowledge embedded in all MRC programs, the MRC has commissioned this Strategic Environment Assessment (SEA) to assist Member states to work together and make the best decisions for the basin.

Twelve hydropower schemes have been proposed for the Lao, Lao-Thai and Cambodian reaches of the Mekong mainstream. Implementation of any or all of the proposed mainstream projects in the Lower Mekong Basin (LMB) could have profound and wide-ranging socio-economic and environmental impacts in all four riparian countries.

This SEA seeks to identify the potential opportunities and risks, as well as contribution of these proposed projects to regional development, by assessing alternative mainstream Mekong hydropower development strategies. In particular the SEA focuses on regional distribution of costs and benefits with respect to economic development, social equity and environmental protection. As such, the SEA supports the wider Basin Development Planning (BDP) process by complementing the MRC BDP assessment of basin-wide development scenarios with more in-depth analysis of power related and cross-sector development opportunities and risks of the proposed mainstream projects in the lower Basin.

The SEA is being coordinated by MRC's cross-cutting Initiative for Sustainable Hydropower (ISH) working with all MRC programmes. The SEA directly enhances the baseline information and assessment framework for subsequent government review of project-specific EIAs prepared by developers. It also informs how the MRC can best enhance its support to Member Countries when the formal process under the 1995 Mekong Agreement for prior consultation on any individual mainstream proposal is triggered (i.e. the Procedures for Notification, Prior Consultation and Agreement or PNPCA). The SEA findings also inform steps that MRC programmes may consider in the next MRC Strategic Plan Cycle (2011-2015) to help address the knowledge gaps and the key areas of uncertainty and risk concerning proposed mainstream developments.

The SEA began in May 2009 and was completed 16 months later with the submission of the final report and recommendations in September 2010. This document is the final in a series of documents arising from an intensive program of consultations in the Lower Mekong Basin and detailed expert analysis of the issues associated with developing hydropower on the Mekong mainstream. The SEA documents have been progressively made available for public and critical review, so that stakeholder engagement could contribute to the SEA in a meaningful way. A full list of documents is available on the SEA pages of the MRC website.

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The SEA team wish to acknowledge the very important support they have received from more than 100 government and non-government agencies and organisations of the Lower Mekong Basin. Their efforts in providing information, shaping the SEAs scope and reviewing progress have been critical to the success of the 16month assessment process.

In particular, the SEA team wishes to acknowledge the support of the four National Mekong Committees of Cambodia, Lao PDR, Thailand and Viet Nam for their efforts in facilitating consultations, and also the technical programmes of the Mekong River Commission Secretariat for providing the SEA team with the wealth of resources and information available within the Secretariat.

Special thanks are extended to the MRC Initiative on Sustainable hydropower (ISH) for the key role that it played to coordinate the SEA work within the MRCS Secretariat and MRC system, and the process of outreach to MRC stakeholders.

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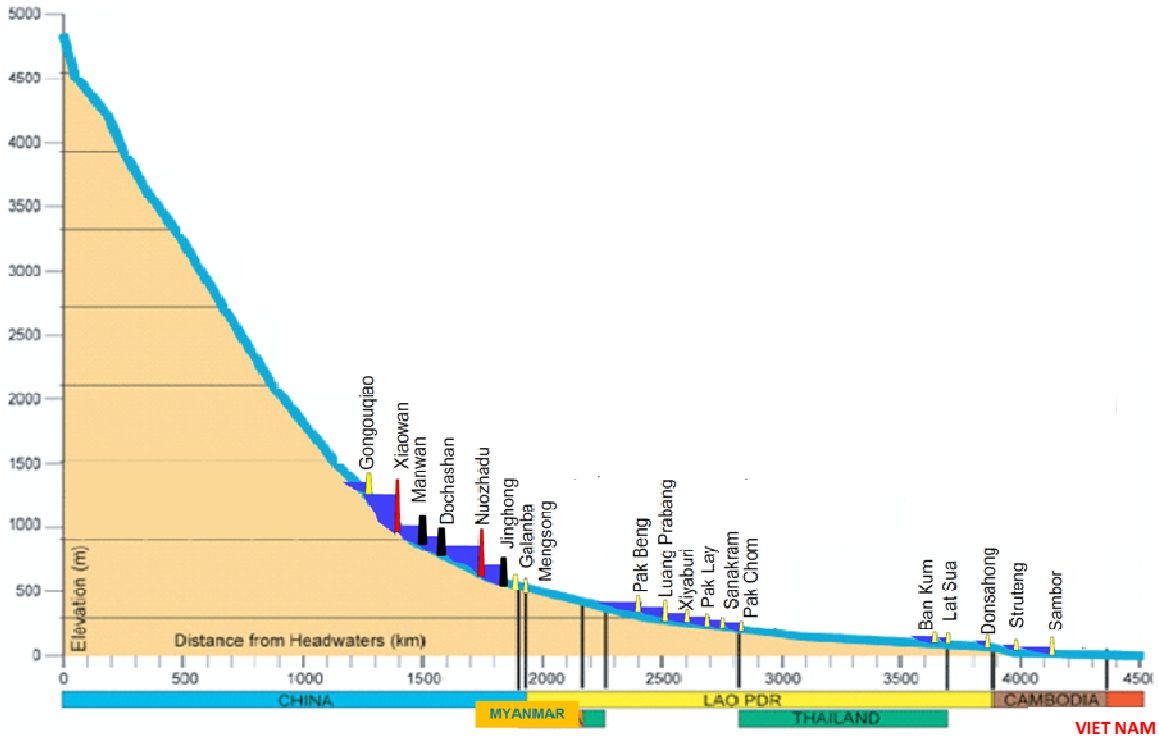
SUMMARY

The Mekong River is one of the last large rivers on Earth not dammed for most of its length, and the only river still flowing freely to the sea through five of six riparian countries - Myanmar, Lao PDR, Thailand, Cambodia and Viet Nam. The mainstream in China is dammed by the first four projects in a planned cascade of up to 8 storage hydropower projects.[1] Since 2006, interest in hydropower has escalated in the Lower Mekong Basin (LMB) accompanied by increasing private sector investment in power infrastructure. Most Mekong River tributaries have cascades of dams in place or planned with some 71 projects expected to be operational by 2030. Over the past few years, investors and developers mostly from China, Malaysia, Thailand and Viet Nam have submitted proposals for twelve hydropower projects for the LMB mainstream drawing on concepts from past decades (Figure S1).[2] Those proposals are among the largest and most significant developments ever considered by LMB countries for the basin.

Ten proposed mainstream projects would involve constructing dams across the entire river channel – 8 in Lao PDR, two of which are on the Lao-Thailand reaches of the mainstream and 2 in Cambodia. Another two projects near the Khone Falls in Lao PDR involve either partial damming (Don Sahong) or a diversion (Thakho). In Yunnan Province of China, eight dams spanning the Lancang River already exist, are under construction or are planned. It is China's decision to develop the Mekong River in Yunnan Province and the resulting changes in seasonal flows which has eased past reluctance to do so in the LMB and made the mainstream projects more economically viable.[3] Other international factors, such as reduced green house gas emissions compared to fossil fuel generation options, and efforts to reduce reliance on imported energy and increase supply diversity make hydropower an increasingly attractive renewable energy resource for LMB countries.

Figure S1: Proposed Mekong mainstream hydropower projects in the LMB and Yunnan Province, China



[1] At latest information, Mengsong, the most downstream project in the Chinese cascade, has been postponed without firm date set for construction.

[2] Eleven of the 12 LMB mainstream projects are based on preliminary feasibility designs developed by the Mekong Secretariat in 1994 and building on earlier concepts for Mekong mainstream hydropower beginning in the 1960s.

[3] The storage reservoirs in China, allow for water to be retained during the wet and released during the dry season providing a more uniform year round flow pattern for downstream hydropower operators.

The governments of Lao PDR and Cambodia have been reviewing the mainstream proposals mainly on a project-by-project basis. Lao PDR has commissioned an optimisation study for the reaches of the Mekong affected by a cascade of six dams above Vientiane. Apart from their consideration in the MRC's Regional Basin Planning process, these projects have been moving forward without an overall spatial or integrated development plan for the River – either within each country or at regional level.[4] In the absence of such a guiding framework, the national power and environment agencies are applying their project-specific review procedures and standards, including Environmental Impact Assessments (EIA), prior to making a national decision in each case.

At regional level, LMB countries have adopted a protocol under the 1995 Mekong Agreement which commits them to notify their neighbors of proposed mainstream projects when they have sufficient information, then consult and reach agreement on whether or not to proceed, and if so, under what conditions. That full Procedure for Notification, Prior Consultation and Agreement (PNPCA) was triggered for the first time on 22 September 2010 with the official notification from Lao PDR of the proposed Xayaburi mainstream project. The mainstream hydropower project proposals will be an important test for the PNPCA and regional cooperation in implementing the 1995 Mekong Agreement.

THE SEA

It is the relatively sudden revival of many proposals at the same time and for the same shared river that led LMB countries to call for a Strategic Environmental Assessment (SEA) of all 12 proposals to be conducted under the MRC framework of cooperation. SEAs address the broader strategic issues usually relating to more than one project. SEAs follow similar steps to EIAs but have much larger boundaries in terms of time, space and subject coverage. The SEA is a tool to examine the broad strategic concerns which need to be resolved and decided prior to making project specific decisions. In this case, the SEA commissioned by the MRC was asked to provide an understanding of the implications of mainstream hydropower development and recommendations on whether and how the proposed projects should best be pursued. The SEA was intended as input to the PNPCA process, to feed into the MRC Basin Development Plan (BDP), and ultimately to support national decisions concerning the mainstream proposals.

The SEA focuses on proposals located in three distinct hydro-ecological zones and assesses them in five different dam groupings: (i) all proposed LMB mainstream dams, (ii) the cluster of 6 Upper Lao projects upstream of Vientiane, (iii) the two Middle-Lao projects immediately up and downstream of Pakse (Ban Koum, Lat Sua), (iv) the two smaller Lower Lao projects at Khone Falls (Don Sahong, Thakho), and (v) the two Cambodian Projects upstream of Kratie (Stung Treng, Sambor).

The SEA has run in four phases over 16 months from May 2009 – (i) a scoping phase to define the key strategic issues of concern to Mekong River development, (ii) a baseline assessment to describe past trends in those issues and their projection to 2030 without mainstream hydropower, (iii) an impact assessment of the effects of mainstream hydropower on those trends, and (iv) a phase to identify ways of avoiding and mitigating the risks and enhancing the benefits. The SEA has been intensively consultative involving over 60 line agencies, 40 NGOs and civil society organizations and some 20 international development organizations in meetings and workshops. The SEA process also included the participation of China through the high level Ecosystem Study Commission for International Rivers (ESCIR).

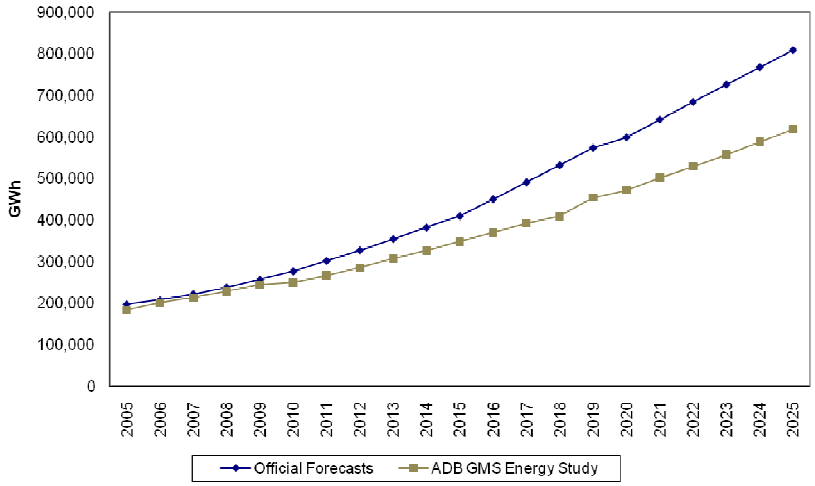
The views and opinions expressed during the consultations have guided and shaped the SEA through all assessment phases. In this report the SEA team has distilled and analysed the views and information of government experts, line agencies and the non-government community. When a divergence of views remains on key issues such as the economic costs and benefits of the mainstream proposals, the SEA team draws its own conclusions based on the evidence before it.

Some important issues raised by stakeholders were beyond the scope of the SEA to critically review. They would have required additional comprehensive research. For example, there remains considerable debate and divergence of opinion on energy demand projections for each country and for the region (Figure S2). In the case of Viet Nam's future national energy demand for example, estimates by the ADB GMS Energy Futures study base case for 2025 represent 54% of official government estimates, a discrepancy equivalent to around

[4] The MRC Basin Development Plan (BDP) represents an important pioneering process in recent years to coordinate regional planning.

3.5 times the annual power production from the 12 mainstream projects.[5] Similarly the question of alternatives was a fundamental consideration presented and discussed with SEA stakeholders but requires much more work. In such cases, the SEA reports the latest official figures and their sources, provides an overview of the situation, draws attention to remaining uncertainties and identifies priorities for further detailed analysis.

Figure S2: LMB Regional demand forecasts to 2025 - Comparison of official government & ADB GMS Energy Futures Study projections



SEA FINDINGS

The SEA baseline and impact assessment established that 96% of power demand to 2025 stems from Thailand and Viet Nam – and those two countries are targeted to purchase close to 90% of the power generated by the mainstream projects. If Thailand and Viet Nam decided not to purchase mainstream power, the projects – all designed for export – would be very unlikely to go ahead.

The main findings of the SEA are summarized below according to what government and non-government stakeholders defined as the "big strategic issues" relating to mainstream development. These issues were identified by hundreds of national participants in the national meetings, round tables and regional workshops. They are:

- Power security and generation including revenue, trade and foreign investment
- Economic development and poverty alleviation
- Ecosystems integrity and diversity – aquatic, terrestrial, hydrological dynamics and sediment/nutrient transport.
- Fisheries and food security (including agriculture)
- Social systems - livelihoods and the living cultures of affected communities

The SEA considers the specific impacts (positive and negative) of the proposed mainstream dams. Those impacts are additional to the effects of the committed 41 large hydropower schemes on Mekong River tributaries by 2015, the 8 storage schemes in the Lancang-Mekong basin in China, as well as cumulative impacts of other non-dam pressures on the Mekong's natural resource systems.[6]

POWER GENERATION AND SECURITY

Over the past few decades, the Mekong region has experienced high rates of economic growth. From 1993 to 2005, economic growth and electricity demand increased at an average annual rate of about 8%, one of the

[5] IRM consultant forecast in 2008 re-published in 2009 in the ADB report "Building a Sustainable Energy Future, The Greater Mekong Subregion in 2009".

[6] The Definite Future Scenario (DF) of the MRC Basin Development Plan, for example, sees up to 41 large hydropower schemes on LMB tributary systems by 2015, in addition to the major high dam schemes in the Lancang-Mekong basin in China. This is based on the number of existing, under construction and committed projects

highest in the world over a sustained period. While the rate of electricity demand growth in the Mekong is high, it has been growing from a low per capita level.[7]

Power demand is expected to grow at 6-7% annually to 2025 as LMB economies diversify and populations grow, with Viet Nam and Thailand expanding grid generation to meet this demand and Cambodia and Lao PDR gradually forming interconnected national grids (Figure S2). National grid supply options include hydropower, renewable energies, nuclear power, conventional thermal power and demand side management.

There is massive potential for hydropower in the Greater Mekong Subregion (GMS) with 176,350 – 250,000 MW technically feasible. The four LMB countries of Cambodia, Lao PDR, Thailand and Viet Nam have an estimated national hydropower potential in the order of 50,000 - 64,750 MW, of which 30,000 MW is available in the Lower Mekong Basin. Including the Lancang River in Yunnan Province, the whole Mekong Basin has a hydropower potential of 53,000 MW.

According to current designs, the 12 LMB mainstream dams represent up to 14,697 MW, or 23 - 28% of the national hydropower potential of the four LMB countries and 5 – 8% of the total hydropower potential in the GMS region. Three clear regional and national trends favour an expansion of hydropower's contribution to the GMS power sector: (i) increase in regional cooperation, trade and planning, (ii) strong national desires to diversify fuel sources and reduce dependency on finite indigenous fossil fuel reserves, and (iii) international trend to reduce GHG emissions for the power sector. Three clear regional and national trends favour an expansion of hydropower's contribution to the GMS power sector: (i) increase in regional cooperation, trade and planning, (ii) strong national desires to diversify fuel sources and reduce dependency on finite indigenous fossil fuel reserves, and (iii) international trend to reduce GHG emissions for the power sector.

If all 12 mainstream dams were developed they would bring substantial increases to power generated and generation capacity in the region. Peak demand requirement forecasts for LMB countries in 2025 total 130,366 MW. The LMB mainstream dams would represent 11% of additional LMB installed capacity[8] required between 2015 and 2025. Without the two Cambodian mainstream projects, this percentage would drop to 9% and 7% if only the Upper Lao cascade (Pak Beng to Pak Chom) was pursued.

Table S1: National power demand forecasts for LMB countries by 2025

	Cambodia	Lao PDR	Thailand	Viet Nam	TOTAL/ Regional
Peak Demand (MW)	2,401	2,696	53,824	72,445	***130,366***
National Energy Demand (GWh/yr)	14,302	16,060	339,479	450,618	***820,458***
LMB mainstream dams Mean Annual Energy (GWh/yr)	19,740	46,054	-	-	***65,794***
Percent contribution of LMB mainstream hydropower to national demand*	13.8%	28.7%	11.6%	4.4%	***8.3%***
Percent contribution of LMB mainstream hydropower to peak demand					***11.3%***

** it is assumed that 90% of LMB mainstream power generation is for export to Thailand and Viet Nam, with 10% for domestic demand*

The 12 mainstream dams represent 6-8% of the projected LMB power demand for 2025, which is equivalent to the expected LMB energy demand growth rate experienced in one year between 2015 and 2025. The official 2025 forecasts estimate LMB regional energy demand to be 820TWh/y, of which the LMB mainstream projects could competitively supply 65TWh/yr against other forms of generation in export markets. Actual exports (to Thailand and Viet Nam) from LMB mainstream projects are likely to total 53TWh/yr (two thirds from Lao PDR and one third from Cambodia) as some power would be consumed in the host countries. If all LMB mainstream projects went ahead, they would meet in the order of 4.4% of the national power demand in Vietnam, 11.6% of the demand in Thailand, 13.8% of the demand in Cambodia, and 28.7% of the demand in Lao PDR by 2025 (Table S1).[9]

Hydrocarbons (i.e., coal, natural gas and oil) now dominate generation (about 85%) but hydropower will continue to be a critical component in the future energy supply mix with Renewable Energy (REs), Demand Side Management (DSM) and Energy Efficiency (EE) complementing the expansion of conventional generation.

[7] By 2008, electricity utilization in the Greater Mekong Subregion (GMS) (940 kWh/person/yr) had reached about two thirds of the developing world average

[8] Installed capacity measured in Watts (W), or multiples thereof, is the rated maximum power generation capacity of installed generators.

[9] Assuming 90% is exported to Thailand and Vietnam

Lao PDR gains most from the overall power benefits directly associated with mainstream hydropower. Lao PDR is likely to receive more than 70% of overall power benefits including revenues and avoided thermal costs, with Cambodia and Thailand receiving 11-12% and Viet Nam receiving 5%. Without mainstream hydropower, Lao PDR has sufficient hydropower potential on Mekong tributaries, in the medium term, to continue generating healthy export earnings and encourage investment into its dynamic economy.

In terms of least-cost power supply, mainstream projects are most critical for the Cambodian power sector, particularly in the long term when plants are transferred to national authorities. Currently, national electricity demand is almost entirely dependent on imported fossil fuels and Cambodia has the most limited range of alternatives for meeting national power demand. Tributary potential is much more limited than Lao PDR. In the medium, there are indications that off-shore areas may hold moderate levels of fossil fuel reserves.[10] As yet there are no official estimates of proven or recoverable amounts. While only a small part of the estimated reserves are likely to be economically recoverable, and sovereignty is contested with Thailand, they represent an important opportunity for development of the domestic energy sector for both countries.[11]

Mainstream hydropower is less significant for the power sectors of Thailand and Viet Nam. Mainstream schemes will have a minor impact on electricity prices (less than 1.5%) and limited effect on the energy supply strategies of those countries due to the size of their power sectors.

There will be some gains in the regional power sector from climate change mitigation potential through the net reduction of green house gas emissions from thermal power generation offset by hydropower. [12]

Establishing effective institutional arrangements and rules under which privately run mainstream projects could operate is complex and has far reaching international implications. Setting the guiding criteria for the operation of many mainstream dams on one river also has international consequences and would ideally involve all four LMB countries, as well as China and Myanmar. The situation is more complex for the two projects on the Lao-Thai border, which would require signing of bi-lateral political protocols, establishment of basic principles and then an international commission either through the MRC or a project authority involving the two nations.

In addition to project specific institutional requirements there will be a need for a joint operation body that would, at least, set specific rules for hourly flow modification and, ideally, perform optimized operation planning to derive maximum value from the cascade and minimum adverse impacts.

ECONOMIC DEVELOPMENT AND POVERTY ALLEVIATION

If all 12 mainstream projects were to go ahead, Lao PDR would receive 70% of export revenues (USD 2.6 billion/year) generated by the mainstream dams, with Cambodia receiving 30% (USD 1.2 billion/year). Lao PDR would benefit most, primarily because of the number of projects located there. The Upper Lao cluster (Pak Beng to Pak Chom) represents two-thirds of the national power benefit. During the period of the hydropower concessions, the bulk of those benefits for Lao PDR and Cambodia would not accrue to the country as a whole or the respective governments -- they would accrue to the developers and financiers of the projects. The same is true of export revenues. While significant, net revenues for host governments are less than the large gross revenue and power benefit figures suggest. They are likely to be between 26–31% of gross revenues during the period of the concession agreement. Lao PDR and Cambodia would be unable to construct these projects without private investment. After the likely 25-year concession period has finished and the ownership of the projects is transferred to the host countries the total financial benefit of these projects will accrue to the host countries.

In Lao PDR, the use of hydropower revenues to fund infrastructure and social development expenditures (including rural roads, health and education spending) is already mandated in National Socio-economic Development Plan and National Growth and Poverty Eradication Strategies.

The large amount of FDI to Cambodia and Lao PDR mainstream hydropower projects imply (approaching USD 25 billion if all 12 projects were to go ahead) is likely to lead to a significant economic stimulus to the

[10] IMF, 2007, IMF Country Report No. 07/386, Cambodia: Statistical Appendix

[11] Current alternatives available for Cambodian domestic bulk supply are imported coal and imported power (e.g. Lao hydropower). In its power systems assessment, the SEA only covers currently available sources

[12] To the extent that the 65,000 GWh/yr of energy from mainstream avoids equivalent generation from thermal power stations (e.g. coal, natural gas and oil) the currently account for about 85% of LMB power generation.

host countries and the region due to the demand for additional inputs (labour, construction materials, engineering inputs and services). Additional government spending due to increased revenues from hydropower could also to contribute to this stimulus.

Lao PDR is likely to see economic growth due to mainstream hydropower investment. The stimulus effects are likely to be significant even though at least 50% of FDI flows associated with mainstream hydropower projects are estimated to be spent on inputs from outside the host country.

Associated risks include the development of macro-economic imbalances due to a booming hydropower sector, particularly in Lao PDR given the size of the hydropower investments relative to the country's economy, and increased government debt related to the funding of equity stakes in the hydropower projects. The nature and extent of opportunities and risks vary greatly during the life of a mainstream project.

Mainstream projects would have significant net negative impacts on the fisheries and agriculture sectors. The losses in fisheries directly due to LMB mainstream dams, if all were to proceed, are expected to be worth USD 476million/year, excluding effects on the coastal and delta fisheries which are likely to be significant but have not been studied. Fifty-four percent of all riverbank gardens on the Mekong River will be lost, which combined with losses in agricultural land for mainstream reservoirs and transmission lines is expected to be worth USD 25.1 million/year. Reduced nutrient loading will require an estimated USD 24million/year to maintain the productivity of floodplain agriculture – 33% directly due to LMB mainstream hydropower. Gains in reservoir fisheries and irrigation are expected to be worth USD 14million/year and USD 15.5 million/year respectively.

Impacts on the fisheries and agriculture sectors can be only partially mitigated. The proposed reservoirs would be capable of producing in the order of 10% of the lost capture fisheries. The adverse impacts on the irrigation sector can be partially mitigated if significant capital is invested to re-equip the irrigation sector for use of reservoir water. [13]

Mainstream hydropower generation projects would contribute to a growing inequality in the LMB countries. Benefits of hydropower would accrue to electricity consumers using national grids, developers, financiers and host governments, whereas most costs would be borne by poor and vulnerable riparian communities and some economic sectors. Benefits are also unevenly shared between countries. If all mainstream projects were to proceed, Viet Nam and Cambodia are likely to suffer net short to medium term losses because the combined effects on fisheries and agriculture would outweigh power benefits.

In the short to medium term poverty would be made worse by any one of the mainstream projects, especially among the poor in rural and urban riparian areas. Fishers, in particular, are over represented in poor and vulnerable LMB communities which would be affected by fisheries losses. Poorer households would also be adversely affected by the direct impacts of hydropower development including resettlement, loss of land, and impacts during the contraction period. Loss of fisheries and associated proteins would lead to declines in nutritional health in LMB populations, particularly in Cambodia and Lao PDR where up to 30% of the national protein supply would be at risk if all mainstream dams were to go ahead. These food security issues are likely to affect both the rural and urban poor. Moreover, any increase in rural poverty is likely to act as another push factor for rural-urban migration compounding urban poverty issues.

Significant improvements in regional cooperation, institutional and regulatory capacity are needed for effective management of mainstream projects and mitigation measures. Worldwide there are a number of benefit sharing mechanisms and mitigation measures for affected economic sectors which have proven successful under specific institutional contexts. The success of extensive mitigation measures needed to address risks and opportunities and the funding of such measures (e.g. national to local benefit sharing, and trans-boundary benefit sharing mechanisms) would be contingent on building substantially increased institutional, administrative and technical capacity in host countries and regionally in time for the project construction and operations start up dates. [14]

The development of mainstream dams would improve navigation conditions for larger vessels when coupled with substantial investment in waterway infrastructure, promotion of multi modal transport chains and monitoring and evaluation of navigation channels, together with a strong financial commitment to develop inland waterway transport in the Upper Mekong. Extensive clearing of the channel waterway up stream of Pak

[13] In most cases, replacement of existing irrigation should be funded as part of project compensation costs.
[14] Benefit sharing; especially revenue sharing is important to ensure the benefits accruing at the regional or national level are transferred to local level.

Beng would still be required to allow passage and the main navigation route from Phnom Penh to the sea would experience greater channel instability, which could be managed through a significant increase in efforts to stabilise the river banks. Connectivity for small freight and passenger transport would be reduced. No mitigation measures are likely to be economically viable for small transport and community use.

ECOSYSTEMS INTEGRITY AND DIVERSITY

The mainstream projects would degrade the longitudinal connectivity of the Mekong ecosystem, compartmentalising it into smaller and far less productive units. The proposed mainstream hydropower represents a fundamental break from the current dynamic equilibrium of the Mekong River which converts the immense potential and kinetic energy of the system into a wide range of eco-morphological processes along its entire length.

The LMB mainstream projects are proposed at a time when the Mekong hydrological regime is undergoing a period of intensive change driven by rapid hydropower development on the LMB tributaries and on the UMB mainstream in Yunnan Province of China. **The LMB mainstream projects would have significant additional basin-wide effects on the future movement of water and sediment through the Mekong basin system, including the coastal and off-shore zone.**

The Mekong River has a strong flood pulse characterised by four distinct seasons and corresponding fluctuations in the water levels. LMB tributary and Chinese hydropower will disturb the timing and duration of these seasons. **With the LMB mainstream projects, upper reaches of Zone 2 (i.e. Chiang Saen to Luang Prabang) and all reaches of the Mekong inundated by the mainstream reservoirs would no longer experience the ecologically important transition seasons.** All other reaches of the Mekong River would experience a reduction in the duration of transition seasons which play an important role in triggering biological processes within riverine and floodplain habitats.

The LMB mainstream dam walls would be sufficiently high that water levels in the reservoirs would be above the highest ever recorded for tens of kilometers upstream. Changes in water levels could be greatly exacerbated by the operational strategy of the projects. “Peaking operation” (i.e. maximising turbine discharge when the buying price for electricity peaks once or twice daily) could greatly increase the speed at which water levels rise and the number of fluctuations from seasonal to daily or even hourly events. **There is the potential for hourly spikes in water level of up to 3-6m at towns and villages located 40-50 km downstream.** Under unplanned and emergency release, peaking events could be larger and could travel that distance downstream in 1-2 hours giving little time for notification.

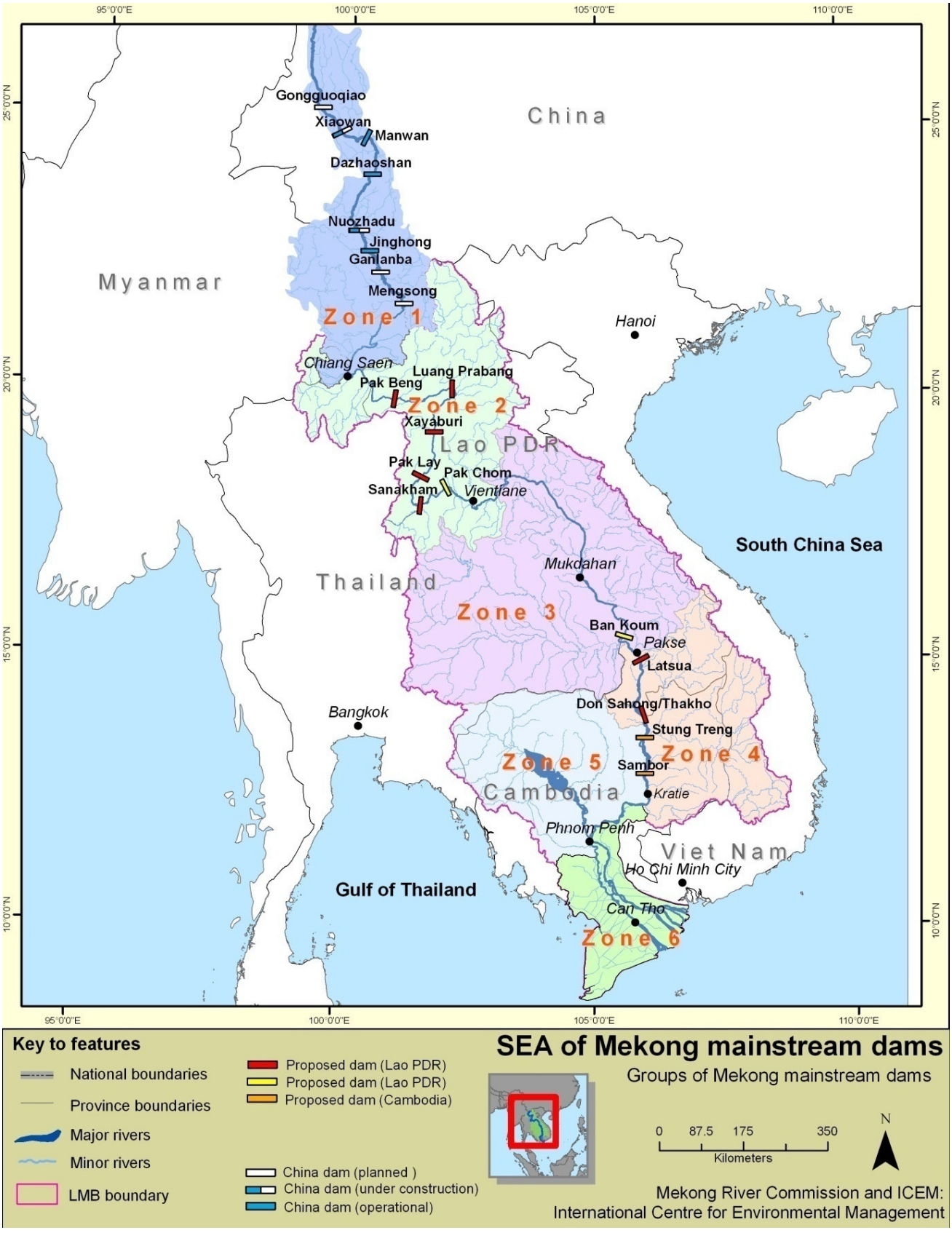
Individual mainstream projects would not affect flooded area /duration of the Cambodian and delta floodplains, nor extent and duration of saline instruction. The cumulative impacts of all mainstream projects on those factors requires further study given that they might have a total storage capacity of several weeks or more depending on how the projects are operated.

The load of suspended sediment in the Mekong River is estimated at 160-165million tonnes/year. In the order of 50% of the load will be removed by storage hydropower projects in China and the 3S rivers. **With all 12 LMB mainstream dams the sediment load would be halved again – i.e. at Kratie it would be 25% of the current load** (~42million tonnes/year). This reduced suspended load will have significant implications for the transport of nutrients which naturally fertilize the Tonle Sap system and 23,000 – 28,000 km2 of floodplain in Cambodian and Viet Nam, as well as de-stabilising the river channels, floodplains and coastline of the Mekong Delta.

Climate change adds a layer of risk and uncertainty in long term planning with both positive and negative potential impacts on the development of hydropower in the Basin. **Climate change would increase the likelihood of extreme events during the life of the mainstream projects, including those which represent the threshold of safety design for the dams**. If not fully accounted for in dam designs and safety measures, the increased likelihood of extreme events with climate change would increase the risk of dam break and failure of key hydraulic components (e.g. spill way gates).

The mainstream projects are likely to result in serious and irreversible environmental damage, losses in long-term health and productivity of natural systems and losses in biological diversity and ecological integrity. The largest impact on the riverine terrestrial system would affect wetlands. Almost 40% of the Mekong River’s wetlands lie within reaches of the river where projects are located - 17% of which would be permanently inundated by the LMB mainstream projects.

Figure S3: The LMB mainstream reservoirs: *55% of the Mekong River (Chiang Saen to Kratie) will be converted into reservoirs*



The mainstream projects would have a significant local impact on agricultural productivity. Around 135,000ha would be inundated by the 11 projects and taken for transmission lines and access roads. Some 150,000ha of riverbank gardens, agricultural lands and irrigation schemes would be directly affected by the 996 km of reservoir created by the 11 projects between Chiang Saen and Kratie (Figure S3).[15] Twenty percent

[15] The 12th mainstream project – Thakho – does not have a reservoir and will not result in inundation of land

of affected agricultural lands would be permanently lost through inundation or clearing, while the use and productivity of the remaining 80% under irrigation schemes would experience increased complication in management and system performance (e.g. water levels varying at an hourly or daily time-step) which would require additional investments to overcome.

The LMB mainstream dams would fundamentally affect the integrity and the productivity of the Mekong aquatic system by: (i) permanently inundating the majority of the river's aquatic habitats, (ii) severing at the local level the seasonal distinctions of the river hydrology, and (iii) cutting the transport of sediment and nutrients between the upland areas and the floodplains. **Based on loss of habitat alone, the mainstream projects would induce a 12-27% reduction in the primary productivity of the aquatic systems (i.e. vegetal productivity), with implications for the overall productivity of the river and in the reservoirs themselves.** Considering the estimated 75% reduction in nutrient loading as a cumulative impact of all the mainstream dams, primary productivity could reduce to a small fraction of present values with severe implications for the aquatic food chain, fish habitat and fisheries. As a conservative estimate, the LMB mainstream projects are expected to be responsible for one third of the reduction in nutrient and sediment loads of the Mekong River. The Yunnan cascade and other tributary developments expected by 2030 would be responsible for the other two-thirds of this reduction.

The mainstream projects would have a negative impact on ecosystems of international importance, a large number of species, and a number of globally endangered species likely leading to their extinction. The loss of habitats would encourage the proliferation of generalist species that do not migrate over long distances, can breed within the body of the reservoir and do not require specialised habitats or hydrological triggers to induce spawning. The species requiring those conditions (e.g. Pangasiid fishes) would experience a sharp decline. The fragmentation of the river system would isolate aquatic populations into pockets leading to a loss of species. If all mainstream projects proceed, 55% of the Mekong River between Chiang Saen and Kratie would be converted into reservoir, shifting the environment from riverine to lacustrine (Figure S3). At least 41 riverine fish species found only in the mainstream upstream of Vientiane would be threatened.

The loss in LMB biodiversity would be a permanent and irreplaceable global loss which could not be compensated. Most impacts of the LMB mainstream dams on the aquatic ecosystems would be unavoidable.

Extraction of energy for LMB mainstream hydro-electricity (up to 14,697 MW) will reduce the available energy for the natural eco-morphological processes of the Mekong River. Consequently, **most of the knock-on impacts of the mainstream projects related to Mekong hydrology, geomorphology, habitat and sediment dynamics would be unavoidable**. Where opportunities for mitigation do exist, they would require reductions in electricity generation through alterations in the design, operations and management of the proposed projects, which would need enforcement by an independent authority with the technical capacity and regulatory mandate to enforce standards at the LMB or preferably basin-wide level.

The impacts on terrestrial ecosystems are generally more locally based and can be mitigated or compensated by measures for rehabilitation and recreation of affected ecosystems and through conservation offset programmes, to compensate for permanent habitat losses. The most difficult systems to offset or rehabilitate would be affected wetlands. Loss of mainstream wetlands could not be compensated or recreated.

FISHERIES AND FOOD SECURITY

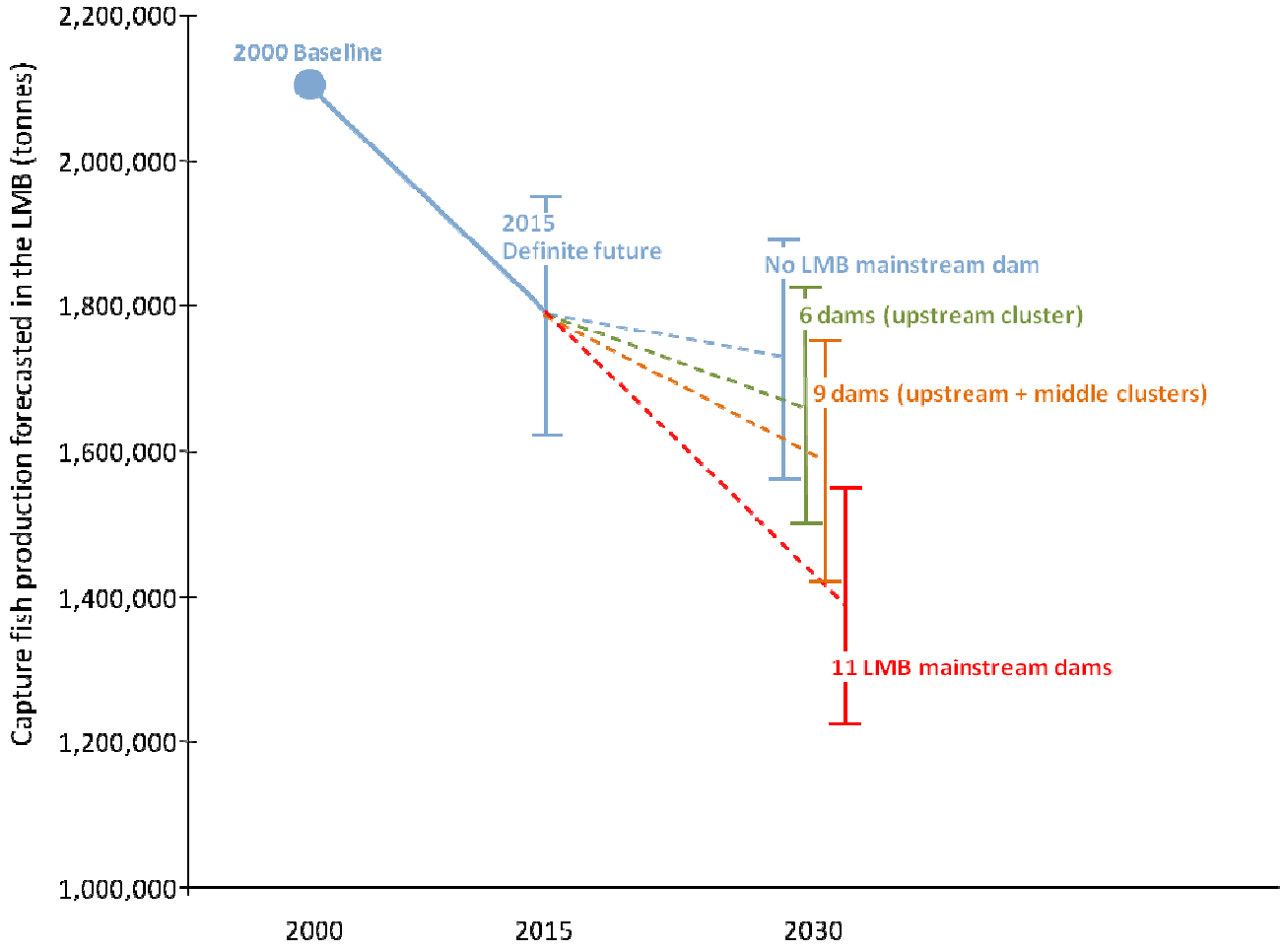
In a river basin where 70% of communities are rural and where inland fisheries are the most intensive in the world, food security and livelihoods are still largely based on river-dependent natural resources. Risks and losses incurred by the Mekong terrestrial and aquatic ecosystems translate into threats to the livelihoods of millions of people – primarily through increasing food insecurity in the basin. If natural resources productivity is reduced, the country's most at risk are Cambodia and Lao PDR.

The LMB mainstream projects enter the Basin at a time when tributary hydropower already threatens the diversity and size of the Mekong fishery. Fish yield in the Mekong is comprised of at least 35% of long-distance migrant species whose migrations would be barred by dams. **The mainstream projects would fundamentally undermine the abundance, productivity and diversity of the Mekong fish resources**, affecting the millions of rural people who rely on it for nutrition and livelihoods.

Figure S4 shows the losses in Mekong fish production due to proposed mainstream and tributary development. In summary by 2030:

- With development basin wide including a total of 77 dams on LMB tributaries and on the Lancang River mainstream, the loss of fish production compared to the 2000 baseline is expected to be 210,000 – 540,000 tonnes or 10-26% *in the absence of mainstream dams*
- **If 11 mainstream dams were in place, the total loss in fish resources would be 550,000 – 880,000 tonnes or 26–42% compared to the 2000 baseline – ~340,000 tonnes of that estimate directly due to mainstream dams. The amount of protein at risk of being lost annually if 11 mainstream dams were built by 2030 represents 110% of the current total annual livestock production of Cambodia and Lao PDR.**
- If 9 mainstream dams were operating upstream of Khone Falls, the loss in fish resources would amount to 350,000 – 680,000 tonnes or 17 – 32% compared to the 2000 baseline, 140,000 tonnes of that estimate directly due to mainstream dams.
- If 6 dams were built upstream of Vientiane, a loss ranging between 270,000 and 600,000 tonnes or 13–29% is expected compared to the situation in 2000 - about 60,000 tonnes of that estimate due to mainstream dams or protein loss annually equivalent to 60% of the current livestock production of Lao PDR .

Figure S4: Potential incremental impact of LMB mainstream dams on fish production basin-wide



Reservoir fisheries cannot compensate for the loss in capture fisheries and at best would produce one tenth of the lost capture fisheries production. In the long term, the reduction in sediment and nutrient outflow predicted for 2030 of from 50% to 75% of the current average annual load would have a major impact on coastal fish production, and subsequently on the Vietnamese fishing sector and fish trade – a sector which has shown strong growth in the last 10 years and produces some 500,000 tonnes of fish annually.

Aquaculture can complement the Mekong capture fisheries sector but cannot replace it in terms of food security. Aquaculture has shown rapid growth in all LMB countries (most developed in Viet Nam). Intensive aquaculture (e.g. Viet Nam) produces fish for export and income but is not accessible to the poor. Extensive aquaculture (e.g. Cambodia) feeds local people but is not very productive. This sector is dependent on: (i) investment, (ii) land/water management, and (iii) capture fisheries for feed (all countries) and juveniles (Cambodia in particular). With management for multiple uses, the LMB mainstream projects could provide the investment and water resources needed for continued growth in the aquaculture sector. The LMB mainstream

projects would reduce the productivity of capture fisheries, diminishing the supply of feed-stock to the aquaculture sector with limited capacity for replacement through reservoir fisheries.

Substantial losses in the fresh and marine capture fisheries and in Delta aquaculture would have basin-wide impacts on the fisheries sector, associated ancillary and processing industries, and fisheries associated livelihoods, and health and nutrition.

Fish passes are not a realistic mitigation option for Mekong mainstream dams. Fish ladders may be a mitigation option for low dams on tributaries, but existing types and sizes of fish ladders cannot accommodate the intensity and diversity of fish migrations on the mainstream. Eight of the proposed mainstream dams are higher than the maximum height at which fish ladders are operational. World-wide fish ladders are efficient when specifically designed for a few particular species that migrate once a year in limited numbers. The Mekong is characterized by more than 50 different migrant species, huge densities during migration peaks and several migration pulses per year. In addition, a cascade of dams would exponentially reduce the overall upstream fish passage rate.

If fish passes are to be successful, they must be considered at the earliest planning stages during the determination of dam location and design and must be designed for identified target fish species. To date, only three of the 11 LMB mainstream dams have explicitly included fish passes, none considered fish passage before location was finalised and none have been designed based on studies for target fish species.

The agricultural sector would be adversely affected by mainstream hydropower development because of inundation of agricultural land and loss of river bank gardens, despite expansions in irrigation associated with the projects. The impacts on agriculture in the Delta are likely to be significant but at this stage have not been investigated or estimated.

The mainstream projects would reduce food security in riparian provinces especially when combined with the potential effects of climate change. Climate change is likely to see (i) agricultural productivity increase in the basin (around 3.6% by 2030) but food security decrease, despite the increasing areas under irrigation and (ii) decreases in fish biodiversity and stability in fisheries sector production despite some climate change benefits of increasing flooded area and nutrient loading.

Agriculture losses may be partially compensated for by an opening up of new agricultural land adjacent to the reservoirs, and provision of irrigation equipment and electricity. There may be issues of equitable access to such improvements especially for the poor as larger irrigation schemes favour centralisation.

SOCIAL SYSTEMS - LIVELIHOODS AND LIVING CULTURES OF AFFECTED COMMUNITIES

Some 29.6million people live and work within 15 km of the Mekong River throughout the LMB. Of these, 2.1 million are local riparian communities living within 5 km of the river who are expected to be most at risk to the direct and indirect impacts of the LMB mainstream dams. Of these, **106,942 people will suffer direct impacts from the 12 LMB mainstream projects, losing their homes, land and require resettlement**. **More than 2 million people in 47 districts living within the proposed reservoirs, dam sites and immediately downstream of the 11 LMB mainstream projects are at highest risk of indirect impacts from the LMB mainstream projects.**

Mainstream projects are likely to have significant effects on riparian communities by disrupting their ways of life, cultures and sense of community. The proposed mainstream development would inhibit community access to, availability and quality of the food they eat and increase the level of hazard or risk they are exposed to.

Some mainstream projects would result in villages being displaced for the second, third and fourth time in 15 years. Repeated compulsory relocation within a relatively short period of time is one of the most impoverishing acts that can occur to communities given the rapid pace of hydropower development. This risk of multiple displacements of affected people in Stung Treng and Kratie is extremely high

The experience in providing the needed long term, consistent and sensitive adjustment and support programs for communities affected by hydropower has not been good in the LMB region. Often it requires capacities and approaches to programme and budget management that are not in place.

Summary of economic opportunities & risks for LMB countries for all 12 LMB mainstream projects

Cambodia

- **Serious adverse consequences for fisheries and fishers, food security and poverty reduction**
- **Significant benefits from power sector development secure and less expensive power for industry and economic diversification in the long term**
- **Fisheries losses likely to out-weigh benefits of power production at least in the short to medium term**

OPPORTUNITIES	RISKS
▪ Significant benefits from less expensive and secure national power supply (replacing costly diesel imports) ▪ Increased competitiveness in manufacturing sector ▪ Increased government revenue from power export and taxes ▪ Increase in irrigable area and agricultural productivity in some areas ▪ Longer term strategic flexibility in power supply once concession periods end	▪ Loss of fisheries resources and significant impact on food security ▪ Livelihoods disruption of over 1.6 million fishers ▪ Loss in GDP through economic losses in fisheries and agriculture ▪ Ancillary services and processing would suffer ▪ Loss of sediments and associated nutrients to Tonle Sap system, and associated adverse impacts on primary production, flood forest and local/migratory fish ▪ Loss of river bank gardens - likely to be significant for riparian communities in some areas ▪ Loss of fertility and agricultural productivity in flood plains ▪ Loss of tourism assets and revenue ▪ Lack of national grid may inhibit equitable distribution of power ▪ Loss of biodiversity

Lao PDR

- **Likely significant overall economic benefit – this is likely to be unevenly distributed**
- **Negative impacts on vulnerable communities likely to be significant**
- **GoL expenditure of increased net revenues could help ameliorate negative impacts**

OPPORTUNITIES	RISKS
▪ Significant benefits from economic stimulus of FDI in LMB mainstream hydropower ▪ May see net revenue benefits in concession period depending on the design of financing agreement and adequate oversight capacity ▪ Likely to see significant benefits after 25 year concessions end and the projects transferred to GoL ▪ Benefits of increased irrigable area and agricultural productivity in some areas ▪ Improvement in navigability for med/large vessels upstream of Vientiane ▪ Longer term strategic flexibility in power supply once concession periods end	▪ Possibility of macro-economic imbalances developing due to booming hydropower sector ▪ Loss of fisheries – likely to affect food security and livelihoods of vulnerable populations ▪ Loss of river bank gardens particularly significant in Lao PDR ▪ Loss of valuable tourism assets ▪ Loss of biodiversity

Thailand

- **Overall economic benefit although insignificant for national economy**
- **Economic risks to livelihoods for riparian communities in the basin**

OPPORTUNITIES	RISKS
▪ Will receive significant portion of the economic benefits of power from imports ▪ Improvement in navigability for med/large vessels in upper reaches of the LMB	▪ Loss of fisheries ▪ Loss of agricultural land ▪ Possible loss of eco-tourism assets

Viet Nam

- **Likely overall economic loss**
- **Losses borne predominantly by poorer communities in the Mekong delta**

OPPORTUNITIES	RISKS
▪ Will receive significant portion of the economic benefits of improved power supply (from imported power)	▪ Significant loss in fresh water and marine capture fisheries and aquaculture – likely to affect livelihoods of fisher folk in delta - especially poorer groups ▪ Loss of sediments and associated nutrients significant adverse economic affects to deltaic sedimentation, fisheries (Mekong and marine) and agriculture

SUMMARY OF CONCLUSIONS

The mainstream projects would bring significant additional power and investment/revenue benefits to the region. They would also bring many serious risks and uncertainties to issues of strategic economic, social and environmental concern to the Mekong countries and communities and for the sustainable development of the Basin. In summary, for each of the big strategic concerns the SEA team concludes:

POWER GENERATION & SECURITY

The LMB mainstream dams present a significant potential contribution to power generation for the LMB region, comprising 23% of the technical hydropower potential in the four LMB countries and 11% of the installed capacity by 2025. Hydropower in the Mekong Basin is a small but an important component of the fossil-fuel dependent LMB power sector. Growth in electricity demand to 2025 will maintain the importance of hydropower as countries seek to diversify fuel sources, reduce carbon emissions and increase regional trade. The LMB mainstream projects could contribute 8% of the 2025 regional demand if all went ahead.

LMB mainstream hydropower is not critical to ensure healthy growth in the LMB regional power sector, but the absence of mainstream projects would limit Cambodia's capacity for indigenous domestic supply options and for export earnings. Though most of the power sector benefits will fall to Lao PDR, the projects are most critical to Cambodia which has few alternatives to importing expensive fossil fuels. Lao PDR – an experienced hydropower producer - has sufficient tributary hydropower potential to ensure healthy growth in the medium term and produce economical electrical energy for domestic supply and export without LMB mainstream projects.

Preparing for climate change today would allow the power sector to enhance the potential of LMB tributary and LMB mainstream hydropower. Most of the Mekong tributaries with strong hydropower potential are projected to experience a net increase in annual discharge through increases in wet season flow due to climate change.

The alternatives to completely blocking the mainstream to produce electricity have not been adequately explored. Internationally, there are a number of recent technological and management innovations for hydropower on large rivers that have not been adequately explored for the Mekong River. Though power output from each project is likely to be less, partial damming of channel branches, in-stream turbines and diversions require detailed feasibility studies given their potential for much reduced natural systems, livelihood impacts and a more sustainable marriage of power and IWRM objectives.

ECONOMIC DEVELOPMENT & POVERTY ALLEVIATION

LMB mainstream hydropower present very significant economic benefits for the regional power sector, most of which (70%) would fall to Lao PDR. The 12 LMB mainstream project proposals represent a significant opportunity for generation of revenues in host countries, providing USD 3-4 billion in annual benefits for Lao PDR and Cambodia. In the order of 25 – 31% of gross revenues would accrue to national host governments during the concession period (typically 25 years), rising close to 100% after the concession period.

The stimulus from LMB mainstream hydropower to national revenue, if properly managed, could contribute significantly to economic development in the host countries. The 12 LMB mainstream hydropower projects would represent significant investments of some USD25 billion into the regional economy. Up to 50% of Foreign Direct Investment (FDI) flows associated with mainstream hydropower is likely to remain inside host countries.

National and regional capacity in public financial management, project capacity and the successful implementation of benefit sharing mechanisms is growing but will not be sufficient to ensure that benefits accruing at the national level are transferred to the local level. In the short to medium term, international financing organisations will play a critical role in developing the required capacity to convert the increased revenue into sustainable and equitable economic development.

The losses experienced by the fisheries and agriculture sectors due to the mainstream dams are an order of magnitude greater than the realistic benefits to those sectors. Fisheries and agriculture , two of the most important economic sectors in the natural resource dependent LMB, will experience losses in the order of USD 500 million/year, with potential benefits from reservoir fisheries and new irrigation potential expected to contribute USD 30 million/year. Once, economic impacts on coastal and delta fisheries are better understood, estimates of losses are likely to significantly increase.

Even with mitigation measures conventionally associated with hydropower projects in the region, LMB mainstream projects would likely contribute to a growing inequality and a short to medium term worsening of LMB poverty in LMB countries.

ECOSYSTEM INTEGRITY AND DIVERSITY

The LMB mainstream projects would induce significant additional basin-wide effects on the Mekong river-dependent ecosystems, the majority of which are unavoidable if the projects go ahead. The LMB mainstream projects are proposed at a time when the Mekong hydrological regime is undergoing a period of intensive change driven by rapid hydropower development on the LMB tributaries and on the UMB mainstream in

China. The LMB mainstream projects would further exacerbate these wide-ranging threats as well as sever the longitudinal connectivity of Mekong ecosystems compartmentalising it into smaller and far less productive units.

LMB mainstream projects would affect flooding through the footprint of their reservoirs, converting 55% of the Lower Mekong River into reservoir with the potential to induce significant and rapid fluctuations in downstream water surface levels at a daily and even hourly time-step. Overall development of hydropower on the Mekong River and tributaries would induce massive reductions in sediment transport and disruption of the hydro-ecological seasons. Tributary and UMB projects would affect flooding depth and duration in the floodplains though seasonal regulation of flows.

The mainstream projects would lead to permanent losses in aquatic and terrestrial biodiversity of global importance and the irreversible degradation of the Mekong River ecology which cannot be mitigated or compensated. Seventeen percent of the Mekong's in-channel wetlands would be lost and a number of charismatic Mekong River species would become extinct.

FISHERIES & FOOD SECURITY

By 2030, if 11 mainstream dams were built, the protein at risk of being lost annually would be the equivalent of 110% the current annual livestock production of Cambodia and Laos. Reservoir fisheries from mainstream dams would compensate at most 10% the losses in capture fisheries. None of the existing fish pass types can accommodate the size and intensity of mainstream fish migrations.

Risks and losses incurred by the Mekong terrestrial and aquatic ecosystems will result in increasing food insecurity for millions of people. Rural and urban communities living within 15 km of the Mekong River would be particularly affected, experiencing greater food insecurity due to the reduction in capture fisheries and net loss of subsistence agriculture and river bank gardens.

Climate change would have a synergistic effect on the mainstream dam food security effects, further reducing fisheries and agricultural productivity in situations of growing food demand.

The financial, institutional civic services and facilities required to address these food security issues along more than 1,500 km of transboundary river bank are immense and beyond the current capacities of the LMB region and its governments to address.

The magnitude of risks in Cambodia, Lao PDR and on Viet Nam's delta economy calls for a detailed assessment of impacts on food security and livelihoods, identification of realistic solutions, and the development of alternative food supply options prior to decisions on the mainstream projects.

SOCIAL SYSTEMS – LIVELIHOODS & LIVING CULTURES

In the short to medium term, the LMB mainstream projects would degrade livelihoods of the poorest communities in Mekong riparian provinces. LMB mainstream hydropower will adversely affect the millions of riparian communities who draw their livelihoods from the river and its natural resources. The livelihoods of at least 2.1million people will be directly or indirectly affected if all mainstream projects were to proceed.

Of those riparian communities directly and indirectly affected, the mainstream projects would lead to significant changes in access to and control over essential livelihood resources and ways of life – i.e., how they live, work, play and interact with one another on a day-to-day basis, their physical safety and the level of risk they are exposed to, and their culture – that is, their shared heritage, customs and values.

REGIONAL COOPERATION AND CONFLICT

When under construction and operating, the proposed developments have the potential to create transboundary impacts and international tensions within the LMB due to i) reduced ecosystem integrity, ii) reduced sediment and nutrient loads, iii) disruption to other uses of the Mekong and iv) reduced productivity in fisheries and agriculture and overall food insecurity in affected sub-basins and the delta.

The framework of regional standards and safeguards relating to transboundary and downstream effects and institutional arrangements for their enforcement are not fully developed and are not adequate to the requirements of the mainstream project risk management.

The LMB mainstream projects provide an opportunity to increase regional cooperation in the power sector, consistent with national and GMS planning.

UNCERTAINTY

Many of the risks associated with the proposed mainstream developments cannot be mitigated at this time, as they would represent a permanent and irreversible loss of environmental, social and economic assets.

There are many and substantial gaps in institutional and procedural arrangements for ensuring the effective management of the construction and operation of the projects and similar gaps in the national capacities to share benefits equitably.

Critical national capacities in terms of personnel and skills continue to grow but are not yet fully in place to oversee, control, monitor and enforce safeguards and operational rules

There are many remaining uncertainties and knowledge gaps associated with the developments. The state of knowledge about the Mekong is not adequate for making informed and responsible decisions about mainstream dams at this time.

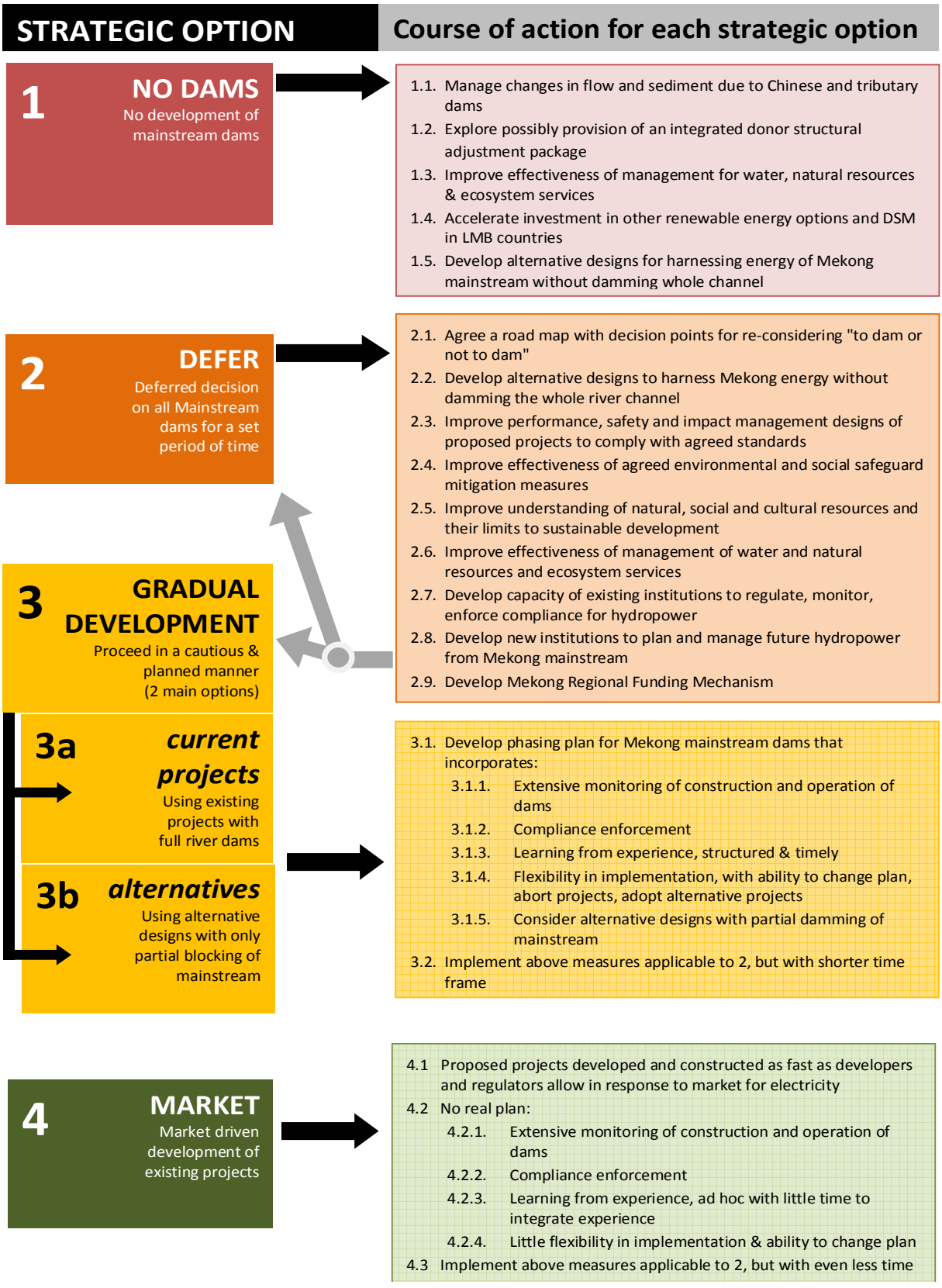
STRATEGIC OPTIONS AND RECOMMENDATIONS

The proposed development of the mainstream Mekong River is the most important strategic decision ever made by LMB countries on use of their shared resources. The goal of an SEA is to influence the strategic decisions relating to the proposed projects – to help shape decisions and plans so that development is equitable and ecologically sustainable. This SEA was conducted to help identify in clear terms the trade-offs involved in strategic options – i.e., what will be lost, what will be gained and who will lose, as well as who will gain?

The SEA addresses a fundamental question - "*To dam or not to dam the Mekong River mainstream*?" In response to that question, the SEA has described and consulted on four strategic options of to LMB countries:

1. No mainstream dams
2. Deferred decision on all mainstream dams for a set period
3. Gradual development of mainstream power
4. Market driven development of the proposed mainstream projects

The SEA team assessed in detail each of the four options, based on the four assessment phases and findings of the SEA. The SEA makes detailed recommendations for each strategic option so that the LMB governments have guidance on critical issues whichever strategy is adopted. The decision flow chart below summarises the SEA recommendations associated with each of the four strategic options.



Comprehensive recommendations for each of the strategic options are set out in the main report to guide LMB countries on whatever the course of action they finally decide concerning the mainstream proposals.

The SEA process was initiated in a context in which stakeholders appeared to hold strongly divergent views on the question of mainstream development. Divergence tended to mirror the sectoral mandates of line agencies and missions of international and local organisations. In practice, when participating as experts rather than government officials or organisation representatives, the SEA team found that there was much common ground among stakeholders. During the 16month consultative process involving one-to-one and round table meetings with some 60 government line agencies and 40 non government organisations in each of

the LMB countries, most stakeholders were concerned about the potential impacts of the proposals, wished to have convincing evidence of the need for them, and felt that there had not been adequate consultation and discussion across governments and with affected communities. A significant number of SEA stakeholders felt that political decision-makers should give due consideration to the strategic option of deferring a decision on mainstream development until key uncertainties are reduced, alternatives had been fully considered and measures to manage development risks were agreed upon through a combination of MRC-led and bilateral processes.

The findings and conclusions of the SEA concerning the significance of the risks and of the many uncertainties and gaps in knowledge which remain, as well as the shared views of most stakeholders involved in the SEA process on the need for further consultation and study, led the team to recommend the adoption of strategic option 2 – deferment of mainstream development – as summarized below.

MAIN RECOMMENDATION OF THE SEA TEAM

Following the analysis of potential impacts and benefits associated with the mainstream projects, and following an intensive program of consultations with more than 100 government and non-government agencies, the SEA team has reached the following main recommendation:

- Given the economic, social, cultural and ecological importance of the Mekong River as a free flowing system connecting the four Lower Mekong Countries;
- Given the increasingly threatened status of natural systems and resources in the region and growing pressures on them;
- Given the far reaching potential effects and remaining uncertainties relating to the proposed mainstream projects;
- Given the need for a new approach to development of the Mekong River better fitting the requirements of the LMB riparian countries and communities in the 21st Century:

The SEA team recommends:

1. **Decisions on mainstream dams should be deferred for a period of ten years (strategic option 2) with reviews every three years to ensure that essential deferment-period activities are being conducted effectively.**

2. As the highest priority, the deferment period would include a comprehensive undertaking of feasibility studies for partial in-channel, diversion and other innovative systems for tapping the power of the mainstream in ways which do not require dams across the full breadth of the river channel. This would involve governments in partnership with the MRC, multi-lateral development banks and developers.
3. The deferment period would also include a comprehensive assessment and fast tracking of tributary projects that are considered feasible and ecologically sustainable according to current international good practice, including retrofitting of existing projects and innovative schemes.
4. The deferment period needs to commence with a systematic distribution of the SEA report within each LMB country in national languages and consultation with line agencies, private sector and the NGO community.

5. **The Mekong mainstream should never be used as a test case for proving and improving full dam hydropower technologies.**

IMMEDIATE NEXT STEPS

At the final SEA regional workshop, national working sessions made recommendations on what should happen to the final SEA report once submitted to the MRCS. The recommendations on the processes to be following were very consistent from one group to the next. The overall intent was to ensure that strategic consultations on the SEA report happen in each country before project specific decisions are made.

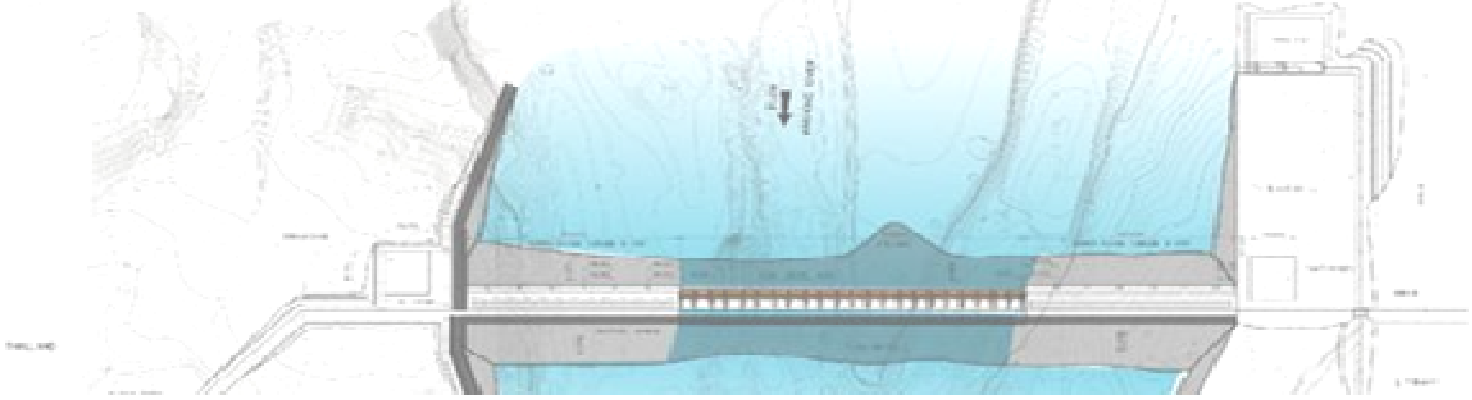
In summary, it was recommended that there should be a systematic distribution of the SEA report within each LMB country in national languages and support given to facilitate consultation on it with line agencies and the

NGO community prior to decisions being made on the mainstream projects. National groups suggested various other steps in the process to optimize usefulness of the SEA report to LMB countries including:

- Consideration of the report by the MRCS Joint Committee
- Consideration of report by the National Mekong Committees
- Further technical consultation on the report with line agencies in each country
- Consideration of the report by national cabinets
- Consideration of the report by natural resources and environment parliamentary committees
- Convene multi-stakeholder conferences in each country and at regional level to discuss the report
- Establish regional technical task forces on the key strategic issues where uncertainties and significant risks remain.

The recommendations of this SEA stem from recognition of the need for upmost caution in making development decisions when so much is at stake and when there are evident threats of serious and irreversible environmental, social and economic damage from the proposed mainstream project proposals. Major development decisions always involve trade-offs and change. The principles of sustainable development require that those trade-offs and changes avoid permanent losses, closure of options for future generations and inequitable distribution of costs and benefits among existing communities and areas. In this case of 12 mainstream project proposals, the SEA has found that there is likely to be permanent losses and, even where avoidance and mitigation measures might reduce unwanted impacts, there remains significant gaps in knowledge and inadequate institutional capacities to effectively implement and enforce them. Importantly, it is evident that alternatives to harnessing energy from the mainstream without full channel dams, and other off-stream options have not been adequately considered.

More time is needed to build greater understanding and capacities, to better explore the options, and to investigate ways to avoid losses which would reduce regional, national and local wellbeing.



PART I: HYDROPOWER ON THE MEKONG RIVER – PROPOSALS AND STRATEGIC OPTIONS

The MRC member countries are faced with the most significant strategic decision ever made affecting the Mekong River – in many respects the natural, cultural and economic backbone of the region. The strategic decision concerns whether or not to construct hydropower dams across the Mekong River - a development which would have far reaching and permanent international, economic, social and economic implications.

This final report of the MRC Strategic Environmental Assessment of 12 hydropower proposals for the mainstream Mekong River is a synthesis of the series of reports prepared for the scoping, baseline, impacts assessment and mitigation phases of the SEA. It summarises the main findings and conclusions from that report series and makes recommendations on the way forward. Further detail and references are provided within the series of SEA reports – available from the MRC and ICEM websites.

1 HYDROPOWER PROJECTS ON THE LANCANG RIVER

The Mekong River is one of the last large rivers on Earth not dammed for most of its length, and the only river still flowing freely to the sea through five countries - Myanmar, Lao PDR, Thailand, Cambodia and Viet Nam.[16] It is dammed in China – the sixth upstream Mekong riparian country - by the first four projects in a planned cascade of up to 8 storage hydropower schemes. Since the River begins in Tibet and passes through Yunnan Province then down through the Lower Mekong countries, it has many names. In China it is called the *Láncāng Jiāng* or "Turbulent River". In the other countries it is variously called “Mother Khong” or “Great River”.

For several thousand years the Mekong’s hydrological regime has remained in dynamic equilibrium with the climate and landscape of the river basin. In the past 15 years, human development in one sector – hydropower – began transforming the hydrology of the basin.[17] The combined effects of hydropower dams on tributaries and mainstream are changing the fundamental characteristics of the river system with pervasive repercussions for natural and social systems and economies.

During 1986-1992, the Mekong flow regime and sediment load was significantly affected for the first time when China constructed a dam across the mainstream – Manwan – in Yunnan Province.[18] The second and third dams, Dachaoshan and Jinghong, were completed in 2003 and 2008. In 2009, China commenced filling the reservoir of its fourth dam, Xiaowan, the highest arch dam in the world at 292 m (958 ft). Xiaowan represents the first time in the history of the basin when a single development will influence the entire hydrological

[16] The Mekong is the world’s 12th longest river and the longest in mainland South-East Asia at approximately 4180 km from its source in Tibet to the coast of Viet Nam. It is the 8th in the world in terms annual water discharge to the sea - some 475 billion cubic metres.

17 Changes to land use and irrigation have had significant impacts at the subcatchment scale but have not induced the same magnitude of change as hydropower at the basin-scale, such that the characteristic features of the Mekong hydrological regime had remained within natural fluctuation.

[18] Manwan Dam with a capacity of 1,750MW

regime of the Mekong Basin. Four more dams are planned for the mainstream in Yunnan Province (Figure 1).[19] An additional hydropower project is under consideration at the conceptual phase on the Lao-Myanmar border for which no information was available. Mainstream dams have greater potential to affect the Mekong River equilibrium than tributary dams which have more localised impacts.

The China dams influence the timing and scale of the natural Mekong pulse on which many other natural, social and economic components of the system are tuned. Only some 14 - 16% of the annual average flow originates from China but during the dry season flows from China make up close to 50%. The China dams have significantly reduced the seasonal difference in the Mekong hydrograph so that less water enters the Lower Mekong Basin in the wet and more in the dry. Because the Upper Mekong gradient is steep, it is a critical source of sediments. Some 55% of sediment and nutrient load reaching Kratie in Cambodia comes from China. The China dams will reduce that loading to around 22% of current levels.

The Mekong is the river with the second highest fish biodiversity in the world. Seven hundred and eighty one fish species have been formally identified and there is likely to be more than 1200 species.. That diversity of life increases as one moves down the mainstream. It reflects the overall productivity and biological stability of the system. Also, it is expressed in the cultural diversity and patterns of life of riparian communities. Some argue that cultural diversity and social stability is closely linked to the maintenance of biological diversity and stability. Current understanding suggests that the China dams have had a relatively small direct impact on fish diversity in the Mekong River – however, little information is available on the importance of that 44% of the river's length in Yunnan province as a nursery and breeding ground and migratory route. Similarly, it is not known how 'clear' water entering the Lower Mekong, possibly with greater temperature variance than before, will affect biodiversity and natural system productivity.

The Chinese decisions to construct mainstream dams have influenced downstream decision makers in the power sector. Until very recently, mainstream dams did not appear in national power development plans of Cambodia, Lao PDR and Thailand. They were off the political agenda because of their potential local and downstream impacts in an international context. The introduction of the Chinese cascade in 1995 and the subsequent changes in seasonal flow for the Mekong River, coupled with the 2003 intergovernmental agreement for regional trade amongst GMS countries have reintroduced LMB mainstream hydropower into the regional and national political agenda. Also, as oil prices rose and became more volatile, and Mekong power demand continued to grow, the potential for hydropower as an export commodity rapidly became more attractive. Further, mainstream power could be well justified as a renewable and climate sensitive resource.

2 PROPOSED LMB MAINSTREAM PROJECTS

Lower Mekong mainstream hydropower proposals are not new. During the 1960s and 1970s, the Mekong Committee drew up plans for a cascade of seven large-scale dams for the lower mainstream. In the 1980s LMB countries rejected the possibility of large storage high dams, including the controversial Pa Mong project. Then in 1994, the Mekong Secretariat released a study proposing a series of dams in 12 locations from Pak Beng, Oudomxay Province in Lao PDR to Tonle Sap in Cambodia with heights ranging in the order of 20-50m above the river bed. The projects were identified without consideration of an appropriate regional planning environment within which they would need to sit. Now, with encouragement by national governments, various companies have picked up and developed those and similar concepts and submitted proposals to the government power regulators. 12 hydropower schemes have been proposed for the Lao, Lao-Thai and Cambodian reaches of the Mekong mainstream (Figure 1). Ten proposals fall within Lao PDR and two within Cambodia. The proposed LMB projects would benefit from the projected increases in dry season flows resulting from dam operation in China.

The project proposals are being considered without an overarching framework of zoning and safeguards for the River against which specific project proposals are considered. An overarching planning guidance for the

[19] A number of hydropower projects are also planned for the reaches of the Lancang River upstream of the 8 Chinese dams considered in the SEA. Detailed information on these projects was not available to the SEA, but preliminary information suggests that the conclusions of the SEA are not likely to be significantly affected by these projects given the large downstream storage capacity of Xiaowan and Nuozahdu.

River with which all development sectors need to comply is not in place regionally or for each national component.[20]

Annex 1 provides the basic information about the size and status of the 12 projects. Generally these proposed projects are classified as run-of-river schemes – ie with water passing directly downstream within a day – although for an average year a max dry season retention time of around 3weeks could be expected. For a dry year the retention time could extend to a month. Sanakham has the largest retention time followed by Sambor, Stung Treng, Luang Prabang and Ban Koum.

Ten of the proposed projects would dam the whole of the river channel – the two exceptions are Don Sahong, which dams one channel of the mainstream, and Thakho which is a river diversion scheme.

Proposed reservoirs in Lao PDR would maintain water above the present high flow level in the existing channel of the Mekong with a relatively small inundation outside the channel. For a number of kilometres upstream from the dam walls, the proposed LMB mainstream reservoirs will maintain elevated water levels above the highest in recorded history and for some projects above the 1 in 1,000 year flood level. Stung Treng and Sambor are significantly larger reservoirs extending well beyond the main channel.

The general layout of the mainstream projects includes the dam extending across the river with sections for the spillways, turbines, penstocks as well as the power house and switchyards on either side. All designs have provision for navigation locks but to date only three (Xayaburi, Lat Sua and Don Sahong) have integrated designs for fish passes. Some dams are located strategically at islands, with the dam being constructed across both or several channels, e.g. at Pak Lay, Sambor and Stung Treng.

2.1 GROUPINGS OF MAINSTREAM PROJECTS

To facilitate the baseline and impact assessment, the Strategic Environmental Assessment (SEA) grouped the proposed mainstream projects in zones defined according to distinctive existing eco-hydrological and social characteristics of the Mekong River (Figure 1). Table 1 lists the projects in four groups – three in Lao PDR and one in Cambodia.

Table 1: Grouping of mainstream project proposals according to hydro-ecological zone

Hydro-ecological zone		Mainstream projects	
1	Lancang River	Eight existing (3), under construction (1) and planned (4) mainstream dams in Yunnan Province, China. *	
2	Chiang Saen to Vientiane	1. Pak Beng, 2. Luang Prabang 3. Xayaburi	4. Pak Lay 5. Sanakham, 6. Pak Chom
3	Vientiane to Pakse	7. Ban Koum 8. Lat Sua	
4	Pakse to Kratie [Lao section above Khone falls]	9. Don Sahong 10. Thakho	
	[Cambodia section below Khone falls]	11. Stung Treng 12. Sambor	
5	Kratie to Phnom Penh		
6	Phnom Penh to South China Sea		

** At latest information, Mengsong, the most downstream project in the Chinese cascade, has been postponed without firm date set for construction.*

[20] The MRC 1995 Agreement and the establishment of the MRC Basin Development Plan (BDP) represent important pioneering steps by the region towards integrated and sustainable planning of development, while specific project level guidance is provided in the 2010 MRC Hydropower sustainable development guidelines. .

Figure 1: Proposed Mekong mainstream hydropower projects & ecological zones

2.1.1 GROUP 1: CASCADE OF 6 DAMS ABOVE VIENTIANE

There are 6 dams above Vientiane, with the upper 5 dams connected in a cascade - the tail waters of the upper dam flowing directly into the headwaters of the next creating a linked stepped reservoir of nearly 800 km. The five dam cascade is located in Lao PDR. The lowest dam, Pak Chom, is shared by Lao PDR and Thailand. In general the river in this stretch of the Mekong is narrow with steep hillsides on either side, so between 80% - 96% of the reservoirs are confined to the Mekong channel – with the exception of Luang Prabang and Pak Lay where only 40% and 33% of the inundated area is confined to the river channel.

Pak Beng is the northern most of the LMB dams, located upstream of the town of Pak Beng, in Lao PDR. The developer is Datang from China, with power destined for Thailand. It has an installed capacity of 1,230 MW with a dam 943 m long, 76 m high and a rated head of 31 m. It has a reservoir area of 87 km^2 and live storage of 442 Mm^3. As originally designed with a Full Supply level at 345 masl, it would have inundated land back into Thailand, but under the Lao Government Optimisation Study for the cascade, the FSL was lowered to 340 masl to avoid this impact. 80% of the reservoir area will be confined to the main channel. The latest estimate of people to be resettled is 6,700.

Luang Prabang is the second dam in the cascade, located above Luang Prabang town, about 3 km above the confluence with the Nam Ou, and the Pak Ou caves. The developer is Petrovietnam Power Corporation and the power is destined for Viet Nam. It has an installed capacity of 1,410 MW and a dam 1,106 m long and 68 m high with a rated head of 40 m. It has a reservoir area of 90 km^2**,** 40% of which is contained within the channel and live storage of 734 Mm^3. The latest estimate of people to be resettled is 12,966.

Xayaburi, the third dam in the cascade is located about 150 km downstream of Luang Prabang town. The developer is SEAN and Ch. Karnchang of Thailand, with the bulk of the power destined for Thailand. It has an installed capacity of 1,260 MW with a dam 810 m long and 32 m high and a rated head of 24 m. It is proposed to operate continuously. It has a reservoir area of 49 km^2 (96% confined within the main channel) and live storage of 225 Mm^3. The proposals and studies for Xayaburi are the most advanced, and is to be the first in line for consideration under the MRC's PNPCA. The latest estimate of people to be resettled is 2,130.

Pak Lay, the fourth dam in the cascade is located just above the district town of Pak Lay in Lao PDR. Two options for its location were proposed and the upper option recommended during the Lao Optimisation Study because it would significantly reduce the number of people to be relocated from about 18,000 to 6,129. The developer is CIEC and Sinohydro of China with power destined for Thailand. It has an installed capacity of 1,320 MW and a dam 630 m long and 35 m high with a rated head of 26 m. It has a reservoir area of 108 km^2 (33% confined within the main channel) and live storage of 384 Mm^3.

Sanakham, the final dam of the cascade to be located fully in Lao PDR, is situated just upstream of the Thai-Lao border, between Loei and Vientiane provinces. The developer is Datang from China and the power destined for Thailand. It has an installed capacity of 700 MW and a dam 1,144 m long and 38 m high with a rated head of 25 m. It has a reservoir area of 81 km^2 (83% confined within the main channel) and live storage of 106 Mm^3. The latest estimate of people to be resettled is 4,000.

Pak Chom is the first of the two dams shared between Thailand and Lao PDR. It is located about 100 km upstream of Vientiane, and is not officially part of the upstream cascade, though its reservoir would flood back towards Sanakham, which is 86 km upstream. There is no developer as yet for Pak Chom, though pre-feasibility studies have been commissioned by the governments of both Thailand and Lao PDR. It has an installed capacity of 1,079 MW with a dam 1,200 m long and 55 m high and a rated head of 22 m. It has a reservoir area of 74 km^2 (92% confined within the main channel) and live storage of 12 Mm^3. The latest estimate for the number of people to be resettled is 535. Pak Chom has 11 associated pumped irrigation schemes for a total of 2,700 ha in both Thailand and Lao PDR.

2.1.2 GROUP 2: TWO DAMS BETWEEN VIENTIANE AND PAKSE

There are two dams between Vientiane and just downstream of Pakse, above and below the confluence with the Mun/Chi River. They would not be operated as a cascade.

Ban Koum is the second of the two dams shared between Thailand and Lao PDR. It is located about 10 km above the confluence of the Mun/Chi River with the Mekong, in a narrow valley with sandstone hills on each side. The developer is Ital-Thai of Thailand with the power destined for Thailand. It has an installed capacity of 1,872 MW and a dam 780 m long and 53 m high with a rated head of 19 m. It has a reservoir area of 133 km^2 (86% confined within the main channel) and little live storage. The latest estimate of people to be resettled is

935. Ban Koum has 22 associated pumped irrigation schemes for a total of 7,870 ha in both Thailand and Lao PDR.

Lat Sua has been relocated to a site 10 km downstream of Pakse. The original site was between Pakse and the Mun/Chi confluence, but since the reservoir would have flooded back to the Mun/Chi River, it was decided to relocate it and reduce the height, so that Pakse would not be affected. The developer is Charoen Energy Water Asia Co of Thailand, and the bulk of the power destined for Thailand. It has an installed capacity of 686 MW and dam 1,300 m long and 27 m high with a rated head of 10.6 m. It has a small reservoir area of 13 km^2 (80% confined within the main channel) and very little live storage. The latest estimate shows that no people will have to be resettled since nearby villages will be protected by embankments. Lat Sua has plans for associated pumped irrigation schemes for a total of 7,300 ha in Lao PDR.

2.1.3 GROUP 3: DAMS IN SIPHANDONE

The hydropower projects in the lowest Lao group are Don Sahong and Thakho in the Siphandone area of Lao PDR, neither of which are full mainstream dams.

Don Sahong dam blocks off the Hou Sahong channel, one of more than ten channels that flow over the Khone falls at the southern end of Siphandone. The Hou Sahong channel is the only channel through the Khone Falls complex which is passable during the dry season. The Don Sahong project would represent an impassable barrier to Mekong dry season fish migration. It takes advantage of the 15 – 18m drop at these falls and attracts a significant proportion of the flow into the small reservoir which forms in the Channel. The developer of this dam is Mega First from Malaysia and the power generated is destined for Thailand. It has an installed capacity of 240 MW and a dam 720 m long and 8.2 m high with a rated head of 17 m. To minimise flooding on the adjacent islands, embankments on either side of the dam will extend up to 2km along the channel. It has a small reservoir area of 290 ha (32% confined within the main channel) and a live storage capacity of 115 Mm^3. The latest estimate shows that 66 people will have to be resettled.

Thakho is a different type of scheme from all the others, being a river diversion rather than a dam. It diverts about 380 m^3/sec from above the Khone-Phapheng Falls, transfers the water by a 1.8 km channel constructed on the land to the east of the Falls and discharges it through a power house about 1.5 km below the Khone Falls. Thakho is a joint venture developed by CNR from France and EDL from Lao. The power generated would be used in the southern Lao power grid. This scheme involves no dam, and no barrier to fish movements and has an added advantage of generating more power during the dry season, because the head differential above and below the falls is greater at that time of year. It has an installed capacity of 50 MW. There is no need for resettlement. To some extent the Thakho project is an alternative to the Don Sahong dam.

2.1.4 GROUP 4: CAMBODIA PROJECTS

The two Cambodian dams at Stung Treng and Sambor are longer than the other dams because they have to cross a wider floodplain, and the reservoirs tend to be larger.

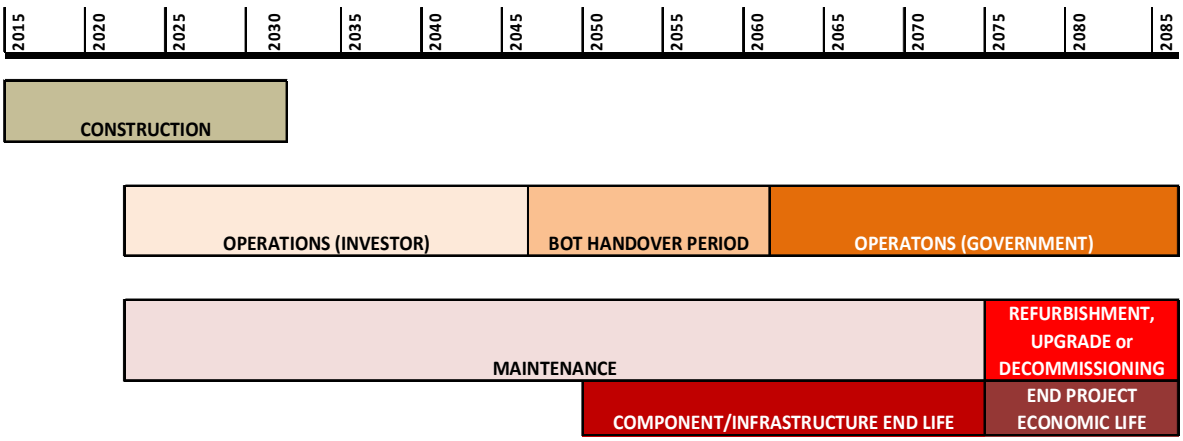
Stung Treng is the uppermost of the two Cambodian dams, and is located about 10 km upstream of Stung Treng town and the confluence with the Sekong/Sesan/Sre Pok Rivers. An MoU for its development had been signed with a Russian company, but when this lapsed, the Song Da company from Viet Nam agreed to carry out feasibility studies. At this stage it is not known where the power is destined for. It has an installed capacity of 980 MW with an 11 km long and 22 m high dam, and a rated head of 15 m. The reservoir would extend up to the Cambodia/Lao border covering 211 km^2 with an active storage of 70 Mm^3. The latest estimate shows that over 10,000 people would have to be resettled.

Sambor is the lowest dam of the LMB mainstream dams, and largest one in Cambodia. It is located near the village of Sambor, upstream of Kratie and would inundate the river channel to just south of Stung Treng town. It is being developed by China Southern Power Grid and the destination for the bulk of the power is Viet Nam. It would have an installed capacity of 2,600 MW, and a dam over 18 km long and 56 m high, with a rated head of 33 m. It would create a reservoir of 620 km^2 with an active storage of 465 Mm^3. The latest estimate shows that over 19,000 people would have to be resettled.

Annex 1 gives the earliest potential commissioning date for each project if approved. Those are the dates that the schemes would start to generate commercially, although test generation would begin beforehand. Typically, these mainstream projects would take 5 to 8 years to construct. The construction period is the most costly but brings significant economic benefits due to the investment stimulus. All the mainstream dams are

proposed to be financed through private sources on a BOT or BOOT basis[21], and most have a 25 or 30 year concession period during which time the developer would pay off the financing debt and generate profits. After this time, the project would be handed back to government to operate for its remaining lifetime (Figure 2). In economic analysis of the dams they are assumed to have a 50 to 100 year life.

Figure 2: Long-term Phasing schedule for mainstream Mekong hydropower



Note: Phasing above is based on a 50year life cycle which is consistent with the time frame used by MRC to compute capital recovery costs. Depending on the operations and maintenance strategies the projects may last for longer than 50years

3 STRATEGIC OPTIONS FOR LMB COUNTRIES IN CONSIDERING THE MAINSTREAM PROJECT PROPOSALS

There are four broad strategic options facing the LMB countries in deciding whether or not to proceed with one or more of the projects proposed for the mainstream Mekong River. Those strategic options lie at the heart of the SEA which has been conducted to support LMB countries to make a more informed choice between them based on the most up to date scientific analysis and views. The four strategic options are:

1	• Decide not to proceed with the mainstream projects
2	• Defer a decision on whether or not to proceed with mainstream projects
3	• Proceed with mainstream development on a gradual phased basis
4	• Proceed with market driven development of the proposed mainstream projects

3.1 OPTION 1 – DECIDE NOT TO PROCEED WITH THE LMB MAINSTREAM PROJECTS.

A decision not to proceed would be made based on a conclusion that *mainstream dams across the entire breadth of the Mekong River are an inappropriate form of development for the Mekong River*. Because of the high risks and uncertainties associated with the proposed projects, no dams across the Mekong mainstream should be developed.

In adopting this option, LMB countries forgo the benefits of the proposed mainstream hydropower projects and would need to find alternative sources of energy to meet the demands for imports into Thailand and Viet Nam, and nationally in Lao PDR and Cambodia. Those might be conventional and renewable sources of energy. The tributaries of the Mekong would become a greater focus for hydropower development, and it is possible

[21] BOT = Build, Operate and Transfer; BOOT = Build, Own, Operate and Transfer

that very different methods of harnessing the power of the Mekong mainstream could be developed. The "no mainstream dams" option is not a strategy for complacency and inaction. Given baseline trends, the use of the water and natural resources of the Mekong still would require more effective and sustainable collaborative management than at present.

3.2 OPTION 2 - DEFERRED DECISION ON ALL LMB MAINSTREAM DAMS FOR A SET PERIOD

This strategic option follows a conclusion that *adequate information and conditions for responsible decision making on the mainstream projects are not in place, and that the risks of serious or irreversible harm are significant.*

The deferment decision is linked to the sustainable development precautionary principle. The precautionary principle holds that, when scientific investigation has found a plausible risk of serious or irreversible environmental and social damage, decision makers have a responsibility to protect the public and environment from possible harm. That protection can be relaxed only if further scientific findings emerge providing sound evidence that no harm will result or effective mitigation is possible. The application of the precautionary principle and the need to take precautionary measures is triggered by the satisfaction of two conditions:

(i) A threat of serious or irreversible environmental and social damage and
(ii) Scientific uncertainty as to the exact nature and extent of that damage.

The threat of serious or irreversible damage must be adequately supported by scientifically plausible evidence. The more significant and the more uncertain the threat, the greater the degree of precaution required.

In this option, a road map for periodic review and reconsideration of the mainstream projects would be needed. Deferment is not an option for complacency or inaction. It would require comprehensive studies on the potential effects on natural and social systems, focused on their limits and management for sustainable development. The effectiveness of safety and mitigation measures of the proposed projects to reduce their impacts to acceptable levels would need to be proven. Existing institutions would have to be strengthened and new ones established to manage trans-boundary implications of development on the Mekong mainstream. Research would be required into alternatives for harnessing energy from the Mekong mainstream that retain the essential connectivity and flows of the river – including partial in-channel hydropower, diversion schemes and other innovative systems.

3.3 OPTION 3 - GRADUAL DEVELOPMENT OF LMB MAINSTREAM POWER

The "gradual development" option is based on a conclusion that *most risks can be mitigated and the potential irreversible impacts and losses associated with one or more mainstream dams are acceptable given the benefits which the development would bring*.[22]

A choice of Option 3 would commit to some of the proposed dams on the Mekong mainstream, and accept the ecological and social changes involved before complete understanding and preparedness for these changes is achieved.

This option accepts a slow and controlled development of hydropower on the mainstream with opportunities for learning from experiences and for adapting development as required, including the possibility of cancelling projects if potential impacts are worse than expected or if better alternatives are proposed. However, *once the decision has been taken to build one mainstream dam, then there is no going back to the no-dam state* – there is no reconsidering the appropriateness of mainstream dams as a form of development for the Mekong River.

This strategic option would require the same studies, capacities and safeguard measures to be put in place as for option 2, but with much less time and opportunity for reflection, planning and implementation. As with Option 4, there would be strong pressure from the different developers for early decisions.

This option would allow for two forms of development: a) the proposed mainstream dam projects and b) alternatives to full-channel dams for harnessing the energy of the Mekong mainstream.

[22] Mainstream dam is used in this report to refer to hydropower projects that completely block the Mekong River channel, except: (i) where otherwise indicated (e.g. partial dams), or (ii) in the specific case of Don Sahong and Thakho which are partial dams and diversions respectively.

3.4 OPTION 4 - MARKET DRIVEN DEVELOPMENT OF LMB MAINSTREAM PROJECTS

This strategic option accepts the basic mainstream dam concept and designs for the Mekong River promoted by developers. The projects would proceed under existing regulatory systems if there was a purchaser (predominantly Viet Nam – EVN and Thailand – EGAT) and according to how quickly developers can prepare and process their proposals. A choice of Option 4 would commit the Mekong to all or many of the proposed mainstream projects without adequate prior knowledge or preparedness for managing the developments and their impacts systematically. The option assumes that safeguards and institutional arrangements for managing and coordinating many dams could be put in place as developments proceed.

This option has a much shorter and uncertain time line for implementation, and little opportunity for learning from experiences and for building the capacities and institutions to manage the developments. There would be no opportunity to plan for optimal use and maintenance of the River or to explore less disruptive alternatives for harnessing energy from the Mekong mainstream. Essentially, the projects would proceed using conventional mainstream hydropower dam technology. Once one project was approved, there would be increased pressures from different developers to go ahead with their projects depending on demand for electricity and the tariffs that can be negotiated.

3.5 DECIDING ON THE STRATEGIC OPTION

Those are the four broad strategic options facing LMB countries in considering the 12 project proposals for the mainstream Mekong. In choosing which strategic course to take, the matters of concern to LMB countries are:

1. The nature and extent of potential benefits of the 12 proposed mainstream projects
2. The nature and extent of risks associated with the proposals
3. The relative strategic importance and significance of the various risks and benefits
4. The levels of remaining uncertainty relating to the risks and benefits

The SEA was initiated to support the LMB countries in gathering and analyzing the best available technical information and stakeholder viewpoints on each of those concerns. It then drew conclusions on whether or not the proposed projects should be implemented and, if so, under what conditions.

The development planning process normally begins with a detailed study of economic feasibility and benefits. Generally, in the Mekong region, ecological and social sustainability considerations have not been well enunciated until after developments have been expressed as project concepts or even detailed project designs. This usually results in a clear definition of benefits early in the process as part of the justification for proceeding from feasibility to detailed design, but with the environmental and social risks being played down, and the resulting economic costs being underestimated. The gaps in knowledge and understanding most often relate to these risks. There has never been any real strategic assessment of the natural resource and social assets of the Mekong, and what should be protected as a foundation for sustainable development.

That imbalance in information available to decision makers early in planning is aggravated in the case of complex developments involving many projects. National environmental and social review systems have not engaged until developments are well advanced in the shape of specific project proposals. Review tools such as Environmental Impact Assessment have found it difficult to step back and address the broader strategic options and their relative effects in terms of sustainability. They come late in the planning process. This is the situation confronting the LMB countries in considering the 12 mainstream proposals. Project designs are well advanced. Momentum and commitment behind the proposals is mounting with increasing time and resources going to their design and with developer-government power sector negotiations moving forward. At national level, they are being assessed through EIA procedures – with a project specific focus so that many of the strategic issues and cumulative effects of the projects are not being captured.

This SEA initiated through MRC allows LMB countries and their decision makers to step back for a broader examination of all the mainstream proposals together and in groups. The SEA attempts to fill the gap providing a more complete assessment of the risks as well as substantiation of the benefits, and consideration of the strategic issues underlying the projects. It is the first SEA to be conducted for Mekong River development and involving the four LMB countries and including the influence of the hydropower development in China. It feeds into the MRC Basin Development Planning process and supports the application of the Procedures for Notification, Prior Consultation and Agreement (PNPCA) which is about to start for one of the mainstream hydropower projects. The PNPCA process is a requirement of the 1995 Mekong Agreement for countries to jointly review any development proposed for the Mekong mainstream with a view to reaching consensus on whether or not it should proceed, and if so, under what conditions.

PART II: ROLE OF THE SEA AND DEVELOPMENT PLANNING CONTEXT

4 THE SEA OF PROPOSED LMB MAINSTREAM PROJECTS

SEAs, which include assessments of cumulative impacts, address the broader strategic issues usually relating to more than one project. SEAs follow similar steps to EIA but have much larger boundaries in terms of time, space and subject coverage. SEAs serve as an umbrella level of analysis that feeds more specific EIAs and improves their quality. The SEA is a tool which examines the broad strategic concerns that need to be resolved and decided prior to making project specific decisions.

In 2008 the MRCS was instructed by the Joint Committee: (i) to conduct a strategic environmental assessment of all mainstream projects in the pipeline and, in parallel, (ii) to prepare Design Guidance for Mekong Mainstream Dams in the Lower Mekong Basin. The guidance is project specific, while the SEA is to explore the broader economic, social and environmental system implications of the projects collectively.

In summary, the SEA is contributing to a decision-making process relating to 12 hydropower schemes proposed for the mainstream Mekong River. These are sovereign decisions of Cambodia (2 proposals) and Lao PDR (10 proposals). Two projects are located on reaches of the river shared by Lao PDR and Thailand – inevitably the Thai government and its procedures will need to be involved in decisions relating to them. Through the MRC Agreement there is a commitment to notify, consult and seek to reach agreement with neighbours. Yet, there is a divergence of opinions on the benefits and costs of the mainstream projects – within government line agencies, within the international community and within the NGO community – those viewpoints need to be captured in the assessment process. An important reason for that divergence is the many remaining gaps and uncertainties in knowledge about the risks and benefits associated with the proposals.

4.1 SEA OBJECTIVES

The SEA was given two sets of objectives relating to (i) sustainable mainstream hydropower and (ii) SEA as a tool in trans-boundary development planning:

Sustainable hydropower:

1. Provide an understanding of the implications of mainstream hydropower development
2. Provide specific policy-level recommendations on whether and how those hydropower projects should best be pursued;
3. Provide an initial baseline and assessment framework for individual mainstream project EIAs, thereby supporting the Procedures for Notification, Prior Consultation and Agreement

SEA as a tool in trans-boundary development planning:

1. Serve as a methodological framework for sub-basin hydropower SEAs in the LMB, which will be carried out as input to MRC's Basin Development Plan; and

2. Include capacity building to strengthen the respective analytical SEA capabilities in the concerned line agencies of the MRC Member States.

4.2 STEPS IN THE SEA PROCESS

The SEA is a staged process with consultation, analysis and documentation at each of four steps (Figure 3).

1. Scoping: In the first step the coverage or scope of the assessment was defined. The scoping identified the strategic themes and issues by asking:

(i) What are the most important issues of concern to development and conservation of the mainstream Mekong?
(ii) How can those issues be categories and prioritised – i.e. given strategic focus?

2. Baseline assessment: The second step is what is referred to as the baseline assessment – which involves gathering information in each country and at regional level on the most important development concerns and analysing their past trends and current status. The main questions addresses were:

(i) What have been past trends for each of the key issues?
(ii) What will the trends look like when projected to 2030?
    a) without mainstream projects and,
    b) when other trends and drivers are considered

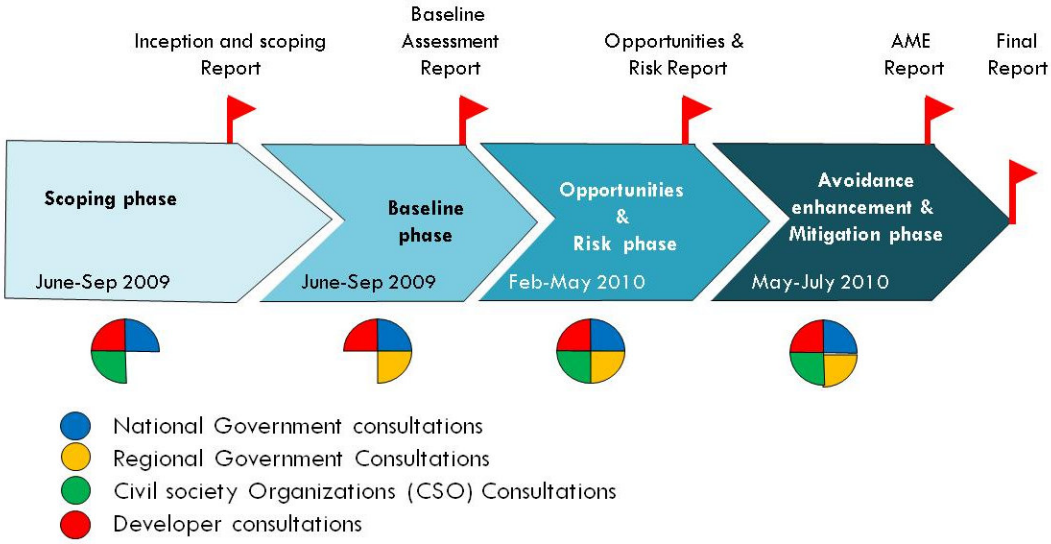
3. Impact assessment: In the third step risks and opportunities from the proposed mainstream projects for the strategic development concerns are assessed. SEAs are a form of sustainability analysis – where economic, social and biophysical trends and effects are considered. The main questions addressed are:

(i) Will the mainstream projects affect the trends in key issues?
(ii) Will those affects provide benefits and/or costs?
(iii) Will those affects enhance or reduce sustainability?

4. Avoidance and mitigation: The fourth step involves defining measures to avoid or mitigate the negative effects of the propose projects and enhance their benefits. The main questions considered are:

(i) How will the most important risks (negative effects) be avoided?
(ii) How will the most important benefits (positive effects) be enhanced?
(iii) How will the negative effects that can't be avoided be mitigated – i.e. be reduced?

Figure 3: The four steps in the SEA process



4.3 SEA CONSULTATIONS & DOCUMENTATION

The SEA process has run from June 2009 to July 2010 involving comprehensive consultation at each stage of the assessment as reflected in Figure 3. A program of round table discussions was conducted in each of the four LMB countries with some 60 line agencies. The SEA included two missions by the MRC ISH to Yunnan Province in China and Chinese delegations participating in SEA workshops. Four national workshops involving line agencies and sector institutes, five national and local workshops for NGOs and civil society organizations, and three regional multi-stakeholder workshops were conducted.

The SEA has involved extensive documentation, review and commentary at each of the four phases. Table 2 lists the analytical reports prepared progressively and made available for review through the MRC website and consultative workshops.

Table 2: SEA progressive documentation

I. Scoping phase reporting

1. Main Inception/Scoping Report
2. Mainstream project profile summaries
3. National scoping consultation summaries
4. SEA theme approach papers and additional studies design papers including:
   (i) Economics theme paper
   (ii) Energy and power theme paper
   (iii) Hydrology & sediment theme paper
   (iv) Terrestrial systems theme paper
   (v) Aquatic systems theme paper
   (vi) Fisheries theme paper
   (vii) Social systems theme paper
   (viii) Climate change theme paper
5. The SEA Communications, Consultations and Capacity Building Plan

II. Baseline assessment reporting

1. Summary Baseline Assessment Report
2. Economics baseline assessment working paper
3. Energy and power baseline assessment working paper
4. Hydrology & sediment baseline assessment working paper
5. Terrestrial systems baseline assessment working paper
6. Aquatic systems baseline assessment working paper
7. Fisheries baseline assessment working paper
8. Social systems baseline assessment working paper
9. Climate change baseline assessment working paper

III. Impact assessment reporting

1. Impact assessment report including:
   (i) Economics impact assessment
   (ii) Energy and power impact assessment
   (iii) Hydrology & sediment impact assessment
   (iv) Terrestrial systems impact assessment
   (v) Aquatic systems impact assessment
   (vi) Fisheries impact assessment
   (vii) Social systems impact assessment
   (viii) Climate change impact assessment

IV. Avoidance, mitigation and enhancement reporting

1. Summary mitigation matrix and paper
2. Economics mitigation working paper
3. Energy and power mitigation working paper
4. Hydrology & sediment mitigation working paper
5. Terrestrial systems mitigation working paper
6. Aquatic systems mitigation working paper
7. Fisheries mitigation working paper
8. Social systems mitigation working paper
9. Climate change mitigation working paper

V. Final synthesis, conclusions and recommendations reporting

Final SEA Report

In addition to the reports, the SEA has prepared some 50 supporting power point presentations with 30 or more going onto the MRC and ICEM websites for downloading for use as communications and training materials.

5 THE DEVELOPMENT PLANNING CONTEXT FOR THE SEA

5.1 STAGES IN MAINSTREAM MEKONG PROJECT PLANNING

The SEA is being conducted as a contribution to formal development planning systems in each of the LMB countries and at regional level. Figure 4 illustrates the four main stages in planning and decision making for the mainstream hydropower proposals. In summary these are:

Stage 1: National planning
Stage 2: Regional review
Stage 3: Decisions at national and regional levels
Stage 4: Implementation at national and regional level

Stage 1: National planning: The project proposals are considered in each country as submitted by developers and can include broader studies for example the "optimization study" initiated by the Lao Government which analysed the hydrological performance of the six "cascade" project proposals. Lao PDR and/or Cambodia could initiate an *ad hoc* SEA of groups of proposals or of mainstream development generally – even without SEA legislative provision. Proposals are being subject to the environmental impact assessment process in Lao PDR and Cambodia but not in Thailand. Whether or not any of the projects proceed hinges on Thailand and Viet Nam deciding to import mainstream power. Therefore, SEAs could be initiated into those import decisions under national SEA regulations and guidance in both countries. Mainstream development raises complex strategic issues for Viet Nam given potential downstream effects on the delta.

Stage 2: Regional review: MRC Prior Notification and Consultation Process (PNPCA) – involves submission of documentation to MRC by host country on a project by project basis, the establishment of a regional technical committee to review the proposal and formal advice to the Joint Committee. The spirit of the PNPCA process is to garner agreement amongst LMB nations on decisions that affect the whole region. Under the Agreement, one or more countries may proceed against the advice of the PNPCA conclusion, but if so, would be responsible for the consequences of any regional impacts as defined in the Agreement. Given that all LMB mainstream projects are targeted for export, a decision to proceed with any one project would require at the minimum two LMB countries - the importing country and the host/exporting country.

Stage 3: Decisions at national and regional levels – the main decision makers are the host country governments for the mainstream projects and the purchasing country governments if they chose to intervene in the project by project negotiation process with a strategic national policy decision to import or not to import mainstream power. The MRC Joint Committee is an advisory forum which can influence national decisions.

Stage 4: Implementation at national and regional level – hydropower development on the mainstream would require complex institutional management and coordination arrangements including trans-boundary agreements on upstream operation and notifications for example between (i) China and Lao PDR, (ii) Lao PDR/Thailand and Cambodia and (iii) Cambodia and Viet Nam. Respective roles of the public and private sectors in Lao PDR/Thailand and Cambodia would need to be well defined.

Status of planning: The national planning process is in the first stage – relating to those things which need to be done before decisions on mainstream projects are made. Planning is moving forward on a project by project basis within each country largely driven by the project proponents – i.e. the individual development companies and investors concerned. The process is continuing under national policies and plans for hydropower development and cross-border power trade, and bilateral MOUs for power exchange and trade (Figure 5).

Each mainstream project proposal is subject to the normal project planning and regulatory procedures of the power development sectors in each country and the respective national environmental impact assessment procedures (Figure 6). Ten project proposals are being reviewed and negotiated according to national procedures in Lao PDR and two (Sambor and Stung Treng) in Cambodia.

To date, the Thai Government has not become formally involved in the planning and assessment process for the two project proposals on Thai reaches of the Mekong River – Ban Koum and Lat Sua. For those projects to move forward to final decision, they would need to be processed through the Thai Government's EIA procedures. Assessment would need to be conducted on a bilateral basis with Lao PDR. Thailand also has guidelines and a commitment to SEA – so, given the strategic importance of the issues, development of the Thai reaches of the mainstream Mekong could be subject to an SEA. Thailand is considering conducting an SEA of major irrigation development in the Mekong riparian provinces involving water off take from the River - and potentially from proposed mainstream hydropower reservoirs.

The national planning procedures for the mainstream projects in Lao PDR and Cambodia are constrained when considering:

(i) cumulative effects of many projects on the one system,
(ii) distant downstream effects within the mainstream channel, floodplain and delta
(iii) multiplier effects on areas and communities outside the main channel,
(iv) trade-offs between all development sectors impacted, and
(v) effects of upstream management of Yunnan and tributary schemes on the operation of downstream projects.

National spatial or integrated development plans for use of the Mekong River are not in place to guide the process and to provide a backdrop of zoning and safeguards against which development is assessed and proceeds. The SEA was initiated by the LMB countries collectively through MRC as part of Stage 1 planning because many of the strategic issues the projects would influence relate to trans-boundary and all-of-river relationships. The SEA is intended to contribute to better understanding of the broader strategic issues which are not being captured by existing national planning processes.

At regional level, the MRC basin development planning process and scenario assessments (including scenarios for "with and without mainstream dams") provide an opportunity to support decision makers in considering the broad trade-offs relating to the proposed projects. The linked MRC Procedures for Notification, Prior Consultation and Agreement (PNPCA), allows for collaborative assessment of mainstream project proposals as they are "notified" by proponent governments and before final decisions are made.

At regional level, the SEA supports both the MRC Basin Development Plan and PNPCA mechanisms as well as feeding directly into planning at national level. The SEA provides the necessary additional strategic analysis and guidance relating to the Mekong River and to the 12 project proposals. It is the first time many projects have been proposed by developers at the same time along the same stretch of river. The normal project by project review procedures at national level are not set up to deal with many projects proposed for one area or using the same resources. This SEA *is* set up to do that – as a pilot being used for the first time by MRC – and is intended as a backdrop strategic assessment for the project specific PNPCA process.

Figure 4: Main stages in planning and decision making for the mainstream hydropower proposals

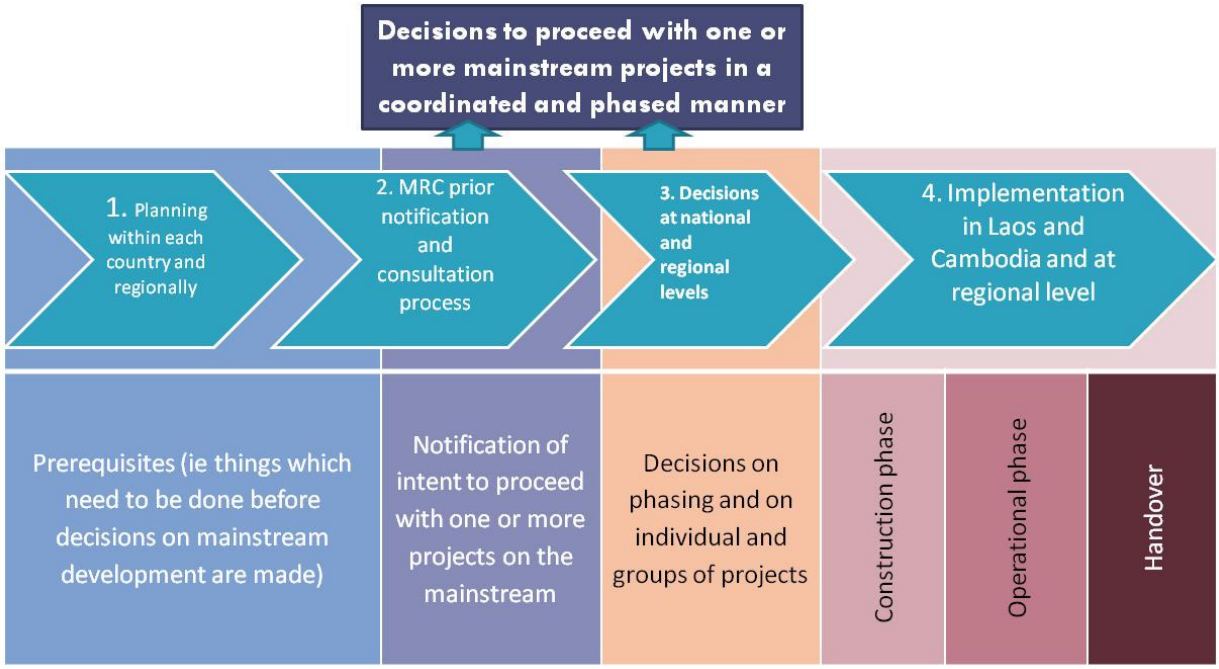


Figure 5: The hydropower development planning "platforms" in the Mekong region

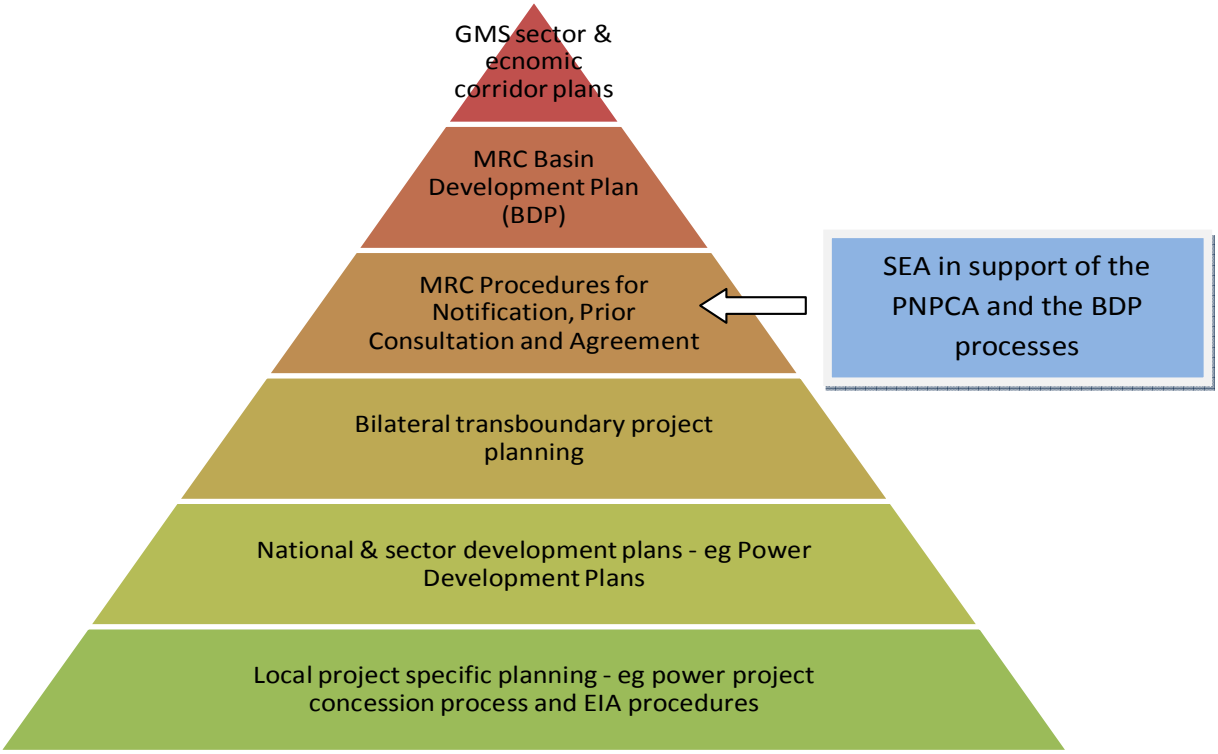
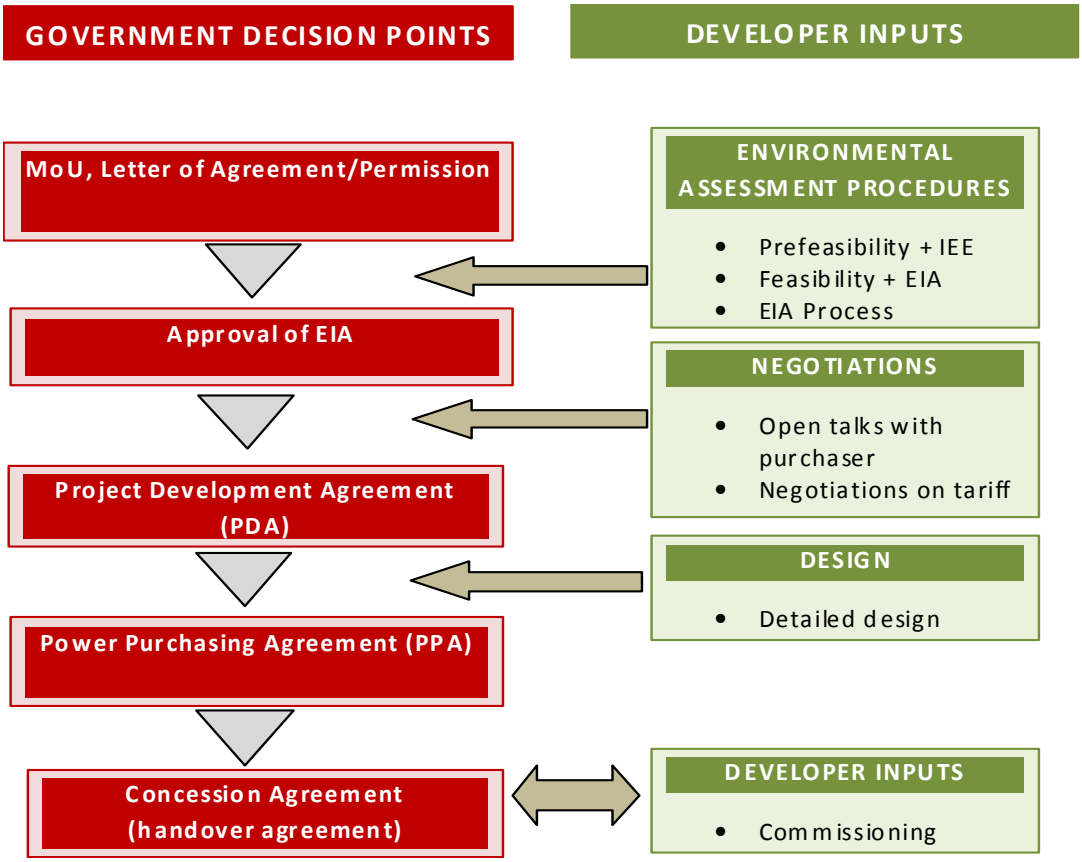


Figure 6: Simplified summary of hydropower project planning process in Lao PDR and Cambodia



5.2 MRC PROCEDURES FOR NOTIFICATION, PRIOR CONSULTATION AND AGREEMENT

The 2003 PNPCA protocol and its 2005 procedural guidelines require Member Countries to notify the MRC in the event they wish to engage in any major infrastructure developments (such as hydropower schemes) on the mainstream Mekong or tributaries, particularly if those developments may have significant trans-boundary impacts on people or the environment downstream.

On 22nd September 2010, the MRC received official notification for the mainstream project in Xayaburi Province from the Government of Lao PDR. During the Xayaburi PNPCA process, the MRC Joint Committee, consisting of representatives from the four Member Countries, will consult to try and reach a common position on the proposed mainstream dam development. It is estimated that the detailed analysis of all the related issues and for the countries to come to a conclusion on project will take some six months. The SEA is part of MRC's preparation for the PNPCA process. It provides an analytical framework of the benefits, costs and impacts of the full set of proposals including cumulative impacts and information on the distribution of costs and benefits.

The MRCS is required to take a proactive role to assist the Joint Committee in assessing whether the proposed use is reasonable and equitable, and whether greater benefits can be derived through cooperation and trade-offs. The MRCS is required to advise the Joint Committee to ensure "due diligence" in the planning process.[23] The PNPCA process requires that the Joint Committee aim to arrive at an agreement relating to the proposed use (PCA 5.4.3.). In considering proposals for mainstream hydropower developments under the PNPCA, the Joint Committee is to avoid inter-state disputes by resolving and determining if the development:

(i) optimises water use;
(ii) provides better benefits than can be derived through cooperation and trade-offs;
(iii) has an established right of claim against further proposed uses;
(iv) assesses the potential impacts on multi-stakeholder's rights and interests; and
(v) provides for planning security.

Terms such as "planning security" from the protocol are not entirely clear and, as this is the first time a mainstream proposal has triggered the PNPCA process, there has not been an opportunity to test their meaning in practice.[24] One point is clear in the intent of the PNPCA protocol – the countries are encouraged "to arrive at an agreement" based on consensus and sustainability principles.

5.3 LMB COUNTRIES SUSTAINABILITY PRINCIPLES APPLIED IN SEA

In conducting project specific EIAs on the mainstream proposals the proponents are required to consider the policy frameworks and commitments of the host government relating to sustainability. As part of the SEA scoping phase, national government teams from various line agencies compiled lists of sustainability objectives set out in national policies and plans relevant to the key issues of development concern to the Mekong River. Those were summarised under the main strategic themes being addressed by the SEA and used in national and regional workshops as a framework against which the mainstream proposals were assessed (Table 3).

[23] The concept of "due diligence" in development relates to:
(i) The degree of care and caution required before making a decision
(ii) The process to identify and quantify social, environmental and economic risks prior to decisions
(iii) The performance of development against agreed standards and with a certain standard of care according to specified safeguards
(iv) The process of making sure that a proponent can do what they agree to – and that managers and regulators can oversee and enforce.

[24] In 2001, notification was received for an earlier form of the Thakho project, but was dropped before consideration.

Table 3: Sustainable development principles distilled from government policies/laws and strategies:

Strategic theme addressed by SEA	Sustainability objective
Energy	▪ Ensuring a secure and diverse energy supply from renewable resources without losses in sustainability of social and natural systems
Economics	▪ Ensuring economic growth and development, and equitable distribution of economic benefits including long term support to vulnerable effected groups and areas
Hydrology and Sediment	▪ Maintaining natural patterns of sediment and nutrient transport and deposition in flood plains and the Delta
Aquatic ecosystems	▪ Maintaining aquatic ecosystems for conservation of biodiversity, connectivity and ecosystem services
Terrestrial and agriculture systems	▪ Maintaining terrestrial ecosystems for conservation of biodiversity, connectivity and ecosystem services ▪ Maintaining and enhancing diversity and productivity of agricultural systems
Fisheries	▪ Maintaining and enhancing diversity and productivity of fisheries resources
Social systems	▪ Ensuring the wellbeing of vulnerable and minority groups ▪ Maintaining a vital (living) cultural diversity (ways of living) and heritage of importance to riparian communities
Climate change	▪ Maintaining and improving options and capacities to adapt to climate change

PART III: BASELINE & IMPACT ASSESSMENT

The SEA impact assessment process worked to the framework of strategic themes and issues defined during the scoping phase. The baseline assessment described past trends in those themes and issues and projected them to 2030 without LMB mainstream hydropower development. The impact assessment summarises the potential effects of mainstream projects on those trends to 2030 and beyond according to the strategic themes and linking the analysis to the baseline findings as appropriate. The impacts assessment first considers the opportunities and risks directly associated with LMB mainstream hydropower *without* any enhancement or mitigation measures. Where suitable mitigation/enhancement measures exist a qualification is made on the institutional and financial requirements as well as the likelihood of success for the LMB regional context.

6 MEKONG HYDROPOWER DEVELOPMENT SCENARIOS

Hydropower is a dominant driver of development in the Lower Mekong Basin. There are three main existing and potential sources of hydropower on the Mekong system:

1. **Upper Mekong Basin (UMB)**: the large elevation drop of the Lancang River offers significant potential for conventional storage hydropower. China is developing a cascade of 8 projects on the Lancang River with a total installed capacity of 15,450 MW. A number of additional storage projects are being considered for the Lancang River upstream of Gongguogiao. Their potential remains unknown, but the remaining Lancang potential is estimated to be in the order of 7,550 - 13,480 MW.[25]

2. **LMB tributaries:** the LMB has a very large tributary hydropower potential. There are some 70 projects under various levels of exploration representing a capacity of 9,364 MW.

3. **LMB mainstream**: more recently, the changes in the hydrological regime expected from UMB hydropower has made mainstream hydropower more attractive for the LMB mainstream where 12 projects are under consideration with the capacity of 14,697 MW.

In terms of meeting national demand, the four LMB countries of Cambodia, Lao PDR, Thailand and Viet Nam have additional national and GMS sources of hydropower potential:

4. **Non-LMB Rivers of Thailand and Viet Nam:** substantial portions of Thai and Vietnamese sovereign territory lie outside the LMB. In Viet Nam, these areas offer additional technical potential of 31,000 MW of which 21,481 MW is additional technical-economic potential[26] and 1,305 – 1,548 MW (Thailand);[27]

[25] Range reflects estimates by the MRC and Dore, J. and Yu Xiaogang. 2004.
[26] Range reflects estimates by King, P., Bird, J., Haas, L. 2007; ADB/MOIT, 2010; and Dai, L.V. 2007. Technical-economic potential includes small hydropower identified in the Viet Nam Power Development Plan VII
[27] Thailand has developed ~2,995 MW of hydropower and is unlikely to develop further technical potential due to political commitments- except for retro-fitting existing irrigation dams.

5. **Myanmar:** Myanmar has a significant and largely under-utilised hydropower potential of 37,000MW.[28]

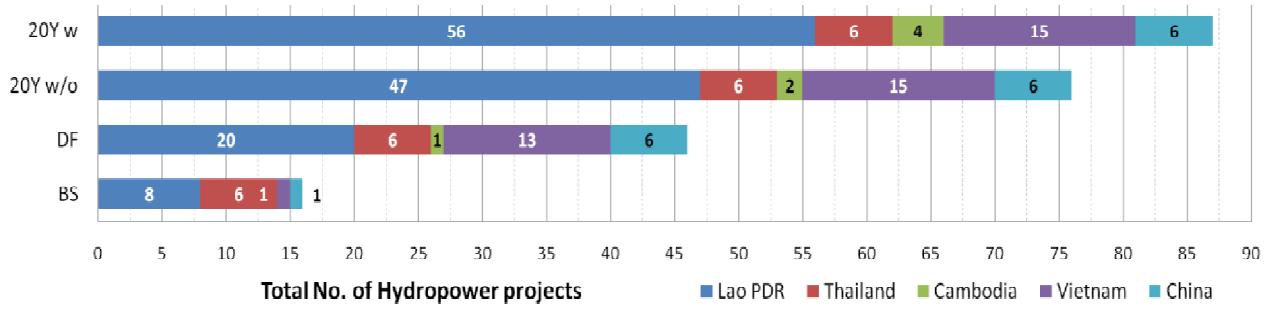
6. **Greater Yunnan Province:** The Lancang/Mekong is one of a number of major river systems flowing through the steep terrain of Yunnan Province. These rivers, including the Nu, Jinsha and the Lancang, have a hydropower potential in the order of 90,000 – 103,130 MW;

At the earliest the proposed LMB mainstream projects could enter the Mekong system in 2020-2030. The dynamism of development in the Mekong basin requires the SEA to project forward a baseline to 2030 so that an accurate assessment of the incremental risks and opportunities posed by the LMB mainstream projects can be given against a realistic projection of the future development context.

Projecting forward a baseline carries with it differing visions for the future and uncertainties. This SEA draws on three development scenarios developed by the MRC Basin Development Program which characterise additional developments in hydropower, irrigation and water supply for the LMB (Figure 7 and Table 5):

1. **Definite future scenario (DFS)**: represents all the *certain* hydropower developments which are existing, under construction or have secured firm agreement for development within the next 5 years (i.e. by 2015)
2. **20Y without LMB mainstream dams (20Y w/o):** includes the additional tributary hydropower and irrigation projects identified by the LMB countries within their plans for development in the next 20 years. This represents the possible increment in tributary development expected by 2030.
3. **20Y with LMB mainstream dams (20Y w)**: includes the additional 12 LMB mainstream hydropower projects which are being considered as development options for the basin.

Figure 7: Summary totals of national hydropower interests in the Mekong Basin



6.1 SEA ASSESSMENT METHODOLOGY

The SEA methodology starts by establishing a baseline which differentiates between impacts of existing and definite development and impacts of planned development well into the future without mainstream projects. That approach allows the SEA to describe the incremental opportunities and risks of the LMB mainstream projects against two levels of basin development, the more distant coinciding with commencement of the mainstream projects operations if approved.

6.1.1 THE SEA BASELINE

The SEA baseline includes two scenarios – (i) the Definite Future baseline to 2015 and (ii) the projected baseline or BDP 20Y without mainstream development scenario to 2030 (Figure 8, Table 4). The Definite Future projects that exist, are under construction or have firm plans to be implemented by 2015, including 6 of the mainstream projects in China, and 41 hydropower projects on the tributaries of the LMB (i.e. 47 projects in all).

The projected SEA baseline to 2030 includes the developments nominated by each LMB country as being part of their planning for the next 20 years as defined in the BDP 20Y without mainstream scenario, which includes some 71 tributary projects and 6 Chinese dams (i.e. 77 projects in all). The SEA projected baseline also includes 6 million ha of irrigated land and water abstraction of 4.6 billion cubic metres.

[28] King, P., Bird, J., Haas, L. 2007

Figure 8: Relationship of the SEA assessment to definite & foreseeable development in the LMB by 2030

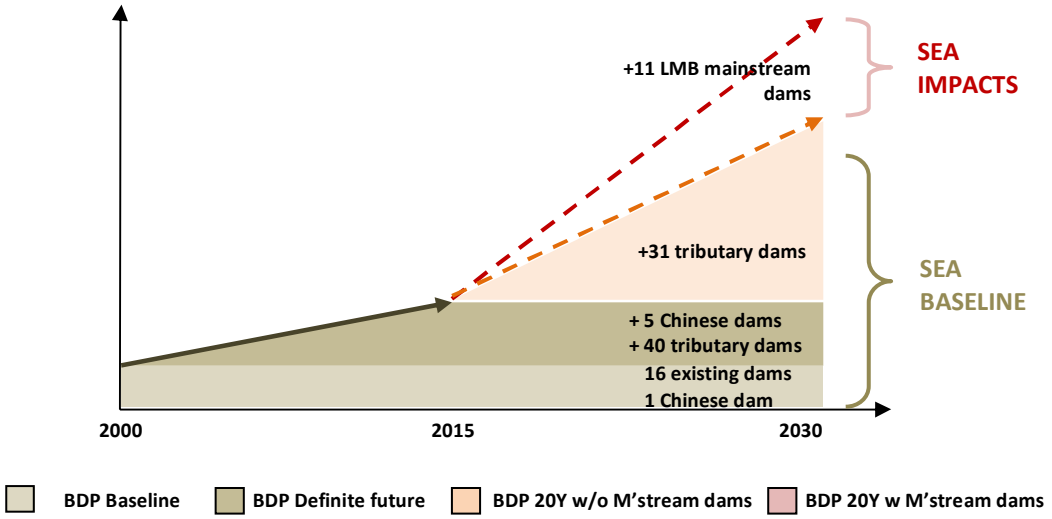


Table 4: Summary of development expected in the BDP scenarios

Type of development	Definite Future (2015)	20 Y without LMB mainstream hydropower (2030)	20Y with LMB mainstream hydropower (2030)
Hydropower development	6 Chinese dams 0 LMB mainstream dams 40 LMB tributary dams	6 Chinese dams 0 LMB mainstream dams 71 LMB tributary dams	6 Chinese dams 11 LMB mainstream dams 71 LMB tributary dams
Irrigation development	4 x 10^6 ha	6 x 10^6 ha	6 x 10^6 ha
Water supply	2,938 x10^6 m³	4,581 x10^6 m³	4,581 x10^6 m³

6.1.2 THE SEA IMPACTS ASSESSMENT

The SEA assesses the incremental impact of the different combinations of the 12 LMB mainstream hydropower projects on top of the 2015 and 2030 baseline scenarios. LMB mainstream projects are not assessed individually, rather as groups of development for each of the hydro-ecological zones of the Mekong River and in combinations of the 4 dam groupings outlined in section 1 (Table 1).

In total, LMB mainstream projects represent 12 out of the 88 hydropower dams existing or planned for the Mekong Basin by 2030.

7 POWER SYSTEMS

7.1 BASELINE

7.1.1 ELECTRICITY DEMAND

Analysis of the significance of mainstream hydropower projects for power generation needs to be considered in the context of the highly dynamic regional power sector. **Viet Nam and Thailand account for the vast majority of power consumption and projections suggest that they will continue to dominate the future demand for electricity in the region accounting for 96% of power demand in the LMB by 2025 (Figure 9).** Consequently, they are the target power markets for most of the current and planned hydropower development in the LMB.

There remains considerable debate and divergence of opinion on energy demand projections for each country and for the region (Figure 10). In the case of Viet Nam's future energy demand for example, estimates by the ADB for 2025 represent 54% of official government estimates, a discrepancy equivalent to around 3.5 times the annual power production from the 12 mainstream projects.

Figure 9: Trends in LMB electricity demand using official forecasts: *all countries show high average annual demand growth rates (2010-2025) of between 5.5% (Thailand) to 11.6% (Cambodia)* [29]

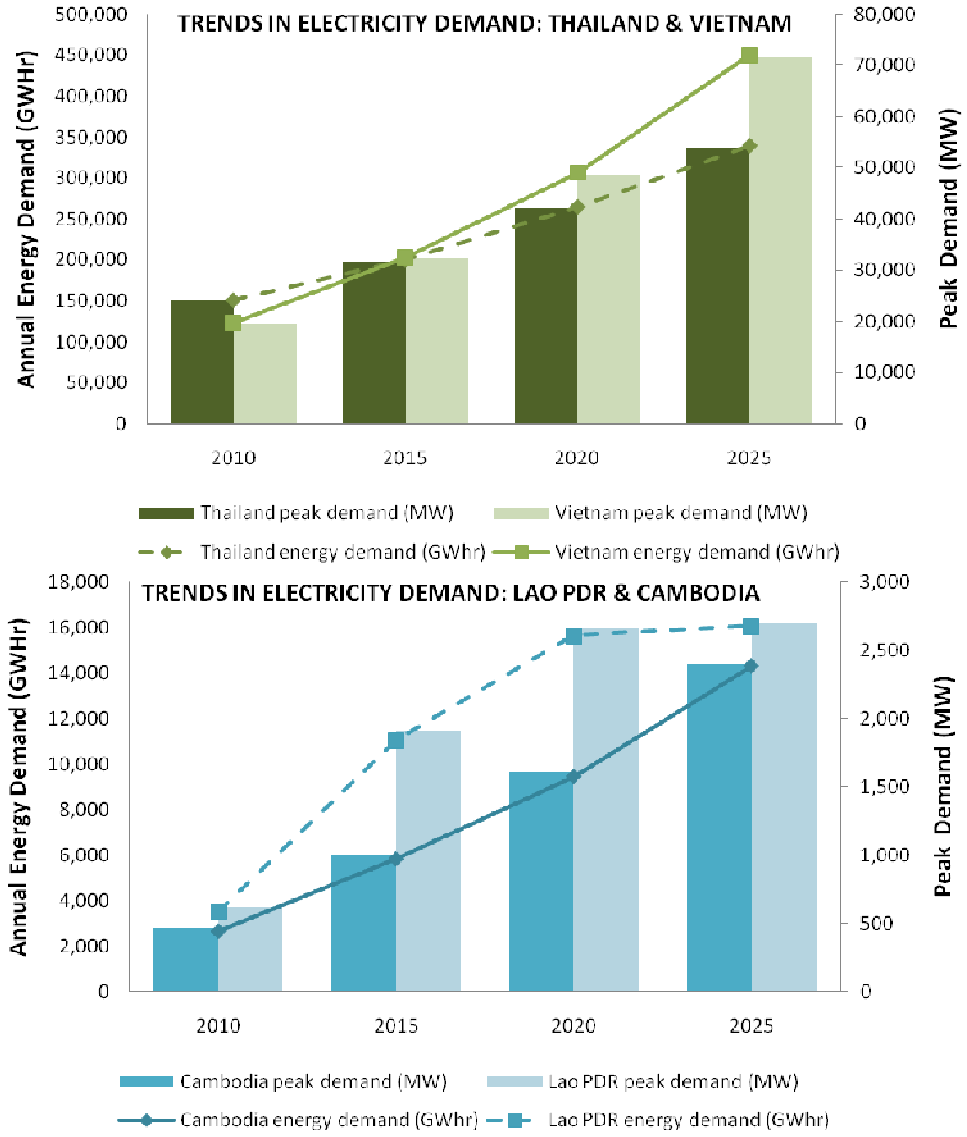
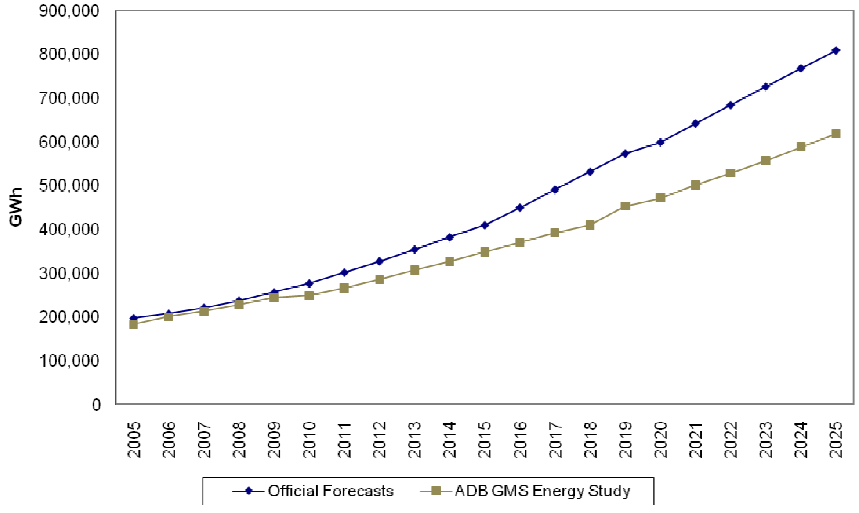


Figure 10: LMB Regional demand forecasts to 2025 - Comparison of official government & ADB GMS Energy Futures study projections[30]



[29] Load forecasts for Lao PDR reflect preliminary official forecasts as reported in ADB RETA 6440. Considerable uncertainty remains on the demand projections and the figures are currently under revision through ADB RETA 6440

[30] Official forecasts reflect National Power Development Plans. The ongoing ADB RETA 6440 is broadly consistent with the official government forecasts presented in this figure.

- ***Thailand***: **the power demand is projected to increase by a factor of 2.2 in the next 15 years**, with average annual projected increase of 2,600 MW/year between 2010 and 2025. Forecasts for the Thai national demand vary between 339,479 GWh to 374,447 GWh by 2025. [31]

- ***Viet Nam***: official government scenarios suggest that Vietnamese power demand will catch up with Thai demand in 2014. **Power demand is projected to increase by a factor of 3.7 in the next 15 years**, with an annual increase in peak demand of 4,600 MW per year between 2010 and 2025. However, projections conducted by the ADB suggest more moderate growth.[32] That inconsistency illustrates the uncertainties relating to power demand projections. Forecasts predicting Viet Nam national demand vary between 231,391 GWh and 450,618 GWh by 2025, based on official and ADB GMS Energy Futures projections.

- ***Cambodia:*** **There is an urgent need for greater domestic generation capacity in Cambodia.** National energy demand is comparatively low but is being met by a very expensive diesel-dependent electricity generation system. **Cambodia also has few attractive tributary projects, only meeting half of the projected incremental national demand between 2010 and 2025.**

- **Lao PDR** has a large potential to produce relatively cheap electrical energy for domestic supply and export, without the LMB mainstream projects.

- **Even aggressive demand-side management measures will only serve to moderate the rate of demand growth**, but this is unlikely to diminish interest in LMB hydropower development

About 20% of the GMS population (74 million people) still has no access to electricity, primarily due to lack of grid access in rural areas. Thailand and Viet Nam have reached electrification ratios of 95% and 85% respectively. Between 1996 -2006, the electrification in Lao PDR increased from 16% to 60%, while Cambodia has no national grid and the lowest rate of electrification in the region.

7.1.2 ENERGY SOURCES & POWER TRADE

90% of LMB electricity generation is from hydrocarbons (natural gas, coal, and petroleum products). The region as a whole imports about 22% of the energy used in electricity generation (oil, coal and gas) and fossil fuel imports for power generation are likely to rise.

- **Lao PDR** has lignite coal deposits now under development**.**

- **Cambodia:** Although there were indications of both off-shore oil and gas in Cambodia, there were no official estimates of proven or recoverable amounts. However, studies in recent years conducted by institutions such as the UNDP, World Bank, IMF and Harvard University have suggested that off-shore oil reserves may be up to 2 billion barrels with 10 trillion cubic feet of gas. While only a small proportion may be recoverable, the IMF estimate that in a moderate production scenario, based upon reserves of 500 million barrels in 3 fields (which is deemed reasonably likely given oil and gas production on either side of Cambodian territorial waters), by 2011 oil revenues could be worth around initially USD 174 million annually, reaching a maximum of USD 1.7 billion annually after 10 years. This suggests that Cambodia may well have significant medium term energy alternatives, which are unlikely to have the immediate negative domestic impacts that are likely to be associated with the pursuit of mainstream hydropower.[33]

- **Thailand's proven natural gas reserves (in the Gulf of Thailand) have 10-12 years left** at current consumption rates.

- **Renewable energy sources offer some immediate and longer-term potential for grid-feeding and off grid applications.** Thailand aims to reach 20% (11,216MW) of its 2022 energy demand from renewable energy sources. This amounts to 78% of Thailand's medium-term RE potential (14,300 MW), including: biomass (7,000 MW); solar 5,000 MW; small hydropower (700 MW) and wind (1,600 MW).

[31] Range reflects variation between official government forecasts and ADB GMS Energy Futures orecasts
[32] IRM consultant forecast in 2008 re-published in 2009 in the ADB report "Building a Sustainable Energy Future, The Greater Mekong Subregion in 2009".
[33] IMF. 2007.IMF Country Report No.07/293, Cambodia: selected issues & statistical appendix

- **Both Viet Nam and Thailand include nuclear power in their PDPs. In Viet Nam** there are plans for up to 8 reactors supplying 20% of grid supply by 2030and Thailand aims to have 5-7 nuclear reactors within the same time horizon.
- **Cogeneration and other non-conventional energy resources are untapped resources**.[34]
- **Demand side management has become an important component of Thai and Vietnamese PDPs**.
- By 2007, Thailand DSM initiatives had reduced peak demand by an estimated 1,435.2 MW and energy consumption by 8,148.3 GWh/yr. Viet Nam has shown more modest progress, reducing peak demand by an estimated 120 MW and energy consumption by 496 GWh/yr by 2007.

High demands and limited energy reserves will encourage Thailand and Viet Nam to look to their neighbours for power supply:

- **Thailand doubled its planned power imports between 2003 and 2009**. Thailand and Lao PDR expanded power under their MOU from 3,000 MW in 2003 to 5,000 MW in 2005 to the current 7,000 MW.
- **Thailand's new PDP seeks to reduce the national dependency on its diminishing reserves of natural gas.** The new Thailand PDP issued in January 2010 expects potential imports of up to 25% of peak demand from neighbouring counties and China by 2030, along with expanding RE technologies, coal import, nuclear power, and reducing current dependence on natural gas (now 73% of generation).
- **Viet Nam's transition to market driven electricity pricing and diminishing coal reserves will foster more power imports.** For Viet Nam the question of power imports remains dominated by the high demand growth picture and import pricing considerations. It is expected that Viet Nam will need to import coal for power generation from international markets from 2014, as well as develop nuclear power.

About 10% of LMB hydropower potential has been exploited. There is massive potential for hydropower in the Greater Mekong Subregion (GMS) with 176,350 – 250,000 MW technically feasible. The four LMB countries of Cambodia, Lao PDR, Thailand and Viet Nam have an estimated combined national hydropower potential in the order of 50,000 - 64,750 MW, of which 30,000 MW is available in the Lower Mekong Basin. Including the Lancang River in Yunnan Province, the Mekong Basin has a hydropower potential of 53,000 MW (Table 5).

- **Lao PDR with its small domestic demand and large hydropower potential is the main power exporter in the region.** By 2030, investments in Lao tributary hydropower amounting to USD 11.9 billion are expected to produce some 28,571 GWh/yr of hydroelectricity for export. These export revenues would be worth an estimated USD 2.1 billion/year to the Lao national economy.[35]
- **In Cambodia the poor infrastructure network and limited supply options increase national reliance on imported energy or mainstream hydropower.** Any solution to Cambodia's power demand requires a major and costly expansion in the national grid. A new energy supply option is needed to break the national reliance on imported diesel. **By 2030, investments in Cambodian tributary projects amounting to USD1.3 billion will produce some 1,618 GWh/yr of hydroelectricity. The associ**ated gross export revenue earnings would amount to USD 100 million/year. Additional energy strategies for Cambodia might include the development of offshore oil and gas resources and associated power plants, coal plants and hydropower imports from Lao PDR.
- **Viet Nam has a large technical-economic hydropower potential of 20,000 – 24,000 MW, only 2,519 MW of which lies within the Lower Mekong Basin**.
- Due to political commitments, Thailand is unlikely to develop further hydropower projects within its national boundary, the remaining 1,305 – 1,548 MW of potential is predominantly through the retro-fitting of irrigation dams and not in the Lower Mekong Basin.

[34] Cogeneration is a form of energy recycling in which the exhaust heat from a power production process is captured and used for industrial or domestic heating

[35] The small size of the Lao national demand means that individual mining projects each with demands of several hundred MW can induce significant spikes in national demand. Future expansion of the mining and industrial processing industries would affect Lao PDR demand figures.

Table 5: Identified LMB Hydropower Projects by Level of Development

COUNTRY		PROJECT STATUS				
		IN OPERATION	UNDER CONSTRUCTION	UNDER LICENSE	PLANNED	TOTAL
LAOS	Projects	10	8	22	60	**100**
	Capacity (MW)	662	2,558	4,126	13,561	**20,907**
	Annual Energy (GWh)	3,356	11,390	20,308	59,502	**94,556**
	Investment (Million US$ 2008)	1,020	3,256	8,560	26,997	**39,832**
CAMBODIA	Projects	1	0	0	13	**14**
	Capacity (MW)	1	0	0	5,589	**5,590**
	Annual Energy (GWh)	3	0	0	27,125	**27,128**
	Investment (Million US$ 2008)	7	0	0	18,575	**18,582**
VIETNAM	Projects	7	5	1	1	**14**
	Capacity (MW)	1,204	1,016	250	49	**2,519**
	Annual Energy (GWh)	5,954	4,623	1,056	181	**11,815**
	Investment (Million US$ 2008)	1,435	1,312	381	97	**3,225**
THAILAND	Projects	7	0	0	0	**7**
	Capacity (MW)	745	0	0	0	**745**
	Annual Energy (GWh)	532	0	0	0	**532**
	Investment (Million US$ 2008)	1,940	0	0	0	**1,940**
ALL COUNTRIES	Projects	**25**	**13**	**23**	**74**	**135**
	Capacity (MW)	**2,612**	**3,574**	**4,376**	**19,199**	**29,760**
	Annual Energy (GWh)	**9,846**	**16,013**	**21,365**	**86,808**	**134,031**
	Investment (Million US$ 2008)	**4,402**	**4,568**	**8,941**	**45,669**	**63,580**

7.2 IMPACTS ASSESSMENT

Demand from Thai and Vietnamese markets is driving the mainstream hydropower projects in Lao PDR and Cambodia. Thailand and Viet Nam are the primary export markets for LMB mainstream hydropower, and together are likely to account for around 90% of the electrical energy generated by these projects, of which Thailand will import around two-thirds and Viet Nam one-third. However, given the size of the power sectors in these countries the impact on power price is likely to be limited. In contrast, the expectation is that the remaining 10% of power generated by these projects will be destined for domestic consumption, by 2025 this would account for around 14% of domestic consumption power consumption in Cambodia and 29% in Lao PDR. Alternative (thermal) generation costs for these countries could be two to four times the cost of hydropower development. For Lao PDR which has significant untapped tributary hydropower potential the mainstream projects are of less significance to the domestic power sector than for Cambodia which has limited tributary potential.

7.2.1 POWER FROM THE LMB MAINSTREAM PROJECTS

The 12 proposed mainstream projects would represent ~16% (or 13,427 MW) of total installed hydropower capacity in the region by 2025, contributing ~12% of the electrical energy generated by hydropower with 34.4 TWh/yr from Lao PDR and 17.8 TWH/yr from Cambodia (Figure 11).

Mainstream hydroelectric projects proposed for Lao PDR and Cambodia represent approximately 60% of new energy potential from hydroelectric projects identified in the Lower Mekong Basin for consideration by 2030 (i.e. of hydropower schemes not yet operating or undergoing firm development).

Table 6: National power demand forecasts for LMB countries by 2025

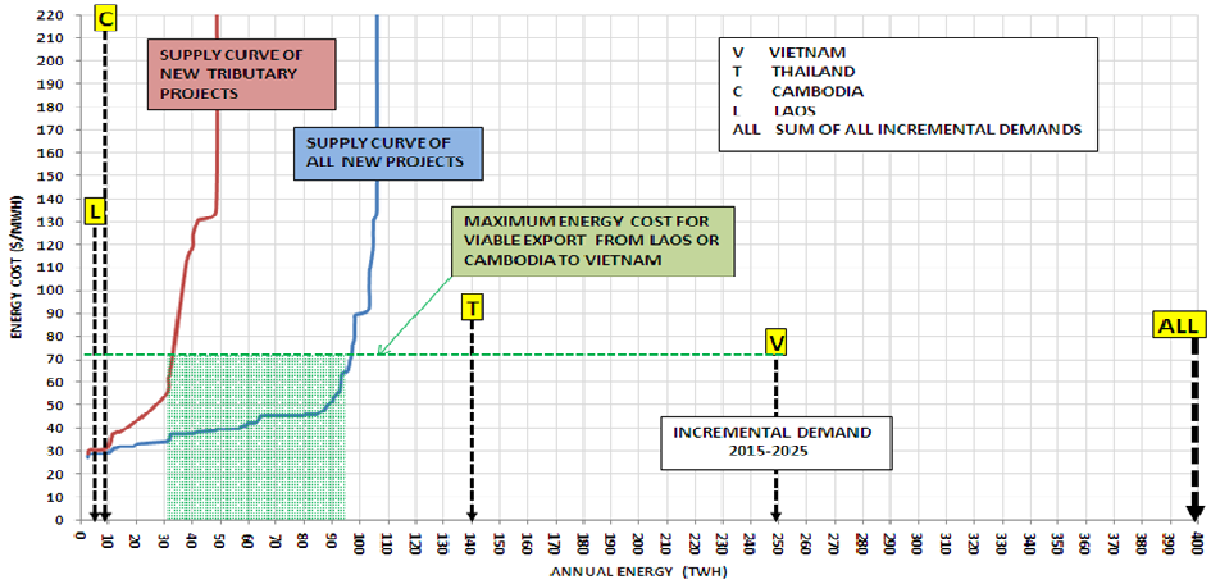
	Cambodia	Lao PDR	Thailand	Viet Nam	TOTAL/ Regional
Peak Demand (MW)	2,401	2,696	53,824	72,445	***130,366***
National Energy Demand (GWh/yr)	14,302	16,060	339,479	450,618	***820,458***
LMB mainstream dams Mean Annual Energy (GWh/yr)	19,740	46,054	-	-	***65,794***
Percent contribution of LMB mainstream hydropower to national demand*	13.8%	28.7%	11.6%	4.4%	***8.3%***
Percent contribution of LMB mainstream hydropower to peak demand					***11.3%***

** it is assumed that 90% of LMB mainstream power generation is for export to Thailand and Viet Nam, with 10% for domestic demand*

The LMB mainstream projects represent only 6-8% of the projected LMB power needs for 2025. This is the equivalent to the average projected incremental growth in energy demand the LMB experiences in a year (taking 11 mainstream dams into consideration and assuming a total installed capacity of 14,000 MW and 66,000 GWh per year).[36]

The mainstream proposals are most critical to power sector development in Cambodia even though energy from mainstream projects would be used regionally.[37] Cambodia has the most limited range of alternatives for meeting national power demand. As yet has no proven fossil fuel reserves, it also has limited tributary potential. Even so, if all Cambodia's tributary projects were developed, they would probably reduce the energy costs (highest in the LMB) by about 30%.

Figure 11: Assessing the benefits of LMB mainstream hydropower to the power sectors (supply curves): *the mainstream LMB projects will supply an additional 66.5 TWh/yr at projected market competitive prices for the region (green band).*



The Lao hydroelectric industry can develop tributary projects for domestic use and power export can continue at a healthy pace without mainstream projects given the large inventory of economically attractive tributary projects in Lao PDR suitable for power export. Without mainstream development, the potential scale of annual export earnings would be reduced.

As significant tributary potential exists in Lao PDR, LMB mainstream hydropower development is unlikely to make power cheaper from a domestic supply perspective.

For Viet Nam and Thailand, LMB mainstream hydropower is of minor significance to national energy demand. While the net power benefit attributable to mainstream dams is estimated to be in the region of USD 655 million annually for Thailand and Viet Nam, this constitutes less than 1% of the estimated annual value of the power sector by 2025. Power price and energy security considerations are more important for importing countries. The Thai and Vietnamese power sectors are characterised by a relatively low thermal generation cost. Therefore, mainstream hydropower will have a minor impact on electricity prices in those power systems (reducing costs to consumers by about 1.5%). Given the expected size of Thai and Vietnamese power demand, the mainstream projects will not radically alter the national energy supply strategies of those countries applying least-cost criteria alone. Yet, coal fired plants equivalent to the 12 mainstream projects would require around 15 million tonnes of coal a year, much of which would need to be imported.

[36] Thakho – the smallest of the mainstream projects - was not included in the assessment of installed capacity, and would have the smallest contribution to regional installed capacity of all the proposed LMP mainstream projects

[37] Several circumstances determine that the two mainstream projects in Cambodia (Sambor and Stung Treng) are important to Cambodia's power sector. First, Cambodia has a very expensive generation system almost entirely dependent on imported oil. Thus, not only does Cambodia have to provide affordable power to meet incremental demand, but it also needs to replace its existing generation as much as possible. Second, Cambodia has a very small inventory of attractive tributary projects. The energy potential of these projects is not sufficient to meet incremental demands, let alone replace existing generation or export. Third, Cambodia has no significant experience in hydroelectric development or operation and thus will rely much more than Lao PDR on foreign partnerships, which can only be attracted by mainstream projects enabled by power exports.

If LMB mainstream projects were not pursued:

Thailand & Viet Nam

- Limited direct impacts on power systems of importing countries (Thailand and Viet Nam).
- Tariffs would not be appreciably affected.
- No compromise of national energy supply strategies based on least-cost criteria
- Reduction in supply diversity

Cambodia & Lao PDR

- Impacts on Cambodia's domestic power sector would be greatest of all LMB countries.
- Cambodia may pursue coal imports for bulk power supply.
- Lao, but particularly Cambodia, would experience reduced potential power export revenue earnings (earnings are more limited in initial years as debt is serviced, equity contribution recovered).

7.2.2 DIRECT ECONOMIC BENEFITS OF MAINSTREAM PROJECTS ON THE POWER SECTOR

The LMB mainstream dams represent a significant overall power benefit for the LMB countries of USD 3-4 billion/yr by 2030 (Figure 12)**.** Economic benefits depend on the future generation mix assumed.[38]

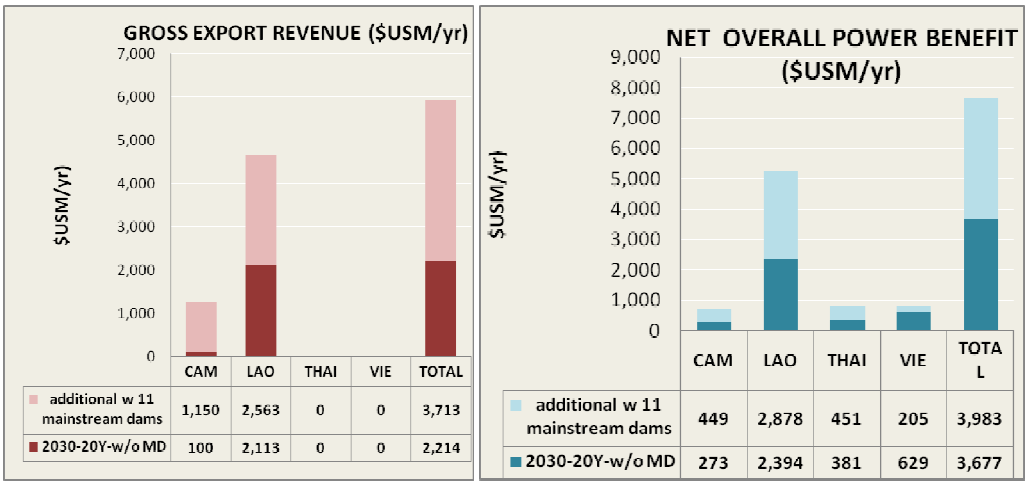
Lao PDR is the greatest beneficiary of the economic benefits directly associated with mainstream hydropower. Lao PDR is likely to receive more than 70% of overall benefits associated with the 12 projects, with Cambodia and Thailand receiving 11-12% and Viet Nam 5%.

Estimates of investments required to develop the mainstream projects are in the order of USD 18 to 25 billion dollars ~75% in Lao PDR and ~25% in Cambodia (Figure 13).

Lao PDR will receive 70% of export revenues generated by LMB mainstream hydropower (USD 2.6 billion), with Cambodia receiving 30% (USD 1.2 billion). For Lao PDR, the upper cluster represents two-thirds of the national net power benefit (Figure 11). *The bulk of these benefits for Lao PDR and Cambodia do not accrue to the country as a whole or the respective governments, rather during the concession period they accrue to the developers and financiers of the projects. The same is true to the export revenues.*

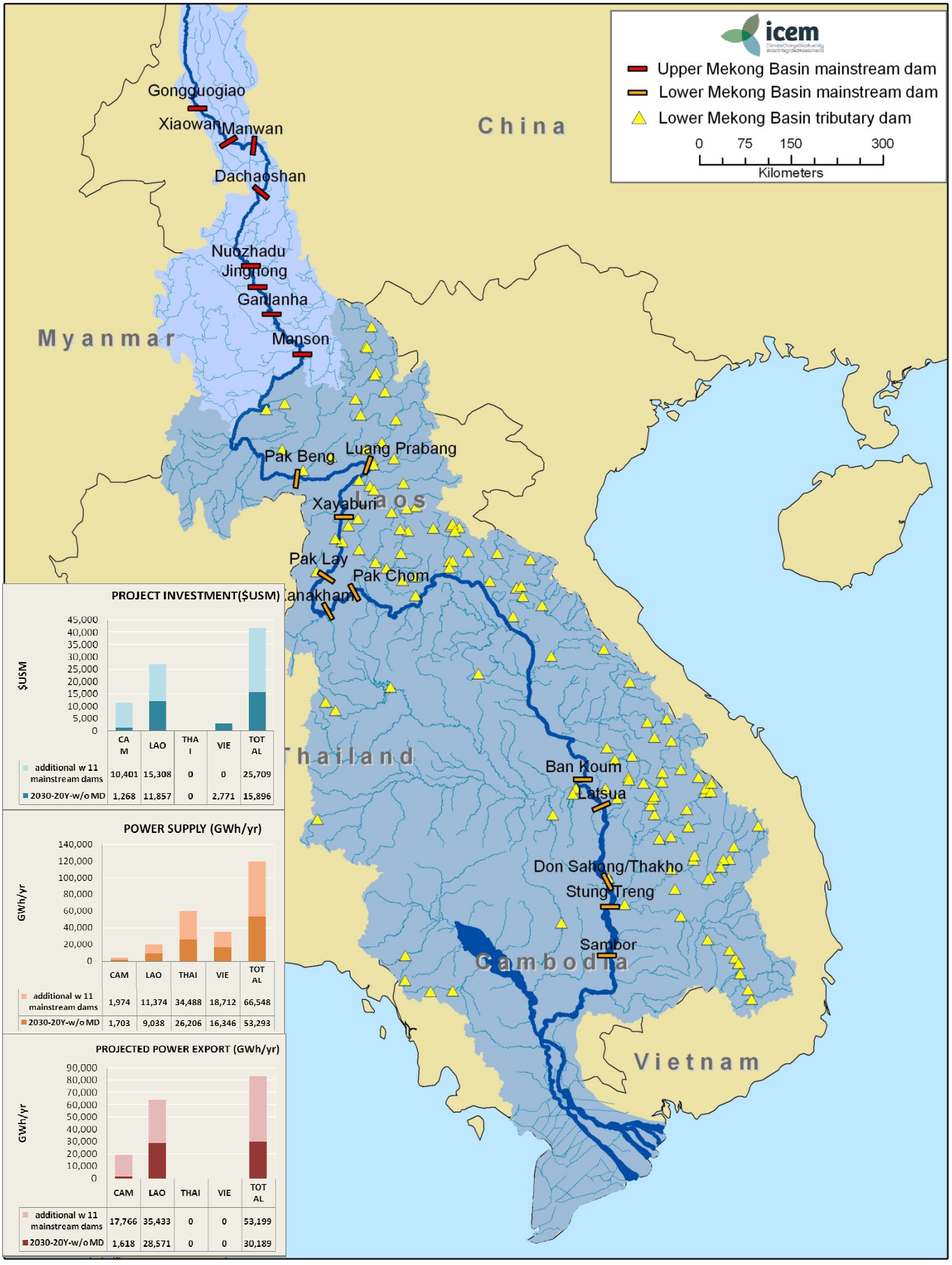
The LMB mainstream projects can only be developed jointly by the host country and the export market country (or conceivably a third party foreign investor) under complex financial and trade arrangements, which in some circumstances may go beyond the electricity sectors to involve commercial commitments of a bi-lateral or regional nature. This is because of the magnitude of investment required relative to the host countries financing ability.

Figure 12: Benefits of LMB mainstream hydropower to the LMB countries: *(left) gross export revenue; and (right) Net overall power benefit*



[38] The annual gross benefit of the project from power supply is calculated for each country by the product of the power supplied by the replacement cost of power in each country. For the host country the net annual benefit is the sum of the benefits from power supply and from export less the annual cost of the project. For importing countries the net overall power benefit is the difference between the replacement value of imported power and the cost of import calculated at the proxy trade price.

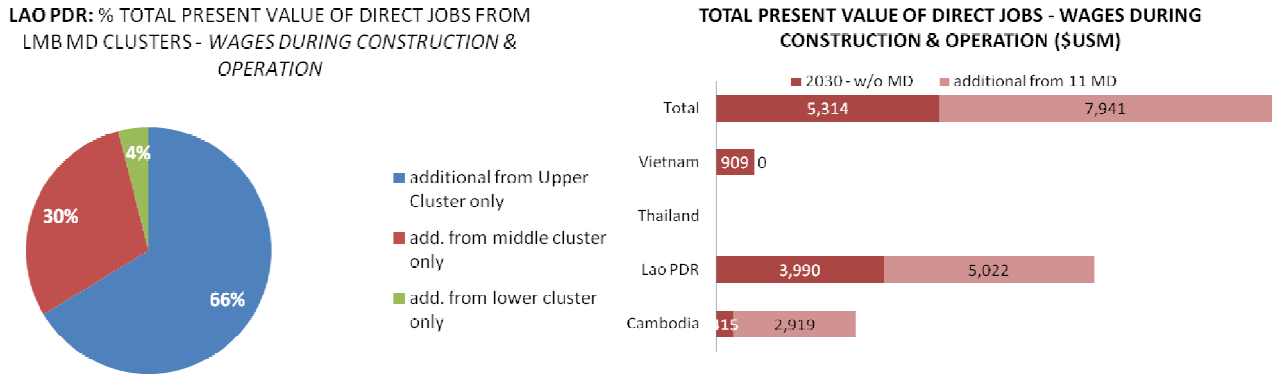
Figure 13: National summary of the power sector impacts



7.2.3 OTHER BENEFITS FOR THE POWER SECTOR

A number of non-power opportunities associated with hydropower development in the LMB exist which can offer both regional and national benefits.

Figure 14: Total present employment value of mainstream groups: *(top) % of project groups to overall benefit, (bottom) national employment benefit from both construction & operations*



Direct job creation is expected to generate an estimated USD 7.9billion in wages with almost 85% of this arising during the construction phase. Much of the labour (especially for skilled and semi-skilled jobs) is likely to be imported from surrounding countries other than the host countries (especially Viet Nam and China). The distribution of job creation during both construction and operation is estimated to be ~USD 5 billion for Lao PDR and ~USD 3 billion for Cambodia based on the number and size of mainstream projects in their territories (Figure 14).

At least 50% of project inputs including engineering services, electrical and mechanical equipment are likely to be sourced from outside the host countries and LMB region. Within the LMB region only Thailand has some capacity for manufacturing some of the expensive hydraulic components required though it is expected that the majority will need to be sourced from outside the region.

The LMB mainstream dams are calculated to have a gross GHG off-set potential of equivalent to around 52 million tonnes CO^2e/yr by 2030. Net emissions reductions are estimated to be around 40-50 million tonnes CO^2e/yr[3940].

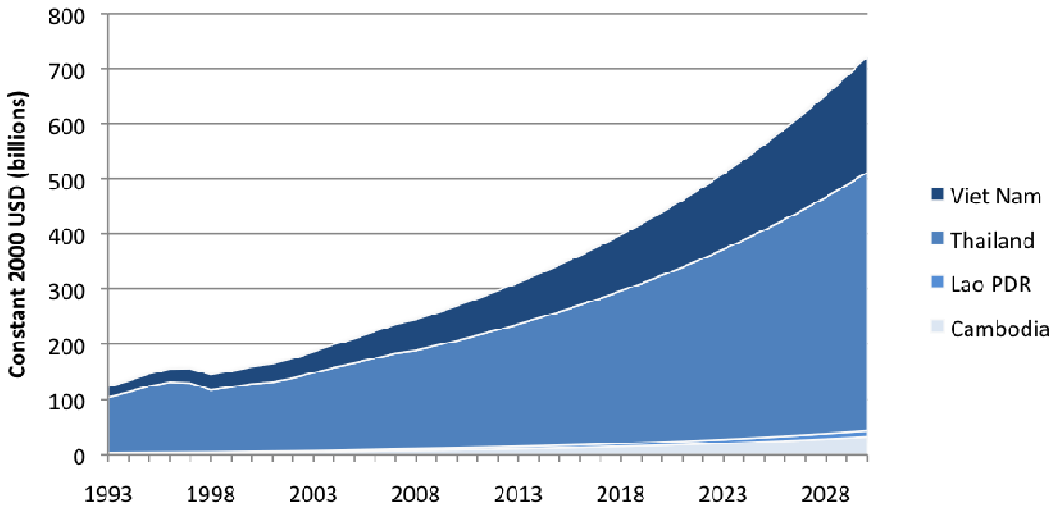
8 ECONOMIC SYSTEMS

In common with other countries in the wider East Asia region, over the last two decades the four countries of the LMB have experienced rapid economic development. This has largely been driven by industrial growth, and in particular growth in manufacturing production for export. Development has been associated with rapid urbanization, poverty reduction, and increases in consumption and personal income. Economic growth patterns vary greatly across the four countries reflecting different development histories and resource endowments. Thailand's longer history of economic growth and relative economic maturity is reflected in the size and structure of its economy which accounted for 73% of LMB GDP in 2008, followed by Viet Nam accounting for 23%, and Cambodia and Lao PDR accounting for 3% and 1% respectively.

Figure 15 shows a projection of economic performance in the region. According to these projections, Thailand will remain by far the largest economy in 2030 although a faster growth rate in Viet Nam will mean it accounts for an increasing proportion of LMB productivity. The region as a whole is expected to grow 240% from 2005 levels by 2030.

[39] The level of emissions from reservoirs is contested- see climate change analysis in the SEA impact assessment report.
[40] If these projects were eligible for off-sets then at a price of USD 18.7 tonne of CO_2 e (equivalent to the average price of EU ETS European Union Allowances in 2009) they could be worth between USD 748 million and USD 935 million annually. However, this is highly unlikely given (i) that these projects are unlikely to be deemed "additional" and would have gone ahead whether or not carbon financing was available; and (ii) it is unclear how they could meet sustainability criteria – which are likely to be tightened in the future.

Figure 15: LMB countries economic growth 1993-2030



8.1 BASELINE

8.1.1 MACROECONOMIC IMPLICATIONS OF LARGE SCALE NATURAL RESOURCE DEVELOPMENT

Macro-economic opportunities and risks relate to the large scale and rapidly increasing levels of investment in natural resources (i.e. hydropower, mining and plantation development) in particular in Lao PDR (and possibly Cambodia). This potentially represents a significant boost for this small economy crowding in investment and increasing consumption across a number of sectors.

Net revenues accruing to government from natural resource exploitation and hydropower in particular represent a significant source of potential funding for social development expenditures. For example, revenues from NT2 have been ring-fenced for health and education expenditures[41]. Conversely, such rapid growth in these natural resource sectors potentially poses a risk to competing sectors by driving up relative price levels resulting in exchange rate appreciation. This has the potential to reduce the internal and external competitiveness of other sectors in the economy (such as agriculture and manufacturing).

Large scale and rapidly increasing investment in natural resources (and in particular hydropower) in the region is largely funded by the foreign private sector. Investment in LMB hydropower over the last two decades has been expanding rapidly. In the past 10 years hydropower investment has grown from ~USD200 million to more than USD 1 billion. The same period has seen investment shift away from Thailand as potential development opportunities are mostly utilised towards Lao PDR and Viet Nam.

Tributary hydropower development in the LMB represents a massive investment and the generation of substantial foreign exchange for some countries (Table 7). In the special case of Lao PDR, investment in large hydropower and mining projects added an estimated 2.5 percent to GDP growth in 2007, or about USD 18 million in 2007.

Looking to the future, excluding LMB mainstream projects, annual investment in tributary hydropower in the basin is expected to peak in 2011-2012 at around USD 1.9 billion, with the vast majority of this investment being concentrated in Lao PDR, reaching a peak annual inflow of USD 1.7 billion in hydropower investment.

[41] Although as financial resources are typically highly fungible these expenditures cannot really be considered independent of total government expenditure. As Stiglitz remarked, because financial resources are fungible the developmental benefit of an extra dollar of development expenditures is only that of government expenditures at the margin.

Table 7: Planned investment in LMB hydropower – average annual investment 1990-2016 (million USD)

	Cambodia	Lao PDR	Thailand	Viet Nam	LMB total
Average 1990-2016	29	429	32	90	580
Average 1990-2009	0	235	43	105	383
Average 2010-2016	110	985	0	47	1,142

LAO PDR[42]: **The high-levels of growth experienced by Lao PDR have been driven by investments in raw materials including agro-forestry plantations, mining and hydropower**. These investments have undoubtedly added to growth in GDP, have boosted export earnings from commodities exports, and seem to be an important source of foreign exchange.

This influx of foreign exchange is likely to have profound effects on the key macro economic variables in Lao PDR, potentially leading to exchange rate appreciation. Further, Lao PDR is regarded as a country with a high risk of debt distress both from external and internal indebtedness. The implications of any additional debt obligations the government of Lao PDR incurs as a result of hydropower development need to be considered very carefully.

8.1.2 DIRECT EMPLOYMENT FROM TRIBUTARY HYDROPOWER

Development of tributary hydropower implies the creation of significant short-term employment in the region, resulting in an estimated USD 5.3 billion in wages for the LMB. Total present value of wages from direct employment during construction and operations of tributary projects amount to USD 3.9 billion (Lao PDR), USD 0.4 billion (Cambodia), and USD 0.9 billion (Viet Nam) by 2030.

8.1.3 DISTRIBUTIONAL TRENDS IN THE LMB

Rural populations in the basin are likely to remain relatively stable despite high natural growth rates as rapid rural-urban migration continues, driven by declining natural resources bases in upland areas and increasing employment opportunities in lowland and urban areas. Poverty rates in the basin are higher in remote upland areas and lower closer to the main stream and in larger urban settlements. Nevertheless, population densities are higher in lowland areas close to the river so the absolute numbers of poor are greater closer to the mainstream and in urban areas. This trend is increasing with rural-urban migration. Despite rapid growth in industry and service sectors, agriculture and fisheries remain important for livelihoods across the basin.

SLOWING POPULATION GROWTH: In all LMB countries, population rates have begun to slow and will continue to decline. While population growth rates in Cambodia and Lao PDR are still relatively high (1.81% in both countries), they have been slowing down over the last 10 years. Viet Nam and Thailand, in contrast have lower- but still slowing population growth rates (1.19% and 0.93% respectively).

INCREASING MIGRATION: Increasing proportions of the LMB population are moving across national and international boundaries – usually from rural to urban areas. Migrations are driven primarily by a perception of improved income earning opportunities elsewhere and facilitated by ever-improving transportation infrastructure. The two main types of migration in the LMB migration[43] are:

(i) migrations to urban centres.[44] Only in Lao PDR are rural populations increasing in proportion to the national population, and
(ii) migrations to Thailand from neighbouring countries.

POVERTY REDUCTION TRENDS: Economic growth has brought significant reductions in poverty rates across the LMB. **Over the next 20 years levels of absolute poverty are likely to decline, and poverty concentrated in remote and economically marginal locations is likely to remain a problem..**

- **Thailand:** rapid poverty reduction took place in the high growth decade of the 1980s, poverty has now stabilised at ~2%. This suggests that some proportion of the poor remain untouched by economic growth.

[42] Lao PDR is singled out here as it is the smallest economy in the region by a considerable margin
[43] In all likelihood figures underestimate the scale of rural-urban and cross border migration much of it is temporary and unofficial.
[44] Only in Lao PDR do figures show growth in the proportion of rural population in total population.

- **Viet Nam:** rapid poverty reduction in the last 12 years, dropping from over 60% in 1993 to ~20% by 2006.
- **Lao PDR:** poverty rate reduced from 55% to 45% between 1992 and 2004.
- **Cambodia:** slower reduction with poverty levels reducing from 49% in 1994 to ~40% in 2005.

LIVELIHOODS: There are a number of important livelihoods trends likely to emerge over the next 20 years in the LMB:

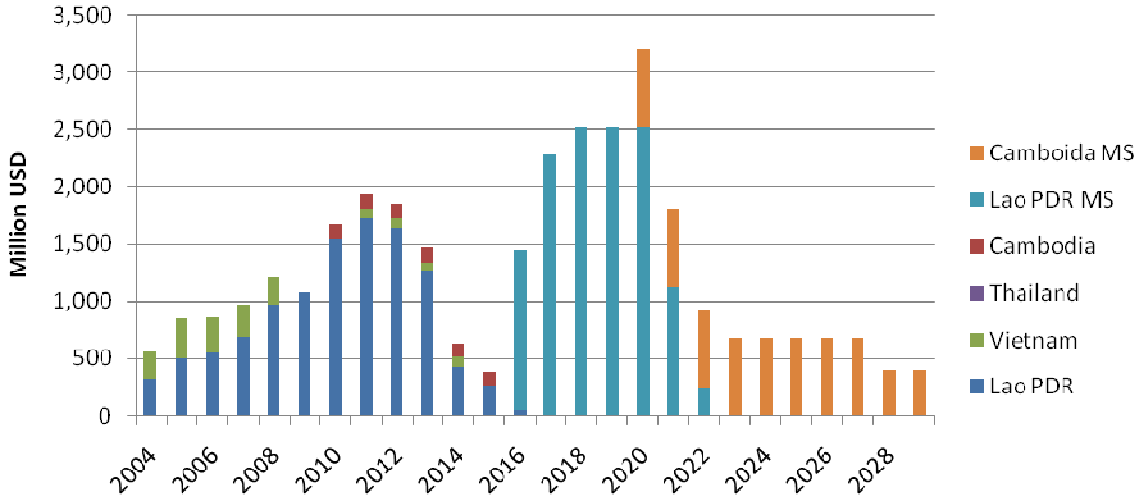
- **The number of people involved in the cash economy is likely to increase** both as rural-urban migration increases and opportunities for wage employment in rural areas increases, overall the proportion of the labour force engaged in wage labour will increase. Sales of cash crops are also likely to increase as marketing agricultural goods becomes more common with better access to markets through improved infrastructure.
- **Commercial agriculture is likely to expand, with increasing mechanisation and consolidation of land holdings especially in Thailand and Viet Nam**, this will be associated with declining rural populations, and increasing farm productivity and income.
- **Rural livelihoods dependant on stressed natural resources may also come under pressure.** This will exacerbate inequalities between rural and urban areas as natural resource bases upon which rural livelihoods depend are increasingly exploited as a source of inputs to the industrial sector.

8.2 IMPACTS ASSESSMENT

8.2.1 CAPITAL INVESTMENT

The scale of proposed FDI in the 12 proposed mainstream projects between 2010 and 2030 is an estimated USD 18-25 billion. This is large relative to the size of the host country economies Based on available investment schedules, mainstream hydropower development would imply extra investment for the period of 2016-2029 of on average USD 1.5 billion a year. Figure 16 gives an estimated investment schedule[45] for hydropower development in the LMB. These investments are particularly large relative to the size of the Lao PDR economy (Figure 17). Most of the funding for these developments is expected to come from sources external to Cambodia and Lao PDR.

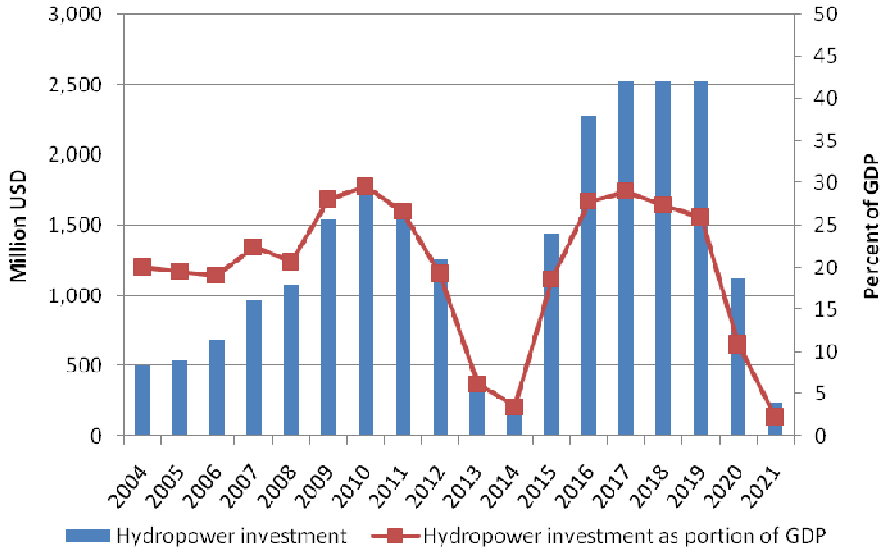
Figure 16: Estimated annual investment in LMB hydropower 2004-2029



A significant portion of this investment will 'pass through' the host countries as many inputs (engineering, equipment and skilled labour etc) will need to be sourced from outside these economies. Most expenditures on civil works (construction of dams including inputs such as concrete, sand and aggregate, steel and unskilled labour), are likely to be sourced locally.

[45] This schedule is based on the best available data. However, changes in design, other unforeseen construction contingencies and changes in price levels mean investment costs liable to significant changes. Moreover, the time schedule for these projects is likely to change also depending upon a range of contingencies.

Figure 17: Hydropower investment in Lao PDR 2004-2021*: investments comprise up to 30% of the Lao GDP.*



8.2.2 REVENUE GENERATION

There will be significant longer-term opportunities from export revenue for the exporting countries. Those opportunities will be more limited during the 25-year concession periods. These additional revenues offer the opportunity for increased investment in national and local development, including public services and poverty alleviation. However, there is little information on the revenue flow over time and how revenues are likely to be spent. This will depend on how the financing for these projects is structured.[46]

Macro economic impacts are likely to be of particular significance for Lao PDR due to the size of the LMB mainstream hydropower projects relative to the rest of the economy. These will result from i) an influx of investment capital and foreign exchange revenue due to mainstream hydropower development and possibly, ii) increased levels of government debt needed to fund government equity stakes in these developments.

A booming hydropower sector and increased government expenditures could lead to macro-economic imbalances, real exchange rate appreciation and thus have a negative economic impact on other sectors such as manufacturing and agriculture. Both sectors are important for poverty reduction.

Increased levels of host country government debt could pose a concern in the short to medium term to the extent that: i) national debt obligations are incurred for government equity share in LMB schemes; and, ii) the traditional sources of concessionary finance are not available to fund government equity contributions. It is not clear to what extent any extra cost of debt-service, and increased risk premiums on sovereign debt will be offset by increased revenues from these projects in the short term.

8.2.3 SECTOR IMPACTS

Mainstream development is likely to imply increased risks and opportunities across a number of sectors. Sectors likely to be significantly affected by mainstream dam construction include fisheries, agriculture and forestry, tourism, navigation, construction, and mining and industry sectors. Table 8 estimates the likely impacts in terms of changes in output. For example, for paddy production losses and gains due to the developments have been included. The values are indicative and generally do not represent economic benefits or costs, nor do they capture most indirect economic impacts due to the hydropower developments.

[46] Experience in Lao PDR on exporting power from tributary projects that are private sector developed shows a net positive revenue flow to Government during the concession period (25 years).

Table 8: Summary of sector costs and benefits due to mainstream development (to 2030 assuming all 12 MSHP dams go ahead)

Description	Indicative values	Cause of loss/gain	Annual net loss/gain due to mainstream development	Future trends with mainstream development	Nett gain/ loss
Fisheries	Fish production	Loss (capture fisheries)	▪ Direct loss of 340,000 tonnes tonnes/year ▪ Loss of USD 476 million/year	Fish migration routes will be blocked and flood pulses will be disrupted, decline in fish populations likely to result. This is likely to be true both for migratory species and species which depend upon flood plains for Some of this loss may be off-set by the introduction of reservoir aquaculture but potential yields from this remain highly uncertain.	**Net loss**
		Gain (reservoir fisheries)	▪ Most likely 10,000 tonnes (30,000 max) ▪ USD 14 million/year (42 million max)		
		Loss (marine fisheries from loss of nutrients to the sediment plume)	▪ Loss of 4,535 tonnes of phosphates to marine area/year ▪ Replacement value of around USD 40 million/year	Mekong delta marine fisheries estimated catch in 2008 was 563,000 tonnes worth between USD 1.1 – 2 billion. Productivity of the fisheries in this area is closely related to the sediment plume and associated nutrients delivered by the Mekong river. No data available linking nutrient levels in sediment plume with fisheries productivity. Replacement cost of nutrients used as a basic indicator.	
	Ancillary and up-stream industries (boat manufacture)	Loss (knock-on effect of fisheries loss)	▪ Loss of 2 million boats without engines, worth USD 1,000-2,000 each ▪ USD 2-4 billion – likely to decline in proportion to the fisheries	Industries include boat and fishing tackle manufacture, salt production , ice production, and up-stream industries include fish processing (manufacture of fish sauce, dried fish and other fish products)	
Agriculture and forestry	Riverbank garden production	Loss (riverbank gardens)	▪ Loss of 54% of river bank gardens in zones 2,3 and 4 ▪ Loss of USD 21 million/year	Loss of river bank gardens due to inundation of long stretches of the mainstream river in zones 2, 3 and 4. This estimate does not include any difficulties in cultivating riverbank gardens downstream of the dams.	**Net loss**
	Paddy production	Loss (inundated paddy and transmission lines)	▪ Loss of 7,962 ha of paddy ▪ Loss of 22,475 tonnes of rice/year ▪ Loss of USD 4.1 million/year	Relatively small losses from inundation of paddy more than offset by gains resulting from increased irrigation associated with mainstream hydropower development.	
		Loss (value of nutrients (Phosphates) to agriculture)	▪ Loss of 3,400 tonnes of phosphates to flood plains/year ▪ Replacement value of fertiliser around USD 24 million/year	Any reduction in sediment load and flooding will lead to a decrease in associated nutrient replenishment. Measured as loss of phosphates due to sediment trapping at each of the MSHP dams. While productivity implications for agriculture could not be calculated, cost of artificial replacements given.	
		Gain(increased irrigation)	▪ Gain of 17,866 ha of paddy ▪ Gain of 77,701 tonnes of rice/year ▪ Gain of USD 15.54 million/year	Irrigation projects associated with the hydropower developments are likely to improve land productivity and rice production in some areas.	

Tourism	Tourism revenues	Loss (degradation of natural resource base)	N/A	Some valuable environmental assets (e.g. charismatic species like the Irawaddy dolphin & locations) upon which burgeoning ecotourism industry is based will be degraded or lost due to changes in the hydrology and ecology of the mainstream resulting from these projects.	**Net loss**
		Gain (HP project viewing)	N/A	Large hydro-electricity projects often attract (mainly domestic) tourism (for example Hoa Binh dam in northern Viet Nam)	
Navigation	Freight transport	Gain (increased navigability)	N/A	Mainstream hydropower is likely to increase the navigability of the river as it will increase the depth of the river along significant stretches. However, this will be dependent upon designing dams such that they allow navigation. Which projects go ahead will affect the overall navigability of the river. Therefore, impacts on navigability and are dependent upon dam design. Mainstream hydropower will increase instability of the river channels along the important navigation routes between the delta mouth and Phnom Penh	**Unsure**
	Passenger transport	Gain (increased navigability)	N/A		
		Loss (decreased longitudinal connectivity)	N/A	Even with navigation locks these projects will increase the time taken and probable costs of navigation	
Construction	Sand and gravel extraction output	Loss (reduced sediment load)	N/A	Unlikely to be significant in the short term.	**N/A**
Aquatic plants	Subsistence	Loss (loss of habitat)	N/A	Changes in mainstream habitats will increase loss of currently economically important aquatic plants.	**Net loss**
Wetlands	Clean water supply, plants for food and medicines, fuel wood, nutrient recycling, water purification wildlife habitats groundwater recharge, flood control, carbon sequestration, storm protection etc	Loss (due to reservoir creation)	Loss of between USD 4 million and USD 13.8 million per year (2000 prices)	Most of the in-stream wetlands will be lost in zones 2, 3 and 4 with significant impacts on their productivity and the in all likelihood other ecosystem services they provide (for more information on the calculation of these values see background methodological paper)	**Net loss**
Flooding/ flood control	Nutrient replenishment, wildlife habitat, damage to goods and livelihoods	Gain (reduction in flooding)	N/A	Some minor flood control effects, but there benefits offset by unpredictability of decisions for opening/closing spillway gates and flushing gates at the dams	**Net loss**
Saline intrusion	Crop productivity	N/A	N/A	No significant impact	**N/A**

8.2.4 DISTRIBUTIONAL IMPACTS & POVERTY ALLEVIATION

The poor would be disproportionally negatively impacted by the mainstream hydropower development. Higher poverty rates are usually found in remote up-land areas away from the mainstream. However, higher population densities mean that the absolute number of poor is higher in low-land areas closer to the mainstream. This trend has been increasing as livelihood opportunities develop in low-land (and associated urban areas), and as the natural resource base in upland areas are degraded. Negative impacts on the already vulnerable rural poor may increase rural-urban migration, and have knock-on implications for urban poverty rates.

The impact on food security and economic costs associated with increased malnutrition amongst vulnerable populations are likely to be high.

Mainstream projects are likely to have a significant impact on the nutritional status of the poor given the extent of the expected reduction in fisheries**.** LMB populations are highly dependent on fish as a source of protein. The poor depend proportionately more on fish (and other aquatic animal) consumption than other groups and they are likely to be unable to diversify their consumption away to other food sources easily.

Impacts related to the loss of agricultural land (in inundated areas and river bank gardens), off-shore fisheries and flood plain agriculture (through the loss of sediment and associated nutrients), are likely to fall more heavily on poorer groups. The urban poor may be particularly at risk from any impact resulting in an increase in food prices. This may be aggravated by increases in urban poverty from increased rural-urban migration due to the declining natural resource base. In the longer term climate change impacts could compound these negative impacts.

The expected loss of fisheries due to mainstream hydropower development is likely to be a key impact on the poor. The poor tend to be more vulnerable to adverse changes in environmental conditions. They have fewer assets, savings, skills and knowledge that give flexibility in making adjustments to livelihood strategies in response to changes in environmental conditions. Amongst fishers, poverty rates are higher than national averages.[47] In Cambodia over 1 million people depend on fisheries at risk from mainstream development.

Significant improvements in regional cooperation and institutional and regulatory capacity are needed for effective management of mainstream projects and mitigation measures. Worldwide there are a number of benefit sharing mechanisms and mitigation measures for affected economic sectors which have proven successful under specific institutional contexts. The success of extensive mitigation measures needed to address risks and enhance opportunities, and the funding of such measures (e.g. national to local benefit sharing, and trans-boundary benefit sharing mechanisms) would be contingent on building substantially increased institutional, administrative and technical capacity in host countries and regionally. This would need to be done by the proposed construction and operations start up dates for the projects. [48]

8.2.5 CAMBODIA

Cambodia would receive increased foreign exchange earnings from power exports, increased direct investment in the hydropower facilities themselves, and increased government revenues. In the longer term, improved power supply and reduced power price could be significant, however if fossil fuel exploitation in Cambodia waters progresses as expected, mainstream hydropower will not be the critical component of the energy supply mix in Cambodia as it is often portrayed. Employment opportunities in the construction, operations and maintenance of the hydropower facilities will also be important.

Cambodia would experience a highly significant reduction in capture fisheries which would have a significant macro-economic impact and an adverse poverty reduction impact especially in vulnerable riparian populations. In the case of the projects sited in Cambodia direct impacts due to loss of land, assets and other livelihoods are likely to be important. It is important to bear in mind that even if the Cambodian projects did

[47] As most fishers are from areas where poverty rates tend to be above the national average with the possible exception of Lao PDR where upland areas are some of the poorest

[48] Benefit sharing; especially revenue sharing is important to ensure the benefits accruing at the regional or national level are transferred to local level.

not go ahead fisheries in Cambodia would be adversely affected by projects in Lao PDR/Thailand albeit to a lesser extent.

Cambodia is likely to bear the brunt of the decline in fisheries due to the importance of this sector and the dependence of large sections of the population on fisheries for their livelihoods and as a key source of nutrition. Domestic hydropower projects will bring benefits but is not clear whether the financial and economic gain these may imply will offset the less obvious costs borne by fisheries dependant populations.

8.2.6 LAO PDR

Benefits of mainstream hydropower development for Lao PDR include increased foreign exchange earnings from power exports, increased direct investment in the hydropower facilities themselves, increased government revenues and the generation of the employment opportunities in the construction, operations and maintenance of the hydropower facilities.

Negative impacts include loss of production land, housing, other productive facilities; infrastructure and amenities are all likely to be significant in both upstream and downstream areas. In particular:

- **Loss of river bank gardens** and negative impacts on in-stream infrastructure due to changing water levels and increased erosion will be costs that are likely to be borne by local populations and local governments respectively.
- **Loss of aquatic resources** is likely to be significant for populations along the river, this impact is likely to be less wide spread than in Cambodia. Nevertheless, loss of aquatic flora and fauna, and fisheries productivity is likely to have highly significant if localised poverty and nutritional implications similar to those outlined for Cambodia.
- **Indirect impacts though exchange rate appreciation** may have negative implications for some sectors such as manufacturing and agriculture – although this will depend upon the macro-economic management policies and capacities of the government.

A key question for Lao PDR is the extent to which the government will be able to use net revenues from hydropower to address the uncompensated impacts of these developments, and more broadly, to improve productive capacity and competitiveness in sectors which are important for poverty reduction (i.e. manufacturing and agricultural sectors).

8.2.7 THAILAND

Benefits for Thailand are not significant in terms of the overall national economy or power sector. While there are economic benefits from a cheaper and more stable electricity price from mainstream projects, given the size of Thai power demand it would have quite a small impact. Thai project investors and developers will reap benefits as will their suppliers (mainly construction firms, engineering firms and their employees). Increased profits for these companies will also lead to greater tax returns. However, when considered against the size and diversity of the Thai economy these impacts are not significant.

Key economic costs will be borne by river dependant populations especially fishers and those engaged in riparian subsistence livelihood strategies. The north east of Thailand is the poorest in the country, however compared to the other LMB countries the population in the Thai portion of the basin is comparatively well off. This population also has greater opportunities to diversify livelihoods away from dependency on the river resource base. Therefore, while the initial impact on the Thai river basin population is likely to be significant, this population is likely to be able to adapt more effectively that affected communities in the other riparian countries.

8.2.8 VIET NAM

Viet Nam will accrue fewer benefits from mainstream project development than any other LMB country. The most significant benefit would be the additional power supply. Key benefits for Viet Nam are likely to be of a much reduced scale to those for Thailand as fewer project inputs are likely to come from Viet Nam. On the other hand, the benefits of the additional power supply are likely to be more significant - reflecting supply

shortfalls and the overall size of Vietnamese power demand. However, these beneficial impacts are not significant to the national economy that would likely continue its growth with or without the projects.

Mainstream development will result in changes in seasonal flow rates, sediment and nutrient transport and river ecosystems in the Delta. Reduction in sediment loads and associated nutrient flows to the delta flood plains and to the large marine fisheries off the Vietnamese cost is likely to imply significant costs for both agriculture and marine capture fisheries. The impact on freshwater capture fisheries is likely an additional negative impact experienced by river dependent communities in the Delta where capture fisheries are an important livelihood component. The significant loss of fisheries will have serious implications for fisheries dependent livelihoods and nutrition in the Mekong delta. The poor are likely to be most severely affected by these fisheries impacts as unlike land or other privately owned assets these represent a common resource accessible to the poor.

Table 9: Economic summary of opportunities & risks for LMB

Cambodia ▪ **Serious adverse consequences for fisheries and fishers, food security and poverty reduction** ▪ **Significant benefits from power sector development secure and less expensive power for industry and economic diversification in the long term** ▪ **Fisheries losses likely to out-weigh benefits of power production at least in the short to medium term**	
OPPORTUNITIES	RISKS
▪ Significant benefits from less expensive and secure national power supply (replacing costly diesel imports) ▪ Increased competitiveness in manufacturing sector ▪ Increased government revenue from power export and taxes ▪ Increase in irrigable area and agricultural productivity in some areas ▪ Longer term strategic flexibility in power supply once concession periods end	▪ Loss of fisheries resources and significant impact on food security ▪ Livelihoods disruption of over 1.6 million fishers ▪ Loss in GDP through economic losses in fisheries and agriculture ▪ Ancillary services and processing would suffer ▪ Loss of sediments and associated nutrients to Tonle Sap system, and associated adverse impacts on primary production, flood forest and local/migratory fish ▪ Loss of river bank gardens - likely to be significant for riparian communities in some areas ▪ Loss of fertility and agricultural productivity in flood plains ▪ Loss of tourism assets and revenue ▪ Lack of national grid may inhibit equitable distribution of power ▪ Loss of biodiversity
Lao PDR ▪ **Likely significant overall economic benefit – this is likely to be unevenly distributed** ▪ **Negative impacts on vulnerable communities likely to be significant** ▪ **GoL expenditure of increased net revenues could help ameliorate negative impacts**	
OPPORTUNITIES	RISKS
▪ Significant benefits from economic stimulus of FDI in LMB mainstream hydropower ▪ May see net revenue benefits in concession period depending on the design of financing agreement and adequate oversight capacity ▪ Likely to see significant benefits after 25 year concessions end and the projects transferred to GoL ▪ Benefits of increased irrigable area and agricultural productivity in some areas ▪ Improvement in navigability for med/large vessels upstream of Vientiane ▪ Longer term strategic flexibility in power supply once concession periods end	▪ Possibility of macro-economic imbalances developing due to booming hydropower sector ▪ Loss of fisheries – likely to affect food security and livelihoods of vulnerable populations ▪ Loss of river bank gardens particularly significant in Lao PDR ▪ Loss of valuable tourism assets ▪ Loss of biodiversity
Thailand ▪ **Overall economic benefit although insignificant for national economy** ▪ **Economic risks to livelihoods for riparian communities in the basin**	
OPPORTUNITIES	RISKS
▪ Will receive significant portion of the economic benefits of power from imports ▪ Improvement in navigability for med/large vessels in upper	▪ Loss of fisheries ▪ Loss of agricultural land ▪ Possible loss of eco-tourism assets

reaches of the LMB	
Viet Nam ▪ **Likely overall economic loss** ▪ **Losses borne predominantly by poorer communities in the Mekong delta**	
OPPORTUNITIES	RISKS
▪ Will receive significant portion of the economic benefits of improved power supply (from imported power)	▪ Significant loss in fresh water and marine capture fisheries and aquaculture – likely to affect livelihoods of fisher folk in delta - especially poorer groups ▪ Loss of sediments and associated nutrients significant adverse economic affects to deltaic sedimentation, fisheries (Mekong and marine) and agriculture

9 HYDROLOGY & SEDIMENT REGIME

The Mekong River is 4,880km long with a total fall of 4,583 m, area of 795,000 km² and average annual flow of 505km³. Originating in the Tibetan plateau the river spans a wide range of geologic, climate, drainage and ecological zones. The unifying hydrological feature of the system is the river's flood pulse, which sees the individual rainfall-runoff events throughout the catchment coalesce into a stable and predictable hydrograph with distinct hydrological seasons (Figure 18). For the Lower Mekong Basin (LMB) it is the Mekong flood pulse, high nutrient loading and basin area which drives the river's high levels of aquatic and terrestrial biodiversity and system productivity.

The annual hydrograph for the Mekong River has three important features which are critical in establishing the current hydrological regime: (i) **SW Monsoon:** the response of the hydrograph to the SW monsoon exhibits a single amplitude peak complemented by a highly predictable phase; (ii) **Flood arrival**: the onset of the flood season occurs within a consistent and small time window with a standard deviation of approximately two weeks; (iii) **Long low-flow period:** there is a long period of low flows which facilitates the seasonal transition from aquatic (flooded) to terrestrial (dry lands) environments. This predictability of the river hydrology has resulted in a good understanding of the natural equilibrium that is manifest throughout the 90 years of sampling.

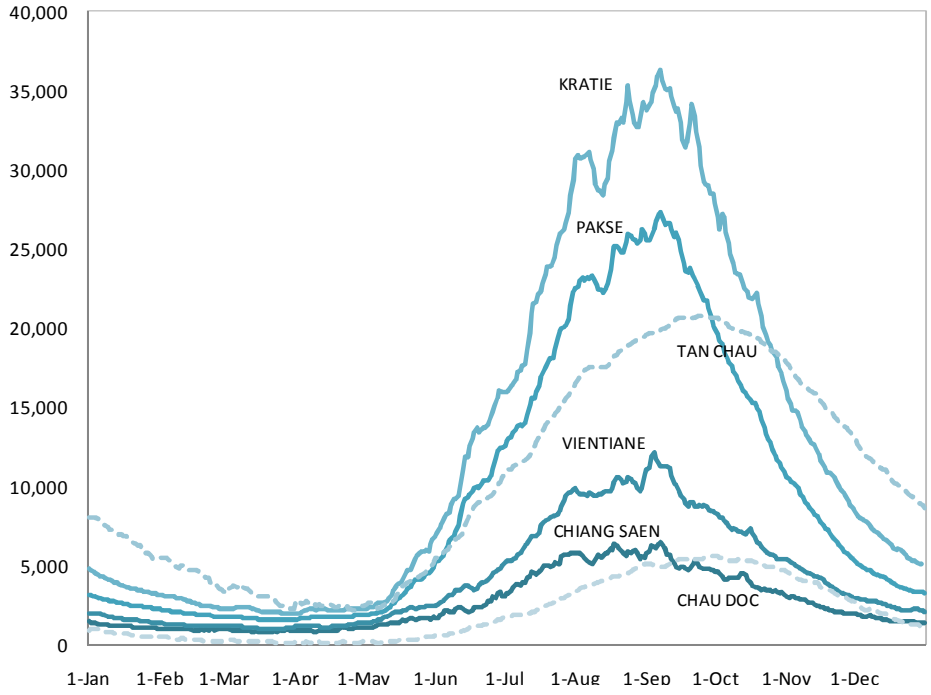
Given the stability of the natural hydrological regime, change over short time scales will arise from human activity in the basin. From a surface water point of view, development in the basin can affect the availability of water, the consumption of water, and the storage of water at seasonal and inter-annual time-scales:

1. **Water Availability:** land clearing and deforestation which has resulted in an average 15-20% reduction in forest cover since the 1960s. This has changed local hydrology but has not had significant impact on the basin-wide hydrological regime. Climate change will change the timing and duration of precipitation events affecting water availability at the basin scale (c.f. climate change section).

2. **Water consumption:** water consumption in the LMB will experience significant increases by 2030: irrigated areas will increase from 6.6million ha to 9.7million ha, while water supply will increase to from 2,832 mcm/yr to 4,381 mcm/yr.

3. **Water storage***:* Under the BDP 20Y scenario the number of tributary dams will increase from 16 to 76 which corresponds to a 700% increase in active storage capacity (9.9 – 69.8km³) or a capacity to store 14% of the Mekong's mean annual flow by 2030. By number more than 80% of these projects are in Lao PDR and Viet Nam, however, the 6 projects in China (known as the Yunnan cascade) collectively account for 23.7km³ of this storage (36% or total basin storage) with 94% of Chinese storage coming from just 2 projects. **This represents the first time that a development sector will threaten to significantly alter the hydrological regime of the entire Mekong Basin**.

Figure 17: Average annual hydrographs of the Mekong River (BDP baseline scenario)



9.1 BASELINE

9.1.1 STREAM POWER

Stream power is the rate at which energy is lost in moving over the bed of the river, and lost to turbulent flow dissipation (5-50MW/km). This large variation results from the 'pulsing' nature of the Mekong River which experiences dramatic changes in flow between wet and dry seasons. Stream power is important to almost all aspects of the river, including movement of coarse and fine sized sediment, the development of deep pools in the bedrock, channel geomorphology, bank erosion, and formation of mid-channel islands.

The 20 year scenario trend is for the peak stream power to shift downwards by between 10-30%, associated with smoothing of the annual hydrograph because of regulation by proposed dams/reservoirs with large storage. The 8 dams proposed in the UMB are the dominant driver behind the reduction in stream power as they regulate the river storing wet season flows for release during the dry season. Consequently, the largest reduction in maxima occurs in the upper reaches of the LMB (10-30% in Zone 2) with the change reducing in significance further downstream (5-10% in Zone 3, 4, 5 and ~5% in Zone 6).

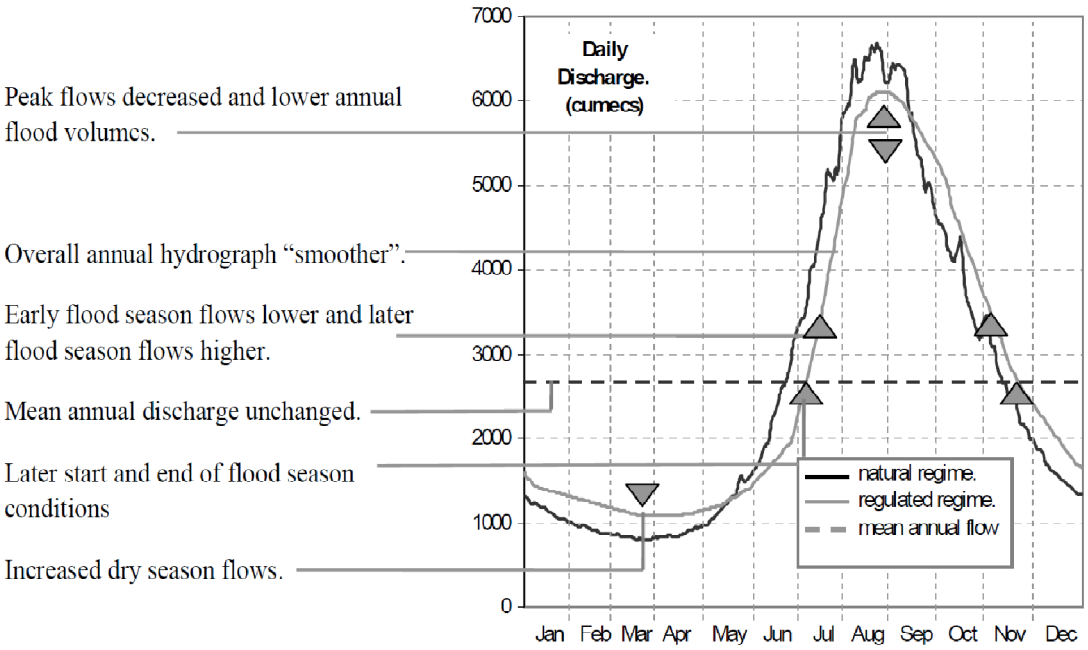
This reduction is predicted to reduce the efficiency of important geomorphological processes such as sediment transport, seasonal cycles in deep pools and flushing of sediments out into the marine environments, but it will not prevent any of them from occurring.

9.1.2 WATER SURFACE LEVEL CHANGES

Water surface levels in the Mekong mainstream fluctuate relatively slowly, because of the large size of the river. Rates of change of water surface elevation are highest with the arrival of the flood pulse, and are typically up to about +/- 0.16 m/day at Luang Prabang, +/- 0.11 m/day at Pakse and about 0.09 m/day at Stung Treng. Riparian communities and users of the Mekong River depend on the seasonal and daily fluctuation in water surface levels for fishing, agriculture and transport. River bank inhabitants, such as fisherman living in floating homes, are used to river levels that fluctuate slowly, and they typically have many days to anticipate the onset of floods.

The present trend (with 20 year scenario) is for a reduction in the hydrograph maxima, and an increase in the hydrograph minima, associated with water storage in large capacity reservoirs (Figure 19). *Extremities of water levels* are critical for the aquatic ecology. The overall hydrograph will be smoother, especially in the transition to flood season which will see a reduction in the important freshwater '*spates*' which drive many ecosystem functions.

Figure 19: Generic characteristics of the changes to the Mekong hydrograph from UMB and tributary storage hydropower



HOURLY AND RAPID FLUCTUATIONS IN WATER LEVELS**:** Historically the Mekong River has not experienced rapid fluctuations in water levels with changes limited to centimetres per day. The Chinese dams in Yunnan province have already induced noticeable changes in water levels at Chiang Saen at a daily Time Step. **Under the 20 year scenario these changes will increase in magnitude depending on how the tributary hydropower dams are operated, and the effectiveness of a proposed re-regulating structure downstream of the China dams.**

FLOOD TIMING: **The major impact from the combined effect of the Yunnan cascade and the tributary developments will be the loss of the transition seasons in Zone 2 resulting from a more even hydrograph**. The *spates* and first flushes of the transition to flood play an important part in triggering key ecosystem functions of the Mekong system including spawning and migration of aquatic biota as discussed in the aquatic and fisheries themes and will no longer occur under the 2030 foreseeable future scenario

- ***Onset :*** The timing of Transition from the dry to the flood season will be most affected, starting ~7-8weeks earlier at Chiang Saen and ~1 week at Kratie.

- ***Duration:*** Upstream of Pakse will experience a 2-4week reduction in the duration of the transition season from Dry to Flood, which will drop to ~1 week in the Mekong floodplain. The duration of the flood season is not expected to be significantly affected except at the uppermost reaches of the LMB where the UMB flows still dominate wet season volumes.

- ***Magnitude:*** dry seasonal flows will increase by 70% at the most upstream stations decreasing to 10% at the Mekong Delta. Conversely, wet season flows will decrease by up to 18% at upstream stations decreasing to 2% change at the Mekong Delta.

FLOODED AREA: **2030 will see a typical reduction of ~300,000 ha in flooded area, the majority of which will affect areas with flood depths greater than 3m (Figure 20).** This will affect more than 15% of the flooded area in Thailand and Lao, and less than 5% of the area in Cambodia and Viet Nam.

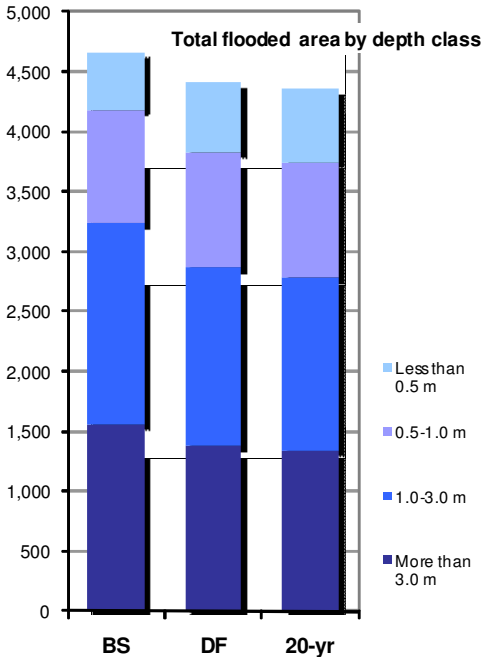
Fig 20: Change in flooded area for different BDP scenarios: *The dominant influence of the Lancang cascade on changes to flooded area reflects that the majority of storage capacity available with proposed hydropower development is contained within these 8 Upper Mekong dams*

Flooded area assessments '000 ha

Baseline	Lao	Thailand	Cambodia	Vietnam	Total
Less than 0.5 m	18	17	142	307	484
0.5-1.0 m	25	24	228	668	945
1.0-3.0 m	82	89	708	794	1,673
More than 3.0 m	270	232	1,055	5	1,562
Totals	**395**	**363**	**2,133**	**1,773**	**4,664**

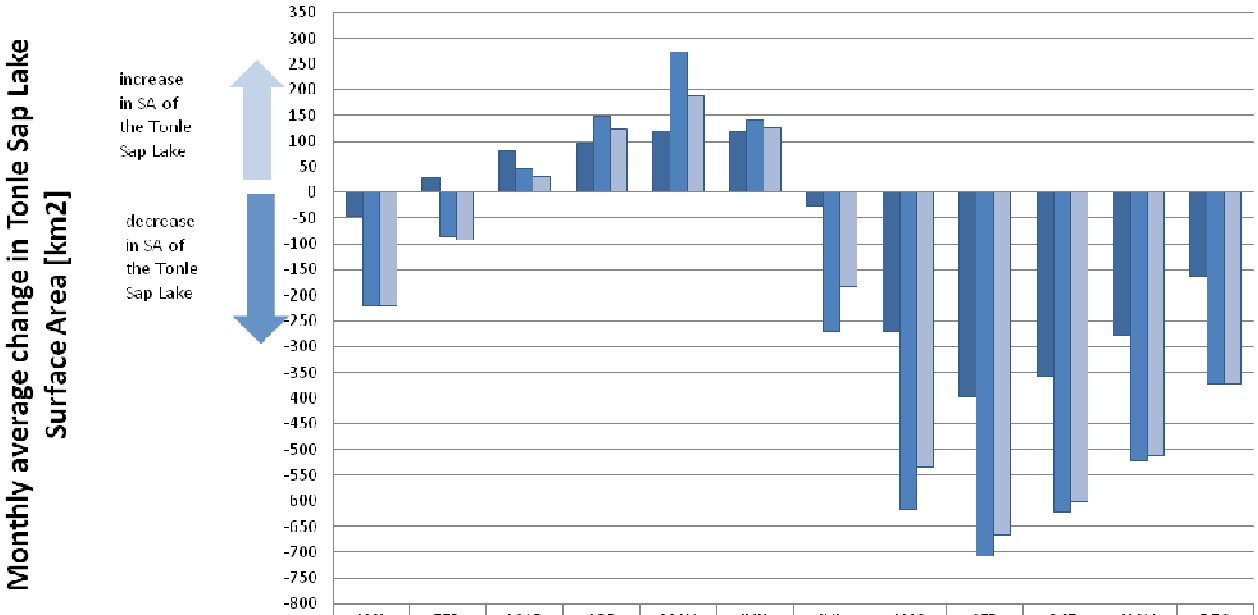
Definite Future Scenario	Lao	Thailand	Cambodia	Vietnam	Total
Less than 0.5 m	17	18	175	374	584
0.5-1.0 m	20	22	205	712	959
1.0-3.0 m	72	79	673	666	1,490
More than 3.0 m	224	177	977	3	1,380
Totals	**332**	**296**	**2,029**	**1,756**	**4,413**
Reductions from baseline	16%	18%	5%	1%	5%

20-year Foreseeable Future	Lao	Thailand	Cambodia	Vietnam	Total
Less than 0.5 m	18	19	177	395	609
0.5-1.0 m	18	21	208	717	963
1.0-3.0 m	69	77	664	634	1,444
More than 3.0 m	223	170	943	3	1,339
Totals	**329**	**287**	**1,991**	**1,748**	**4,355**
Reductions from baseline	17%	21%	7%	1%	7%
Change from Definite Future	**-1%**	**-3%**	**-2%**	**0%**	**-1%**



TONLE SAP: **By 2030, UMB and tributary hydropower will induce a 500-600km2 (5-10%) reduction in area of the Tonle Sap Lake subject to the seasonal flood pulse and oscillation between terrestrial and aquatic environments (Figure 21).** Hydropower regulation will reduce the hydraulic gradient driving flow in and out of the Tonle Sap system and consequently increase the dry season inundated area (+5 to +8%) while also reducing the wet season inundated area of the lake (-3 to -5%).

Fig 21: Changes to the average monthly area of the Tonle Sap lake under: (i) baseline, (ii) definite future, and (iii) 20Y BDP scenarios.



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
KAMPONG LUONG (KPL) SA(BS-DF)	-48	30	81	95	120	118	-27	-270	-397	-357	-278	-163
KAMPONG LUONG (KPL) SA (BS - 20Y)	-221	-87	45	149	274	140	-272	-618	-708	-622	-522	-373
KAMPONG LUONG (KPL) SA (BS - 20Y w/o)	-219	-93	31	124	188	125	-183	-585	-666	-602	-513	-373

FLOOD PROTECTION: **Flood protection benefits from storage reservoirs on the LMB tributaries and on the Lancang mainstream are highly debated and not a finding confirmed by the SEA.**

It is a commonly held view that large storage project can provide benefits of flood protection by withholding some flood waters. For the Mekong system, storage hydropower will not provide flood protection for two key reasons:

1. The **Annual** flooding cycle due to the Mekong flood pulse is a positive factor on which much of the natural system, fisheries and agriculture productivity depends. There is no need to protect downstream areas from these regular seasonal events.[49]

2. **Extreme** flooding is a hazard from which downstream areas and communities would need protection. Yet, the experience in the region shows that extreme flood events threaten the safety of large reservoirs and operators are likely to pass through most of the flood waters. In some cases dam management has have aggravated the situation by increasing downstream flows to empty storage space ahead of an extreme event.

Storage project on the Lancang River and the LMB Mekong tributaries will regulate seasonal flows smoothing the annual hydrograph – it remains to be seen whether these projects can be managed to provide flood protection during extreme events. Their capacity to do so would require institutional arrangements between project operators and governments which allow for coordinated multiple-use management.

9.1.3 FATE & TRANSPORT OF COARSE SIZED SEDIMENT

There will be a 75-81% reduction in the Lancang River sediment load due to the 8 UMB hydropower projects. The average annual sediment load arriving at Chiang Saen will reduce from 90Mt/yr to 20Mt/yr. For the downstream river, a reduction in the transport of medium sized sediment is felt first, as this is rapidly depleted from storage on the bed and banks of the river, while the sedimentary nature of the river bed coarsens in response. The reduced sediment will first manifest as erosion problems near Chiang Saen and then work progressively downstream. This downstream migration of the erosion zone will be slowed by the presence of deep pools in Zone 2 which typically require 1 water year to cross, such that it may take in the order of 1-2 decades before coarse sized sediment is no longer supplied to the alluvial reach starting 40km to the north of Vientiane (Figure 22).

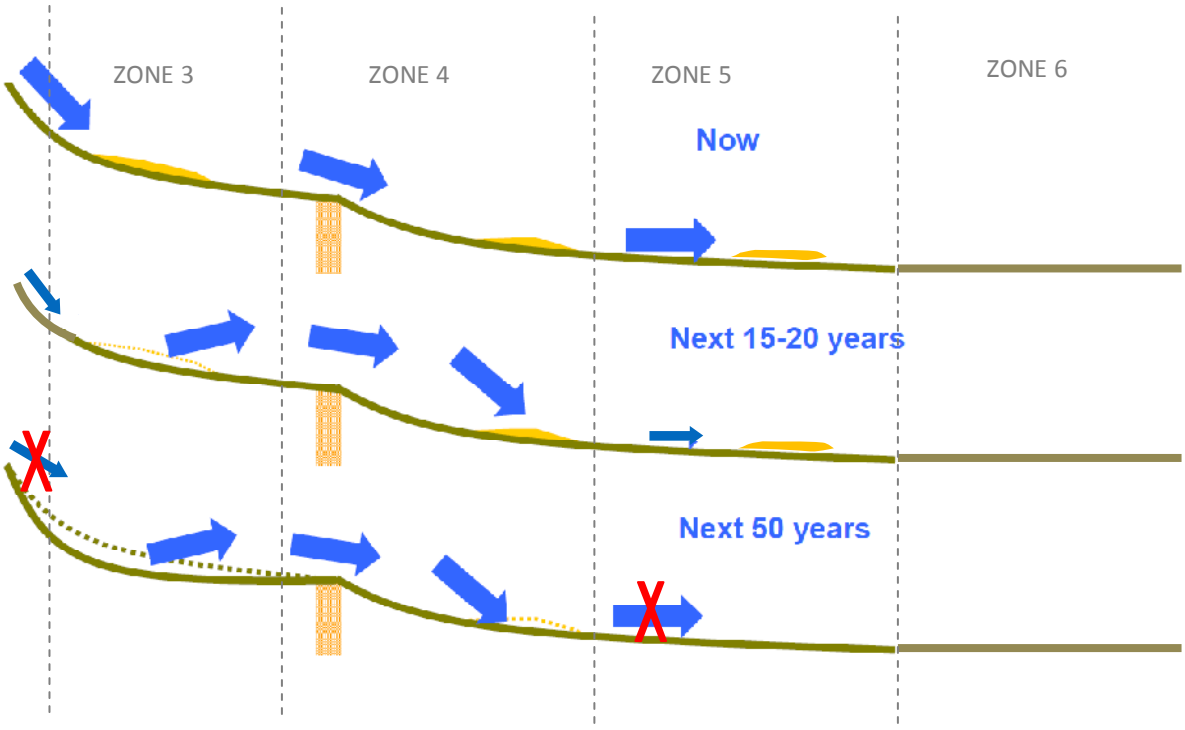
Reduced sediment loads (predominantly due to the UMB projects) will increase the erosion of medium-sized sediments currently stored within the river bed and banks of Zone 3 and 4. This will first manifest within the vicinity of Vientiane and take in the order of 15-30 years to translate down to Kratie, after which time problems of bank instability will begin to be felt between Kratie and Phnom Penh. There is no significant transport of coarse-sized sediment downstream of Phnom Penh.

DEEP POOLS: There are at least 335 deep pools along the thalweg of the Mekong mainstream, which play an important role in regulating the downstream progression of sediment and building in-channel features such as islands and sand bars and other critical habitats for aquatic productivity.

In the absence of LMB mainstream dams, the significant amount of sediments and good longitudinal connectivity stored in the Mekong channel will allow the deep pools to continue functioning as normal in the short and medium term. Reduced sediment loads will only impact on the medium to long-term functioning of the Mekong deep pools, due to the ~11,000 million tonnes of sediments stored within Mekong channel.

[49] Viet Nam has formally recognised the benefits of the annual flood cycle by including its 'living with floods' initiative into formal water resources master planning for the Mekong Delta.

Fig 22: Future coarse & medium sediment dynamics without LMB mainstream: *(**top**) currently there is a progressive movement of coarse and medium-sized sediments downstream from Zone 2 to Zone 5. Zone 3 and 4 act as zones of transport with Zone 5 as the main site of deposition for coarse/medium sized sediments; (**middle**) 80% of sediment supply from Mekong headwaters will be trapped behind hydropower development in China increasing erosion of channel deposits at the top of Zone 3. As medium sized bed material is remobilised coarse sized sediments will remain armouring the channel. Further downstream the river will re-instate a dynamic equilibrium between erosion and deposition and the new balance is likely to see reduced deposition in Zone 5 over the next 15-20 years; (**bottom**) available sediments in the river are depleted over the next 50 years the supply of medium sized sediments to Zone 5 will decrease to zero. The effects of erosion will be felt throughout Zone 3 with changes to the location of the thalweg and an increase in bank instability. During all time phases, there will not be any supply of sand-sized sediments to the Mekong Delta as the stream transport power will not be able to maintain suspension of these fractions past Zone 5.*



9.1.4 FATE & TRANSPORT OF FINE-SIZED SEDIMENT

The present trend is for significant reductions in the transport of fine material, because of the operation of reservoirs with large storage in China and on major tributaries. In the 20Y foreseeable future scenario, the sediment loads in Zone 2 will drop by ~80%, while further downstream at Kratie the load is expected to halve. The SEA estimates a sediment load of 90 Mt/yr at Chiang Saen, 84 Mt/yr at Vientiane with the addition of ~25 Mt/yr from the 3S basins and 56 Mt/yr from the remaining catchments between the Nam Hinboun and the Se Done, giving an average annual load of 165 Mt/yr at Kratie. With UMB and tributaries hydropower, these loads will be reduced to in the order of 20 Mt/yr (Chiang Saen and Vientiane), 88 Mt/yr (Kratie).

The 2030 trend without LMB mainstream dams is for the supply of fine sediments and nutrients to the floodplains and delta of the Mekong River will be halved (Table 10). This will impact on some 18,000 km2 of Cambodian floodplain and 5,000-10,000 km2 of Mekong Delta floodplain as well as reduce the nutrient load in the Mekong marine sediment plume.

Table 10: Indicative changes to the fate of sediment downstream of Kratie: *the 20Y foreseeable future is predicted to halve the sediment load arriving at Kratie primarily due to trapping by the dams in Zone 1 and in the 3 S basins.*

	AVERAGE ANNUAL DEPOSITION VOLUME	
	BDP Baseline	20Y Without LMB mainstream dams
SITE OF DEPOSITION	Sediment [Mt/yr]	Sediment [Mt/yr]
Kratie: annual sediment transport rate	***165***	***88***
Cambodian floodplain	25	13
Tonle Sap flood plain	9	5
Mekong Delta floodplain	26	14
Mekong river mouth	5	3
Ca Mau Peninsula	<1	0
Offshore coastal shelf (<20km from the coast)	100	53

9.2 IMPACTS ASSESSMENT

The LMB mainstream projects are proposed at a time when the Mekong hydrological regime is undergoing a period of intensive change driven by rapid hydropower development on the LMB tributaries and on the UMB mainstream in Yunnan Province of China. **The LMB mainstream projects will have additional wide effects on the future movement of water and sediment through the Mekong basin system.**

Both the opportunities and risks presented by the LMB mainstream projects arise from the concentration of the majority of the river's energy dissipation on short reaches of the Mekong River at the turbines and gates of the proposed mainstream projects. **The extraction of some 13,427 MW of energy from the Mekong system for electricity generation presents an unavoidable trade-off for decision makers as this energy will no longer be available to maintain the complex hydro-ecological and geomorphologic dynamics that sustain the river's ecosystems (Table 11)**.

Table 11: Percentage of wet season stream power used directly in electricity production[50]

LMB mainstream dam site	Reservoir Length (km)	Stream power used for electricity production during an average high flow season
Pak Beng	180	57%
Luang Prabang	150	75%
Xayaburi	102	79%
Pak Lay	110	74%
Sanakham	90	47%
Pakchom	85	72%
Ban Koum	155	25%
Lat Sua	10	~100%
Don Sahong	5	~100%
Stung Treng	45	40%
Sambor	90	53%

9.2.1 STREAM POWER

Stream power links key hydraulic features of the Mekong system, including: power production, energy dissipation, geomorphology, flow turbulence and sediment transport and is a measure of the energy available in the system to facilitate these processes.

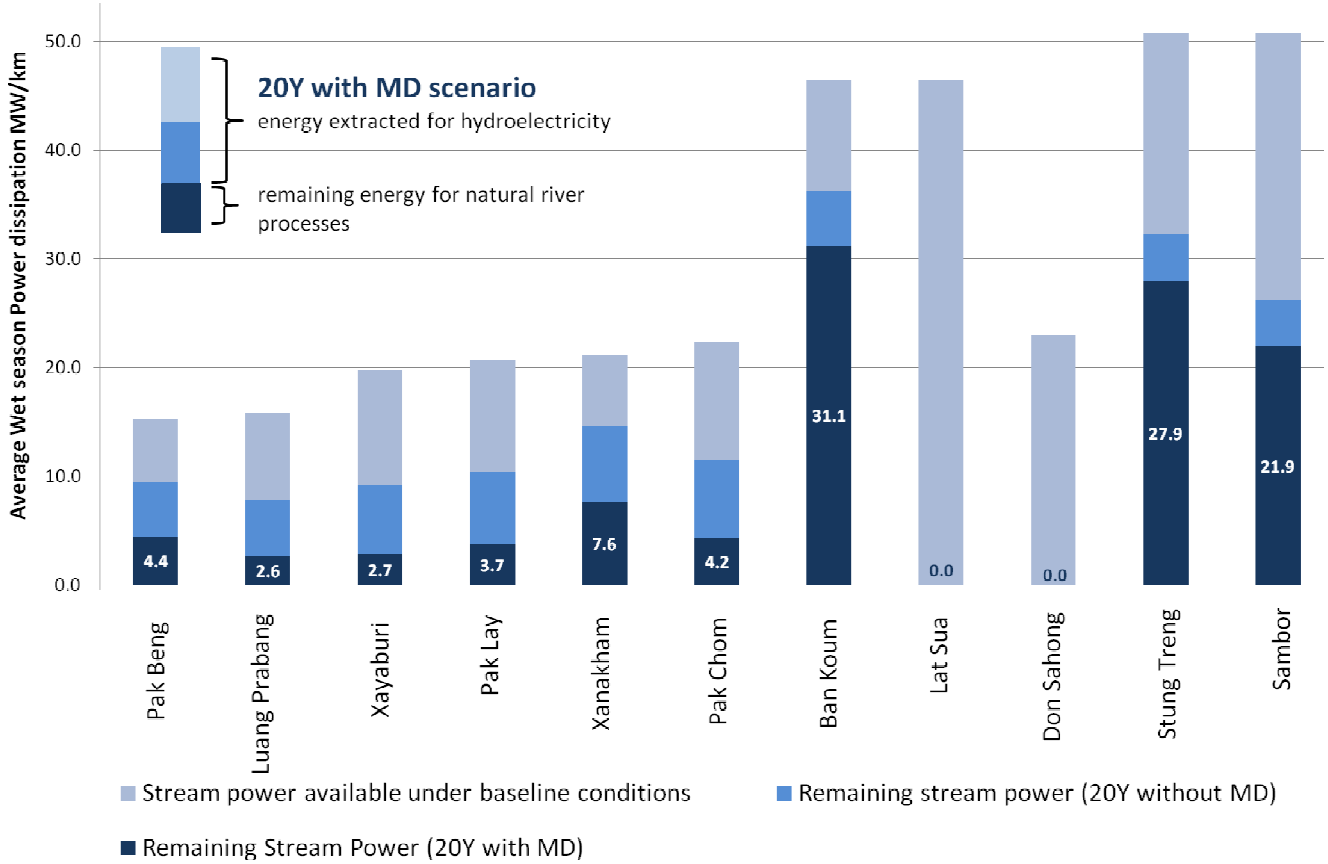
[50] Figures are based on a turbine efficiency of e = 85%. Don Sahong estimates are based on the mean annual discharge estimated for the Hou Sahong channel of the Mekong during the wet season

With the LMB mainstream projects, 55% of the total length of mainstream between Chiang Saen & Kratie will be converted to reservoir transforming the river from a live river to a series of impoundments with slow water movement interspersed by downstream stretches with rapidly changing flow in response to dam operations (Figure 23). The effect of this on stream power is to concentrate the relatively uniform dissipation of energy along the entire length of the river (5-50 MW/km) to large expressions of energy in small reaches centred on the dam wall (up to 2,000 MW) with no dissipation along the hundreds of kilometres of reservoir.[51]

This concentration of energy presents significant benefit for electricity production, however it will also irreversibly alter other important natural processes, including: (i) major changes to sediment transport of all sizes, (ii) functioning of deep pools, (iii) major changes in transport of organic and woody debris, (iv) significant and irreversible changes in fisheries migration and passage, (v) additionally, stream power changes will have links with risk factors for anthropogenic uses of the river, such as detriments to navigation and detriments to fishing opportunities.

During the dry low-flow season, close to 100% of stream power will be extracted for electricity generation. During the wet high flow season: Lat Sua, Don Sahong and the 6 dams within the upper cluster will induce the most significant reduction in available stream power (75-100%) (Figure 23). At Sanakham, Ban Koum, Stung Treng and Sambor 40-50% of stream power will remain for natural processes.

Figure 23: Changes to stream power at the mainstream dam sites: *the development of hydropower on the Mekong mainstream will concentrate energy dissipation at the dam sites as the projects generate electricity. This will result in a decrease in energy dissipated along the channel bed of the reservoirs and reaches sufficiently far downstream of the dam wall.*



[51] Under a natural hydrological regime there are some sites where energy dissipation is concentrated, for example Khone Falls, however the process is overwhelmingly more uniform than with the LMB mainstream projects

Figure 24: The LMB mainstream reservoirs: *55% of the Mekong River (Chiang Saen to Kratie) will be converted into reservoirs*

9.2.2 RETENTION TIMES & STORAGE CAPACITY

Hydropower projects generate electricity by utilising the stream power available within a river system and converting the kinetic energy of flow into electrical energy. For rivers with large flows, energy can be extracted from the flow itself, or an impoundment can be built to store potential energy and control generation through dam release leading to two distinct types of hydropower: storage and run-of-river projects. Large storage volumes compared to the Mean Annual Flow (MAF) are typical of conventional storage

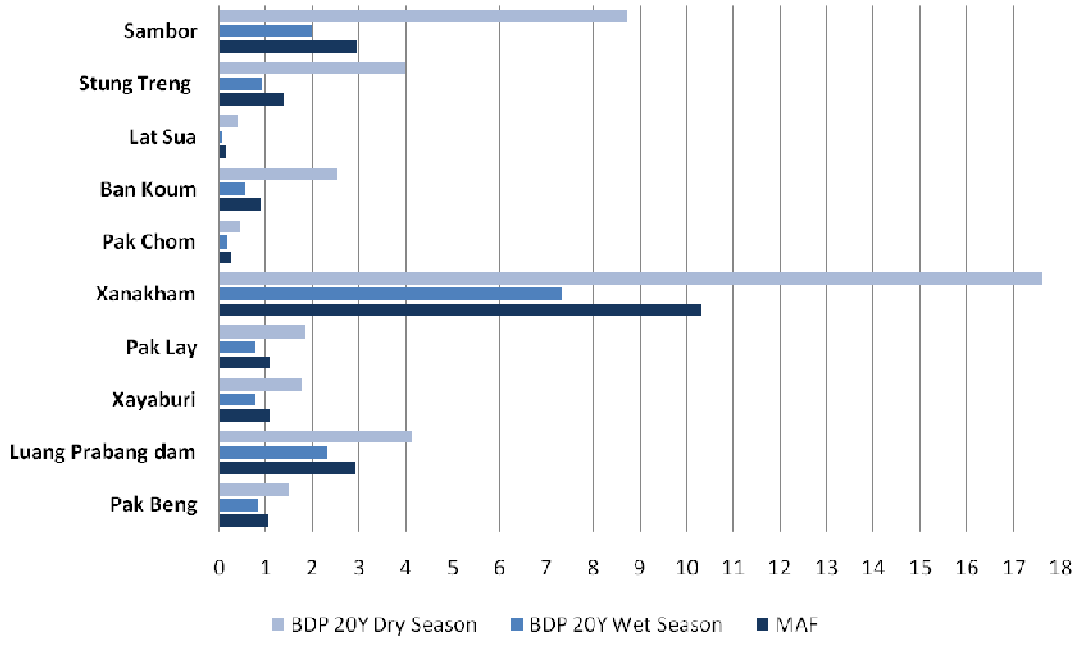
hydropower (e.g. Nam Theun 2**), LMB mainstream dams have the capacity to store less than 3% of the MAF - this percentage increases significantly during the dry season and decreases during the wet season (Table 11).**

Table 11: Storage capacity of selected Mekong Basin hydropower

Hydropower project	MAF km3/yr	Storage Volume km3	Storage/MAF
Nam Theun 2	15.4	11	71.43%
Nam Ngum	20.7	10.4	50.24%
Nuozhadu	55.19	22.4	40.59%
Xiaowan	38.47	14.56	37.85%
Sanakham	133.8	3.78	2.83%
Manwan	38.79	0.9	2.32%
Sambor	405.8	3.49	0.86%
Luang Prabang	100	0.80	0.80%
Stung Treng	432.5	1.55	0.36%
Xayaburi	124.8	0.37	0.30%
Pak Lay	130.7	0.39	0.30%
Pak Beng	96.5	0.28	0.29%
Ban Koum	294.6	0.63	0.22%
Pak Chom	141.6	0.10	0.07%
Lat Sua	294.6	0.12	0.04%
Don Sahong	325.1	0.03	0.01%
Thakho		-	-

Based on their storage capacity, some LMB mainstream dams have the capacity to retain flows for 2-3 weeks during an average dry season and 1-2 weeks during an average wet season (Figure 25). Preliminary assessment of Sanakham reveals that during a dry year (e.g. the 1993 dry season), the retention time could increase to one month**.** Depending on operational strategies the cascade of 11 dams could cumulatively induce longer delays in the arrival of flows to the Cambodian and deltaic floodplains. This would need detailed modelling before predictions could be made.

Figure 25: LMB mainstream dam retention times (days): *the proposed LMB mainstream projects are closer to run-of-river projects than conventional storage dams with a maximum average potential retention time in the order of 2-3weeks during the dry season, and 1-2weeks during the wet season.*



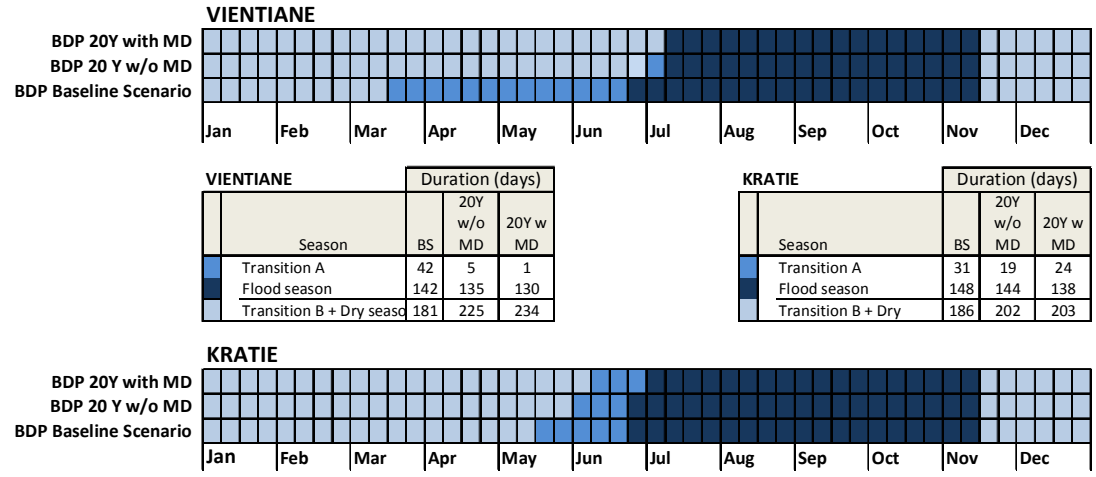
9.2.3 HYDRO-ECOLOGICAL SEASONS

The Mekong River has a strong flood pulse characterised by 4 distinct seasons and corresponding fluctuations in the water levels. LMB tributary and UMB Chinese hydropower will alter the timing and duration of these seasons.

Without LMB mainstream hydropower, the important hydro-ecological seasons of the Mekong River will already experience significant stresses, shortening the length of the biologically important transition seasons.

When combined with the LMB mainstream projects upper reaches of the LMB will no longer experience the ecologically important transition seasons (Figure 26). All reaches between Chiang Saen and Kratie will experience a reduction in the duration of transition seasons which play an important role in triggering biological processes within riverine and floodplain habitats.

Figure 26: Changes to the Mekong hydro-ecological seasons



VIENTIANE	Duration (days)		
Season	BS	20Y w/o MD	20Y w MD
Transition A	42	5	1
Flood season	142	135	130
Transition B + Dry seaso	181	225	234

KRATIE	Duration (days)		
Season	BS	20Y w/o MD	20Y w MD
Transition A	31	19	24
Flood season	148	144	138
Transition B + Dry	186	202	203

9.2.4 WATER SURFACE LEVEL CHANGES

Changes in water levels from the LMB mainstream projects will adversely affect riverbank gardening along the Mekong River and in major and minor tributaries near the mainstream, the habitability of floating homes that are downstream of the dams, fish habitat, and the viability of water intakes/pump stations adjacent to the river and tributary mouths**.**

If all LMB mainstream projects were to go ahead, they could induce changes to: (i) the flooded areas of Cambodia and the delta, (ii) extent of saline intrusion, and (iii) flooding in the Tonle Sap system depending on how the 12 projects are operated and the level of coordination between projects. Each project alone would not induce significant changes to these components of the Mekong system.

For 7 of the proposed projects, the dams will be sufficiently high that water levels in the reservoirs behind the dams will be above the highest ever recorded river elevations for significant distances upstream. This will have significant implications for riparian communities and riparian use of the river. Areas that were previously floodplains areas at tributary confluences, channel banks and in-channel islands will be drowned by the proposed reservoirs. More than 5-10% of the river valley between Chiang Saen and Sambor will be affected by receiving year-round inundation at levels never experienced in the history of data collection for the river. This will have significant impacts on:

- **Irrigation infrastructure:** almost half of all irrigation pump stations existing and planned for the Mekong mainstream (309 units) will be affected by increased water levels. **This will directly affect ~32,000ha of planned and existing agricultural land with mainstream irrigation schemes:**
    - ***Within Reservoirs:*** For ~15% of all pump stations there is the possibility of reduced pumping heads from elevated water levels, however, these pump stations will need rebuilding,

relocation and resizing to allow for operation at these new water levels and to turn the reduced pumping head into an economic advantage.

- ***Downstream of reservoirs:*** new flow regime imposed by the mainstream projects will induce migration of the river thalweg and would require pump relocation
- ***Operations:*** Potential for daily fluctuation in the order of meters which would increase the complexity of pump operations and the need for more sophisticated controls

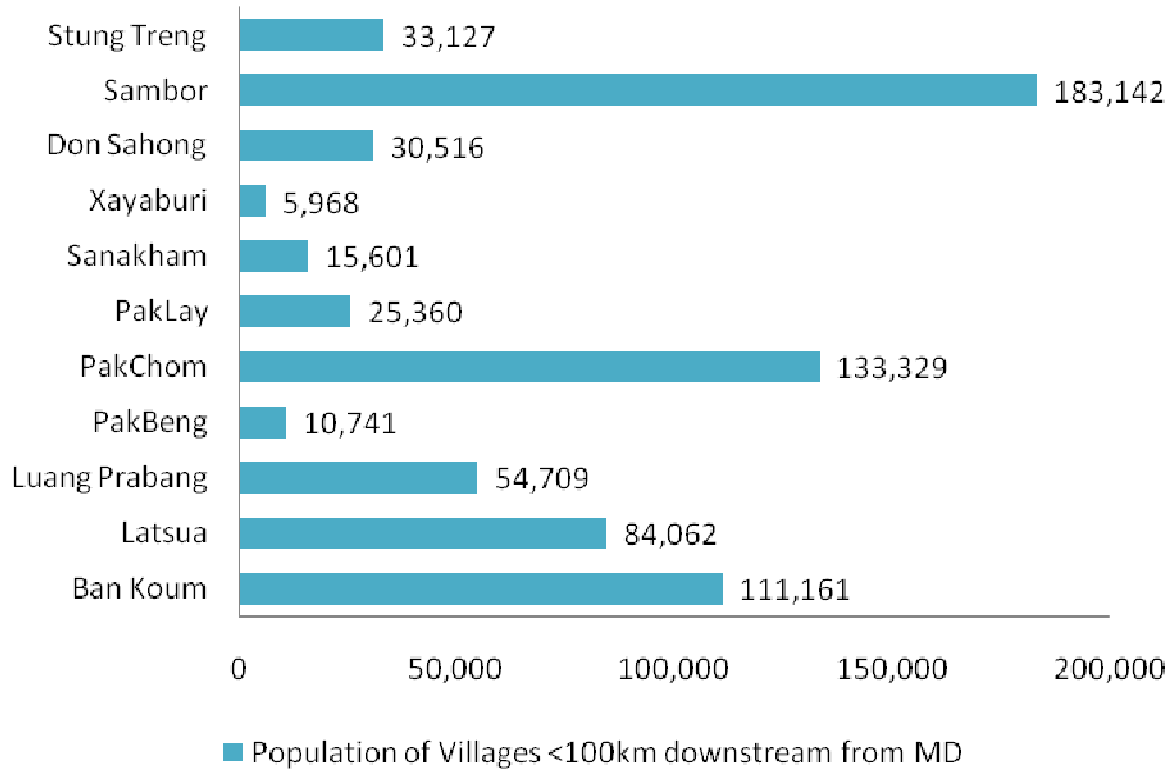
- **River bank agriculture:** Loss of bank side growing areas from permanent inundation, with partial losses of additional bank side growing areas for several hundred km of the mainstream river, associated with high water levels (see terrestrial paper).
- **Floodplains:** the majority of floodplains hydrologically connected to the mainstream in Zone 2 and 3 will be permanently lost as will seasonal in-channel features (island, silt terraces, sand bars)
- **Navigation:** medium and large sized river transport will benefit from the improved channel navigability improving conditions for river cruise operations and the competitiveness of freight/large-scale cargo transport upstream of Vientiane. Small scale and subsistence river transport will also benefit from safer navigation conditions due to the elevated water column.

9.2.5 OPERATIONAL STRATEGY – PEAKING VS CONTINUOUS

The changes in water levels could be greatly exacerbated by the operational strategy of projects. Peaking operation - maximising turbine discharge when the buying price for electricity peaks at a daily time-step - could greatly increase the rate of fluctuation of water levels from a historically seasonal phenomena to a daily or even hourly phenomena.

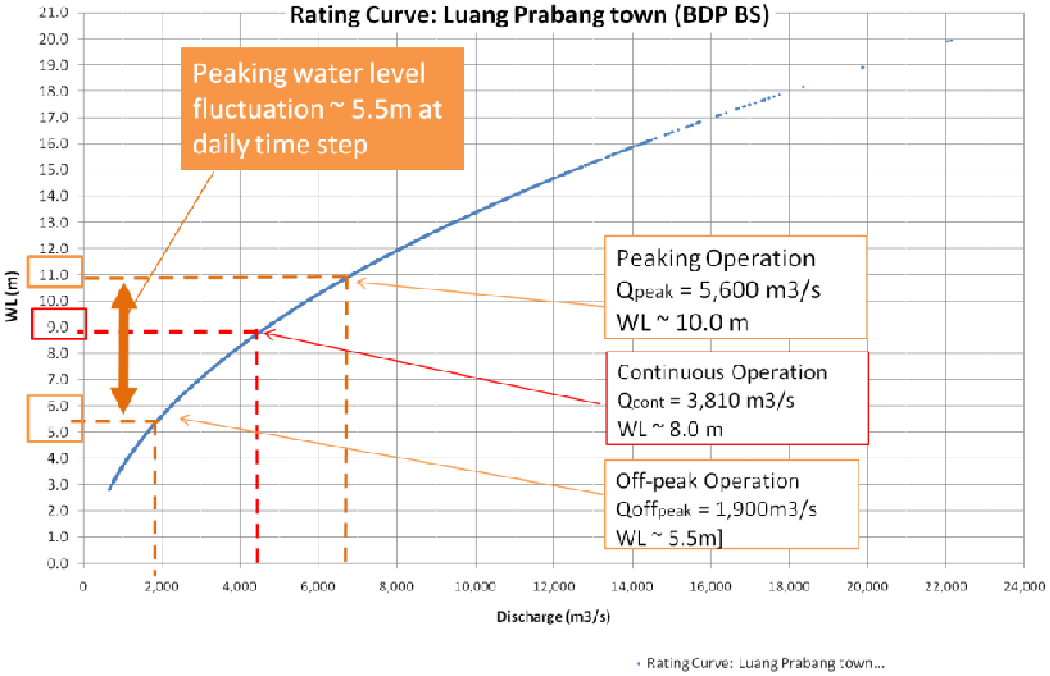
There is the potential for hourly spikes in water level of up to 3-6 m at towns and villages located 40-50 km downstream (Figure 27). Under unplanned and emergency releases these peaking events could be larger and could translate this distance downstream in 1-2 hours giving little time for notification.

Figure 27: Potential peaking affected populations downstream of LMB mainstream dams: *the projects with the greatest peaking potential have significant populations living immediately downstream who would be at risk of unprecedented daily water level fluctuations if peaking operations were utilised*



430,000 people live within 100km downstream of the LMB mainstream projects with the highest peaking potential (Sanakham, Luang Prabang, Sambor, Stung Treng, Ban Koum, Pak Lay and Xayaburi) and would be exposed to rapid fluctuations in water levels if peaking operation is used (Figure 28).

Figure 28: Implications of peaking operation: *peaking operations could allow project operators to maximise profit potential by providing electricity when it is most valuable (peak load times) because of the speed at which hydroelectric turbines can be brought online and offline. However, this would greatly exacerbate the downstream change in water levels, with*



Re-regulating reservoirs for the LMB mainstream projects are unlikely to be feasible due to the size of reservoir required to dampen rapid fluctuations in water levels. Preliminary analysis undertaken by the team suggest that re-regulating reservoirs would need to be at least in the order of 50 km (in the order of 50% of the length of the proposed mainstream reservoirs) if they are to even out small time-scale fluctuations in water levels. This is not a feasible option for the Mekong given the proximity of the projects to populated areas and the number of re-regulating reservoirs which would be required.

9.2.6 COARSE SIZED SEDIMENT

Currently, there are no anthropogenic obstacles to bed load transport in the LMB mainstream, such that coarse sized sediment (coarse sand, gravel, cobbles) is conveyed downstream via saltation by a distance of a few tens of meters (through deep pools) to a few kilometres. The Yunnan cascade of existing and proposed hydropower projects will reduce the bed load arriving in the LMB. This will result in a coarsening of the bed load as the river attempts to compensate by depleting storage of medium sized particles from the bed and banks.

The addition of the LMB mainstream projects will:

- **Significantly reduce stream power and water velocity resulting in enhanced sedimentation and the formation of large deltaic-type deposits at the head of each of the reservoirs**. This will see sediment accumulate in sections of the river where it has never accumulated in the past;
- **Increase the rate of sedimentation in areas of the reservoir** not influenced by scour flow from the spillway and sediment gates – dependent on the sequencing of construction;[52]
- **Change the mechanics of sediment transport,** by reducing the velocity of mean annual flood flow through the reservoir so that medium sized particles which moved in suspension will now move only

[52] Upstream scour/sediment removal associated with opening gates can only induce localised scour affects and will likely affect sedimentation near the dam wall not along the 100km of reservoir.

partially in suspension and coarse sized particles which had moved partially in suspension and partially as bed load will now move as bed load or not at all causing greater retention rates in the impoundment of both medium and coarse sediment;

- **Increase down-cutting and channel bed and bank erosion in alluvial reaches of the Mekong** (Zone 3); projects proposed for Zone 2 will further reduce the supply of bed load to the alluvial reach between Vientiane to Pakse, which will induce re-mobilisation of the channel and bed sediments within the reach, increasing loss of riparian vegetation & agricultural areas (islands and riverbanks) as well as altering the course of the river thalweg.
- **Accelerate the escalation of erosion problems and channel instability felt at Vientiane and Phnom Penh**. There are substantial reserves of coarse and medium sediments stored in-channel in Zone 3 (~14,000 mcm) which would delay the arrival of erosion problems expected from the Chinese dams at Phnom Penh by 1-2decades, the lower and middle cluster of dams would reduce this buffer period to the order of a few water years. Similarly in the order of 300-2,000 mcm of coarse and medium sands are stored in-channel in Zone 2, mainstream projects in the upper cluster would prevent the remobilisation of these sediments and hence eliminate any buffering of the effects at Vientiane of reduced sediment loads arriving from China.

The implications of coarse and medium sized sediment transport will differ between upstream and downstream reaches of proposed LMB mainstream dams:

- ***Upstream of dams:*** In general, coarse sized sediment is the first fraction size to deposit, therefore **the most upstream dam in a cascade or the first dam built will induce proportionately larger accumulation of coarse sized materials than dams downstream in the cascade**. If all the dams were built, this would put Pak Beng, Ban Koum, Don Sahong and Stung Treng as having the most impact of coarse sediment transport, though it depends heavily on the sequencing.
- ***Downstream of the dams***, **coarse-sized sediment is likely to be the last sediment size to be transported and the erosion of smaller sizes will result in the armouring of the downstream river reach.**

9.2.7 FINE SIZED SEDIMENT

The load of suspended sediment is estimated at 160-165million tonnes/y. Up to 50% of this will be removed by storage projects in China and the 3S region**.**

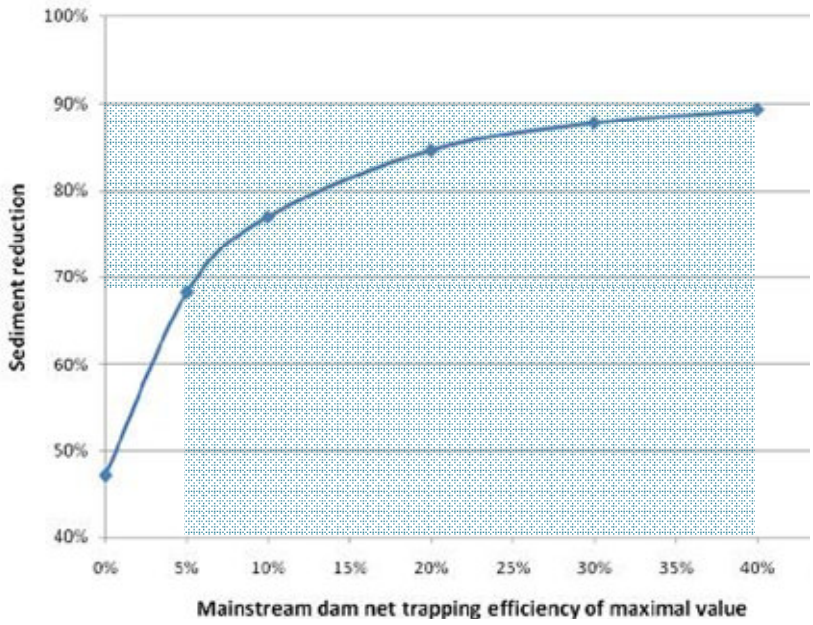
With the LMB mainstream dams the sediment load would be halved again, such that the load at Kratie would be ~25% of the current load (~42million tonnes/year) (Figure 29, 31). This is considered a conservative estimate in light of the uncertainty surrounding: (i) understanding of fines sediment transport, and (ii) understanding of LMB mainstream dams trapping efficiencies and in-reservoir sediment dynamics.

Trapping efficiencies of mainstream projects are highly dependent on particle sizes transported by the river, and are estimated to be in the range 0.1% to 50%.

The greatest reduction in sediment load occurs within the first 10-20 TE percentage points, after which further reductions begin to plateau such that there are only minor reductions in sediment load when trapping efficiencies surpass 40%. Consequently, **even modest trapping efficiencies from the LMB mainstream projects will contribute significantly to the reduced sediment load expected by 2030.**

Fine sized sediments play a fundamental role in the Mekong floodplains and delta, in the Cambodian floodplain the gradient flattens and the load is primarily clay silt and fine sand, with maximum transport of suspended load from Stung Treng to Kampong Cham. Net deposition of fine-sized sediments is concentrated in the Cambodian and deltaic floodplains as well as the river mouth.

Figure 29: Cumulative sediment trapping efficiencies of Mekong Basin hydropower. *Up to 50% of the Mekong sediment load will be removed by tributary and UMB hydropower. Even small LMB mainstream trapping efficiencies of 5-10% will induce a total reduction in Mekong sediments of 70-78%. Higher LMB mainstream trapping efficiencies of 20 – 40% would result in a total reduction in Mekong sediments in the order of 85-90%.*



The addition of the LMB mainstream projects will:

- **Reduce velocities in the reservoir and induce some deposition of fines in backwater areas of the reservoirs**. This trapping of fines will primarily be an impact during the first decade of operation of the proposed mainstream dams, as it is likely that siltation will reach a long-term equilibrium fairly quickly (one to two decades) because the reservoirs are relatively small.
- **Decrease the concentration of suspended sediments in the channel downstream of reservoirs**;

This reduced suspended load will have significant implications for the transport of nutrients and stability of the Mekong Delta (Table 13).

Table 13: Approximate annual average estimates of Mekong sediment and nutrients deposition: *Under baseline conditions ~20% of the sediment load at Kratie deposits on the Cambodian floodplain (including Tonle Sap); 16% in the Mekong Delta floodplain, 3% at the river mouth and ~60% is transported into the marine environment where it deposits predominantly within 20km from the coastline. The reduction in sediment load at Kratie will see a proportionate reduction in the volume of deposition at each site downstream*

	ANNUAL DEPOSITION VOLUME					
	BDP Baseline		Without LMB mainstream dams		With LMB mainstream (assume net maximal trapping efficiency of LMB cascade of 10%) TE(total) = 75%	
SITE OF DEPOSITION	Sediment [Mt/yr]	Nutrient (Total P) [t/yr]	Sediment [Mt/yr]	Nutrient (Total P) [t/yr]	Sediment [Mt/yr]	Nutrient (Total P) [t/yr]
Kratie: annual sediment transport rate	***165***	***26,376***	***88***	***14,061***	***41***	***6,594***
Cambodian floodplain	25	*3,958*	13	*2,111*	6	*989*
Tonle Sap flood plain	9	*1,439*	5	*768*	2	*360*
Mekong Delta floodplain	26	*4,157*	14	*2,210*	7	*1,039*
Mekong river mouth	5	*800*	3	*427*	1	*200*
Ca Mau Peninsula	<1	*32*	<<1	*14*	~0	*8*
Offshore coastal shelf (<20km from the coast)	100	*15,990*	53	*8,533*	25	*3,998*

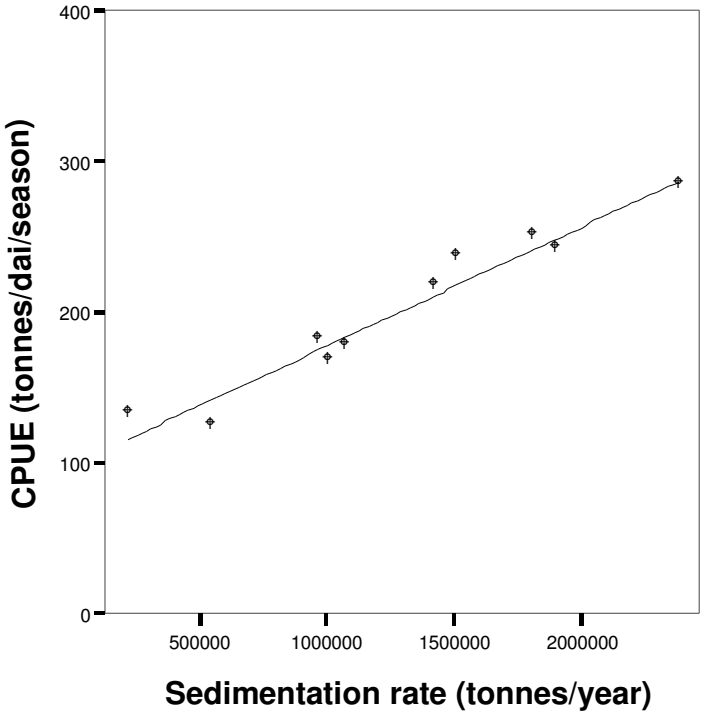
9.2.8 NUTRIENTS

Currently, some 26,400 tonnes/yr of nutrients are supplied to the Mekong floodplains and delta by the fine-sized suspended sediment load.

In the 2030 with LMB mainstream scenario, this load will be reduced by 75% (25% due to mainstream dams) or to ~6,600 tonnes/yr. The reduced sediment load will have critical impacts on the natural and human systems which rely on these nutrients, including primary production, flooded forests, floodplain fisheries and agriculture, specifically:

- ***Cambodian floodplain:*** ~18,000 km2 of the Cambodian Floodplain is naturally fertilised by nutrients attached to suspended sediments, the mainstream dams will **reduce loading from 4,000 tonnes/yr to less than 1,000 tonnes/yr**;
- ***Mekong Delta floodplain:*** A conservative estimate suggests that at least 5,000 km2 of the Mekong delta freshwater area relies on overbank siltation for enriching agricultural land adjacent to the delta channels and primary canal network, the mainstream dams will **reduce loading from 4,000 tonnes/yr to 1,000 tonnes/yr;**
- ***Tonle Sap productivity:*** there is a correlation between sediment load and aquatic productivity in the Cambodian floodplain and the Tonle Sap system (Figure 30). At the moment sediment input to and output from the lake is balanced and the lake is biologically very productive. If mainstream dams halve nutrient input on top of the reductions expected by tributary and Chinese hydropower (from ~5,500 tonnes to 2,250 tonnes to 1,200 tonnes per year) an impact on primary production is to be expected. This will in turn have an impact on Tonle Sap fish resources (60% of Cambodia's yield), in addition to the loss of at least 309,000 ha of floodplains forecasted by 2030 if all dams are constructed;
- ***Marine fishery:*** The productivity of the Mekong delta coastal fishery is due to the shallow coastal shelf, preponderance of estuarine environments and the deposition of approximately 60% of the Mekong sediment load observed at Kratie. **Coastal fishery zones will experience reduced primary production with implications for the whole marine fisheries and industries that rely on these fisheries;**

Figure 30: Correlation between fish biomass and rate of sedimentation for the Tonle Sap system: *using linear regression there is a 95% correlation between fish biomass and sedimentation indicating a strong correlation between productivity of the Tonle Sap and its sediment load.*

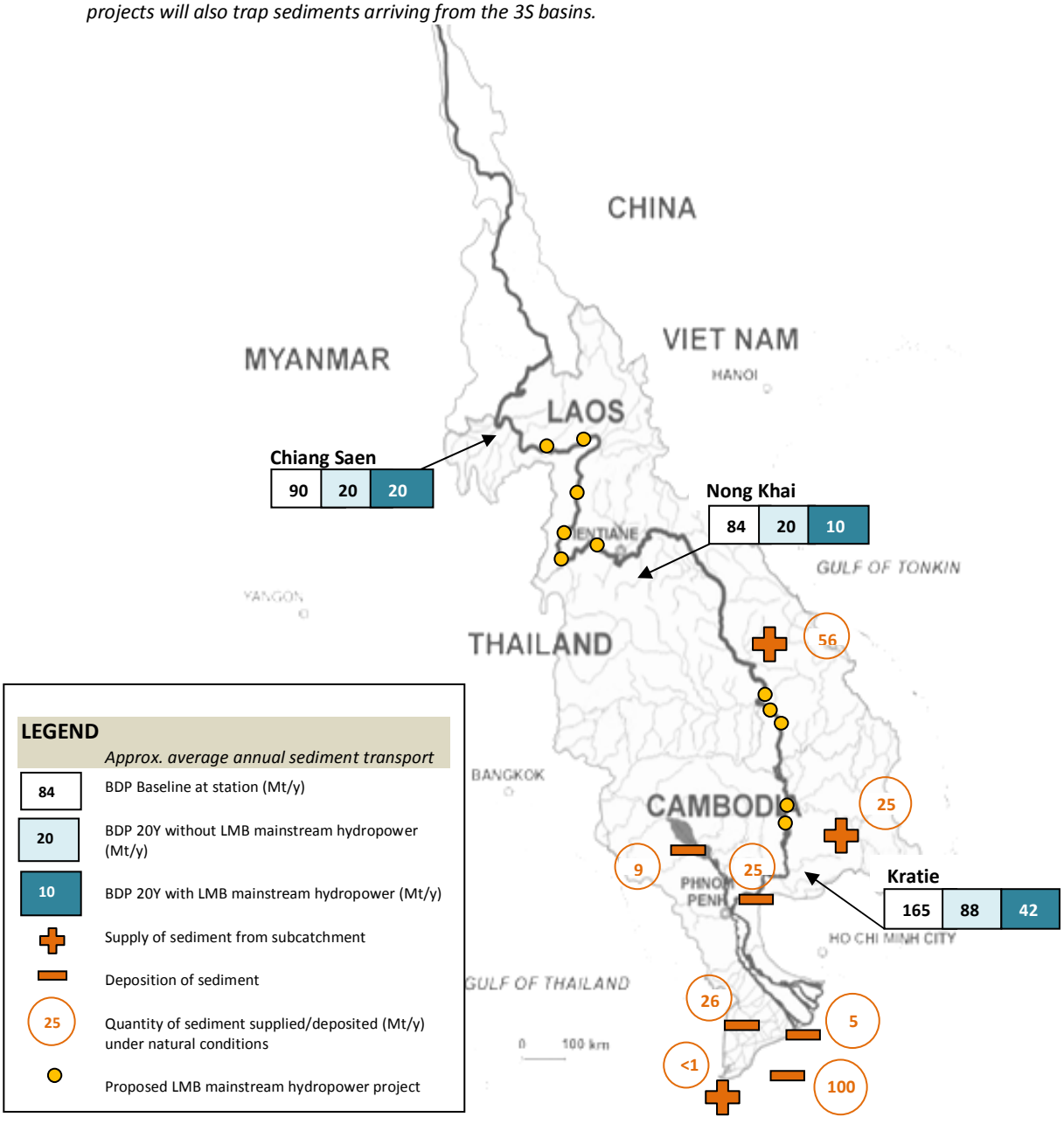


9.2.9 DELTA STABILITY

The reduced suspended load will reduce the Mekong marine sediment plume affecting:

- **Greater instability and erosion of channels in the delta** including in-channel islands, which are heavily populated and amongst the most fertile zones of the delta,
- **Knock-on effects for irrigation works and inland water-way transport** and the requirement of more frequent maintenance schedules
- **Increased coastal erosion and reduced delta-building along the eastern shoreline of the delta** with knock on effects on aquatic habitats and coastal shrimp farming

Figure 31: Approximate average annual suspended sediment transport balance: *Under baseline conditions an average of 165Mt/yr arrives at Kratie and is then deposited downstream throughout the Mekong floodplains, the channel and on the Mekong marine shelf. 90 Mt/yr originates from upstream of Chiang Saen and ~25 Mt/yr from the 3S regions (totals in white squares).By 2030 without the LMB mainstream the load at Chiang Saen and Kratie will drop to 20 Mt/yr and 88 Mt/yr respectively (light blue squares). This represents a halving of the sediment load without LMB mainstream projects. With the LMB mainstream projects this will halve again to ~42Mt/yr. The Zone 2 projects will trap ~50% of the load arriving from China, the Zone 3 projects will trap important contributions from the left-bank tributaries in Lao PDR, while Zone 4 projects will also trap sediments arriving from the 3S basins.*



10 TERRESTRIAL SYSTEMS

10.1 BASELINE

10.1.1 LAND USE

There is a wide variety of terrestrial land use along the Mekong River with surrounding areas becoming increasingly degraded and cleared for cultivation. The terrestrial ecosystems surrounding the Mekong start from extensive forest cover in Zones 1 and 2 (80-90%), which decreases markedly as the river passes through zones 3, 4, 5 and 6; agricultural land becomes progressively higher percentage of land use, especially in NE Thailand, southern Lao PDR, and below Kratie in Zone 5 and in the Delta (41-67% in these areas) (Figure 31).

Government policies tend to be towards intensification of agriculture, with increased irrigation in Lao PDR and Cambodia. In Zone 2 livelihoods are almost entirely dependent on agriculture. In NE Thailand water for further irrigation is a limiting factor, and availability of suitable land is a limiting factor in the Viet Nam Delta. Wetlands become an increasing proportion of riparian habitat downstream reaching 10% in Zone 6 (Figure 31).

10.1.2 TERRESTRIAL BIODIVERSITY

Almost 50% of the Mekong riparian corridor is considered as Key Biodiversity Areas (KBAs) of global significance but poor management and lack of protected area zoning will see the continued degradation of the corridor over next 20 years (Table 14)**. M**ore than 1,005 km of 2040 km of the Lower Mekong (Chiang Saen to the sea) are identified as Key Biodiversity Areas, but only about 100 km of the river actually lies within a nationally protected area.

Table 14: Lengths of the Mekong mainstream considered as Key Biodiversity Area and protected

Zone	Length of river channel	Length of river considered as KBA	Length protected
	km	km	**km**
1	220	100+	**0**
2	795	495+	**0**
3	715	100	**100**
4	310	310	**0**
5a	335	0	**0**
5b		Whole of Tonle Sap	**14,812 km^2**
6	225	Various wetlands in floodplain	**27,425 ha**
Total	**2600**	**1005+**	**100+**

Without the LMB mainstream dams, the main threats to terrestrial biodiversity, include expansion of agriculture, land concessions (Cambodia) and loss of floodplain habitat as a hydrological consequence of regulation by UMB and tributary hydropower. 500-600 km2 of flooded forest in the Tonle Sap system will be lost due to the regulating effects of hydropower on the seasonal flow extrema.

10.1.3 AGRICULTURE

By 2030, agricultural land under irrigation will increase by 3.1million ha to a total of 9.7million ha, a significant proportion of this lies within the Mekong riparian corridor (Table 15). This increase is primarily due to government policies in Lao PDR and Cambodia for the intensification of agriculture and irrigation.

There are some critical limiting factors hindering the expansion of agriculture:

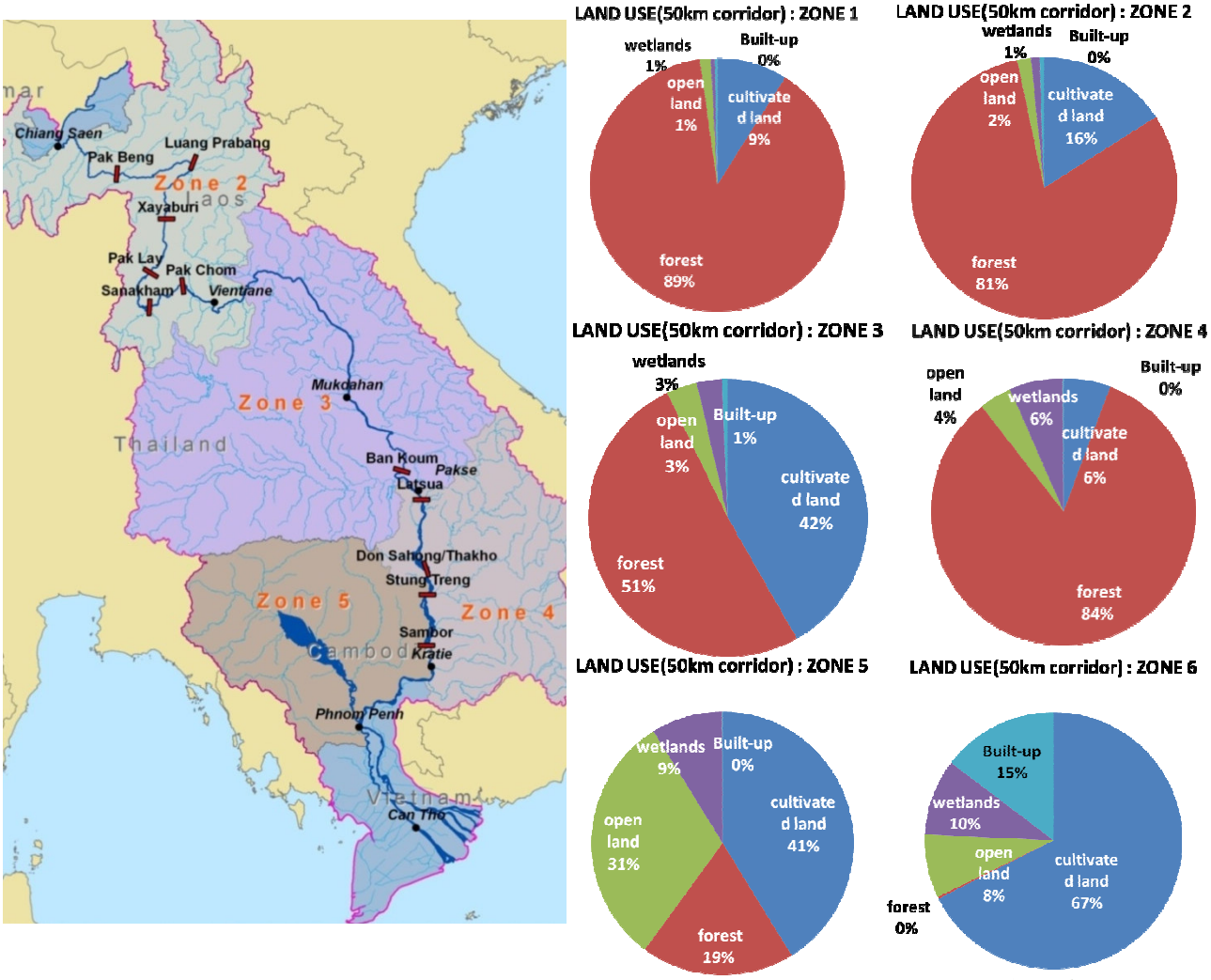
- **Thailand: the year-round availability of water is the single-most important factor limiting increased agricultural productivity in NE Thailand**. Since the 1960s Thailand has explored the feasibility of mega-irrigation projects taking Mekong waters into agricultural lands of NE Thailand, however, the flat topography means that there are few new sites for large reservoir storage in the Chi-Mun catchment which limits the potential for 'mega-irrigation'.

- **Viet Nam: the limiting factor in Viet Nam is land**; with more than 65% of the land area already converted to agricultural use, there is little opportunity for expansion. Most of the freshwater floodplain has already been converted to multiple cropping and saline intrusion limits the further expansion of this technique.
- **Cambodia & Lao PDR: the dominant limiting factor is the lack of adequate infrastructure and resources** to shift production from rain-fed farming to irrigated methods.
- **River bank gardens are an important contributor to the livelihoods of riparian communities**, and although these have not been systematically studied, their contribution in each zone is estimated to be 10 – 60 million US per year.

Table 15: Estimates of size and value of paddy field within 50km of the Mekong River

Zone		1	2	3	4	5	6
	Unit	China to Chiang Saen	Chiang Saen to Vientiane	Vientiane to Pakse	Pakse to Kratie	Kratie to Phnom Penh and Tonle Sap	Phnom Penh to the Sea
Paddy field area in 50 km corridor of river	sq.km	500.22	3,655.09	22,916.31	1,625.64	13,910.25	19,810.05
Yield	t/ha/yr	1.00	2.00	3.50	2.60	2.60	5.00
Annual production	t/yr	50,022	731,019	8,020,710	422,666	3,616,666	9,905,024
Value @ 0.2 USD/kg	**USD million**	**10.00**	**146.20**	**1,604.14**	**84.53**	**723.33**	**1,981.00**

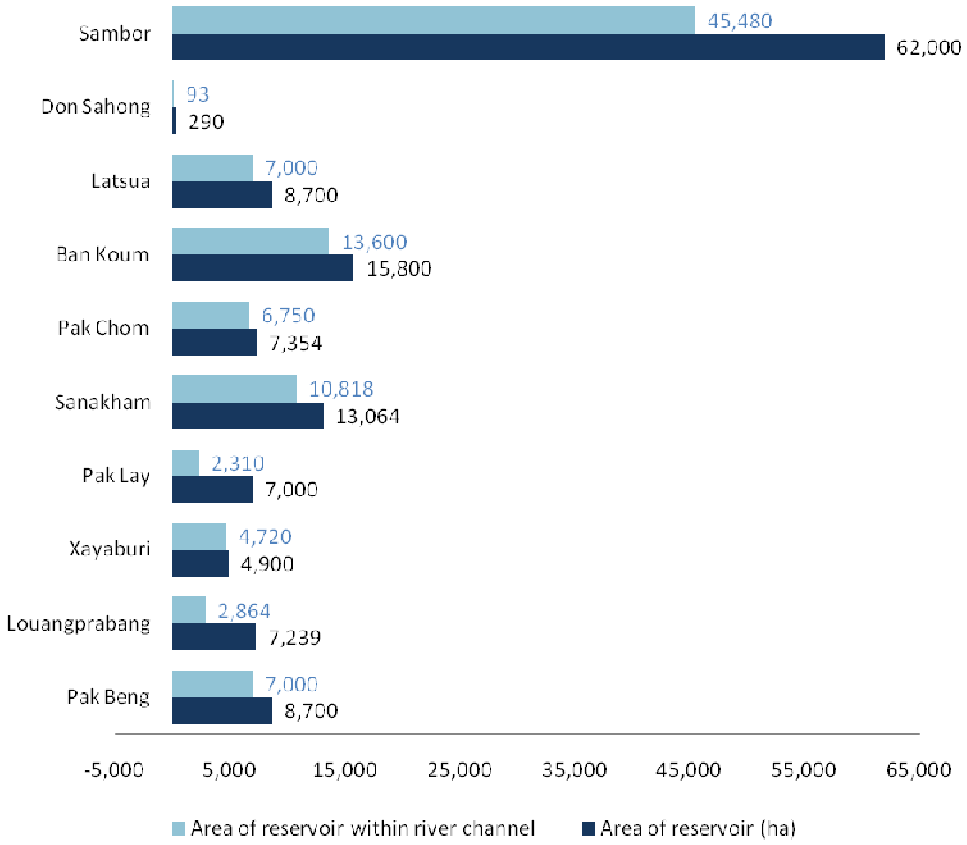
Figure 32: current riparian land use of the Mekong River: *there is a decrease in forest cover and an increase in cultivated land between Yunnan Province and the sea, which is closely correlated to terrain and population density. Wetlands also become an important terrestrial habitat as the River flattens into the floodplains of southern Lao PDR (Siphandone), Cambodia and the Mekong delta*



10.2 IMPACTS ASSESSMENT

10 of the LMB mainstream projects would have a significant local impact on the terrestrial biodiversity and agricultural productivity in the ~135,000ha inundated by the 10 projects and land taken for transmission lines and access roads.[53] These impacts manifest primarily through the permanent inundation of terrestrial features and changes in water availability.

Figure 33: LMB mainstream reservoir areas inside and outside the Mekong channel



Approximately 75% of reservoir area (100,000 ha) is contained within the Mekong river channel. Don Sahong, Pak Lay and Luang Prabang have less than 40% of the reservoir contained within the channel, while Xayaburi, Ban Koum and Pak Chom have more than 85% contained within the channel (Figure 32).

25,000ha of forest land would be inundated, together with the 8,000 ha of cultivated land. Much of the forests adjacent to the Mekong are already rather degraded, although some mature river bank vegetation would be lost. Flooded forests and shrublands in the river channel, especially in the reservoirs of Pak Chom, Ban Koum and the two Cambodian dams would be lost. The two Cambodian dams differ in that they would flood larger areas, including forest and cultivated land - Sambor alone would flood more than 16,000ha of terrestrial lands (almost 50% of the total).

The reservoirs would change the landscape of the Mekong river valley, permanently maintaining the water levels above the current high flow levels with little seasonal change. In some reaches of the river (5-10%) immediately up stream of the dam walls water levels would be above any in recorded history and above the levels associated with the 1 in 1,000 year flood event. **1,370 km2 of riverine terrestrial lands would be permanently inundated by the elevated water levels of the 11 LMB mainstream reservoirs**.

[53] This does not include Stung Treng for which no information was available; nor does it include Thakho which does not inundate land as it is a diversion project.

The largest impact on the riverine terrestrial system would affect wetlands. Almost 40% of the Mekong River's wetlands lie within reaches of the river where projects are located - 17% of which would be permanently inundated by the LMB mainstream projects (Table 16).

Table 16: Comparison of landuse in 50 km corridor along each bank of Lower Mekong with areas inundated by mainstream dams

Land use type		% of total existing land use type within Z2-Z4[54]	% Z2-Z4 land use type inundated by LMB MD
Total cultivated land	Area (km2)	*35,793*	*63.5*
	%	***47.4%***	***0.2%***
Total forest cover	Area (km2)	*100,486*	*543.50*
	%	***86.1%***	***0.5%***
Total open land	Area (km2)	*4,288*	*28.40*
	%	***21.3%***	***0.7%***
Total wetlands	Area (km2)	*4,355*	*734.50*
	%	***38.9%***	***16.9%***
Built-up area	Area (km2)	714	1.76
	%	***13.2%***	***0.2%***
TOTAL	Area (km2)	145,636	1,369.90
	%	***63.6%***	***0.9%***

Some 150,000 ha of riverbank gardens, agricultural lands and irrigation schemes would be directly affected by the 996 km of reservoir created by the 11 projects between Chiang Saen and Kratie. 20% of affected agricultural lands would be permanently lost through inundation or clearing, while the use and productivity of the remaining 80% under irrigation schemes would experience increased complication in management and system performance:

Loss of river bank gardens (RBGs) in the reservoir areas, and for some distance below dams would affect ~450,000 households, with some significant impacts on livelihoods of riparian communities including the loss of an important rural food source (Table 17).

Table 17: Losses in River Bank Gardens (RBGs) due to LMB mainstream dams

ZONE	River dependent rural pop (2005)	River dependent HH <15km river	river dependent HH affected LMB MDs	no. HH with RBGs affected by LMB MD	Total area of RBG lost due to reservoirs (ha)
2	313,939	62,788	54,811	7,564	1,891
3	1,343,182	268,636	59,906	7,488	1,872
4	232,397	46,479	20,141	2,216	554
5	3,581,952	716,390	no change	49,431	12,358
6	6,482,368	1,296,474	no change	381,163	95,291
Totals	**11,953,838**	**2,390,767**	**134,858**	**447,862**	**111,966**

A minimum 9,000 ha of agricultural and irrigated land would be inundated due to 10 of the mainstream projects.[55] Sambor and Lat Sua would have the largest known impacts flooding more than 50% of this total (~5,000 ha) primarily due to the flatter terrain of the Mekong in these zones. There are important agricultural areas in northern Lao PDR; with Pak Beng inundating some 1,657 ha of agricultural land with significant areas also affected by the Pak Lay (830 ha) and Sanakham (762 ha). The steep terrain and remoteness of northern

[54] The area totals for each land use type refer to the 50km corridor around the Mekong mainstream and used in this analysis.
[55] This does not consider any loss of irrigated land associated with Stung Treng for which there is currently no available information.

Lao would provide a great barrier in locating near-by replacement farms than in southern Lao PDR and Cambodia.

- **A further 32,000 ha would have pumping and irrigation off-take infrastructure compromised.** Some 304 downstream pump stations would need to be relocated, resized and equipped with improved controls. In addition, with shot-timescale fluctuations in dam discharges, the gravity fed colmatages of the Cambodian floodplain are at risk of reduced efficiencies increasing the pumping demand of this important agricultural region.

- **Some 10,000-15,000 ha of land would be cleared for transmission and access roads for 7 of the LMB mainstream projects**.[56] 75% of which would be forest land and 25% cultivated land.

Table 18: Values of lost RBGs (River Bank Gardens)

ZONE	Present yield of vegetables produced (kg)	yield of vegetables lost (tonnes)	total value lost per year (USD million)
2	12,997	11,346	9.08
3	50,369	11,232	8.99
4	7,669	3,323	2.66
5	74,146	0	0.00
6	571,745	0	0.00
Totals	**716,926**	**25,901**	**20.72**

The net balance of agricultural opportunities and losses (including river bank gardens) would likely be negative. Increasing in agricultural activity planned in the irrigation schemes of the mainstream dams' amount to USD15 million/yr, while losses associated with agricultural land (USD5.4 million/yr) and river bank gardens (USD 20.7million/yr) would more than offset any potential gains (Table 18).

The LMB mainstream projects would worsen the distribution of agricultural benefits amongst riverine communities with agricultural losses incurred along its entire length affecting in the order of 20% of the 11.9million river dependent Mekong population, while the benefits would be localised at irrigation schemes near individual dam sites.

The LMB mainstream projects would preference larger and medium sized irrigation projects which have proven to be less reliable and less flexible in sustaining livelihoods in the Mekong region:

- The global and LMB experience with larger irrigation schemes is that they underperform. In Cambodia a review of 900,000 ha irrigated by some 2,500 schemes found that 62% did not work, 32% partially worked and only 6% of all schemes worked well.
- Larger schemes favour rice paddy farming and are less flexible to farmers needs and crop diversification. Changes to cropping and farming patterns typically require expensive re-engineering of the irrigation infrastructure

The projects would have an impact on terrestrial and aquatic biodiversity which is of international significance – about half the length of the Lower Mekong has been recognized as Key Biodiversity Areas.

- **80% of the Key Biodiversity Areas (KBA) along the Mekong River would be affected by the dam**s with loss of landscape value, habitat diversity and breeding and feeding areas for characteristic species, especially birds (79% of KBAs in Zone 2, & 100% of KBAs in Zone 3 & 4).
- **The globally important Siphandone wetlands would be directly affected with reduced seasonal variability and loss of wetland habitats**
- **An internationally Ramsar site above Stung Treng would be directly affected.** Notification to the Ramsar Convention Secretariat that the Stung Treng site should be placed on the Montreux Record of threatened wetlands with de-designation being likely if the Stung Treng dam is built.
- **The mainstream dams would have only a minor contribution on the reduction of flooded forest and wetland areas of the Tonle Sap** as predicted in the 20Y with mainstream dam scenario. 93-98% of the

[56] No information was available for Pak Beng, Pak Lay, Sanakham, Lat Sua, Stung Treng

change would be directly related to regulation of the Mekong hydrology by tributary and Chinese hydropower, with 2-7% attributed to mainstream dams.

- **Poor or uncoordinated management of the mainstream cascades could result in retention times in the order of several weeks**, which would impact on the timing and rate of transition between terrestrial and aquatic phases of the downstream flooded forests and wetlands.

11 AQUATIC SYSTEMS

11.1 BASELINE

Without the LMB mainstream dams the trends by zone are summarised as:

- **Zone 1:** River morphology and aquatic ecology in Zone 1 will change significantly over next 20 years due to the presence of the Yunnan cascade.
- **Zone 2:** Continued gradual degradation of the river in Zone 2, with loss of fish diversity and production and reduction in river weed
- **Zone 3:** General further degradation of the habitat and biodiversity
- **Zone 4:** Indicators of environmental degradation are present in Zone 4 and are likely to increase – loss of habitat, loss of biodiversity, decline in fish production, bioaccumulation of toxic compounds in the food chain, recent increases in filamentous algae
- **Zone 5:** Increased pressure on the aquatic ecosystem in Zone 5, especially in the Tonle Sap from hydrological changes, extent of flooding, increased pollution, and harvests of aquatic resources exceeding the productivity base
- **Zone 6:** Increasing population pressure in Zone 6 will add to the pollution load and tend towards declining water quality, changing hydrology and sediment flows will alter delta dynamics, especially under the increasing influence of climate change.

11.1.1 BIODIVERSITY & AQUATIC HABITATS OF THE MEKONG RIVER

The Mekong River is one of the most biodiverse river systems in the world, second only to the Amazon, with 781 species scientifically described from the whole system. The aquatic ecosystems of the Mekong are relatively natural at the moment, with high diversity of aquatic habitats – rapids, deep pools, sandbars etc. that all contribute to the very high biodiversity in the river. There have been some changes in recent years, e.g. the development of two upstream dams in China, and on some of the tributaries in the LMB, that have begun to alter the hydrology and patterns of sediment discharge, so that the river morphology is beginning to change. As these developments increase in size and number, so this process of change will continue in the absence of the mainstream dams.

Pressures from human activities are increasingly putting river dependent fauna at risk, with a minimum of 28 species listed as endangered or vulnerable. This includes many of the charismatic Mekong species.

The biodiversity of the Mekong as measured by fish species biodiversity will tend to decrease over the next 20 years, mainly under pressure from over exploitation, from the decreased diversity of aquatic habitats and in some locations due to declining water quality (Table 19). The passage of migratory fish species up and down the Mekong mainstream will be maintained.

Table 29: Number of fish species in each zone of Mekong mainstream

Zone	Z1 China	Z2 Chiang Saen - Vientiane	Z3 Vientiane - Pakse	Z4 Pakse - Kratie	Z5 Kratie - Phnom Penh and Tonle Sap	Z6 Phnom Penh - Delta
Number of families	13	12	NA	36	40	56
Number of species	151	140	NA	252	284	486
Endemic species	19	26	NA	40	31	28
Introduced species	7	4	NA	5	4	3
Native species	125	110	NA	207	249	455
Percentage of endemics	12.6	18.6	NA	15.9	10.9	5.8
Percentage of all Mekong species (781)	19.3	17.9	NA	32.3	36.4	62.2

11.1.2 PRODUCTIVITY OF MEKONG AQUATIC HABITATS

Changing hydrology and sediment flows resulting from the dams in China and the tributaries will alter the river morphology and the productivity of different parts of the river channel in the mainstream. Raised dry season water levels and decreasing sediment coming down the river will tend to reduce the diversity and productivity of the Mekong mainstream

The contribution to total NPP (Net Primary Productivity) from in-channel features due to the exposure in dry season ranges from 15% – 64% in the different zones (Table 20). This represents a total LMB in-channel NPP of 980,330 – 1,584,496TonsC/yr.:

- Zone 4 has the highest in-channel productivity (up to 545,000tonC/yr) with Z2, Z3 and Z5 varying each producing up to 380,000tonsC/yr.
- Zone 2 has the highest proportion of productivity confined to the Mekong channel

Table 20: Estimates of in-channel seasonal NPP in the LMB

Zone	Total NPP of exposed areas (TonsC/yr)		% contribution of in-channel NPP to total NPP for the Mekong riparian corridor	
	min	max	min	max
Z1	N/A	N/A	N/A	N/A
Z2	204,323	381,403	33%	64%
Z3	245,486	342,531	15%	39%
Z4	324,465	545,093	25%	56%
Z5	206,056	315,470	20%	48%
Z6	N/A	N/A	N/A	N/A
TOTALS	**980,330**	**1,584,496**	**15%**	**64%**

Halving of the Mekong River annual sediment load will further reduce primary productivity of the Mekong River. The cascade of 8 dams planned for Yunnan Province and the tributary projects of the LMB will reduce the sediment load of the Mekong River by 50% at Kratie and in the order of 80% in Zone 2. A significant load of nutrients is attached to these sediments resulting in a significant reduction in nutrient loads which will further reduce the productivity of the Mekong system.

It is not possible to relate the changes in primary productivity to fish catches, because of the complexity of the relationships, and the fact that fish catches are dependent largely upon the catch effort as well as the standing stock. Nevertheless, net primary productivity is an indicator of the relative richness of the zone

11.1.3 CAPACITY OF THE MEKONG'S ECOSYSTEM REGULATING SERVICES – WATER QUALITY

Whilst the river is relatively clean and in good ecosystem health at present, there are increasing point sources of pollution, e.g. urban areas, and dispersed sources, e.g. agricultural run-off, which are currently

mitigated by the large dilution effect of the river flow.[57] The result of this is that poor water quality is often rather localised, and quickly diluted, with rapid improvement in water quality e.g. after high polluting loads from urban areas.

- **Acidification of surface waters is the most significant water quality issue**, with a noticeable trend throughout Zone 3 (Vientiane – Pakse)
- **Organic loads are increasingly becoming a problem at Vientiane, Nakhom Phanom and Khong Chiam**, reflective of the large population centres at these sites.
- Nitrogen and phosphorous loads are not problematic at any reach between Chiang Saen and Pakse.
- Mineralisation is affecting water quality downstream of Chiang Saen and Vientiane.

There are **signs of decreasing water quality – a trend which is expected to increase in the future with growth of population.** These trends are strongest for downstream areas of the LMB and also near growing population centres.

- **Xiang Kok has shown the most significant deterioration of ecological health in the past 5 years**
- The important wetlands of Songkhram and Siphandone continue to show good ecological health and are not affected by the poorer health upstream at Vientiane and Nakhom Phranom suggesting that the large Mekong flows continues to dilute contaminants and ameliorate poor water quality issues.
- The Mekong branch in the delta continues to display poorer ecological health than the Bassac branch.

In general, zones 2 and 3 continue to maintain its key ecological features better than the lower zones (Table 21):

- **Geomorphology:** Channel form remains unmodified in Zone 4 and has undergone only moderate modification in other zones.
- **In-channel/bank vegetation:** has undergone minor to extensive modification in all zones, with degradation particularly prevalent in Zone 3 and 5.
- **Invertebrates, fish, water birds, frogs & reptiles**: Most aquatic fauna have be moderately modified throughout the LMB, with generally better preservation in Zone 2 and Zone 3.

Table 21: Results of the IBFM specialist assessments of ecological status of different river zones: *A = Excellent/Unmodified; B = Good/largely natural; C = satisfactory/moderately modified; D = room for improvement; E = improvement necessary/largely modified*

Discipline	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Geomorphology (channel form)	B+	B+	A	B+	C
Water Quality (chemical only)	B	B	B	B	B-E
Vegetation - In Channel/River bank	C	C*	B*	D*	C-D
		D#	C#	B-E#	
Invertebrates	B	B	B+	B-	C
Fish	C	C	C	C	D
Water Birds	C	C	D+	D+	D+
Frogs/Reptiles	C	C	D+	D+	D+
	B-	B-	C+	C+	C+

11.1.4 VALUE OF THE MEKONG RIVER'S CULTURAL ECOSYSTEM SERVICES – INSPIRATION, RECREATION & TOURISM

[57] Good refers to the MRC IBFM score card rating and corresponds to "largely natural" conditions

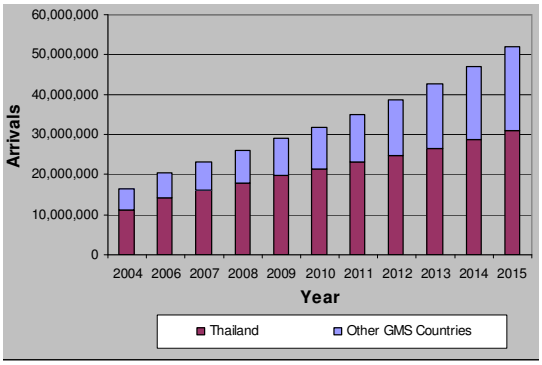
TOURISM & RECREATION

The Mekong is recognised as having an immense cultural value for the riparian cities and communities and for tourism. The tourist attraction of a large, dramatic, near-natural river, a feature of the GMS tourism strategy, is expected to continue to increase in the future.

Thailand continues to dominate tourism in the Mekong basin, however other national tourism sectors are growing proportionately faster (Figure 34**).**

In Lao PDR, projections indicate that international arrivals will grow from 1.6 million visitors in 2007 to 3.5 million visitors by 2015, with tourism revenue rising from USD 233 million to USD 399 million. Dependency on tourism for livelihoods varies from 2-3% in Xayabouri province up to 20% in some areas of Champassak

Figure 34: Trends in tourism: *(a) Trends in tourism arrivals to the GMS; (b) estimated value of tourism expenditure in 6 GMS countries*



	Estimated value of tourism expenditure in GMS		
	US$ Billion		
Sub Sectors	**2004**	**2010**	**2015**
Hotel and Food	5.27	10.51	18.67
Transportation	1.94	3.87	6.87
Shopping	4.07	8.11	14.4
Tours	1.19	2.37	4.21
Other Services	2.33	4.64	8.25
TOTAL	**14.8**	**29.5**	**52.4**

CULTURAL VALUE

The cultural value and landscape of the Mekong mainstream will remain generally intact over the next 20 years, although increased dry season water levels and decreasing sediments will mean that areas of sandbars and beaches will be lost. This will significantly reduce the availability of the dried areas in the river channel for dry season recreation by local residents in all zones. The value of the Mekong mainstream as a tourist attraction will be marginally impacted by these changes.

11.2 IMPACTS ASSESSMENT

11.2.1 AQUATIC BIODIVERSITY

The loss of habitats would encourage the proliferation of generalist species that can breed within the body of the reservoir and do not require specialised habitats or hydrological triggers to induce spawning.

The fragmentation of the river system by the 11 mainstream dams would isolate aquatic populations into pockets leading to a loss of species.

- ***Fish***: biodiversity losses would be most significant for fish species which could see losses of up to half the recorded species in some zones (also see fisheries impact assessment section).
- ***Mollusks***: The Mekong has the highest number of freshwater snails in the world many of these species would be threatened by the loss in habitat
- **Amphibians:** depend upon the wetland pools left by receding floodwaters for breeding these species would be affected in all zones of the Mekong River
- ***River dependent birds***: bird species that rely on exposed sand bars and riverbanks for breeding and nesting would suffer from lost habitats. In Zone 2 and northern Zone 3 these include the River

Lapwings, and Pranticoles. In Zone 3 and Zone 4 these include various storks (painted and woolly necked), greater and lesser Adjutants, and ibises such as the Great Ibis, Black-shouldered Ibis, endangered River Terns and the endemic Mekong wagtails.

- ***Irrawaddy dolphin:*** The mainstream dams are likely to be the final threat leading to the **extinction of the critically endangered Irrawaddy dolphin**.
- ***Giant Mekong Catfish***: Depending on the migration routes the wild populations of the **Giant Mekong Catfish would face local extinction from the Cambodian floodplains** and potentially total extinction if the populations in Zone 4 and Zone 2 are linked.
- ***Siamese crocodiles*** are found in the Stung Treng Ramsar site, this population of **Siamese crocodiles would face local extirpation** due to the mainstream dams.
- ***Turtles:*** significant reduction in most species of turtles living in the Mekong, including the Cantor giant soft-shell turtle, due to loss of sand-bars and seasonal breeding habitats
- ***Otters:*** the mainstream dams would reduce the availability of suitable habitats and potentially fragment populations of Otters living in the Mekong and Tonle Sap systems – including the three critical species: (i) hairy-nosed otter(endangered), (ii) smooth-coated otter (vulnerable), and (iii) oriental small-clawed otter (vulnerable).

11.2.2 WATER QUALITY

The impacts on water quality differ during construction and operational phases. Depending on the phasing of mainstream projects, the construction period impacts could be drawn out well beyond a single project construction phase of some 5 to 8 years.

Construction: **the adverse water quality impacts during construction are likely to be worst during the dry season**.

- ***Increased sediment loads***: rock blasting and earth moving activities are likely to increase sediment loads which could have significant localised implications smothering gravel beds and riffles downstream and impacting on fish spawning.
- ***Increased organic matter:*** increased solid and wastewater loading with localised implications
- ***Increased oxygen demand:*** the Cambodian projects would flood large land areas causing the decomposition of vegetative matter
- ***Spillages:*** localised implications from fuels, oils, toxic compounds, concrete & other construction materials' into the downstream areas.

Operational phase: **the long-term implications of the LMB mainstream projects to the water quality of the Mekong River would be less severe than during construction:**

- ***Reduced turbidity:*** the sediment load would drop by 75% (1/3 of which is directly related to the mainstream dams) this would in the long term reduce the turbidity of the water column
- ***Reduced organic matter transport***: The Mekong River transports a significant amount of vegetative and woody debris along its length which play an important role in the recycling of nutrients back into the Mekong system. The mainstream dams would cause the concentration of this matter within the reservoirs severing one of the important longitudinal bio-chemical connections between the headwaters and floodplains of the Mekong system.
- ***Cumulative effects***: predictions suggest that by 2030; phosphorous and nitrogen levels would increase by 100% and 85% respectively, while waste water discharges would increase by 35% which may lead to seasonal localised reductions in water quality in some of the mainstream reservoirs.
- ***Increased risk of major pollution events***: products used during operations, for example transformer oil, have the potential to cause catastrophic impacts on water quality through spillages, leaks and component failure.

11.2.3 CULTURAL & ECOSYSTEM SERVICES

Significant changes to cultural ecosystem values of the river would affect the social, cultural and religious structure of communities along the river, especially those adjacent to the reservoirs or immediately downstream of the dams. These changes would have important livelihood and economic implications and include:

- ***Festivals***: changes and loss of relevance may be expected in festivals and cultural events associated with the river and its seasons.
- ***Way of life:*** Most (80%) of the Mekong riverine communities are dependent on the natural resources of the Mekong River for their livelihoods. The changes predicted for the mainstream projects would require changes in farming, fishing, and transportation practices as well as recreational activities.
- ***Tourism:*** The perception and willingness to pay for river based activities of visitors and tourists to the Mekong region would be affected, especially during the construction period, and tourism products and marketing would have to be changed once the dams and reservoirs have been created to re-develop river based tourism.

11.2.4 ASSESSMENT OF RISKS BY PROJECT GROUPS

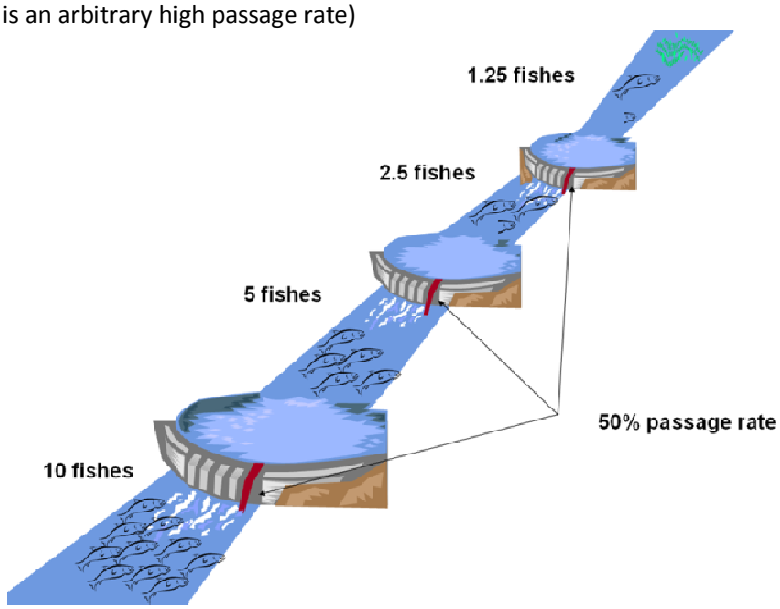
UPPER LAO PROJECTS (PAK BENG – PAK CHOM)

The cascade of 6 dams upstream of Vientiane would cause very significant changes to aquatic ecosystems. Over 80% of zone 2 would be changed from a free flowing river to a regulated cascade of reservoirs. Similar proportions of all the aquatic habitats (rocks and rapids, riffles, sand bars and deep pools) would be changed, with a consequent loss of breeding and spawning areas (Figure 35).

The biggest loss would be on connectivity between the sea and the Upper Mekong. Even if all the dams in the cascade are fitted with efficient and effective fish passages, *the stretch of six dams in cascade over a distance of nearly 800 km represents an impossible barrier for the long distance migratory species*.

The aquatic biodiversity would become seriously impoverished, the more so because there are few major tributaries entering the zone, which can provide alternative spawning areas. There would be local species extirpations, possibly as much as 20 – 30% of current species numbers. Productivity of this zone would also decrease, especially for Mekong river weed.

Figure 35: Exponential reduction of the overall upstream fish passage rate in case of a cascade of dams (50% is an arbitrary high passage rate)



Inundation of the LMB mainstream reservoirs will result in the loss of critical in-channel and riparian aquatic habitats above Vientiane, (e.g. Pak Chom) represents a loss of a unique area in the Mekong (Figure 35). The river reach 40km north of Vientiane marks the transition between the bedrock confined, steep-gradient, meandering channel of Zone 2 and the alluvial reaches of Zone 3 with wider channels. This area is possibly comparable in importance, though not in scale, to aquatic ecology of the other areas of aquatic habitat diversity lower down the system, e.g. in Siphandone.

The cascade of projects would have an immediate downstream impact extending at least down to Vientiane as a result of daily variations in flow, and sediment trapping and flushing discharges. However, these would certainly have been balanced out by the time the river has passed through the rest of Zone 3. *The biggest impact from an aquatic ecology point of view would be as a barrier to migration of fish.* The lower part of Zone 2 acts as a transition between the upper reaches and middle reaches of the Lower Mekong and hence indirectly with the lower reaches, the delta and the sea.

MIDDLE LAO PROJECTS (BAN KOUM – LAT SUA)

The two projects in the middle reaches of the Mekong - Ban Koum (Lao-Thai) and Lat Sua (Lao PDR), would have less an effect on Zone 3 itself than the cascade above Vientiane would have on Zone 2.

However, Ban Koum occupies a stretch of the river, which is distinct and ecologically significant in the context of Zone 3, containing almost all the deep pools and rocky/rapid areas in the Zone. These two dams are intended to operate as near to run-of river as possible with minimum daily draw down, and so should have little impact downstream in terms of daily flow variation. However **the direct influence of Ban Koum would be felt in the aquatic ecology as far downstream as Pakse, and the direct influence of Lat Sua would be felt well down into Siphandone**, but probably not beyond Khone Falls.

These two dams would act as a significant break in the connectivity of the mainstream between the lower parts of the Mekong and the middle and upper reaches and fish passages would not be effective for more than a few species. The relevance of fish passage in this section is not just for the fishery in the mainstream, but also for the tributaries in southern and central Lao PDR and the Chi-Mun system of Thailand. **Fish productivity and biodiversity would be lost from these tributaries of northeast Thailand and southern and central Lao PDR as a result of these two middle reach dams (Figure 37)**.

Figure 36: The Pak Chom reservoir: *showing the seasonally exposed in-channel wetland areas, with the diversity of habitat*

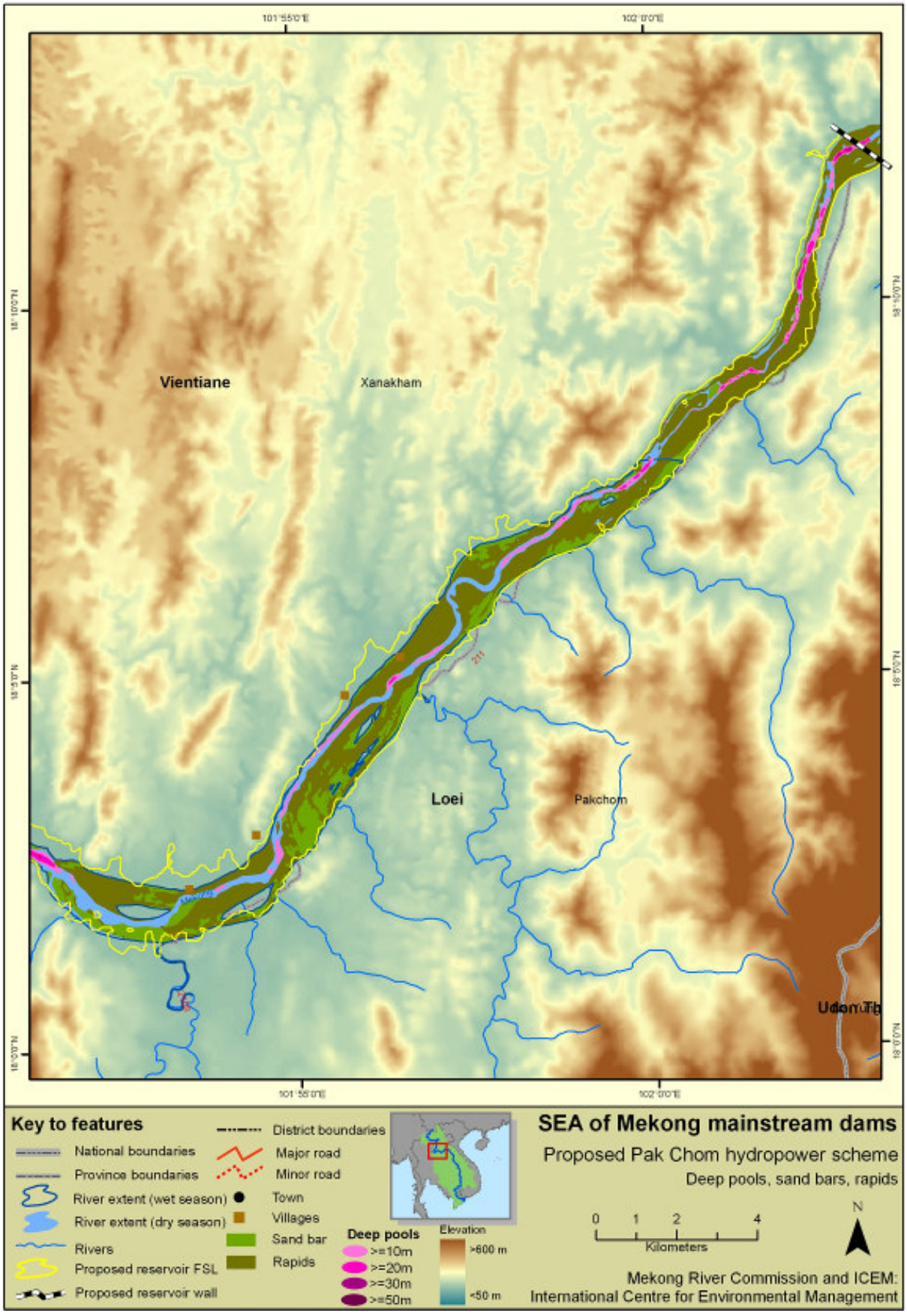
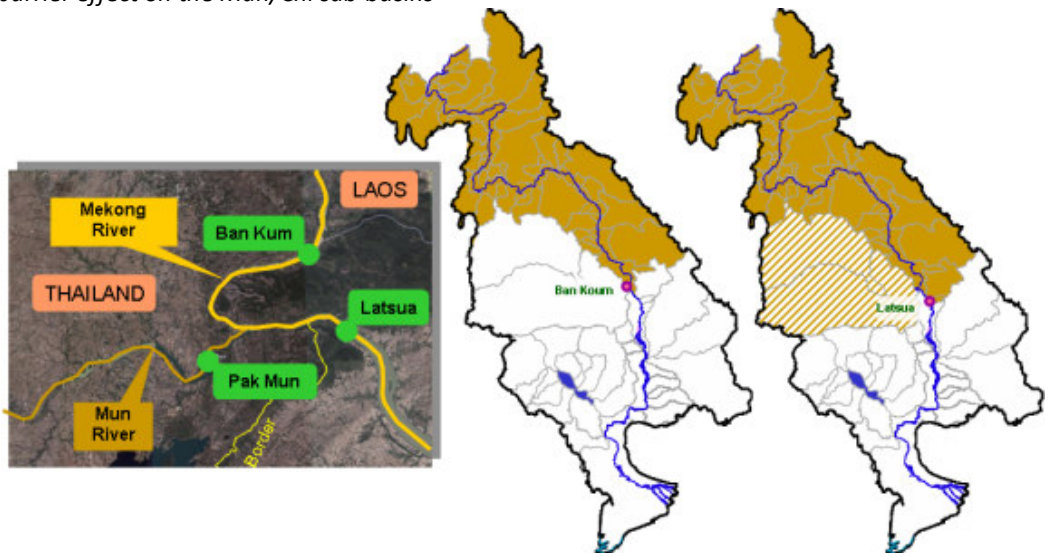


Figure 37: Barrier effects of the Ban Koum and Lat Sua projects: *Location of Ban Koum and Lat Sua dams and barrier effect on the Mun/Chi sub-basins*



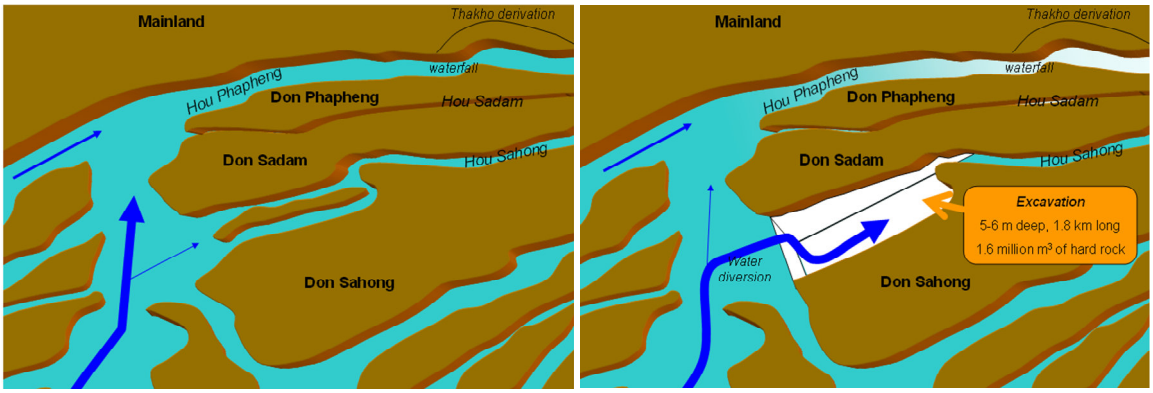
LOWER LAO PROJECTS (DON SAHONG & THAKHO)

The smaller hydropower schemes at Khone Falls – Don Sahong and Thakho – are of significance for different reasons.

Thakho HPP is true run-of-river project involving a diversion of a proportion of water around the Khone Falls. It would have no effect upon fish migration nor would it permanently inundated aquatic habitats upstream.

Don Sahong would block the only channel that is known to provide a year-round route for migrating fish. This would be a barrier for some of the important small commercial species that use it during the dry season. Latest plans indicate that Don Sahong would also deepen the entrance to the *Hou Sahong* channel to attract a larger proportion of seasonal flows in order to increase electricity production. In the dry season this would reduce the flow component through the other channels of the Mekong especially in the *Hou Phapheng* which passes the largest component of the dry season flow (figure 38).

Figure 38: Proposed Don Sahong channel excavation: *1.6 million tonnes would be excavated from the Hou Sahong channel to encourage a greater proportion of the dry season flow and enhance electricity generation potential.*



CAMBODIAN PROJECTS (STUNG TRENG - SAMBOR)

The Cambodian projects would inundate one of the richest and most biologically diverse areas of the entire Mekong system, an area of global importance to aquatic biodiversity. This is a unique area with immense diversity of river morphology, aquatic habitats and landscape value, both in the Mekong system, but also in other major river systems. Because of the topography and nature of the river channel, the area of inundation

would be much larger than the dams upstream, and cover many of the islands, deep pools, rocks and rapids and sandbars.

The **Cambodian projects would involve the loss of rare and endangered aquatic species, e.g. the Giant Mekong catfish, and, combined to the Don Sahong Dam, would most probably be the final threat for the Irrawaddy Dolphin** whose dry season habitat lies within the impacted area.

If these lower Mekong dams were to be constructed, the biggest impact would be in terms of the connectivity of the system, especially for fish migration. The Mekong above Kratie to the Lao border and up the Khone Falls is an important destination for fish migrating out of the Tonle Sap. The combination of Sambor and Stung Treng dams would effectively stop this. Sambor dam would also stop the important fish migration route up the 3S rivers, especially the Sekong. The downstream flows from Stung Treng dam might also alter the ability of migratory fish to navigate up the 3S rivers.

Downstream of Sambor, the aquatic ecology of the river below Kratie would be affected by changing daily flow patterns and sediment trapping and flushing. The reservoirs of **Sambor and Stung Treng would have the highest sediment trapping efficiencies of all LMB mainstream projects destabilising downstream channels and between Kratie and Phnom Penh and cutting overbank siltation in the Cambodian floodplain**.

12 FISHERIES

The Mekong fishery is the world's largest freshwater fishery. It comprises a massive inland fishery producing some 2.1 million tonnes per year (close to 20% of the world's freshwater fish yield) and a substantial coastal fishery producing in the order of 0.5 million tonnes per year.

The Mekong is a fish biodiversity hotspot. With 781 known species scientifically, it is home to the second highest fish biodiversity in the world after the Amazon River. The Mekong is also characterised by very intensive fish migrations. At least a third of Mekong fish species need to migrate between downstream floodplains where they feed and upstream tributaries where they breed. Dams are a major obstacle to these migrations.

12.1 BASELINE

12.1.1 BIODIVERSITY

The Mekong is a fish biodiversity hotspot. With 781 known species scientifically, it is home to the second highest fish biodiversity in the world after the Amazon River. The Mekong is also characterised by very intensive fish migrations, **at least a third of Mekong fish species need to migrate between downstream floodplains where they feed and upstream tributaries where they breed**. Dams are a major obstacle to these migrations.

At least 250,000 ha of floodplains will be lost by 2030 due to the proposed tributary projects. This will reduce the available habitat putting increased pressures on the fishery.

12.1.2 MIGRATIONS

Migrations in the Lower Mekong Basin take place in three distinct migration systems: the lower migration system (from the Delta up to Khone Falls), the middle migration system (from Khone Falls up to Vientiane) and the upper migration system (from Vientiane up to China). Catches are important in the two first systems (about half of the total catch each) and comparatively very small (around 60,000 tonnes per year) in the upper migrations system. The Hou Sahong channel is the only migration pathway over the Khone Falls which can facilitate dry season passage for the important middle migration system. Dams have a different impact on fish

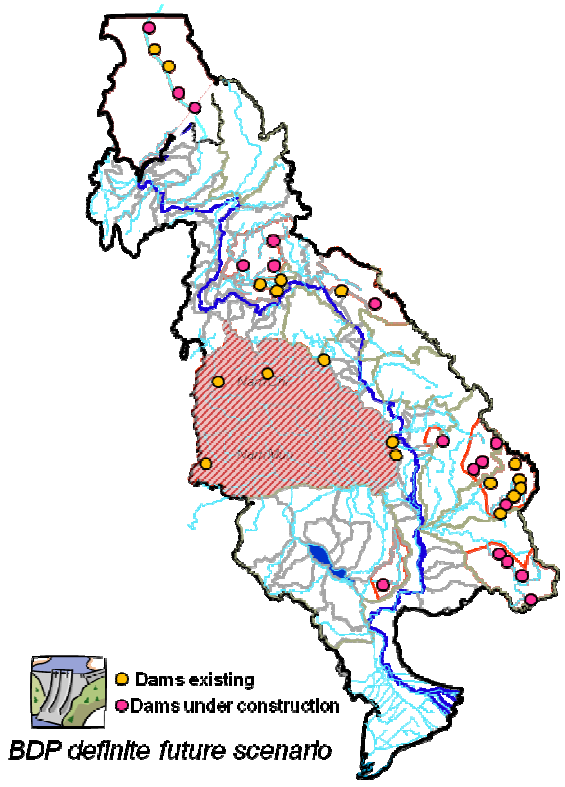
species depending on the "guild" or ecological group they belong to. Mekong fish guilds have different physiological capabilities, requirements or behaviors and are characterised by three colors:

- "White fish" are very sentitive to damming because species of this ecological group need to migrate over long distances to complete their life cycle.
- "Grey fish"migrate between floodplains and local tributaries and are not very sensitive to mainstream dams. "
- Black fish" have a short home range, are very robust and can adapt to reservoir environment; they are the leastat risk from damming.

The presence of 77 tributary dams in the basin by 2030 will result in obstruction of 37% of fish migration routes.

- In 2000, 20.6% of the Lower Mekong Basin was already barred by 16 dams and was inaccessible to fish species having to migrate to the upstream parts of the river network.
- In 2015, this area will have increased by 14% (from 164,000 to 188,000 km^2) (Figure 39);
- If no mainstream dams are built, the surface area made inaccessible to long distance migrant fish by dams on tributaries will represent 37.3% of the watershed

Figure 39: Subcatchments of the Mekong Basin blocked by hydropower development by 2015



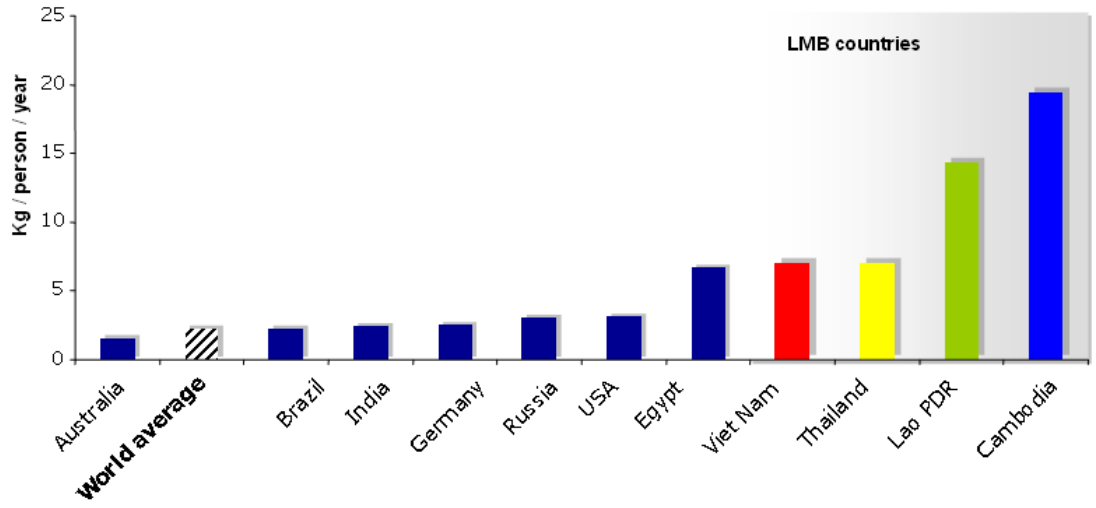
12.1.3 FISH PRODUCTION

CAPTURE FISHERIES

The most reliable estimate of fish production in the Mekong basin is 2.1 million tonnes per year, with estimates varying from 0.75 to 2.6 million tonnes per year**.** By FAO records, this represents 22% of the world's freshwater fisheries. This catch of fish is supplemented by about half a million tonnes of other aquatic animals (freshwater shrimps, snails, crabs, frogs, etc) complementing the catch and the diet of riparian people. .

Freshwater fish supply is critical for food security in the basin, particularly in Cambodia. The four Mekong countries feature the highest consumption of freshwater fish in the world. Cambodia in particular holds the world record for consumption of freshwater fish. The share of protein coming from freshwater fish in people's diet represents between 2.2 and 8.6 times the world average, and alternatives to fish proteins are not always available. Thus, in the whole LMB there is much more freshwater fish harvested than cattle produced, and in Cambodia and Lao PDR, fish production amounts to twice the combined production of pork and chicken. Chicken and pork are alternatives to fish in three of the Lower Mekong countries, but not in Cambodia where fish is by far the dominant source of protein.

Figure 40: Current estimates of fish production for the 3 key Mekong migratory systems



By 2030, tributary and UMB hydropower will reduce the productivity of the Mekong fishery by 210,000 – 560,000 tonnes/yr. This represents a 10-26% reduction in basin-wide productivity.

RESERVOIR FISHERIES:

By 2030, Reservoir fish production in all the tributary and UMB dams is likely to reach 53,000tonnes/yr (range of 15,000 – 240,000).

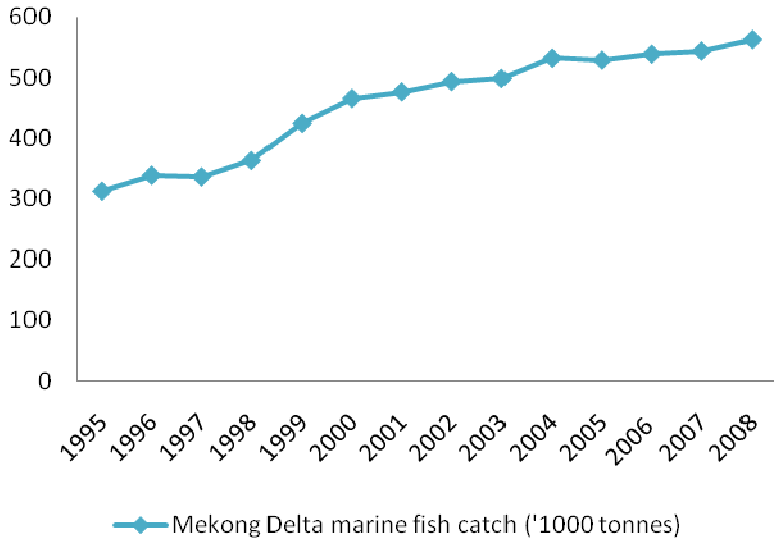
12.1.4 MEKONG MARINE FISHERY

The Mekong marine fishery is poorly understood and is producing more than 0.5million tonnes of fish per year. Past trends indicate that the sector has grown by 80% in the last 15 years. The most recent catch statistics suggesting that production has reached 726,000 tonnes in 2009. It is unclear whether production in the coastal fishery is limited by fish stock or fishing effort. Even less is known of the important scallop fishery at the mouth of the Mekong distributaries (Figure 41).

The Mekong marine fishery is dependent on the approximate 100 Mt of sediments and 16,000 tonnes of attached nutrients which are deposited by the Mekong plume in the shallow near coastal shelf of the delta.

The UMB and tributary dams will induce a 50% reduction in the arrival of sediments and nutrients to the coastal zone. This will have a significant impact on marine fisheries, though the magnitude and time-scales remain unclear.

Figure 41: Marine fish catch totals for 8 coastal provinces in the Mekong delta *(Long An, Tien Giang, Ben Tre, Tra Vinh, Kien Giang, Soc Trang, Bac Lieu, Ca Mau)*



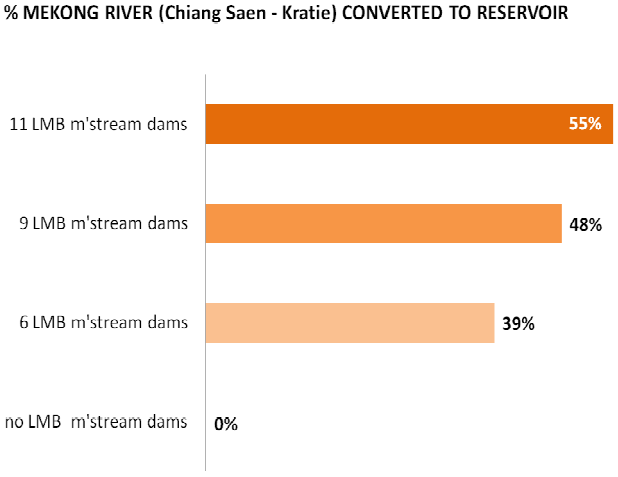
12.2 IMPACTS ASSESSMENT

12.2.1 CHANGES IN BIODIVERSITY

If all LMB mainstream dams proceed, 55% of the Mekong River between Chiang Saen and Kratie would be converted into reservoir, shifting the environment from riverine to lacustrine (Figure 23; 41).[58] This would have major impacts on species composition and productivity:

- The **reservoirs resulting from dam construction would flood critical riverine wetland habitats along the Mekong channel**, resulting in the loss of 76% of all rapids; 48% of all deep pools; and 16% of all sand bars in the section between the Chinese border and Sambor.[59]
- **Reservoirs would not be able to support the same fish species diversity as the more diversified natural riverine system, and would result in a loss of the number of Mekong fish species**. An additional 58,000 hectares of floodplain habitat would be lost due to dam development and subsequent changes in flooding.

Figure 42: Percentage of Mekong converted to reservoir



At least 41 mainstream species out of 262 species in the ecological zone upstream of Vientiane are threatened by a severe alteration of their habitat. There is no information as to whether any of these species threatened can complete their life cycle in reservoirs. The family most exposed would be Balitoridae (river loaches), with about 10% of its 93 Mekong species at risk. The iconic, endemic and critically endangered Mekong Giant catfish would become extinct in the wild since its main breeding area is located in this area, near Chiang Saen. However, beyond these 41 mainstream species, it is not possible to separate the impacts

[58] this corresponds to 43% of the length of the Mekong between the Chinese border and the sea
[59] see Aquatic & Terrestrial section

of the 6 proposed mainstream dams from the 17 proposed tributary dams.

Impacts of the middle and lower clusters of dams on biodiversity are unclear. **Fish biodiversity in these zones is high (386 and 669 species respectively) and would decrease**, but the specific impact of mainstream dams compared to that of other drivers such as land use changes, habitat fragmentation or agricultural intensification could not be quantified.

Fifty-eight species are highly vulnerable to mainstream dam development and a further 26 species are at medium risk of impact. Those 86 species only represent species at risk because of their migratory behaviour; the figure does not include the many species at risk because of environmental changes brought about by dams (e.g.: another 41 species found only in the mainstream upstream of Vientiane are at risk if a cluster of 6 dams turns 90% of this river section into a reservoir). **Overall the total number of species at risk of mainstream dam development is likely to be greater than 100 but is not precisely known**.

In a tropical system characterised by a few dominant species and many rare ones, the proportion of species at risk (11% or more) does not reflect the fraction of harvest at risk (35% or more).

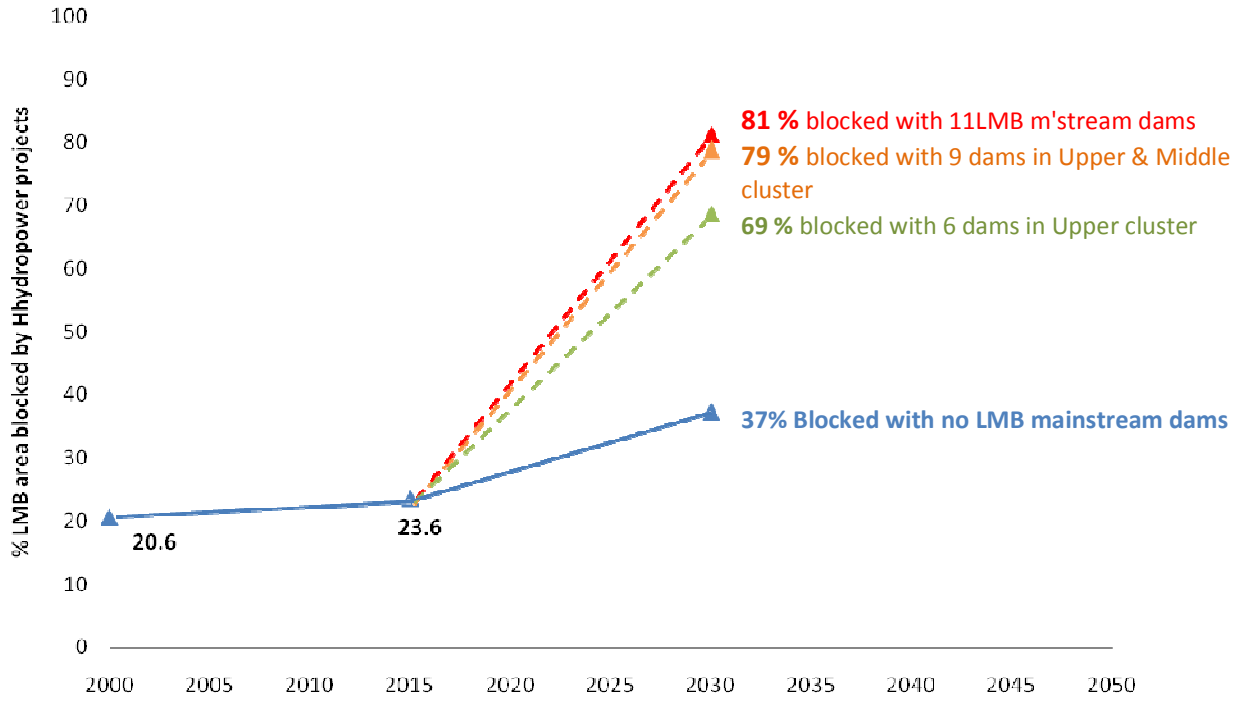
12.2.2 CHANGES IN MIGRATIONS

A minimum of 35% of the LMB fish harvest is made of long-distance migrant species whose migrations would be barred by dams. Mainstream dams would obstruct migrations between upstream breeding zones and floodplain feeding zones, dams located lower in the Basin blocking more migration routes than those located upstream (Figure 43).

Not all dams have the same impact; the barrier effect on migration reflects the proportion of upstream tributaries blocked by the project. Dams of the Cambodian cluster have the highest impact on fish migrations; in particular the Sambor dam would block access of migrant floodplain fish to 81% of the basin. These dams would block the migration of at least 43 species representing a third of the total annual Mekong fish yield.

The **Lao upstream cluster of dams would block migration of at least 23 fish species, the Lao middle cluster of dams would block migration of at least 41 fish species and the Cambodian cluster of dams would block migration of at least 43 fish species.**

Figure 43: Barrier effects of LMB mainstream dams: *Area of the LMB catchment (%) blocked to fish migrations by the Upper, Middle and Lower clusters of dams*



There are limited alternative migration routes for long distance migrant fish species. Twenty-eight of the 41 species known to migrate through Khone Falls have an alternative in the 3S system (except if Lower Sesan 2 or the 40 other dams considered in these 3 watersheds are built) and 15 in the Mun/Chi system (except if the Pak Mun dam is closed or the Lat Sua dam is built).

The Chi-Mun and 3S systems are amongst the most important for spawning & breeding. The Lat Sua dam, although located only 34 km below the Ban Koum dam, would have much greater negative impact on fish migrations and production because it would block access to the Mun/Chi system (70,000 km^2). The Lat Sua dam would also have a greater impact on fish migrations than the Pak Mun Dam because it would block Mun River fish migrations as well as species migrating up the mainstream.

Fish passes are not a realistic mitigation option for Mekong mainstream dams. Existing types and sizes of fish ladders cannot accommodate the intensity and diversity of fish migrations on the mainstream.[60] Seven of the proposed mainstream dams are higher than the maximum height at which fish ladders are operational (~30m). World-wide, effective fish ladders are those that have been specifically designed for a few well known target species that migrate annually in limited numbers under similar hydrological conditions; in contrast the Mekong is characterised by more than 50 different migrant species with different requirements, huge densities during migration peaks (more than 30 tonnes per hour in the Tonle Sap River) and several migration pulses per year under very different hydrological conditions. This abundance and diversity makes the design of generic and efficient fish passes for mainstream dams unrealistic. Don Sahong, whose height is only 10m, is the only dam for which a fish pass (in this case a nature-like bypass channel) might be operational.

Only three of the 11 mainstream dam projects have explicit and detailed plans for fish pass facilities. The inefficiency of fish passes on the mainstream as a mitigation measure is also predictable because of additional reasons:

i) in case of a cascade of dams the number of fishes able to cross several successive dams and passes decreases exponentially (e.g. out of 100 fishes having to migrate through 3 fish passes characterised by a good 50% passage rate, only 12 remain after the 3rd dam; see figure 34, section 11.6);

ii) the type and design of fish passes that work are based on *behavioural studies of target fish species* (where they swim in the river, their swimming capabilities, their attraction by a range of current speeds, etc); in the Mekong, there are no such studies available for any species; designing a fish ladder in absence of such information will lead to failure;

iii) even an efficient fish ladder does not guarantee the survival of a species if the environment upstream of the ladder is not suitable; upstream of Vientiane, if 6 dams are developed, 90% of the running river will be turned into a reservoir and specific target studies are need to determine whether Mekong migratory species can carry out their life cycle in these conditions.

Table 22: mainstream dams and fish passes planned in project documents[61]

	Dam height (m)	Fish pass
Pak Beng	76	No mention
Louang Prabang	68	No mention
Xayaburi	32	2 fish ladders, opening 3m x 10m
Pak Lay	35	Mentioned but no details
Sanakham	38	Mentioned but no details
Pakchom	55	Mentioned but no details
Ban Koum	53	Mentioned but no details
Latsua	27	800m x 10m x 3m; 4 fish entrances 10m wide
Don Sahong	10.6	Excavated by-pass channel
Thakho diversion	No dam (diversion)	Not required
Stung Treng	22	No mention
Sambor	56	3,398 m long; no details

[60] This conclusion was confirmed by a panel of international experts convened by the MRC in September 2008 and by extensive experience from South America

[61] Project documents include EIAs, IEEs and feasibility studies, see SEA Inception report, volume II

For low dams, fish ladders may be a mitigation option, but it is essential then that they are considered at the earliest planning stages during the determination of dam location and design. In all cases, knowledge of the requirements of target species is needed to ensure the efficiency of the fish pass considered.

12.2.3 CHANGES IN CAPTURE FISH PRODUCTION

In 2015 the loss of fish compared to the 2000 baseline is expected to range between 150,000 and 480,000 tonnes annually. This fish loss will be due to 31 new dams on tributaries and to other factors such as loss of floodplains, habitat fragmentation, fishing intensification, etc. This corresponds to 50 - 160% of the total cumulated livestock production of Cambodia and Lao PDR in 2008.

In 2030, with development basin wide and a total of 77 dams on tributaries, the loss of fish compared to year 2000 is expected to amount to 210,000 – 540,000 tonnes *in the absence of mainstream dams*. This represents a loss of 10 to 26% of the baseline production or 3-4% of the 2015 production, even though mainstream dams are not built.

In 2030, *if 6 dams are built upstream of Vientiane*, a loss ranging between 270,000 and 600,000 tonnes is expected compared to the situation in 2000 (i.e. minus 13 – 29%). The additional loss compared to the situation in 2030 without mainstream dams would represent about 60,000 tonnes. In the latter case this amount of protein at risk of being lost annually if 6 mainstream dams are built by 2030 represents 60% of the current livestock production in Lao PDR. This assessment is *very* conservative and corresponds only to the loss of catch in the habitats modified. It does not reflect the loss of recruitment, i.e. the loss of larvae and juveniles bred upstream and harvested downstream as adults. For this reason the actual impact of the upstream group of mainstream projects is likely to be substantially higher than 60,000 tonnes - but at this time it cannot be quantified.

In 2030, *if 9 mainstream dams are built upstream of Khone Falls*, the loss in fish resources forecasted would amount to 350,000 – 680,000 tonnes compared to 2000 (i.e. minus 17 – 32%), or to around 200,000 tonnes compared to 2015. This would also represent a loss of about 140,000 tonnes compared to the situation in 2030 without mainstream dams. Again, this is a very conservative estimate. This biomass at risk of loss between 2015 and 2030 corresponds to the whole annual freshwater fish production of Brazil or to the whole annual meat production in Cambodia.

In 2030, *if 11 mainstream dams are built in the LMB*, the total fish loss forecasted would amount to 550,000 – 880,000 tonnes compared to the baseline (i.e. minus 26 – 42%) and to about 400,000 tonnes compared to the situation in 2015. It would also correspond to a loss of ~340,000 tonnes compared to the situation in 2030 without mainstream dams. This latter amount of protein at risk of being lost annually if 11 mainstream dams are built by 2030 represents more (110%) than the current cumulated annual livestock production of Cambodia and Lao PDR. 550,000 – 880,000 tonnes of fish at risk is a huge number; by comparison the annual freshwater fish production of the whole West Africa (15 countries) amounts to around 600,000 tonnes. This fish loss would have critical consequences on food security in the LMB countries, in particular in Cambodia and Lao PDR.

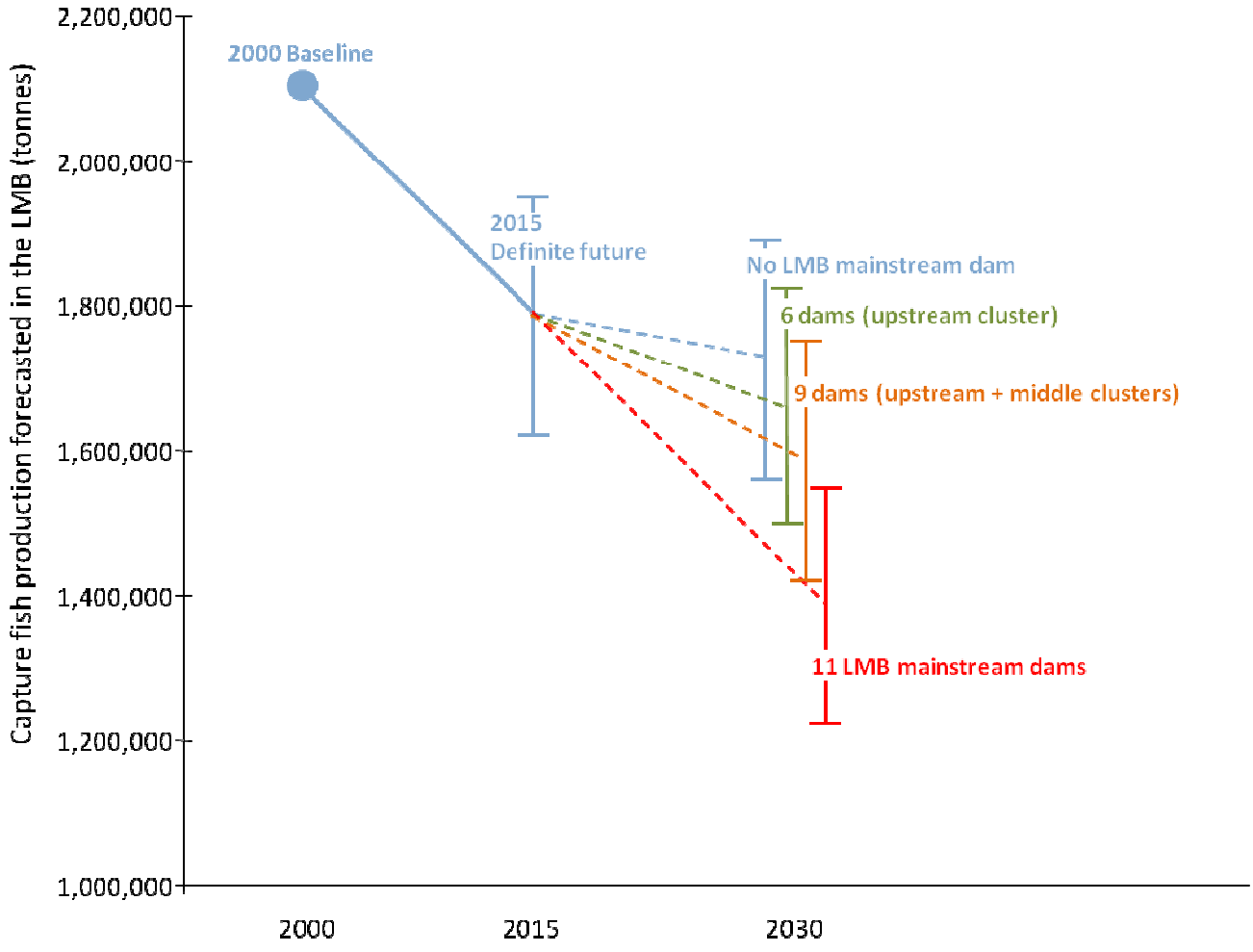
Above figures are based on the most detailed estimates available, produced by the MRC Fisheries Programme for the BDP2, and based on changes in habitats and the productivity of each habitat. **These estimates are very conservative** since they are a sum of local situations (*before* and *after)* but do not reflect the impact that a change in a given place (e.g. a breeding site upstream) can have on another place (e.g. a fishing ground downstream). In other words this approach undervalues the loss of upstream sites where fisheries are not intensive but where juveniles of migrant species are generated before they migrate downstream where they get caught.

Thus fish production would decline even in absence of mainstream dams, but mainstream dams would exacerbate the trend, resulting in extremely high losses.

Table 23: Fish production losses forecasted for different development scenarios

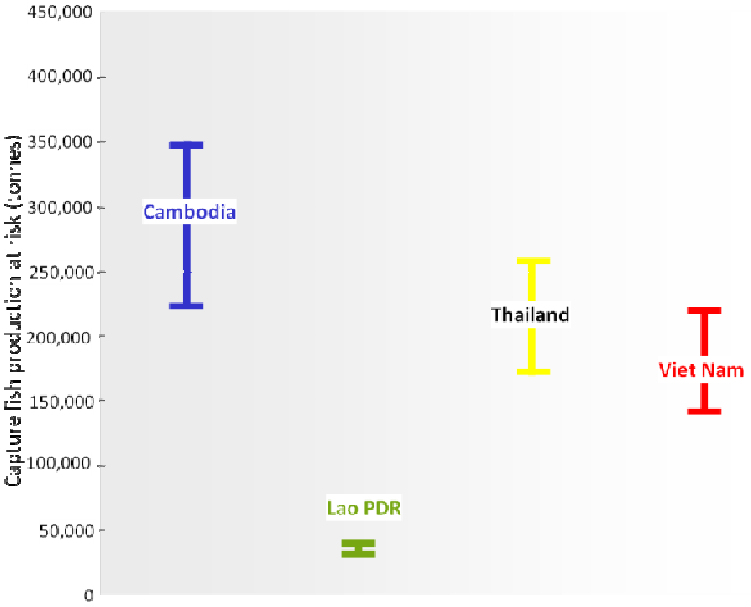
	2000 (baseline) 16 dams on tributaries, 2.1 million tonnes of fish produced				
	2015	2030			
	47 dams on tributaries	77 dams on tributaries			
	No mainstream dams	**No mainstream dams**	**6 MS dams**	**9 MS dams**	**11 MS dams**
Fish losses in 2015 compared to 2000 (t)	150,000 - 480,000	-	-	-	
Fish losses in 2030 compared to 2000 (t)	-	210,000 - 540,000	270,000 - 600,000	350,000 - 680,000	550,000 - 880,000
Fish losses in 2030 compared to 2015 (t)	-	~60,000	~120,000	~200,000	~400,000
Fish losses in 2030 compared to 2030 with no mainstream dams (t)	-	-	~60,000	~140,000	~340,000

Figure 44: Potential impact of mainstream dams on fish production basin-wide



Cambodia is the country most exposed to fish losses, and Lao PDR the country least exposed (Figure 45).

Figure 45: Capture fish production at risk in each country if all mainstream dams are built

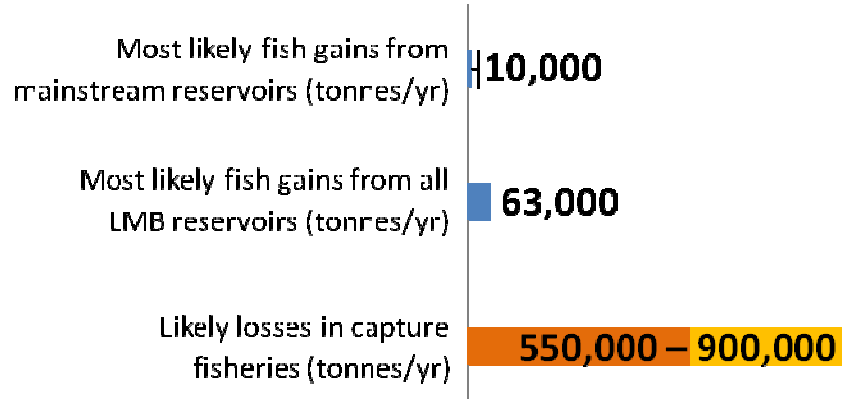


Dams located upstream of Vientiane would have less impact on fishery resources than those located further downstream. Lat Sua, Stung Treng and in particular Sambor dams would have the largest impact on fish production. The impacts on fisheries production varies for each project depending on: (i) distance from the major Mekong floodplains, (ii) position in relation to the important tributaries of the Mekong Basin.

12.2.4 CHANGES IN RESERVOIR FISH PRODUCTION

Reservoir fisheries cannot compensate for the loss in capture fisheries and would produce ~1/10th of the lost capture fisheries production. The total annual reservoir fish production for the entire Lower Mekong Basin would range between 25,000 – 250,000 tonnes, the most likely scenario being 63,000 tonnes of reservoir fish per year or about 11% of the minimum loss of 600,000 tonnes/yr from capture fisheries (Figure 46).

Figure 46: Reservoir fish production compared to capture fish production at risk from dam development: *orange bar represents losses expected without LMB mainstream dams; yellow bar represents losses with LMB mainstream dams*



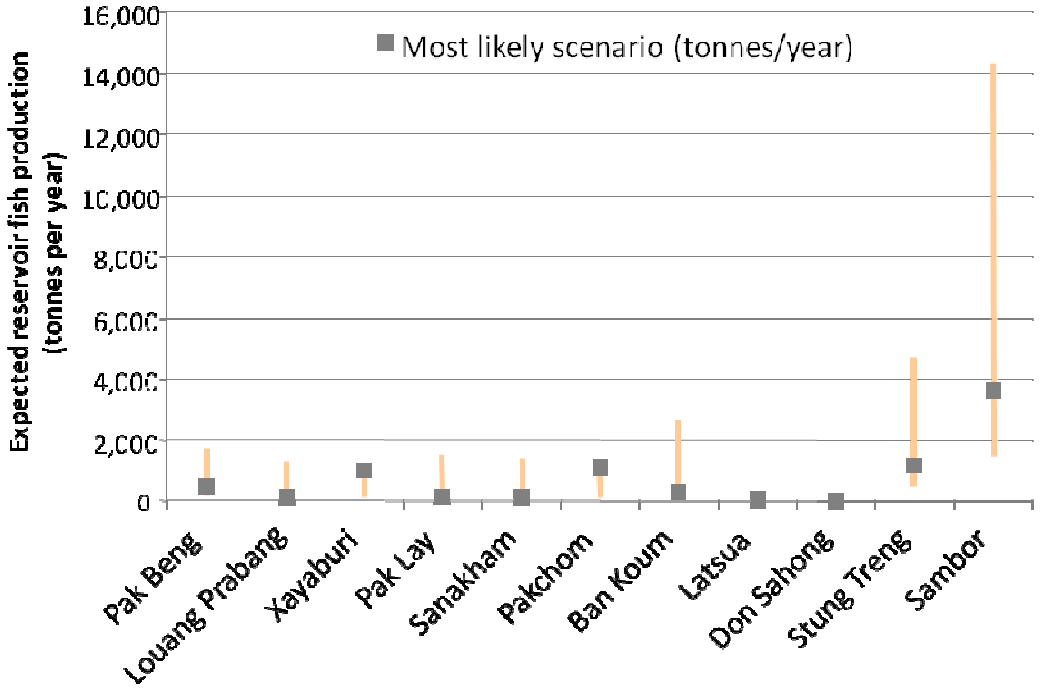
LMB mainstream reservoirs are predicted to collectively produce 10,000 tonnes of fish per year, the best-case scenario being in the order of 30,000 tonnes per year. Reservoir productivity is influenced by i) surface area; ii) storage volumes in the superficial layers of dam; iii) connectivity to upstream tributaries.

Dams in cascades can reduce the productivity of reservoir fisheries by creating a barrier to upstream migration of reservoir species towards tributaries. Connectivity allows native fish still living in reservoirs to

migrate towards their breeding grounds in upstream tributaries. Loss of upstream connectivity by additional dam construction reduces downstream reservoir productivity.

Sambor, Stung Treng, Pak Chom and Xayaburi dam projects display the greatest potential of all LMB mainstream projects for reservoir fish production (Figure 47). The relationship between reservoir surface area and volume is the key parameter influencing the productivity of reservoir fisheries. The LMB mainstream dams create long elongated reservoirs largely confined to the main channel and so have limited fishery potential.

Figure 47: Reservoir fish production expected from the 11 mainstream projects



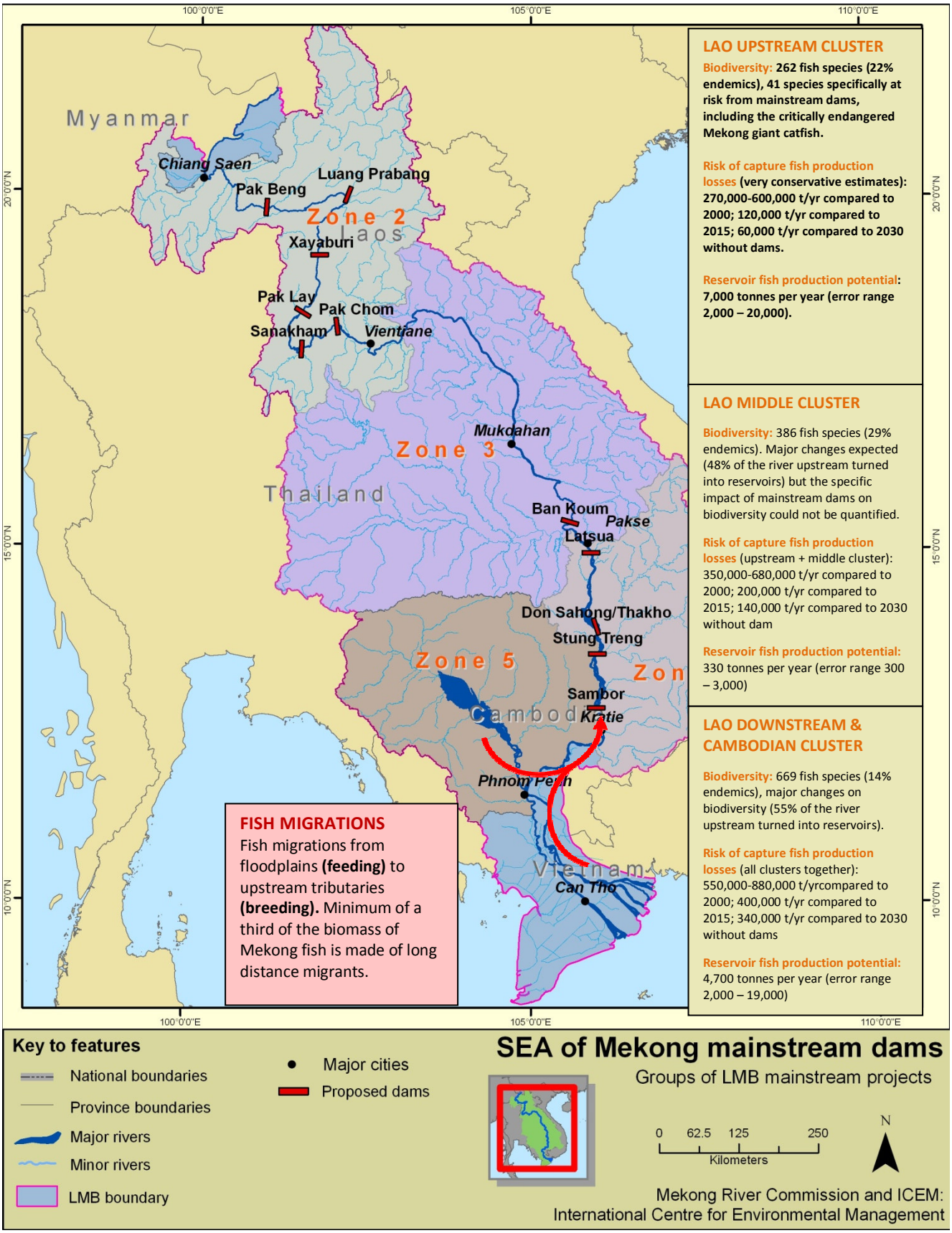
Aquaculture can complement the Mekong capture fisheries sector but cannot replace it in terms of food security. Aquaculture has shown rapid growth in all LMB countries but does not significantly contribute to rural food security in riparian countries. Intensive aquaculture (e.g. Viet Nam) produces fish for export and income but is not accessible to the poor, extensive aquaculture (e.g. Cambodia) feeds local people but is not very productive. This sector is dependent on: (i) investment, (ii) land/water management, and (iii) capture fisheries for feed (all countries) and juveniles (Cambodia in particular). With management for multiple use, the LMB mainstream projects could provide investment and water resources for continued growth in aquaculture; however these projects would also reduce the productivity of capture fisheries, diminishing the supply of feed to the aquaculture sector.

12.2.5 MEKONG MARINE FISHERY

Mekong marine fisheries are a productive component of the Mekong system and are dependent on the nutrient and sediment dynamics of the river. The Mekong marine fishery is a significant component of the Vietnamese delta economy, with a production in the order of 500,000 – 726,000 tonnes per year and utilising almost 6,000 fishing boats**.** A conservative estimate of the nutrient inputs to the coastal zone represent an approximate 100 Mt of sediments and 16,000 tonnes of attached nutrients which are deposited by the Mekong plume in the shallow near coastal shelf of the delta. The Chinese mainstream and LMB tributary dams will induce a 50% reduction in the arrival of sediments and nutrients to the coastal zone by 2030. The mainstream dams would be directly responsible for an additional 50% reduction reducing the annual loading to 27Mt/y of sediments and 4,500 t/y of nutrients to the marine environment.

Sediment retention by dams is expected to have a major impact on coastal fish production, and subsequently on the Vietnamese fishing sector and fish trade. This would also impact the delta aquaculture sector which is dependent on protein from marine 'trash-fish' to feed the aquaculture fish for feedstock.

Figure 48: Regional overview of fishery losses due to LMB mainstream dams



However the timescales and extent of the decline remain unknown because the marine fishery is poorly studied and little understood.

Experience from other dams and coastal fisheries worldwide indicate that sediment retention by dams can have a significant impact on coastal fish production. However agricultural development and urbanization are alternative sources of phosphates, organic matter and other fertilisers. A thorough analysis of expected nutrient inputs from these anthropogenic sources and their positive impact on coastal fisheries remains to be undertaken.

12.2.6 FOOD SECURITY

Loss in inland fish production would have major implications for food security given the dependency of the LMB region on fish as a source of protein. 300,000 tonnes of fish lost in Cambodia would represent 150% of the current total livestock production; 30,000 tonnes of fish lost in Lao PDR would represent a third of the current protein supply of the country (Thailand and Viet Nam, where the livestock sector is more developed, would lose less than 5% each). The impact of such potential losses of fish protein on health and poverty in Cambodia and Lao PDR has not been assessed. Conversely, it is unclear how much time, land, forage and irrigation would be needed to achieve enough growth in the livestock sector so that fish protein lost can be replaced with meat protein.

From a food security perspective, replacing capture fisheries production by aquaculture production is not realistic, because:

- the aquaculture sector depends largely on capture fisheries for feed (high value aquaculture fish being mostly carnivores fed with processed capture fish meat);
- intensive aquaculture requires a lot of investment and targets high value markets; it contributes to exports and GDP but usually not to rural food security;
- extensive aquaculture contributes usefully to local food security, poverty alleviation and livelihood diversification but is not very productive;
- at the national scale, producing one tonne of aquaculture fish requires land, feed, maintenance, time, and is ultimately much more costly than catching one tonne of fish from the wild when this good is naturally present (replacement cost is much higher than protection cost).

13 SOCIAL SYSTEMS

13.1 BASELINE

13.1.1 POVERTY, ETHNIC GROUPS & NATURAL RESOURCE BASED LIVELIHOODS

Impressive steps made by LMB countries to meet MDG goals in poverty reduction, but regression in key areas. Between 1990 and 2009 Thailand and Viet Nam reduced their undernourished populations by more than 50%, while Cambodia and Lao PDR achieved a third reduction. Educational levels improved, as did overall health statistics. However, MDG monitoring reports also indicate that about one third of MDG's measurable trends show slow or no progress at all. Cambodia even shows regression on Underweight Children (Goal 1) and Child Mortality (Goal 4), while Lao PDR shows regression on the percentage of the population living on less than $1 a day (Goal 1), and Viet Nam on HIV/AIDS prevalence (Goal 6).

Increased vulnerability of rural populations as all countries show continued natural resource depletion/ contamination, coupled with very high livelihood dependence of all LMB countries (Thailand less so) on river and land resources, particularly among ethnic minorities. When livelihoods are disrupted or natural-resource dependent communities are increasingly removed from traditional livelihood sources, then the incidence of stunting, wasting and other diseases associated with poverty, increases as the food chain is disrupted or cut off. Dependence on wild foods, including aquatic species, is extremely important for both food security and

nutritional intake, and cannot be easily substituted by meat from livestock due to problems of storage, transport, land availability to raise livestock, and costs of maintaining domestic animals.

The countries of the LMB show a rich ethnic diversity, with many distinct ethnic groups speaking many languages and dialects. Cambodia has an estimated 36 minority groups, comprising some 4% of the population, while Thailand owns to 9 main ethnic minorities comprising an estimated 1.22% of the population. Lao PDR and Viet Nam have the greatest representation of ethnic groups in their populations, with 48 groups and 47.5% of the population in Lao PDR, and 54 groups accounting for some 14% of the population in Viet Nam

National revenues from hydropower are increasing, but the link between revenue generation and poverty alleviation in all LMB countries is yet to be demonstrated. Regional studies of the LMB hydropower sector by the World Bank have shown that there is no necessary connection between hydropower development and poverty reduction. However, Nam Theun 2 (NT2), with considerable support by international financing organisations and detailed scrutiny by a range of international organisations, has shown promising results. The project serves to highlight the significant institutional and financial capacity development required by LMB countries if the hydropower sector is to contribute to poverty alleviation.

13.1.2 HEALTH & NUTRITION

Status of health issues related to poverty, population movement and water resource management vary in different LMB countries**.**

Disease transmission is closely associated with poor nutrition, lack of potable water sources, and poor environmental sanitation. The spread of regional road networks and increase in migration and human trafficking throughout the LMB adds another dimension which is important for the transmission of some types of disease.

The status of these issues in the LMB is directly associated with (i) ease of access to adequate health infrastructure and personnel; (ii) drainage and clean water resource management with its associated health and sanitation consequences; (iii) knowledge and awareness levels, which may be associated with relative vulnerability to food insecurity; and (iv) access to free sources of high nutritional value from natural resources, such as fish, non-timber forest products, and wild game. Stunting and wasting are characteristics of malnutrition more common in Lao PDR and Cambodia than in Thailand and Viet Nam, affecting both life expectancy as well as children's health.

Public expenditure on health in all LMB countries is uneven, and while Thailand has removed clean water supply and sanitation from its MDG targets (having achieved this by 2007), the other LMB countries retain the target and have some way to go before achieving it. Some health and nutrition issues can be addressed by improved financial resource allocation, but others are associated with ease of access to the natural resource base and other productive resources.

13.1.3 RESETTLEMENT

LMB countries show numerous policy and procedural gaps in land acquisition and compensation compared to international best practice. Lack of consistent national or trans-boundary mitigation frameworks present challenges to achieving policy equity in project implementation, while limited human capacity and/or political will to effectively monitor developers and require them to satisfactorily meet policy commitments, remain obstacles to socially equitable resettlement practice. Key issues include:

- **Tendency to approve hydropower projects without satisfactory EIAs, lack of baselines, and unsatisfactory implementation procedures.**
- **Limited national capacity to undertake social and environmental planning and monitoring of hydropower projects or to enforce national standards.**
- **Hydropower developers not allocating sufficient budgets for social and environmental safeguards until project is operational and generating revenue, well after impacts are felt.**

- **Land expropriation practices through forced displacement and concessions awards already causing communities to lose natural resource livelihood base.**

13.2 IMPACTS ASSESSMENT

Though the Mekong riparian communities vary remarkably in terms of ethnicity, poverty, level of development, social structures and economic base, they all share an overwhelming dependence on the natural resources of Mekong for their livelihoods. Some 29.6million people live and work within 15km of the Mekong River throughout the LMB. **Of these, 2.1 million are local riparian communities living within 5km of the river who are expected to be most at risk to the direct and indirect impacts of the LMB mainstream dams.**

Of critical concern in the social assessment of opportunities and risks is the equity of division of impacts amongst Mekong communities. The adverse impacts of the mainstream projects on Mekong social systems is the culmination of direct impacts to the land and waterways of a community, their vulnerability to change and the level of support offered by LMB governments. On the other hand, the positive impacts of the mainstream projects largely depend on the governments' capacity to share benefits across sectors, provinces and socio-economic divides.

The impact on Mekong riparian communities depends on their location in relation to the LMB mainstream dams. In the SEA direct impacts relate to three distinct zones in relation to the hydropower dam and its reservoir:

1. **Reservoirs zones**: the creation of reservoirs would inundate significant proportions of village and agricultural land forcing many communities to relocate to higher land or other provinces.
2. **Dam site:** the dams and supporting access roads and infrastructure would also cause the loss of land and requirements for resettlement, in addition, during the construction phase the large influx of migrant workers would have major repercussions on the host communities. Some would be positive – such as an increased economic stimulus for the service industry, and others would be negative such as the proliferation of STDs and other health risks
3. **Downstream:** downstream of the dam sites, communities would be affected by changes to water levels and the geomorphology of the river which would have knock on impacts for safety, agriculture, fisheries and bank stability.

13.2.1 PEOPLE DIRECTLY AFFECTED

Preliminary overall estimates of total people directly affected amount to 106,942. These estimates are conservative and would likely rise given more detailed information from developers and from Resettlement Plans. Pak Beng, Luang Prabang, Pak Lay, Stung Treng and Sambor account for the majority of the directly affected populations.

The Upper Lao cascade of 6 dams will directly affect the largest number of people of all Zones, totalling an estimated 76,290 people, the majority of whom are ethnic minorities in Lao living below the poverty line and highly dependent on the natural resource base.

Resettlement is the largest direct impact facing Mekong communities affecting a minimum of 63,112 people or ~60% of those directly affected. Sambor, Luang Prabang and Stung Treng account for most of the required resettlement (Table 24; figure 48).

Table 24: Preliminary totals of people directly affected by the Mekong mainstream dams

No.	Dam Name	Total Affected Villages	Total Affected HHs	Total Affected Persons	Number of Resettled Villages	Number of Resettled HHs	Number of Resettled Persons
1	Pakbeng (1)	57	6,831	35,365	28	774	6,700
2	Louang Prabang (2)	36	2,516	12,966	36	2516	12,966
3	Xayaboury (3)	29	1,988	4,378	10	391	2,130
4	Pak Lay (4)	27	1,079	19,046	16	NA	6,129
5	Sanakham (2)	10	800	4,000	10	800	4,000
6	Pak Chom (2)	2	107	535	2	107	535
7	Ban Koum (2)	4	187	935	4	186	935
8	Lat Sua (2)	0	NA	NA	NA	NA	NA
9	Don Sahong (2)	4	14	66	4	14	66
10	Thakho (2)	0	0	0	0	0	0
11	Stung Treng (2)	21	2,059	10,617	21	2,059	10,617
12	Sambor (2)	NA	1020	19034	NA	NA	19034
Preliminary Totals		**190**	**16601**	**106942**	**131**	**6847**	**63112**

Data Sources: NA=Not Available.

* indicates figures from 1994 study by Compagnie Nationale du Rhone, Acres International Ltd. & Mekong Secretariat Study team. No updated information available to SEA

1. Data from Initial Environmental Examination (IEE), Pak Beng Hydropower Project, Lao PDR, December 2008, Earthsystems, Norconsult & SEA Inception Report, Vol. 2, Project Profiles

2. SEA Inception Report, Vol. 2, Project Profiles

3. Final Report, Social Impact Assessment of Xayabouri Hydroelectric Power Project, Lao PDR, August 2008, Team Consulting Engineering & Management Co. Ltd., Ch.Karnchang Public Company Ltd. & SEA Inception

4. Initial Environmental Examination (IEE), Pak Lay Hydropower Project, Lao PDR, June 2008, Earthsystems, Norconsult, CEIEC & Sinohydro Joint Venture. Figures taken are for the maximum impacts downstream option.

13.2.2 PEOPLE INDIRECTLY AFFECTED

More than 2 million people in 47 districts living within the head ponds, dam sites and immediately downstream of the 11 LMB mainstream projects are at highest risk of indirect impacts from the LMB mainstream projects.

Indirect impacts are also likely to affect those people living or working within access (i.e. 15kms) of the Mekong mainstream, its tributaries and wetlands, but who are not expected to be resettled, or to lose land or housing:

- 29.6million people are at risk in a 15km Mekong impact corridor in Lao PDR, Thailand & Cambodia
- 14 million people (13,849,801) are at risk of indirect impacts in the Vietnamese delta
- Poor management of dams and erratic water releases would increase numbers of affected people, e.g. an additional 76,368 population in Pakse at risk of Lat Sua or Ban Koum failures

Local riparian communities are normally the most exposed to indirect impacts, namely district populations within a 5km reach of the Mekong mainstream. Cumulative impacts may take some time to make themselves known, e.g. erosion in the Vietnamese delta and consequences for agriculturally-dependent households. Also, if health/drainage/sanitation programmes are not implemented adequately by developers, there would be higher numbers of people affected.

Figure 49: Percentage of district populations directly affected by the LMB mainstream dams

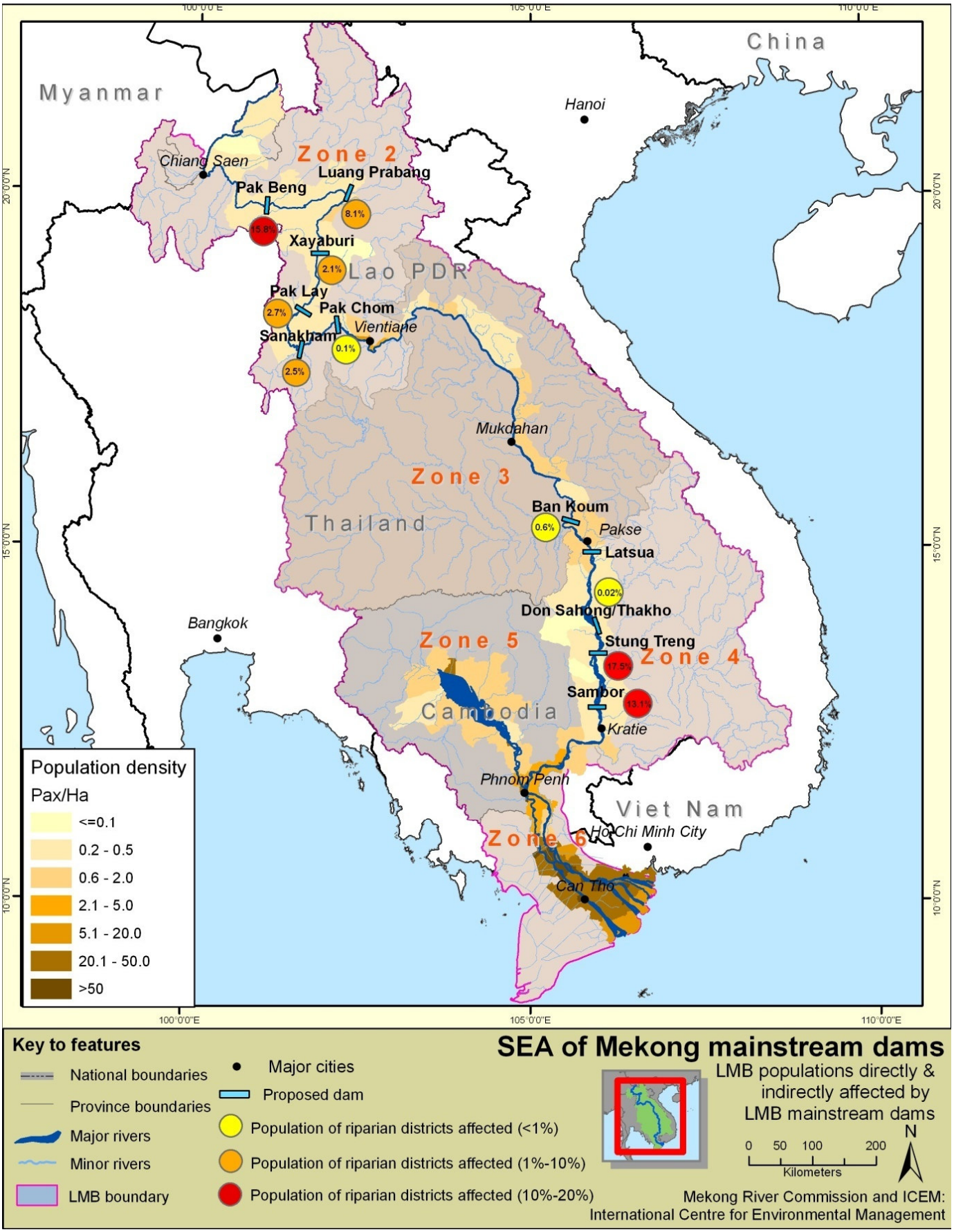
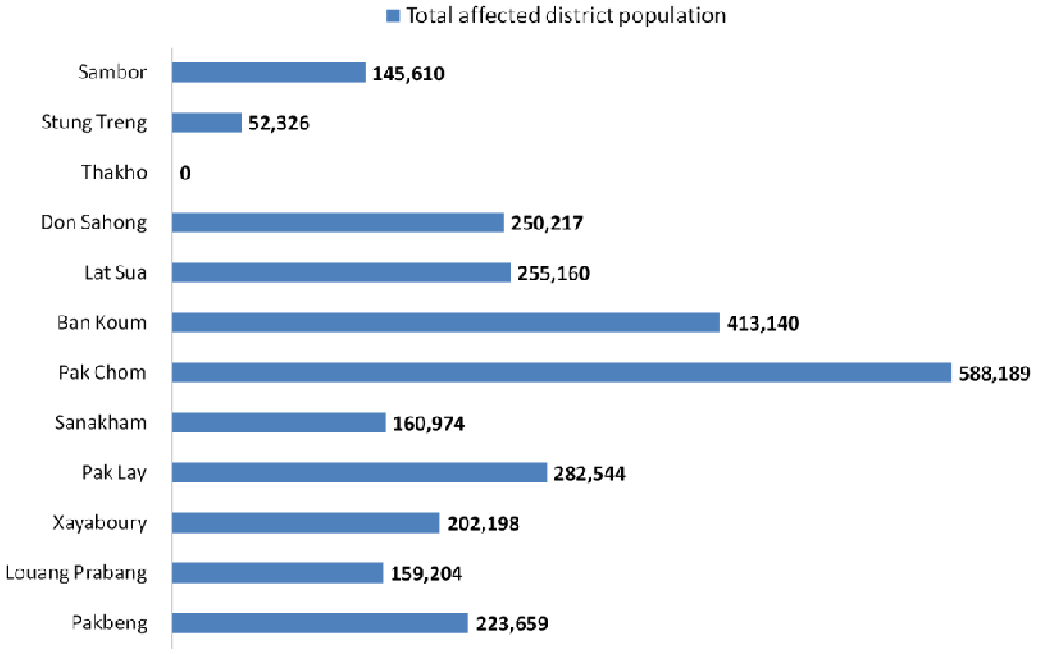


Table 25 and Figure 50 provide details of the potential for individual projects to have indirect effects on people.

Table 25: Potential indirect impact of mainstream projects on people

Mainstream project	Indirect impacts and people affected
Pak Beng	223,659 people: has the highest potential to adversely affect the poor and will affect the highest proportion of district populations (15.8%). 7 out of the 8 districts impacted are classified as poor or very poor
Pak Chom	588,189 people: Pak Chom will have the largest impact of any dam on the surrounding communities (Figure 45)..
All other Upper Lao projects	Will individually affect between 160,000 – 280,000 people
Luang Prabang	Would affect 8.1% of total affected district population.
Pak Lay	6.7% of total affected district population
Sanakham	2.5% of total affected district population
Xayabori	2.1% of total affected district population
Pak Chom	0.1% of district populations
Ban Koum & Lat Sua	668,300 people: Will directly affect only a small number of people (~1,000), but large number indirectly
Don Sahong	250,217 people: Like Ban Koum, the project will have minor direct social impacts (<100 people) but significant indirect impacts. Has the smallest reservoir footprint of all mainstream dams.
Sambor and Strung Treng	197,936 people: The Cambodian projects will dominate the direct social impacts and have significant indirect impacts

Figure 50: Preliminary totals of indirectly affected populations



13.2.3 EQUITY

The LMB mainstream dams would make rural communities more vulnerable by reducing the productivity of the natural resource on which their livelihoods depend. All LMB Mekong countries have a high livelihood dependency on water and land resources - the highest in Lao PDR, the lowest in Thailand. The most vulnerable are those with low occupational or income source diversity. Particularly:

- In locations with high levels of poverty (e.g. Lao districts in Zone 2; Cambodian fishing communities in Stung Treng and Tonle Sap; Vietnamese agriculturally/fisheries-dependent communities in the Mekong Delta)
- The high proportion of already poor ethnic minorities in Zones 2 & 4 who may experience difficulty in adjusting to new economic structures
- The poor & ethnic groups already relocated or losing land before the mainstream projects and would lose a second or potentially a third time (Zones 2 & 4)

There is an inequitable distribution of impact among farmers: Those people losing agricultural land would not be the same people who would benefit from improved irrigation opportunities. The projects favour medium and large irrigation schemes, while the loss of agricultural area would be felt be small-plot farm holders.

13.2.4 MULTIPLE RELOCATION

Some mainstream projects would result in villages being displaced for the fourth time in 15 years. Repeated compulsory relocation within a relatively short period of time is one of the most impoverishing acts that can occur to communities given the rapid pace of hydropower development. Some ethnic minority communities have already been relocated once or twice in the preceding 10 years (e.g. a Hmong village in Pak Beng impact zone), and are already among the most disadvantaged in terms of poverty levels and poor social conditions. Households in Ban Houay Xong, Nan district, potentially affected by the Xayaburi hydropower project, were moved from the uplands to the lowlands in the mid-1990's but placed into an area which frequently flooded, and after 7 years were obliged to relocate themselves twice with no outside assistance to try and re-establish their village and livelihoods again.

The risk of double jeopardy for both directly and indirectly affected people in Stung Treng and Kratie is extremely high, given that the number of poor has been increased by prevailing land sequestration practice for commercial concessions. Stung Treng is reported to have the highest level of level of compulsory land sequestration for distribution to concessions holders.

13.2.5 ASSESSMENT BY PROJECT GROUP

UPPER LAO PROJECTS (PAK BENG – PAK CHOM)

The 6 projects in Upper Lao (upstream of Vientiane) would affect 10 provinces and 32 districts in Thailand and Lao PDR. Zonal population totals just over 1.3 million people (1,351,350), of which 77% is rural.[62] The majority of directly affected population is Lao, many ethnic minorities living below the poverty line and highly dependent on the natural resource base. No figures for directly affected people in Thailand are available at this time.

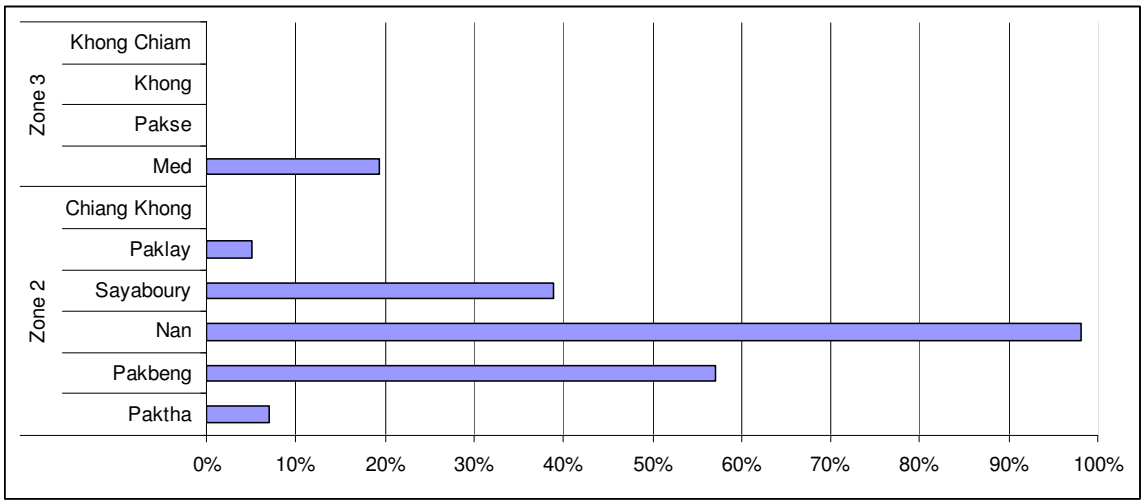
This cascade of 6 dams would directly affect the largest number of people of all Zones, totalling an estimated 76,290 people. An estimated total[63] of 8,418.5has of agricultural land and 6,523has of forests including spirit forest would be lost in Zone 2. Cultural artefacts, such as cemeteries and temples would also be lost. Impacts on fisheries may result in loss of cultural events associated with the Mekong River's life, such as the Giant Mekong Catfish festival in Chiang Khong, which is dependent on the survival of the species. Replacement agricultural land is very scarce and may result in communities clearing more areas, risking increased erosion in turn leading to additional unexpected relocation. The zone would see a loss of river-based livelihoods.

[62] All Zonal population figures in this section are taken from MRC Technical Paper No. 30, SIMVA, March 2010, Table 5
[63] These figures are minimum totals as of this report's date. All land acquisition data is drawn from project-specific IEEs or from SEA team questionnaires to developers. Two developers did not complete the estimate for land acquisition. Estimates of acquired land provided by developers only relate to those directly affected by relocation, and do not include land acquisition for associated facilities such as access roads, transmission lines, etc. Total land loss may thus be higher.

Projects in districts with higher incidences of poverty would have a more severe impact than in relatively prosperous districts. **Pak Beng has the highest potential to adversely affect the poor**. This dam would affect 8 Lao districts, of which 7 are officially classified as poor or very poor. Pak Beng would also directly affect a much higher proportion of district population than any other dam in Zone 2, at 15.8%. **Luang Prabang** would affect 8.1% of total affected district populations, and Pak Lay 6.7%, Sanakham 2.5%, Xayaburi 2.1%, and Pak Chom an estimated 0.1% of district population.

The Upper Lao Cascade would have both positive and negative impacts on food security. Food security is a serious concern for many riparian communities. In Zone 2 levels up to 100% of the population in some districts would suffer food insecurity for more than 6months of the year (Figure 51). In some areas with larger irrigation potential (near the Vientiane plain) additional investment in pumping infrastructure would allow communities to increase the productivity of farm areas having a positive impact on food security. In the remaining areas of Zone 2, the mainstream dams would adversely impact the natural resource base for livelihoods, exacerbating issues of food security.

Figure 51: Lao & Thai case study districts: percentage families experiencing food insecurity for more than 6 months a year



The upper Lao cascade would also have some positive benefits, particularly in the larger and more prosperous populations in the vicinity of the Vientiane plain who are dependent on fixed riparian agriculture and fisheries and have better urban access and market connectivity.

- **Infrastructure access**: The 6 mainstream dams would improve the road and transport infrastructure as well as electricity supply in these communities

Improved irrigation opportunities: projects like Pak Chom have high irrigation potentials and with investment in suitable pumping equipment could lead to improved agricultural incomes

MIDDLE & LOWER LAO PROJECTS (BAN KOUM – THAKHO)

The three projects in the middle and lower Lao clusters would directly affect small populations (in the order of a few thousand). The major direct impact would be resettlement of people living within the reservoir zone of the Ban Koum and Lat Sua project. Ban Koum is estimated to directly affect 0.6% of district populations. Communities are almost entirely of Lao and Thai-Lao ethnicity.

The three projects would have some of the largest indirect impacts on the Mekong social system, affecting almost 1million people between them:

- **Livelihoods would be adversely affected by reduced connectivity. There is also the real risk of daily fluctuations in water levels which would make it increasingly difficult for small craft to navigate safely.** Transportation is a vital component to community livelihoods within Zone 3, many small craft

owners earn their living from navigating within national river systems, as well as across the Mekong itself.

- **Permanent and seasonal loss of riverbank gardens due to increased flow regimes with associated impacts on livelihoods.** Riverbank land in this Zone is highly productive and intensively cultivated. Riparian land in this Zone is among the most expensive and productive in both Thailand and Lao PDR and it would be difficult to find comparable relocation sites for affected households. The two dams would acquire 1,667.6 ha of agricultural land, of which 332 ha is irrigated.
- **No significant impacts are expected on cultural or historic sites in Zone 3**, though riverside temples and sacred trees are at risk from increased erosion
- **Increased safety risks for towns & communities up and downstream - The population at risk in Pakse is 76,368, with a population density of 611 persons per square km:** the Ban Koum and Lat Sua sites mark the transition zone to the floodplain areas of Siphandone. Backwaters from Lat Sua in event of failure of floodgate opening could result in flooding in Pakse with consequent loss of life, property and assets. The extent and rapidity with which gates may be opened at Ban Koum would also affect both livelihoods and safety in Pakse.
- **Elevated groundwater levels – benefits domestic water supply, risks water logging & increased vector disease (Zone 3 & Zone 4)**
- **Loss in capture fisheries would have a severe impact on local livelihoods** given the high dependence on commercial and subsistence fisheries in this zone.

For all Lao projects, the relocation of valley communities to upland areas would have complex synergistic effects on both food security and disaster threats. Experience in the Lancang catchment has shown that the customary lifestyles of ethnic minority communities has seen relocated groups move further up-hill slopes rather than sever their attachment with customary lands and livelihoods methods. Subsequent clearing of steeper hill-slopes has lead to increased erosion and greater risks of landslides. These migration trends have been observed in China and are expected for northern Lao PDR. This is more likely if developers opt for a cash compensation approach to resettlement.

CAMBODIAN PROJECTS (STUNG TRENG & SAMBOR)

Stung Treng and Sambor would create a situation of extreme crisis for the populations of affected provinces, and could provoke an emergency food security situation for the poor. These two dams have the highest potential to seriously worsen the incidence of poverty in Cambodia. All reports on LMB food security acknowledge that rice sufficiency (through cultivating or purchase) is a primary way in which communities define food security.

Stung Treng at 17.5% and Sambor at 13.1% of district populations would have the highest direct impacts on the largest percentage of affected district populations than any of the other 12 dams, with the exception of Pak Beng. Some 30,000 Cambodians would be resettled as a direct consequence of Sambor and Stung Treng dams. This is particularly worrying for Cambodia, as these two dams would have a proportionately higher impact on the poor in the two provinces of Stung Treng and Kratie, both of which have the highest poverty rates in the country at 46% each.

More than 1million fisheries-dependent people could lose their livelihoods, including in the Tonle Sap where an estimated 14% of surveyed households defined their main occupation as fishing, but where the vast majority of its population derives secondary or associated livelihoods, as well as subsistence, from fisheries.

- **Fisheries losses would disproportionately affect the poor**: poor households have a higher dependence on fisheries than better-off households, with fisheries contributing more than 30% more of poor households' income than of better-off households.
- **Fisheries losses would disproportionately affect minority groups:** the Cham (Muslim Khmer) is almost totally dependent on fisheries for their livelihoods, and as such, have developed a range of

fishery skills and knowledge superior to other ethnic groups. They tend to be semi-nomadic, travelling to Stung Treng with the onset of the rainy season.

Tourism related livelihoods may be adversely affected by losses in some tourism sectors who see the natural beauty of locations as well as interactions with the rare Irrawaddy Dolphin. Tourism is an important livelihood contribution in the Stung Treng Ramsar site as well as at Khone Falls. However, other sectors may see enhanced tourism at dam sites.

14 NAVIGATION

In the LMB navigation is most significant for Zone 2 and Zone 6 of the Mekong River.

14.1 BASELINE

14.1.1 SUBSISTENCE USERS

Local communities continue to use the Mekong River as an important means of transport; linking communities and villages for trade, social and economics means. And for poor rural communities boats provide an affordable and easily accessible means of transport which is environmentally friendly. Small boats carry agricultural products to markets and provide access to schools, health care and other social services. Subsistence users still use the Mekong River from Pak Beng to Pak Chom (Zone 2), Ban Koum and Lat Sua (Zone 3) and Stung Treng and Sambor (Zone 4).

There has been a decline in small and medium users for transport on the Mekong River over the last ten years with the improvement of roads and access to public road transport and private vehicles. However the Mekong River is still an important means of transportation for a large number of riparian communities and riverine population growth coupled with increased agriculture/aquaculture will continue community reliance on river transport.

Without mainstream dams, there are no foreseeable barriers to long-haul connectivity of subsistence users.

The increased water levels expected from tributary and UMB flow regulation may improve will dry season navigability in some reaches, especially in Zone 2.

14.1.2 PASSENGER TRANSPORT

ZONE 2: **An important navigation activity in the Upper Mekong in Lao PDR is passenger transport and cruises.** Passenger transport has always been challenging due to rapids and low water levels, and has been restricted to small slow boats with shallow draught to accommodate the low water levels in the dry season.The Chinese government has recently agreed to provide the Government of Lao PDR (GoL) with 15 million USD to further improve navigation conditions on the river between Houei Say and Luang Prabang.

Cargo operations in Zone 2 has decreased significantly in Lao PDR, due to road construction and companies opting for road instead of using cargo vessels in the dangerous navigation conditions north of Luang Prabang. - The domestic river trade is predominantly agricultural products, consumables and arts and crafts from local communities for sale in Luang Prabang.

Freight transport in other sections of the Upper Mekong in Lao PDR has also gone through a decline in demand and today is characterised by low productivity. The fast growth of mining activities in the Lao PDR on the other hand will, in many cases, solely rely on river transportation to carry large quantities of mining products and raw materials, mainly to P.R. China

Tourism is one of the fastest growing sectors in the Greater Mekong Subregion and river cruises are a growing component of this market. Between 20,000 and 25,000 tourist cruise passengers travel the upper Mekong each year (Zone 1).

ZONE 3: Currently**, downstream of Savanakhet up to the Khone Falls navigation is very limited. The transport of passengers has declined in Flow Zone 3 due to improved roads and the opening of the Second Thai-Lao Friendship Bridge from Mukdahan to Savannakhet in 2006**. Long-haul transport is not expected to be a significant feature in this zone, especially for larger-scale commercial trade because the zone remains 'cut-off' by the Khone falls in the south.

ZONE 4: **The passenger traffic into and out of Stung Treng port has been declining in recent years with no predicted growth in passenger transport over the next 20years**. River cruises are an important and emerging user of thee waterways between Phnom Penh and Kampong Cham and up to Stung Treng with projections of continued growth in this user-group to 2030.

14.1.3 FREIGHT TRANSPORT

ZONE 2: **River regulating works between Jinghong China and Chiang Saen, Thailand has improved the navigability of the Upper Mekong and resulted in increased trade between the two countries**.

- The total volume of the freight traffic between Thailand and Yunnan over the Mekong River increased from zero (2000) to about 260,000 tonnes in the fiscal years of 2006 and 2007.
- **The volume of this trade is expected to increase by 8-11 per cent per year**. The development of the Chiang Saen Port II will provide even further opportunities for economic growth and trade between Thailand and China.

Cargo operations in Zone 2 has decreased significantly in Lao PDR, due to road construction and companies opting for road instead of using cargo vessels in the dangerous navigation conditions north of Luang Prabang.

- **The domestic trade is predominantly agricultural products, consumables and arts and crafts** from local communities for sale in Luang Prabang.
  Freight transport in other sections of the Upper Mekong in Lao PDR has also gone through a decline in demand and today is characterised by low productivity.

ZONE 3: There is a clear trend of limited and declining freight transport due to improved road networks. Increased navigability from the seasonal regulatioN of flows expected by 2030 may re-invigorate plans for the development of a Mekong River port network between Vientiane and Savannakhet. However, the Khone Falls will continue to serve as a barrier to long-haul freight transport.

ZONE 4: **Freight transport is expected to show marginal rates of growth over the next 20 years (2-6% p.a.)**. The introduction of domestic cement production industry may see throughput reach 12,000 – 20,000 tonnes/year by 2020 if the river channel can accommodate 200 DWT vessels,

ZONE 5 & 6 (PHNOM PENH – THE SEA): **River and sea ports in the Mekong Delta are one of the most significant trade regions in Viet Nam.** In the Mekong Delta almost 70 per cent of goods; rice, construction materials and consumables are transported by water.

14.2 IMPACTS ASSESSMENT

The LMB mainstream dams would change the way the Mekong River is used for the transportation of goods and people.

The Mekong Delta will remain the most important navigation zone with some of the highest river transport uses and approximately 70% of good transported through its waterways. **The delta is vulnerable and sensitive to projected changes in sediment transport (reductions of ~75%), and likely that there will be a detriment to**

navigation in this area, because of destabilization of river banks, especially near ports, from downcutting and bed erosion.

In the upper reaches, some users (large vessels and tourist cruises) would benefit from the improved navigability provided by more reliable and consistent water depths whilst some others (subsistence users) would suffer from reduced longitudinal and cross-border connectivity for small boats. The construction of mainstream dams for hydropower dams provides an opportunity to improve the navigability of the Mekong River by providing more reliable and consistent water depths that would facilitate larger vessel capacities. The opportunities associated with increased navigability include the passage of 1,000T vessels providing adequate ship locks are incorporated into the design. The number of proposed projects and the size of the ship locks mean that small and medium users would have less freedom of travel up and down the river as they would need to wait for a number of boats before acquiring passage through a ship lock.

14.2.1 CHANGES TO NAVIGABILITY

It is predominantly the Upper Lao cascade of 6 projects which has the potential to improve navigability of the Mekong River:

- The construction of the six mainstream projects between Pak Beng to Pak Chom could provide opportunities for the future development of passenger and freight transport from Vientiane, Lao PDR to Jinghong, China.
- **Improved navigability only results if the full cascade is developed.** If only one or a few of the proposed Hydropower dam are constructed then there would only be partial accessibility and limited improvements to navigability for passenger transport due to shallow clearance in the dry season (Figure 52).
- **Improved navigability depends on the effective and coordinated operation of the projects** - more than just ship-locks.
- **Sediment build up behind the mainstream dams may impact on the navigational channel and the entrance to ship locks.** A large volume of sediment is likely to accumulate along the length of the reservoirs. This would be most pronounced at the reservoir headwaters where large deltaic deposits are expected to form in the medium term. These deposits would reduce the navigability and would likely require expensive periodic dredging to maintain year-round navigation.

The other mainstream projects would have a minor or no impact on improved navigability:

- The construction of the mainstreams dams in Sambor and Stung Treng could provide opportunities for the development of navigation between Khone Falls and Phnom Penh.
- The construction of the mainstream dams in Ban Koum and Lat Sua would provide only limited opportunities for developing navigation.
- **Improved river-cargo transport does not preclude the need for good rail and road connections** and should be considered as part of a wide improvement of transport and port facilities.

14.2.2 CHANGES TO LONGITUDINAL CONNECTIVITY

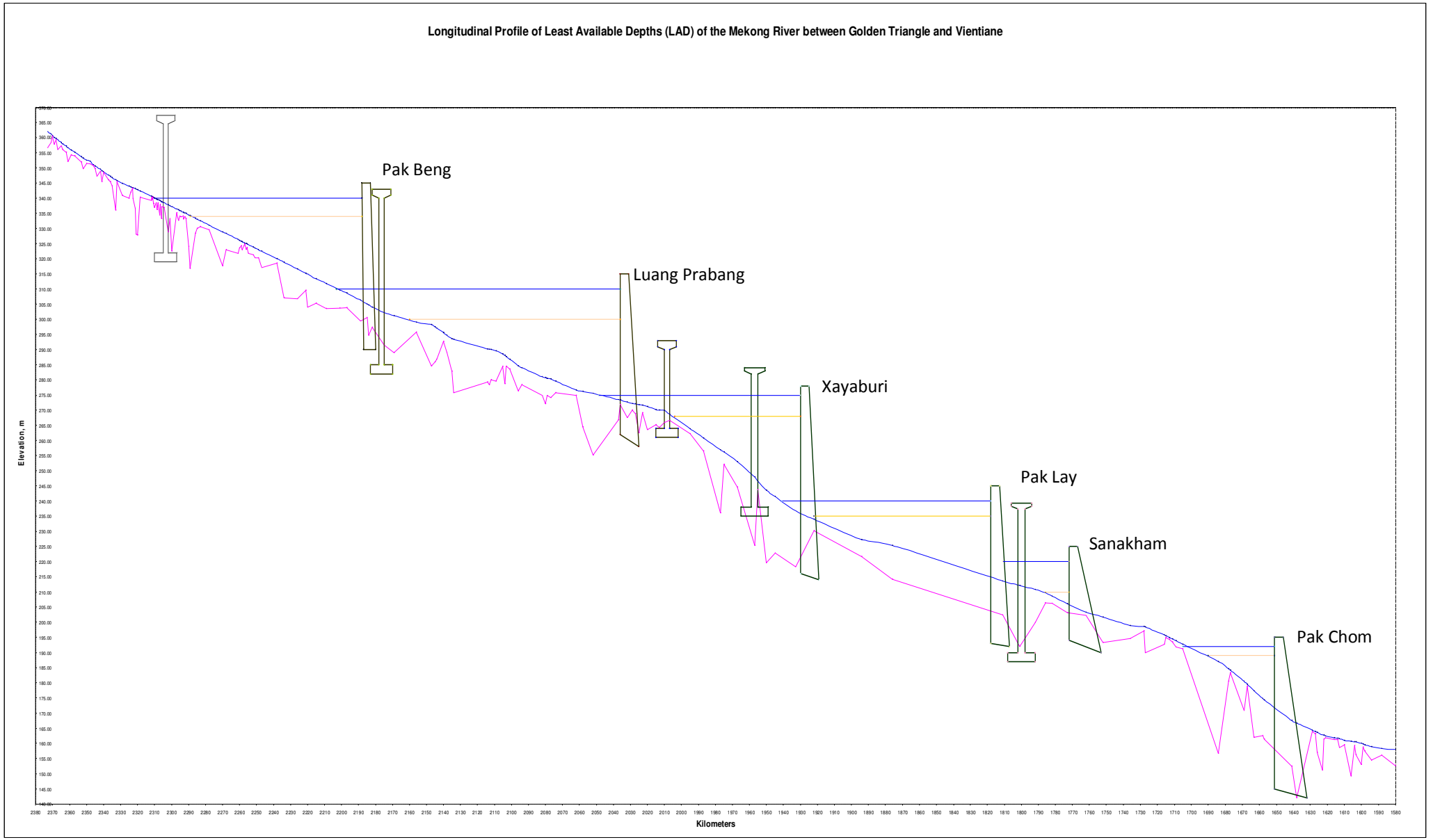
The construction and operation of mainstream dams presents a threat to small and medium scale long-haul and cross-border river transportation on the Mekong River.

- **Decreased connectivity would disproportionately negatively affect small boats and subsistence users of the Mekong River** who may need to wait for the arrival of a large vessel before access through ship locks is made available;
- **Decreased connectivity would be a negative impact of the six mainstream dams between Pak Beng to Pak Chom for passenger transport** if suitable locks are not operational and maintained effectively;
- **Transport for freight, passenger and subsistence users would be impeded during the construction of LMB mainstream dams on the Mekong River;**
- Cost of transport may increase for all users if they are required to pay fees for using ship locks.

14.2.3 CHANGES TO SEA ACCESS & DELTA NAVIGATION

The impacts of the LMB mainstream dams on the transport route between Phnom Penh and the sea remains unclear. Decreased sediment loads would increase bank instability but would also decrease the need for extensive dredging at the mouth of the Mekong River. How the opportunities and risks of these antagonistic forces combine requires more detailed study.

Figure 52: Upper Lao PDR cascade Longitudinal profile of Least Available Depths (LAD) using updated developer operating water levels



15 CLIMATE CHANGE

Climate change adds an additional layer of risk and uncertainty in long term planning potentially with both positive and negative impacts on the development of hydropower in the basin. For hydropower development, the most important predicted changes affect the hydrological regime. All climate change predictions for the Mekong Basin agree that there would be substantial changes to run-off, river discharge and flooding, including by 2050:

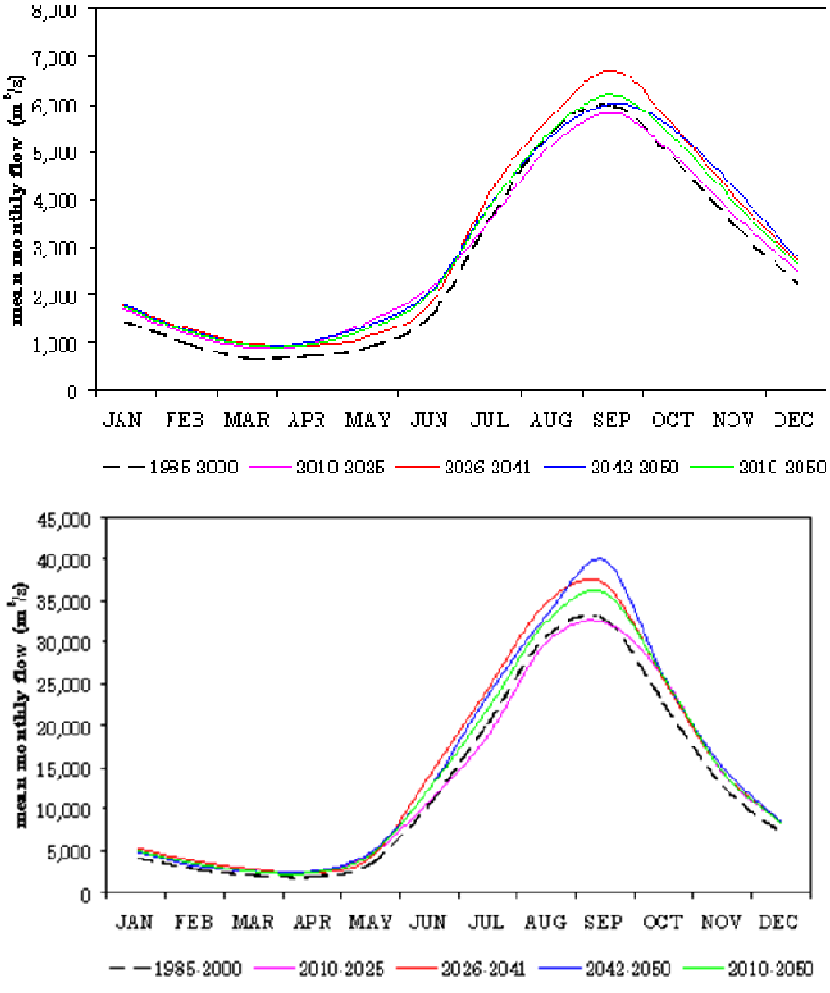
- A range of 15% to 21% increase in the annual run-off varying by sub-catchment,
- A range of 9% to 22% increase in river flow taking in to account the UMB and LMB mainstream and tributary dams,
- An increase in the incidence depth and duration of extreme events coupled with an increase in the overall disparity between wet and dry seasons

15.1 BASELINE

15.1.1 HYDRO-METROLOGICAL TRENDS

CURRENT & PAST TRENDS: **Already, climate changes in the Mekong region are influencing ecosystems, livelihoods and development through changes in regular weather – i.e. daily, seasonal and annual patterns – and through irregular extreme events.** Over the past 3 to 5 decades, trends of increasing mean annual temperature have been recorded in each LMB country. Most notable is the increase in variability from one year to the next. The trends in rainfall are less consistent with increasing variability and extremes between wet and dry in Lao PDR and Cambodia, a decrease in rainfall in Thailand, and decreases in most localities in the north of Viet Nam with increases in most areas of the South during all seasons. All countries have experienced decreasing rainfall during the dry season with aggravated drought and water stress situations in many catchments.

Figure 53: Climate Change impacts on the Mekong River hydrograph compared to Year 2000: *(top) Chiang Saen; (bottom) Kratie*



Future climate to 2030 is projected to include steady increases in mean basin temperature by 0.8°C. Greater increases are expected in northern zones of the basin up to 1.4°C in Yunnan Province. Annual rainfall would increase by 13.5% (0.2m) mainly due to increases during the wet season (May to Oct). Dry season rainfall will increase in northern zones (1 and 2) and decrease in southern zones (3 to 6 – i.e. from Vientiane to the Delta). The overall disparity between wet and dry seasons will increase especially in zones 3 to 6.

- 2030-2039 is projected to have an mean increase in annual flow of ~23% in Zone 2, dropping to an increase of ~15% in zones 3 to 5 (Figure 49)
- The overall average increase against the baseline across the 40 years from 2020 to 2050 is ~10%.

15.1.2 SYNERGISTIC TRENDS

Climate change would see agricultural productivity increase in the basin (around 3.6% by 2030) but food security decrease, despite the increasing areas under irrigation. Those decreases are due to reduced dry season rainfall and runoff in central and southern zones, reduced productivity of rice crops due to an increase in the daily minimum temperature, increasing populations and reduced production in excess of demand and increasing saline intrusion in the Delta due to storm surge and tidal influences and decreases in dry season rainfall and runoff.

Fish biodiversity and stability in fisheries sector production is expected to decrease in the basin despite some climate change benefits of increasing flooded area and nutrient loading. The decreases are due to the complex interplay between decreased agricultural productivity and food security increasing demand and pressure on fish populations, increased riparian populations, reduced fish migration and aquatic biodiversity in zone 1 and in Mekong tributaries due to dam and infrastructure construction, and reduced and disturbed habitat due to a combination of climate change and development. The benefits to productivity of increased nutrients due to increased runoff and erosion with climate change may be offset by reduced sediment due to China and tributary dams, especially in the central highlands of Viet Nam.

The hydropower sector will benefit from the increased flows predicted with climate changes. Increased rainfall, runoff and flow throughout basin would increase hydroelectricity potential in both the tributaries and mainstream.

The hydropower sector will also face an increasingly complex and severe risk profile. Some catchments will experience very high increases in runoff and water volume – possibly beyond the capacity of existing tributary dam schemes – creating risk of failure and need for retrofitting. Increase in extreme wet events and incidence of flood events brings a risk of catastrophic failure (climate change may turn a 1 in 10,000 year flood risk into a more regular event – for example to a 1 in 1,000 flood).

Livelihoods are under increasing stress in the Mekong basin due to pressures on aquatic and terrestrial systems. While there are benefits, overall climate change will increase that stress by increasing the need to make agriculture more productive and extensive and by increasing pressure to exploit aquatic resources. Overall reductions in fish habitat, feeding and nursery areas and increasing water stress in some catchments and the frequency and intensity of drought periods will all have knock-on effects on livelihood activities. Other developments, such as hydropower dams, intensify natural system stress and the negative effects of climate change. Climate changes such as temperature and rainfall increases and increased incidence of flooding will also increase health risks which would reduce labour productivity and increase levels of poverty.

The expansion of reservoir storage in the Mekong Basin provides the technical capacity for drought relief – significant improvements in institutional capacity and regulatory effectiveness are required if this is to be realised. With between 40 and 70 storage projects planned for the LMB tributaries and 8 storage projects on the Lancang River by 2030, the Mekong hydropower sector will have the capacity to store more than 69,000mcm or in the order of 14% of mean annual flow. This provides the technical capacity to mitigate the impacts of drought years on water users, however, in practice there is minimal realisation of multi-use reservoir operation in the LMB. Experience in Viet Nam and Yunnan province has demonstrated little relief during drought for other water users as hydropower operators prioritise their electricity generating potential over other considerations. Changes to the regulatory framework of watershed management would be required if drought relief from storage hydropower is to be realised.

15.2 IMPACTS ASSESSMENT

15.2.1 CHANGES TO EXTREME EVENTS

Extreme events like a 1 in 10,000 flood event would occur more frequently with climate change during an estimated 100 year project life. The predicted increases in river discharge due to climate change and the polarisation of the wet and dry season would alter the frequency of extreme events. Events that are predicted to occur once in 10,000 years are likely to occur once in 1,000 years, whilst the one in 1,000 year event is predicted to occur once in 100 years (Table 26).

Table 26: comparison of changes to the magnitude of extreme events for the same return period over an estimated project life of 100 years: *1 in 10,000 year events would become 1 in 1,000 year events with climate change*

	EXTREME VALUE DISTRIBUTION				EXTREME VALUE DISTRIBUTION			
	Historic Return period flow (EV dist)				Project 2030 Return period flow (EV dist) with CC			
Station	*10yr*	*100yr*	*1,000*	***10,000***	*10yr*	*100yr*	***1,000yr***	*10,000*
Chiang Saen	12,252	14,551	16,808	19,061	13,209	15,769	18,282	20,790
Luang Prabang	17,137	19,912	22,637	25,357	18,783	22,362	25,876	29,384
Vientiane	18,670	21,285	23,852	26,414	19,692	22,745	25,742	28,734
Pakse	40,842	45,344	49,765	54,177	43,459	49,149	54,734	60,311
Kratie	56,254	62,934	69,493	76,040	59,000	66,886	74,629	82,358

Climate change would increase the occurrence of extreme events during the life of the mainstream projects, including those which represent the threshold of safety design. Over a 100 year project life:

- A dam designed for a ***1 in 10,000 year event*** would see the probability of this event occurring over the design life increase from 1% to 10%.
- A component designed for a ***1 in 1,000 year*** event would see the probability of this event occurring over the design life increase from 10% to 63%
- Each dam is almost certain to experience a 1 in 100 yr event with climate change.

The increased likelihood of extreme events with climate change would increase the risk of failure for dams and their key hydraulic components. The magnitude of flows associated with extreme events on the Mekong River is enormous and failure during an extreme event could result in unprecedented fluctuations in downstream flows and water levels with catastrophic consequences for downstream communities. Many of the important cities of the Mekong could be at risk in the case of failure, including Vientiane, Pakse, Luang Prabang as well as Pak Lay, Stung Treng, Kratie, and Kampong Cham.

15.2.2 CHANGES TO RUNOFF, FLOW & FLOODING

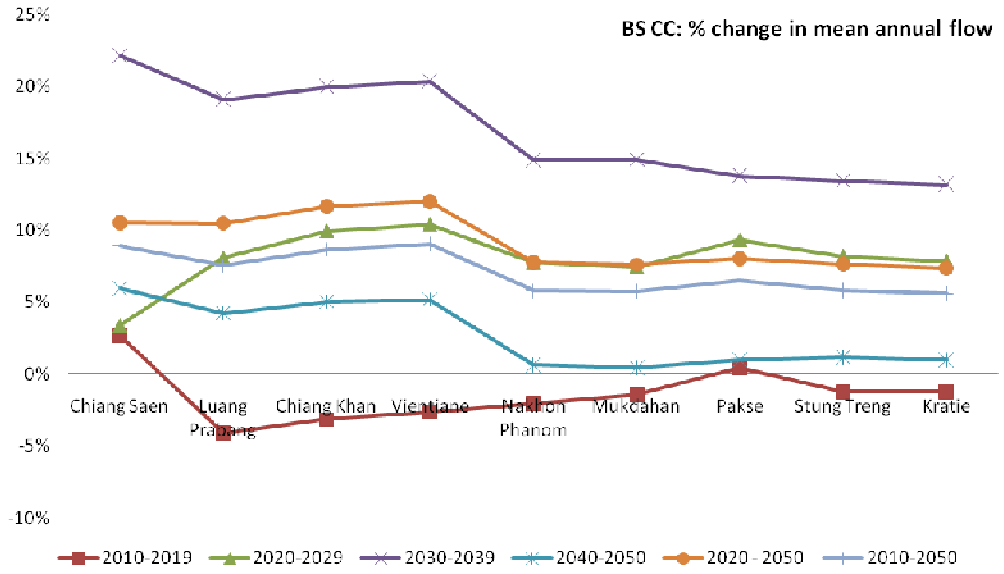
Climate change would increase the impacts of flooding, with a 12-82% change in depth in the floodplain for A2 and a 22% increase in flood duration. There would be an increase in areas in the Delta affected by saline intrusion in the range 249 to 1,882 km^2 or a 1.4% (B2) to 10.5% (A2) increase. Figure 54 shows that:

- 2030-2039 is projected to have an mean increase in annual flow of ~23% in Zone 2, dropping to an increase of ~15% in zones 3 to 5
- The overall average increase against the baseline across the 40 years from 2020 to 2050 is ~10%.

The expected increase in run-off in most catchments increases the electricity generation potential of planned tributary and mainstream projects. Climate change and hydropower development are antagonistic forces on the hydrological regime of the Mekong River, with hydropower regulating seasonal flow and climate change increasing the annual averages as well as increasing the disparity between seasonal flows.

With design modifications tributary projects could harness the additional energy potential and improve their capacity to meet regional and national energy demands. The expected increase in run-off would also increase the electricity generation potential of the mainstream projects provided they are designed to harness it.

Figure 54: Percentage change in mean annual flow due to climate change against the BDP baseline (1986-2000)



15.2.3 SYNERGISTIC IMPACTS ON FOOD SECURITY

Climate change would exacerbate food security issues arising from hydropower development. Food security is one of the critical issues for development of the Mekong Basin. 80% of the basin population relies on natural resources for their livelihoods and the losses in the capture fishery, the loss in agricultural area and river bank gardens and the loss in nutrient supply to the Cambodian, Mekong delta and coastal environments expected from the mainstream dams would increase the insecurity of food availability in the basin. Climate change is projected to exacerbate those impacts in a number of significant ways:

- **Reduced yield of rice and other crops in the Mekong Basin** due to the increases in the minimum daily temperature and the reduction in rainfall during the dry season in some sub- basins. Also, increased runoff during the wet has potential to increase top soil erosion.
- **Increase the water demand of dry season crops.** This would require improved seasonal management of water resources to sustain the same productivity.
- **Increase the seasonal irregularity of water availability**. Extreme events like droughts and floods would become more frequent with climate change

15.2.4 GHG EMISSIONS

The 11 LMB mainstream reservoirs have the potential to reduce the emissions of the regional power sector. Analysis of the emissions avoided by 2030 if 65,000 GWh of power is produced by the mainstream dams including estimates of reservoir emissions indicate that in the order of 50 million tonnes CO2/ yr could be avoided by the mainstream dams. This is equivalent to 15million tonnes of coal-fired generation per annum.

16 NATIONAL WORKING GROUP IMPACT ASSESSMENTS

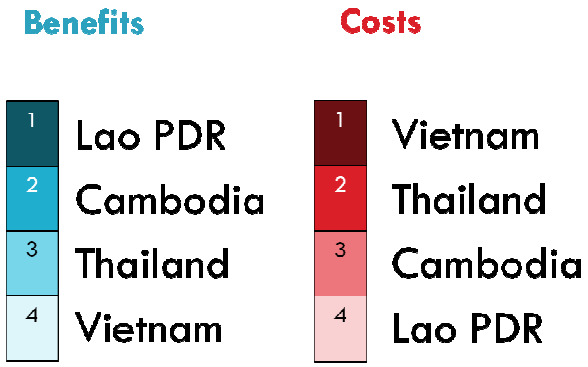
During the regional impact assessment workshop, national groups of government, NGO and academic experts conducted a series of impact assessment working sessions based on the information and analysis from the SEA and their discussions. The national groups were asked to colour-code and score according to the impact of the mainstream dams on each of the three key issue under the 8 themes in response to the question – "Will the mainstream projects affect the trends in each of the key issues during construction or operation?" (Table 27 provides an example of the matrix for the fisheries theme – similar matrices were completed for each of the eight themes) If the response was "Yes", they used the sustainability objective statements for each theme (distilled from government policies during the national workshops) as a guide in responding to the question - "Will those affects provide benefits and/or costs?" The groups then colour coded and scored the impact in a matrix and gave reasons for each score.

Table 27: Impact assessment key issue scoring matrix

Level of impact	Score/ colour	Theme/key issue *(example)*		Sustainability objective
1. Large negative impact		Theme: Fisheries		Maintenance & enhancement of diversity & productivity of fish resources
2. Negative impact				
3. No impact		issues	Score	Comments & reasons for score
4. positive impact		1. changes in migrations		
5. large positive impact		2. changes in diversity		
6. both positive & negative impacts		3. changes in fish production		
7. not relevant				

The results of the session are synthesised in Figure 55 and Table 28. In summary, the national expert groups perceived that Lao PDR and Cambodia would benefit most from the mainstream projects and Thailand and Viet Nam least, even though recognizing that power demand in the latter countries was the driving force for mainstream project feasibility.

Figure 55: Working group national rankings of risks and opportunities



The detailed scoring of impact against the strategic themes and issues of concern to the development and maintenance of the Mekong River is summarised in Table 25. The Viet Nam group concluded that only 7% of trends in key issues would be positively affected. The Lao group on the other hand concluded that there would be a large positive impact on 26% of key issues and another 22% would be both positively and negatively affected.

Conversely, the Viet Nam and Thai national groups perceived that their countries would suffer the greatest negative impacts relative to benefits from mainstream development, with the Lao group considering that their country would have least negative effects relative to benefits (Figure 51). The Viet Nam and Thai groups concluded that 67% and 52% of trends in key issues would be affected negatively by the mainstream projects respectively; with Thailand have the highest number of key issues with large negative impacts. Interestingly, the Cambodian group concluded that 70% of trends in key issues would be affected negatively, but also gave "large positive impact" scores to more issues (19%) than Thailand and Viet Nam.

All groups recognised that benefits would be focused on power & economic themes while risks would focus on natural & social systems, particularly fisheries and hydrology & sediment. All groups were concerned over potential for increased poverty from mainstream development despite recognition of high returns from power sales. The Lao group placed highest significance on the power benefit, while the Viet Nam and Thai groups gave the least significance to this benefit – even though they would consume most of the power.

Table 28: Results of national workshop group assessment of impact significance by key issue

THEME	ISSUE	LAO PDR	CAMBODIA	THAILAND	VIET NAM
Hydrology and sediment	Changes in patterns of maximum water levels, rates of rise and predictability				
	Changes in sediment transport and deposition				
	Changes in nutrient transport				
Terrestrial ecosystems and agriculture	Habitat loss and degradation				
	Changes in Land use				
	Changes in irrigated agriculture				
	Changes in River bank gardens				
Aquatic ecosystems	Change in productivity of aquatic habitats				
	Changes in populations of rare and endangered species				
	Changes in water quality				
Fisheries	Changes in long distance migration				
	Changes in fish species biodiversity				
	Changes in fish production				
Social systems	Changes in poverty and natural resource based livelihoods				
	Changes in health and nutrition				
	Social effects of resettlement, land acquisition and loss of access				
	Changes in cultural values and patterns				
Economics	Contributions to national economy - Export earning				
	Contributions to national economy - Foreign Direct Investment				
	Contributions to local economies (district and community level				
Energy and Power	Achieving energy security				
	Meeting national energy demands				
	Meeting local energy needs				
Climate change	Relative emissions of green-house Gas				
	Direct impacts of climate change on hydropower projects - extreme events & dam security				
	Combined effect of climate change and mainstream dams on food security				

Large negative | Negative | No impact | Positive | Large Positive | Not relevant

17 SUMMARY OF IMPACT SIGNIFICANCE & MITIGATION POTENTIAL

The SEA team used those results of the national group sessions as an input to a more comprehensive impact assessment excise over several days which, for each key issue, assessed the degree of confidence that an impact would occur, the significance of that impact and then the potential for the impact to be avoided, mitigated and enhanced (Table 29). It is possible to introduce avoidance, mitigation and enhancement measures at each stage of mainstream project planning and implementation with the chances of success varying according to capacities, resources and the nature of the impact.

The following definitions were adopted by the team to clarify the distinction between avoidance, mitigation and enhancement in the SEA.

- **AVOIDANCE** means the complete avoidance of one or more possible adverse impacts arising from one or more proposed LMB mainstream schemes.
- **MITIGATION** means the reduction in the intensity or coverage of an impact if one or more projects go ahead.
- **ENHANCEMENT** means improving the benefits derived from one or more of the mainstream projects by improving, for example, development effectiveness, management of risk, regional and local distribution of benefits.

Table 29 provided the framework for the final stage of the SEA in which the team drew conclusions and made avoidance, mitigation and enhancement recommendations.

Table 29: Summary of impact significance and mitigation potential against key issues

Confidence in the occurrence/significance of impacts

● **High**
● **Medium**
○ **low**

Potential for feasible and effective avoidance, mitigation & enhancement measures

☒ **No potential**
☑ **Potential**
☑ **High potential**

	ISSUE	IMPACT Description	Confidence of occurrence	Significance of impact	FEASIBLE POTENTIAL FOR EFFECTIVE… Avoidance	Mitigation	Enhancement
POWER SYSTEMS	***Achieving energy security***						
		Diversification of energy sources	●	◌	-	-	☑
		Increased regional cooperation in the power sector	●	●	-	-	☑
	Meeting national energy demand						
		Contribution to Importing country power demand	●	○	-	-	☑
		Contributing to Host country power demand & access	●	◌	-	-	☑
	Meeting local energy needs						
		Host districts & provinces power demand & access	●	◌	-	-	☑
ECONOMIC SYSTEM	***Contributions to national & local economies***						
	Stimulus effects	Export earnings for host countries	●	◌	-	-	☑
		FDI (Foreign Direct Investment) for host countries	●	◌	-	-	☑
		Increased macro economic (GDP) growth due to booming HP sector and increased government revenues and spending	●	●	☒	☒	☑
	Debt sustainability	Increased short term costs in debt service	◌	◌	☒	☑	☒
	Sector impacts	Lower growth/contraction of natural resource sectors (i.e. fisheries, agriculture)	●	●	☒	☑	☑
		Industrial growth (including mining sector)	○	●	☑	-	☑
		Loss of river –based tourism	●	◌	☒	☑	-
		Increase in reservoir tourism	○	○	-	-	☑
		Shift in local economic base of affected directly & indirectly affected communities	●	●	☒	☑	-
	Poor & marginalised	Increased poverty and loss of livelihoods-base for rural poor	●	●	☒	☑	-
		Rising food prices affecting urban poor	○	●	☒	☑	-
	Civic infrastructure	Damage/loss of fixed assets (local irrigation infrastructure, rendering inappropriate of transport & fishing vessel)	●	○	☒	☑	-
		Development of new infrastructure(large-scale irrigation, roads, bridges)	●	○	-	-	☑
HYDROLOGY & SEDIMENT	***Changes in patterns of maximum water levels, rates of rise and predictability***						
	Reservoir permanent inundation	Extreme elevation of water levels for large stretches of river and the conversion of the system from a wild river to a series of impoundments interspersed with free-flowing reaches	●	●	☑	☑	☒
	Large hourly water surface level changes	Associated with peak power production, water levels could vary by 4-6m and could travel 100-200km downstream in a matter of 1-3hours	●	●	☑	☑	-
	Unexpected rapid changes in turbine flow	breakdowns, transmission line failure/ un-expected load shedding & load resumption	●	●	☒	☑	-
	Catastrophic flood releases	from mismanagement of flood gates, or extreme events	◌	●	☒	☑	-
	Upstream irrigation infrastructure	Upstream: increased water levels will reduce pumping heads for irrigation projects within reservoir areas	●	◌	☒	-	☑
	floodplain inundation (extent & duration)	Predictable changes in extent & duration of flooding, but small in comparison to impact from other dams in the 20Y scenario. The most significant impacts will be in Zone 2&3 flooded areas, which will become permanently inundated	●	○	☑	☒	☒
	Water surface level changes in the Tonle Sap system	Predictable changes in Tonle Sap water levels, but small in comparison to impact from other dams in the 20Y scenario	●	○	☒	☒	☒
	Saline intrusion in the Mekong Delta	variation of water quality at irrigation intakes from hour to hour during low season resulting from fluctuating discharges from Sambor	○	○	☑	☒	-
	Changes in sediment transport and deposition						
	Dissipation of stream power	Hydropower project will concentrate stream power dissipation at the turbines/dams with Very large electrical energy production	●	●	☒	☒	-
		Major loss of downstream bed load transport	●	●	☒	☒	-
	Downstream	Downstream: Changes in WLs and sedimentation patterns would: (i)	●	◌	☒	☑	-

	irrigation infrastructure	render the pump intakes inoperable (drown out and silt up) , (ii) reduce efficiencies of gravity colmatages designed to transport wet season floodwaters					
	Reservoir sedimentation	Enhanced deposition at tail waters of reservoirs (near dam wall)	●	●	☒	☒	-
		Nett accumulation of medium/coarse sediments at the headwater reaches of reservoirs (in flow end) with loss of navigability	●	●	☒	☑	-
	Downstream channel stability	Downstream of dams the river bed will be depleted of medium/coarse sediments causing erosion	●	●	☒	☑	-
	International border	Loss of definition of the thalweg from net accumulation of medium/coarse sediments at headwater reaches of reservoir	●	●	☒	☑	-
	Deep pools	Loss of deep pool river features in specific locations	●	●	☒	☒	-
	Coastal erosion/accretion	Future erosion of coast line and delta channels from change s to geomorphic stability of the delta (inc. loss of mangrove habitat)	●	●	☒	☑	-
	Changes in nutrient transport						
	Floodplain fertilisation	Loss of annual silt/nutrient deposition on the flood plain	●	●	☒	☑	-
	Tonle sap & flooded forest nutrient loading	Loss of annual silt/nutrient deposition entering the Tonle Sap system; fisheries and flood forest	●	●	☒	☒	-
	Coastal zone nutrient loading	Loss of nutrients in the delta outflows and supply nutrient supply to marine fishery	●	●	☒	☒	-
TERESTRIAL SYSTEMS	***Habitat loss and degradation***						
	Terrestrial biodiversity and protected areas	Changes in Key Biodiversity Areas associated with the Mekong River	●	●	☒	☑	-
	Ramsar sites associated with the Mekong	Changes in Protected Areas and Ramsar sites associated with the Mekong	●	●	☒	☑	-
	Terrestrial species diversity	Impacts upon river dependent birds	●	●	☒	☑	-
	Changes in Land use						
	Wetlands	Loss/changes in wetlands due to inundation	●	●	☑	☑	-
	Forest cover	Loss of forest cover through inundation and transmission lines	●	○	☒	☑	☑
	Changes in irrigated agriculture						
	Agricultural land	Loss of agricultural land	●	○	☒	☑	☑
	Irrigation effectiveness	Losses and gains in irrigated agriculture (c.f. hydrology matrix)	●	●	☒	☑	☑
	Changes in River bank gardens						
	Subsistence farming	Loss of river bank gardens and source of livelihood	●	●	☒	☑	-
AQUATIC SYSTEMS	***Change in productivity of aquatic habitats***						
	Habitat diversity	Loss of habitat diversity (zones 2,3 & 4)	●	●	☒	☑	-
	Habitat area	Conversion of river to reservoir	●	●	☒	☑	-
	Primary productivity	Reduction of primary productivity due to loss of wetlands & reduced nutrient loading	●	●	☒	☑	-
	Fish catch	Loss in fish production (c.f. fisheries matrix)	●	●	☒	☑	-
	Changes in populations of rare and endangered species						
	Fish species	Loss of fish species that cannot survive under reservoir conditions	●	●	☒	☑	-
		Increase of species that can survive and thrive in reservoir conditions	●	○	-	-	☑
	Rare, endangered & charismatic species	Loss of Irrawaddy Dolphin and other endangered species	●	●	☒	☒	-
	Upland – sea longitudinal connectivity	Disruption of upstream and downstream movement of fish between zones and the sea	●	●	☒	☒	-
	Changes in water quality						
	Construction impacts	Contamination of river, fish kills, reduced ecosystem health	●	●	☒	☑	-
		High turbidity of river water, with impacts on ecosystem health and water supplies	●	●	☒	☑	-
	Nutrient loading	Loss of nutrients on fine sediments, reduced fertility of river and floodplain (c.f. hydrology matrix)	●	●	☒	☒	-
FISHERIES	***Changes in long distance migration***						
	Upstream of Vientiane	Reduced connectivity & loss of spawning habitats affecting reproductive cycle of fish and some migrations (e.g. Giant Mekong Catfish)	●	○	☒	☑	-
	Vientiane-Pakse	Loss of important fish migration corridor upstream of Khone falls and the loss of aquatic habitat	●	●	☒	☒	-
	Downstream of Pakse	Loss of the main fish migration corridor	●	●	☒	☒	-

SOCIAL SYSTEMS	**Changes in fish species biodiversity**						
	Fish species	Loss of fish species. At least 41known species specifically at risk upstream of Vientiane. Further downstream specific risk on biodiversity could not be quantified	●	○	☒	☒	-
	Changes in fish production						
	Upstream of Vientiane	losses in capture fisheries: 130,000 to 270,000 tonnes	○	○	☒	☒	☑
	Vientiane-Pakse	losses in capture fisheries: 210,000 to 420,000 tonnes	●	●	☒	☒	☑
	Downstream of Pakse	losses in capture fisheries: 220,000 to 440,000 tonnes	●	●	☒	☒	☑
	Changes in poverty and natural resource based livelihoods						
	Poor households	Disproportionate impact on poor households	●	●	☒	☑	☑
	Distribution of natural resource benefits	No impact equity (e.g. those losing cultivable land are not those benefiting from irrigation opportunities	●	●	☒	☑	-
		High proportion of downstream communities permanently losing natural-resource based livelihoods (particularly fishers)	●	●	☒	☑	-
		Cumulative impacts in Viet Nam of lost agricultural productivity, increased agricultural costs, reduced fish production	○	●	-	☑	-
	Multiple relocation	Steep land erosion impacting re-settled communities in upper cascade resulting in additional relocation	○	○	☑	☑	-
	Changes in health and nutrition						
	Incidence of disease	Increased incidence of vector disease	●	●	☑	☑	-
		STD/HIV/AIDs transmission from external labour force	○	○	☑	☑	-
	Protein source & nutrition	Reduction in primary protein source	●	●	☒	☑	-
		Increased stunting & wasting due to loss of natural resource base & multiple disruption of subsistence activities (particularly among ethnic minorities and upper areas of the Mekong)	●	●	☒	☑	-
	Loss of life	Risk of loss of life, property & assets among riparian communities due to poorly managed water releases or dam failure	○	●	☒	☑	-
	Social effects of resettlement, land acquisition and loss of access						
	Assets	Loss of homes, assets, agricultural land, riverbank gardens, forest lands, common-use lands	●	●	☑	☑	-
		Loss of community resources & sites of cultural/historical interest	●	●	☑	☒	-
		Multiple relocations	○	●	☑	☑	-
	Income generating activities	Loss of tans-Mekong River access & navigation based livelihoods for small crafts	●	●	☒	☑	-
		Loss of access to subsistence income (e.g. fishery)	●	●	☒	☑	-
	Cultural assets						
	Cultural heritage	Changes and reduced relevance of river based festivals (e.g. Giant Mekong Catfish festival)	○	○	☒	☑	-
		Loss of ways of life leading to erosion of cultural identities	●	●	☑	☑	-
	Tourism & cultural assets	Severely disrupted river based tourism during construction	●	●	☑	☑	-
		Changes in river-based tourism attractions	●	●	☒	☑	☑
CLIMATE CHANGE	**Green House Gas emissions**						
	Climate change mitigation	Reduction in CO2 emissions from offset fossil fuels	●	●	-	☒	☑
		Increased CO2 emission from reservoirs	●	◯	-	☑	-
	Direct impacts of climate change on hydropower projects – extreme events & dam security						
	Increased run-off & flow	Increased hydropower potential for mainstream & tributary projects	○	●	-	-	☑
		Increased likelihood of extreme events, breach of dam design specifications and failure	○	●	☒	☑	-
	Combined effect of climate change & LMB mainstream dams on food security						
		Reduced food security & constraints to poverty reduction	○	●	☒	☑	-
		Loss of biodiversity & changes to water quality	○	●	☒	☑	-
NAVIGATION	**Longitudinal connectivity**						
	Subsistence & small vessel use	Dams will impede the movement of small vessels across dam structures	●	●	☒	☒	-
	Med-large scale transport	Dams will impede the movement of med/large scale passenger & cargo transport across dam structures	○	○	☒	☑	-
	Freedom of navigation	operation of mainstream hydropower dams will impede Freedom of Navigation, Article 9 of the MRC 1995 Agreement if suitable ship locks are not operational and maintained effectively	●	●	☒	☑	-
	Navigability						
	All users	Increased navigability upstream of Vientiane due to increased water levels	○	●	-	-	☑
		Reduced navigability Stung Treng to the Coast due to channel instability	○	○	☒	☑	-

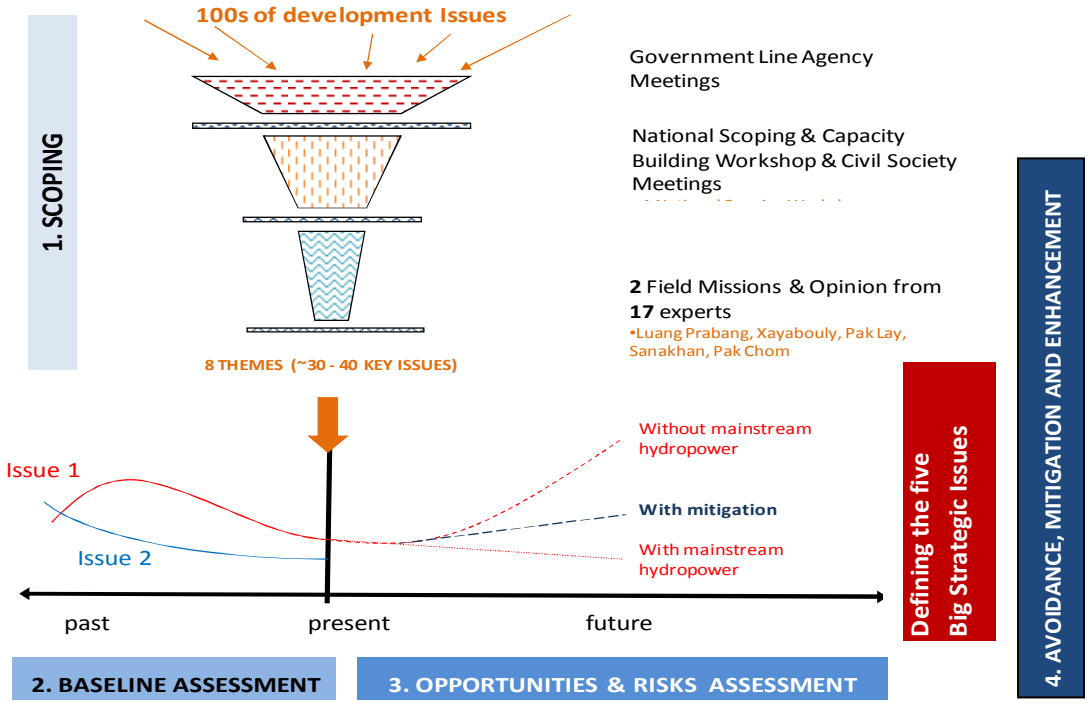
18 THE BIG STRATEGIC ISSUES

The national group impact assessment results and the a priority setting exercise by the team immediately following the regional impact assessment workshop in Vientiane led to the consolidation of themes and key issues into a set of "Big Strategic Issues". The purpose of an SEA is to progressively sharpen the strategic focus of decision making on the most important issues. This SEA led to the definition of five "Big Strategic Issues". Those five provide the framework for presenting the SEA team's findings and conclusions. They are:

- Power generation
  - Revenue generation (including trade and foreign investment)
  - Power security
- Economic development and poverty alleviation
- Ecosystems integrity and diversity (including aquatic, terrestrial, hydrological dynamics and sediment/nutrient transport).
- Fisheries and food security (including agriculture)
- Social systems - livelihoods and living cultures of affected communities

The entire SEA process starting with the many development concerns and working towards defining the key issues and main strategic concerns is illustrated in Figure 56:

Figure 56: SEA process leading to defining of Big Strategic Issues



PART IV: CONCLUSIONS AND RECOMMENDATIONS

Part IV of the SEA synthesis report presents the main conclusions and recommendations arising from the SEA process - from the assessment and consultation at each stage, especially from the final regional workshop on avoidance, mitigation and enhancement. The part is arranged so that the conclusions and main strategic options are considered first, and then the recommended course of action. The rationale for the favoured option is presented, together with the implications if LMB countries chose to select another option. Detailed recommendations follow for needed studies and improvements in policy, institutional arrangements and capacity building, in hydropower and design and mitigation measures, and in environmental and social safeguards. Many of the recommendations are aimed at a regional level – for the MRC in particular – others are proposed for each country

19 CONCLUSIONS

19.1 UNCERTAINTIES ON STRATEGIC CONCERNS

Uncertainties remain relating to strategic concerns and risks – and to the nature, extent and distribution of benefits. The SEA analysis and consultation found remaining uncertainties relating to many of the main strategic issues of concern. Uncertainty remains on levels of risks and of benefits; on whether or not they can be avoided, mitigated or enhanced; on the feasibility of institutional and management responses, and even on some of the basic assumptions relating to the need for the projects and to their alternatives. This section explores some of the strategic issues and questions on which uncertainties persist when considering the mainstream projects proposals.

"*Do river managers know enough about the nature and extent of potential impacts of the proposed projects to make a responsible and informed decision?*"- i.e. is enough known for decision makers to say with assurance that:

1. the benefits outweigh the costs,
2. the benefits can be equitably distributed,
3. most impacts can be offset or compensated, and
4. conditions set for project development can be enforced.

The SEA has found that information gaps remain on issues critical to making responsible judgements on those matters.

"Are the potential social and environmental effects understood?" Uncertainties relating to social and environmental effects remain – with important economic and equity implications. For example, the Mekong River supports the world's largest inland fishery. The direct impacts of mainstream dams on the sector would be substantial – but the system is complex and experts don't have sufficient information to agree on the details. The combined effects on food security of mainstream dams and climate change within project lifetimes could be extreme in some sub-basins – but adequate work has not been done to arrive at clear trends and ranges in effects. Reduced sediment and nutrients entering the Delta would have significant effects on

agriculture, aquaculture and on marine and fresh water capture fisheries – but the experts do not yet have the details. Around 60% of mainstream wetlands would be permanently lost but the added implications for overall river productivity, for food and for species is not understood. Project impacts would affect the poor most directly and immediately, and that the experience in the region with adjustment programs and long term supports has not been good, especially in cases when rivers cross administrative boundaries. But there is no certainty that the institutional capacities and arrangements, enduring program commitments and resources would be in place to make the difference in this case.

"*Are there alternative ways of harnessing the mainstream power without placing dams across the Mekong River and without losing any of its other uses and values?*" The answer appears to be "yes" - but most likely at much less profit and power output – and generally not as attractive to private developers, investors or host governments looking to generate foreign exchange earnings. Alternatives may be unproven and not produce an equivalent amount of energy, but they may be more ecologically and socially benign. Those alternatives have not been reviewed nor has the feasibility of their application at various locations on the river been explored.

"*What would the revenue streams be?"* and *"Who benefits financially from them?"* The annual gross revenue flow from all mainstream proposals has been estimated to be in the range of USD 3.3 to 3.7 billion. Based on experience with other major hydropower projects in the Mekong region, especially Nam Theun II, it is estimated that 25-31% of the total revenue stream would accrue to the governments in Cambodia and Lao PDR during the 25 year concession period– depending on how the financing package for each project was structured.[64] However, it is uncertain to what extent those revenues can or will be used to improve the lot of populations adversely affected populations, especially in the case of trans-boundary impacts. Benefit-sharing mechanisms have been mooted but these would require significant capacity and institutional development, the effectiveness of which is uncertain.

Another set of uncertainties concern net financial and economic benefits over time – funds come on tap at various times and in various proportions over the life of a project – and with varying uncertainties associated with them. Figure 57, based on Sambor[65], illustrates that temporal variation in flow and uncertainty of costs and benefits for the host country (in the case Cambodia). During the construction period (2021 – 2028), there would be a surge in economic benefits to the host economy due to investment stimulus. However, costs would also gradually rise over the construction period. With increasing costs incurred for land acquisition and resettlement, and substantial social and environmental losses as the inundation area is flooded. Once operations start the revenues generated would go to repaying the financing, typically over a ten year period. For the remaining period of the concession revenues would be divided into dividends (paid to shareholders – generally including the host government), taxation (paid to government) and payments for water rights, which is usually a unit charge on water resources. Initially government revenues would be a relatively small proportion of the gross revenue. Only after handover would the full revenues generated go to the government as the owner of the facility, even then there is real uncertainty as to the returns which could be expected. PPAs may need to be renegotiated and while energy prices may well be higher, some facilities may have limited export options giving the importing country considerable negotiating power in determining the tariff they are prepared to pay.[66]

The underlying strategic question facing LMB countries is "*What kind of development is appropriate for the Mekong River in the 21st Century?*" Inevitably, placing large structures across the full width of a river – whether run of the river or storage facilities – is disruptive to natural and social systems. They produce large quantities of power, but at a loss to river connectivity with all this implies. The goal of development in the 21st Century as reflected in global, regional and national policy frameworks is to develop alternatives which keep options and functions open for future generations. It is to change the quality of development in a way which avoids damage and permanent losses, and to safeguard those areas and assets which society wishes to keep for their existing social, environmental and economic values. The absence of an integrated plan for the entire Mekong River means that the mainstream projects are being considered in a context of more general uncertainty, outside an adequate strategic sustainable development framework.

Taking those and other uncertainties identified during the SEA into account, a set of conclusions, strategic options and recommendations were defined by the team.

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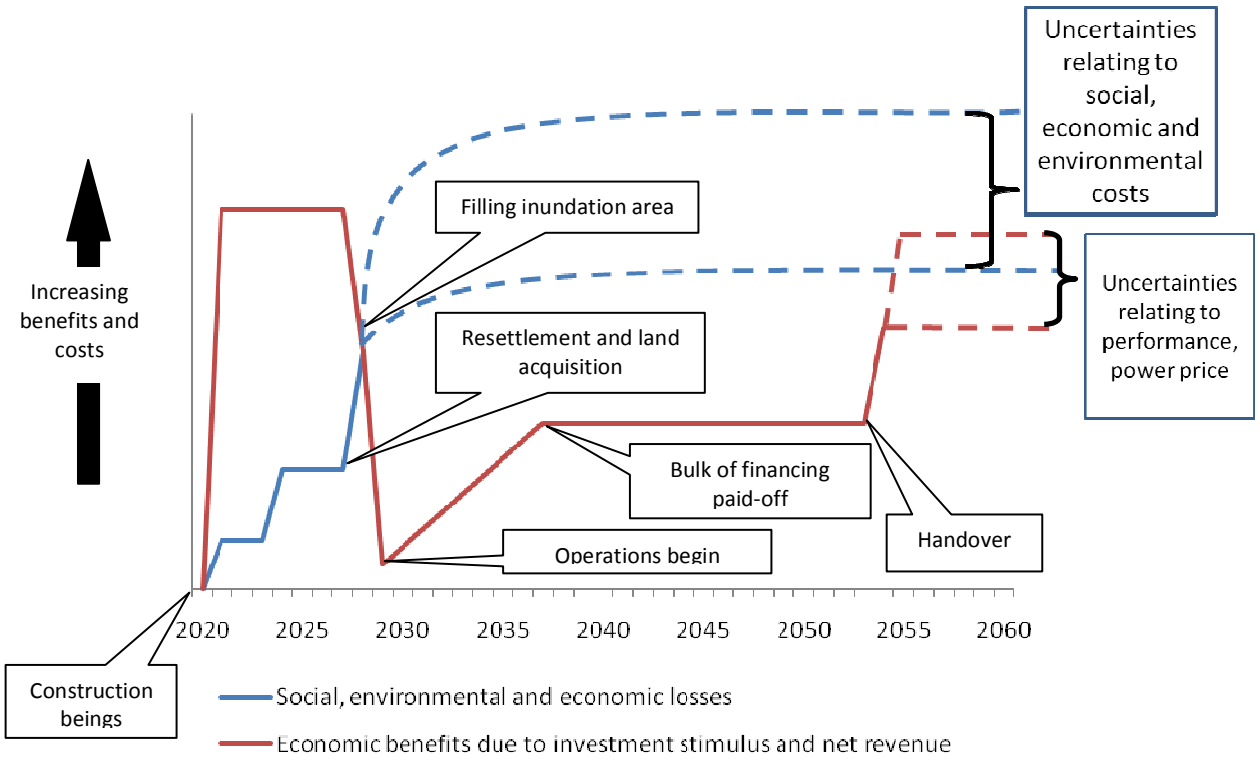
[64] For example, the extent of concessional financing and the amount of government equity.

[65] Sambor was chosen for illustration as it has both significant investment costs and high level of impacts thus showing how these large investments could potentially play out over time.

[66] While this admittedly is less likely to be the case with Sambor which is likely to find a ready domestic market for its power, it is a real consideration for some of the projects in Lao PDR. Reaching other markets than those already serviced by the facilities may imply large investments in transmission infrastructure.

The conclusions of the SEA are summarised according to the big strategic issues identified during the impact assessment phase. The recommendations follow the strategic options and are complemented by detailed annexes to this report.

Figure 57: Flows of costs and benefits during the life of a mainstream dam – based on Sambor



19.2 POWER GENERATION

The key strategic concerns are revenue generation through trade and foreign investment, power security and the challenges of managing many projects on the mainstream. The main conclusions are:

If all 12 mainstream dams were developed this would bring substantial increases to power generated and generation capacity in the region. Export revenue earnings for Cambodia and Lao PDR would be significant and imply increases in net revenues for government public spending. Lao PDR would benefit most because of the number of projects located there.

In terms of least-cost power supply, mainstream projects are only likely to be critical for the Cambodian power sector, and then only in the long term when plants are transferred to Cambodia. If the mainstream projects were not to go ahead, power production for domestic use and export in Lao PDR could continue to expand through tributary options. It would have little effect on domestic power prices.

Mainstream hydropower is not particularly significant for Thailand and Viet Nam. Development of LMB mainstream projects would have a minor impact on electricity prices and would have little effect on the energy supply strategies of those countries.

Establishing effective institutional arrangements and rules under which privately run mainstream projects could operate is complex and has international implications: Many mainstream projects on one river each operated by a different private developer creates entirely new management challenges for LMB countries. In Lao PDR and Cambodia there is limited experience in the development of large hydroelectric projects based on private capital and investment bank financing. Joint public-private mainstream projects would require a very specialised institutional structure with authority to make fast decisions that can have international consequences, such as how to operate the projects under unusual flow conditions.

Setting the guiding criteria for the operation of many mainstream dams has international consequences and would need to involved Cambodia, China, Lao PDR, Thailand and possibly Viet Nam. There is little experience anywhere in the LMB of coordinated management of many dams on one river. For example, rules are required to define to what extent a new project must preserve the hourly flow regime of downstream projects in a more advanced stage of development. Yunnan dams can regulate flows during wet and dry

seasons. LMB mainstream projects have very limited or no capacity to regulate flow during the wet season but they could have considerable hourly regulation at times of low flows. This regulation can result in upstream projects adversely affecting flow arrival to downstream projects and limit the value of power deliveries during peak hours. Specific rules for hourly flow modification need to be set and collaboration to perform optimised operation planning. Coordinated release is a necessity but it would be challenging for developers to anticipate its consequences in terms of peak and off-peak power production.

19.3 ECONOMIC DEVELOPMENT & POVERTY ALLEVIATION

Revenue streams from mainstream projects would provide an important source of revenue to fund development expenditures in host countries. While significant, revenues for host governments are less than the large gross revenue and power benefit figures suggest. Net government revenue for countries hosting the mainstream projects is likely to be less than 25-31% of gross revenues during the period of the concession agreement.

Lao PDR is likely to see significant economic growth due to mainstream hydropower investment.

The stimulus effects on host countries are likely to be significant but less than the large investment figures suggest. At least 50% of FDI flows into host countries for mainstream hydropower projects are likely to be spent on inputs from outside the host country.

Mainstream hydropower generation projects would contribute to growing inequality in the LMB countries. Benefits of hydropower would accrue to end consumers, developers, financiers and host governments, whereas most cost borne by poor and vulnerably riparian communities. Benefits are unevenly shared between countries. Viet Nam and Cambodia are likely to suffer net short to medium term losses associated with mainstream development.

In the short to medium term poverty would be made worse by mainstream projects, especially among poor in rural and urban riparian areas. Fishers are over represented in poor and vulnerable LMB communities which would be affected by fisheries losses. Poorer households would also be adversely affected by the direct impacts of hydropower development including resettlement, loss of land, and impacts during the contraction period. Loss of fisheries and associated proteins would lead to declines in nutritional health in LMB populations.

Rapid growth in the hydropower sector in Lao PDR could lead to inflation and real exchange rate appreciation. This could affect the competitiveness of tradable goods sectors (such as manufacturing and agriculture) relative to other domestic sectors and relative to imports. This may have adverse implications for poverty reduction as tradable goods sectors tend to be important for poverty reduction.

Mainstream projects would have significant negative impacts for other economic sectors some of which cannot be mitigated, especially in the fisheries and agriculture sectors.

The costings, prices, taxes and payments associated with mainstream development is unlikely to include a realistic estimate of the financial costs and savings involved in *protecting* the natural and human capital of the LMB. The financial incentive mechanisms to maximise the maintenance and enhancement of natural and human capital are not in place should the mainstream project go ahead.

The full social and ecological costs of the mainstream projects cannot be internalised through the use of economic and other instruments. The full costs have not been considered as part of the costs of the investment. Adequate mechanisms are not in place to ensure that the full costs of avoiding or compensating for natural system and social impacts are borne by the project investors.

19.4 ECOSYSTEMS INTEGRITY & DIVERSITY

The mainstream projects are likely to result in (i) serious and irreversible environmental damage, (ii) losses in long-term health and productivity of natural systems and (iii) losses in biological diversity and ecological integrity.

The mainstream projects would have a negative impact on (i) a large spatial area and shared resource; (ii) ecosystems and bioregions of international importance; (iii) a large number of species; and (iv) a number of threatened species likely leading to their extinction.

Then in considering avoidance, mitigation and enhancement:

(i) Adequate measures cannot be taken to prevent environmental damage where scientific certainty about the impact is absent;
(ii) Adequate measures cannot be put in place to address threats to the long-term health and productivity of natural systems;
(iii) Adequate arrangements and mechanisms are not in place to ensure that the maintenance of ecological integrity and biological diversity is a fundamental consideration in construction and operation.

19.5 FISHERIES & FOOD SECURITY

Substantial losses in the fresh and marine capture fisheries and in Delta aquaculture would have basin-wide impacts on the fisheries sector, associated ancillary and processing industries, and fisheries associated livelihoods, and health and nutrition.

The agricultural sector would be adversely affected by mainstream hydropower development despite the improvements in irrigation. The impacts on agriculture in the Delta are likely to be significant but at this stage have not been investigated or estimated.

When combined with climate change, the mainstream projects are likely to reduce food security in riparian provinces. Climate change is expected to create food deficit situations in a number of LMB sub-basins through reduced rainfall during the dry seasons, increased soil loss during the wet and increases in temperature. Studies have found that rice yields drop as the daily minimum temperature increases and as nights get hotter. Over the last 25 years, rice yields have fallen by 10-20% in some locations in the LMB.

19.6 SOCIAL SYSTEMS – LIVELIHOODS & LIVING CULTURES

The potential impacts of mainstream projects on social systems have proved more difficult to substantiate due to the gaps in information available to the SEA on riparian communities. Conclusions have been drawn based on what information was available – for example, on numbers of people directly affected, and on the experience with past hydropower development in the region.

The SEA concludes that the mainstream projects are likely to have significant negative effects on riparian communities by disrupting their:

(i) ways of life – i.e., how they live, work, recreate and interact with one another on a day-to-day basis;
(ii) cultures – i.e., patterns of behaviour, shared beliefs, customs and values;
(iii) sense of community – i.e. its cohesion, stability and character;
(iv) natural environment – i.e. all components of the riverine system;
(v) access to and availability and quality of the food they eat;
(vi) physical safety and the level of hazard or risk they are exposed to;
(vii) access to and control over resources underlying livelihoods; and,
(viii) physical, social and spiritual health and wellbeing.

Most of those negative effects cannot be adequately mitigated, especially for the current adult generation.

The experience in providing the needed long term, consistent and sensitive adjustment and support programs for communities affected by hydropower has not been good in the LMB region. Often it requires capacities and long term approaches to program and budget management that are not in place in the LMB.

19.7 SUMMARY OF CONCLUSIONS

While it is clear that the mainstream projects would bring significant additional power and investment/revenue benefits to the region, they would also bring many serious risks and uncertainties to issues of strategic economic, social and environmental concern to the Mekong countries and communities and for the sustainable development of the River.

In summary the SEA concludes:

1. The Mekong is a globally important river, one of the few remaining international rivers undammed over most of its length;
2. One dam across the Lower Mekong mainstream commits the river to irrevocable change;
3. The proposed developments when under construction and operating have the potential to create; international tensions within the LMB due to i) ecosystem integrity, ii) reduced sediment and nutrient loads, iii) disruption to other uses of the Mekong and iv) reduced productivity in fisheries and agriculture;
4. Many of the risks associated with the proposed mainstream developments cannot be mitigated at this time – they would represent a permanent and irreversible loss of environmental, social and economic assets;
5. There are many and substantial gaps in institutional and procedural arrangements for ensuring the effective management of construction and operation of the projects;
6. Critical national capacities in terms of personnel and skills are not yet in place to oversee, control, monitor and enforce safeguards and operational rules;
7. The framework of regional standards and safeguards relating to trans-boundary and downstream effects and institutional arrangements for their enforcement are not fully developed and are not adequate;
8. There are so many remaining uncertainties and serious risks associated with the developments that more studies are needed to better inform responsible decisions making;
9. The state of knowledge about the Mekong is not considered adequate for making an informed decision about mainstream dams at this time;

Those issues require further study, assessment, discussion and resolution among LMB countries, facilitated by MRC, before commitments to mainstream hydropower development are made.

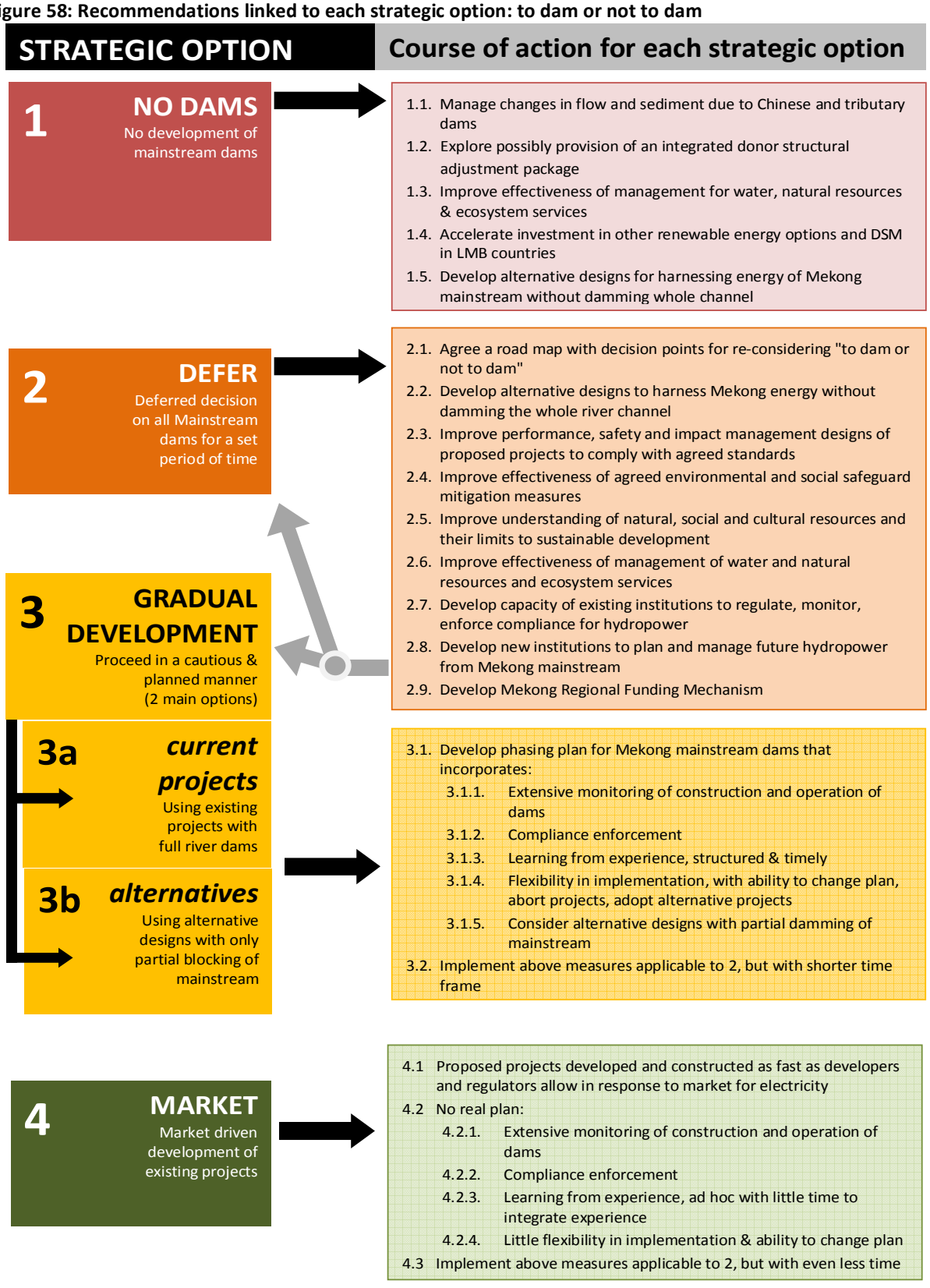
20 NEEDED ACTIONS LINKED TO EACH STRATEGIC OPTION

The SEA addresses a fundamental question - "*To dam or not to dam the Mekong mainstream*?" In response to that question, the SEA has described and consulted on four strategic options:

1. No mainstream dams
2. Deferred decision on all mainstream dams for a set period
3. Gradual development of mainstream power
4. Market driven development of the proposed projects

Figure 58 shows a decision flow chart which outlines the SEA recommendations associated with each of the four strategic options. Those recommended actions are described in detail in the sections to follow and their linked annexes.

Figure 58: Recommendations linked to each strategic option: to dam or not to dam



21 THE MAIN RECOMMENDATION OF THE SEA

Following the analysis of potential impacts and benefits associated with the mainstream projects, and following an intensive program of consultations with more than 100 government and non-government agencies, the SEA team has reached the following main recommendation:

- Given the economic, social, cultural and ecological importance of the Mekong River as a free flowing system connecting the four Lower Mekong Countries;
- Given the increasingly threatened status of natural systems and resources in the region and growing pressures on them; and,
- Given the far reaching potential effects and remaining uncertainties relating to the proposed mainstream projects;
- Given the need for a new approach to development of the Mekong River better fitting the requirements of the LMB riparian countries and communities in the 21st Century;

The SEA team recommends:

1. **Decisions on mainstream dams should be deferred for a period of ten years (strategic option 2) with reviews every three years to ensure that essential deferment-period activities are being conducted effectively.**

2. As the highest priority, the deferment period would include a comprehensive undertaking of feasibility studies for partial in-channel, diversion and other innovative systems for tapping the power of the mainstream in ways which do not require dams across the full breadth of the river channel. This would involve governments in partnership with MRC, multi-lateral development banks and developers.
3. The deferment period would also include a comprehensive assessment and fast tracking of tributary projects that are considered feasible and ecologically sustainable according to current international good practice, including retrofitting of existing projects and innovative schemes.
4. The deferment period needs to commence with a systematic distribution of the SEA report within each LMB country and in national languages and consultation with line agencies, private sector and the NGO community.

5. **The Mekong mainstream should never be used as a test case for proving and improving full dam hydropower technologies.**

22 RECOMMENDATION FOR STRATEGIC OPTION 2 – DEFERMENT

22.1 DEFERMENT AS A CREATIVE AND PRODUCTIVE STRATEGY FOR MAINSTREAM SUSTAINABLE DEVELOPMENT

Deferment must not be a passive postponement of dam building. It needs to be an intensely creative and productive strategy for sustainable development of the Mekong mainstream. Deferment would provide an opportunity to plan for a more sustainable form of hydropower development than is evident in the current proposed mainstream projects. Alternative electricity generating capability needs to be explored from the Mekong mainstream without jeopardizing the ecosystem connectivity of the river and livelihoods of riparian communities, e.g. in-channel partial dams, diversions and alternative schemes, such as hydrokinetic-inland systems (Annex 2).

The history of hydropower development concepts for the Mekong shows a change in thinking from the high dams of the 1950's to the run-of-river schemes developed conceptually in the 1990s, which are being proposed now. This evolution reflects the rise of sustainability guidance in the regional power sector; the next step is to enhance the process of integrating the power sector into the sustainable development of the Mekong and its water resources through a unified planning structure and the development of improved technologies which have ecologically sustainable outcomes.
Mekong hydropower development for the 21st century would combine optimizing electricity generation from the Mekong mainstream with:

- No net loss in natural system assets and enhancement of degraded environments through rehabilitation, maintenance and offsets

- No net loss of cultural and socio-economic assets and diversity among riparian communities and enhancement of livelihood opportunities
- No net loss in the development of other economic sectors using the resources of the Mekong and enhancement of multiple uses of its water and natural resources.

The recommendations for Strategic Option 2 – Deferment are presented below. The general recommendations for the other Strategic options are in the annexes.

22.2 ROAD MAP FOR THE DEFERMENT PERIOD

Agree on a road map with decision points for re-considering "to dam or not to dam". With this option, a road map would be agreed by all four LMB countries specifying when the decision on mainstream dams would be considered again (ie the agreement would include a "sunset clause"). In the meantime, it is essential that a number of different courses of action are followed so that a better informed decision can be taken. The SEA team recommends that the decision is reconsidered after 10 years. Progress in implementing the parallel courses of action for the deferment period should be reviewed every 3 years.

22.3 SOURCING ALTERNATIVE ENERGY SOURCES

Filling the energy gap. At least during the deferment period and beyond if the decision is taken not to go ahead with the Mekong mainstream dams, the energy that would have been provided by these dams would need to be substituted by conventional power sources, improved generation capacity on the tributaries and alternative sources of energy. National power plans would have to be adjusted to take deferment into account, bearing in mind that the Mekong mainstream dams are predicted to contribute 6% of the total regional electricity demand by 2030.

Filling the economic gap. The contribution of the export earnings from hydropower to the national economies of Lao PDRand Cambodia would be foregone during the deferral period. Alternative pathways need to be found for economic development not dependant on the immediate economic benefit from Mekong mainstream hydropower. *That may involve special adjustment packages consolidated by international development partners, especially for Cambodia.*

Develop alternative designs for harnessing energy of Mekong mainstream without damming the whole channel. The critical feature of the Mekong that would be lost by the proposed mainstream dams is its ecological connectivity. Schemes that do not threaten this connectivity could be developed, even though the electricity generated might be at least an order of magnitude lower. It is recommended that a technical review of such technologies be undertaken followed by feasibility studies of appropriate schemes within the next 5 years. By the time the deferment period is over, the feasibility of these alternative schemes needs to be understood and a comprehensive assessment of them conducted so that comparisons can be made with the existing full dam proposals.

22.4 MEKONG MAINSTREAM PLAN

Prepare a "plan" for the Mekong mainstream. The intention here is not to prepare a a comprehensive economic development plan for the Mekong mainstream. Instead, what is required is a framework of zoning and safeguards against which any proposals for development could be assessed. The framework would set in place those things the LMB countries wish to keep for future generations. Such a development planning framework would consider the natural and social resources and values, determine the environmental conditions that need to be maintained and the critical assets and stretches of the river that should be protected. This is different from the Basin Development Plan and should not include individual projects, sectoral development proposals or development scenarios.

Preparing the mainstream planning framework would require a series of studies to:

- *Improve understanding of natural, social and cultural resources and their limits to sustainable development.* One of the main areas of uncertainty is in the understanding of the Mekong ecosystems, the natural resources and the social and cultural resources that are dependent on them. Not enough is known

about the pressures and limits to which these systems can be taken without irrevocable harm. During the deferment period a systematic set of studies of these systems and resources need to be carried out to increase understanding of them and their limits. These studies contribute to the development of the Mekong mainstream plan.

- *Improve effectiveness of management of water and natural resources and ecosystem services.* Not enough is known about the ways in which the hydrology and natural systems of the Mekong can be managed without further degradation. Systematic management approaches, safeguards and procedures are needed covering the mainstream and tributaries whether or not mainstream dams are eventually accepted.

22.5 INSTITUTIONS & CAPACITY

Develop capacity of existing institutions to regulate, monitor and enforce compliance for hydropower. The pace and scale of development of hydropower in the region is stretching the capacity of existing institutions. Deferment allows institutional strengthening to become firmly grounded in the different national institutions. This recommendation includes a range of institutional strengthening and capacity building measures at regional, national and provincial levels to enable a more effective oversight and management of hydropower development of the Mekong mainstream and on the tributaries.

Strengthen the capacity of power sector agencies for planning and regulation of sustainable hydropower development. The proposals for the Mekong mainstream are aimed at maximizing electricity generation and profit, though this may be at the expense of other development sectors. Some recognition of the need for moderation has been incorporated in recent optimization studies. This recommendation is aimed at encouraging multi-sector planning and regulation for multiple-use of the water and natural resources whether on the mainstream or tributaries.

Develop new regional institutional mechanisms to plan and manage multi-sector development on the Mekong mainstream. The MRC contributes to Mekong Basin planning through the BDP process. The BDP has adopted development scenarios based on national project concepts for the entire basin. It has not focused on developing specific plans for the Mekong mainstream. Through the PNPCA process, MRC has a capacity to review, consult and advise on specific project proposals. The MRC has no mechanism for basin-wide regulation of hydropower or other forms of sector development on the Mekong mainstream. It is recommended that the potential for MRC to undertake these responsibilities be considered through review of the 1995 Mekong Agreement and formulation of additional protocols. Ideally, China would need to be involved in such a planning, review and regulatory mechanism – full Mekong River coverage may need to be developed in stages.

Develop an independent regulatory authority for mainstream hydropower which has the technical capacity, and legal mandate to set and enforce design, maintenance and operational standards.

Develop a Mekong River Basin Management Fund. A Mekong regional funding mechanism should be established to finance a range of activities including trans-boundary mitigation and benefit sharing, heritage protection and enhancement, research and development, and monitoring. The fund would help support planning and coordination of Mekong mainstream development. Sources of revenue could include revenue from tariffs, contributions from developers, development partners (bi-lateral and multilateral IFIs) and Dialogue partners. New financing sources such as international carbon financing might also be applied. The MRC might be an appropriate vehicle to administer such a fund. It is recommended that the feasibility of establishing a Mekong Fund be studied during the early part of the deferment period, leading to implementation. The fund is needed whether or not mainstream hydropower is eventually accepted.

22.6 MAKING HYDROPOWER SUSTAINABLE

Improve performance, safety and impact management designs of hydropower projects to comply with agreed standards and sustainability criteria. The proposals for the Mekong mainstream dams are being promoted by a number of developers with different approaches and experience in dam construction and operation. Only recently has the MRC produced preliminary technical design guidance for hydropower, which has been accepted by the four LMB countries. The guidance is a step towards definitive standards for hydropower. In the deferment period, it is recommended that these standards be finalised and be applied consistently to

existing and any future mainstream and alternatives proposals. Also, all hydropower proposals should be assessed according to the sustainability criteria described by the International Hydropower Association in its Sustainability Assessment Protocol.

*Improve effectiveness of mitigation measures to comply with agreed environmental and social safeguard*s. As with the design recommendation above, greater attention to the detail of mitigation measures for environmental and social safeguards for hydropower projects is required to fit with the sustainability criteria. It is recommended that during the deferment period each mainstream project should reconsider and improve the proposed mitigation measures in the light of best international practice and technology.

Develop and start implementing alternative livelihood and nutritional security replacement programs. Socially sustainable programmes for development of alternative livelihood options to increase incomes of potentially affected persons along the Mekong mainstream (not just those displaced by the reservoirs) are needed. One aim would be to supplement dependence on wild fish capture from the Mekong as a source of nutritional security. Such programs are needed to enhance adaptability and resilience whether or not mainstream project are eventually accepted.

22.7 THE TEN-YEAR DEFERMENT TIMEFRAME

The ten-year time frame for deferment is recommended because it allows sufficient time to reduce uncertainties about the changes in the natural and socio-economic systems, and uncertainties about the effectiveness of proposed avoidance and mitigation measures.

Ten years is required for:

(i) Confirming that changes in the river – flows sediments, river morphology, ecosystems – predicted under the "definite future scenario" by 2015 are accurate, giving greater confidence in the predictions for 2030 and beyond.
(ii) Confirming (or not) that the proposed mainstream projects are the best available, most effective and sustainable technology, having considered the feasibility of other alternatives for generating electricity from the Mekong mainstream
(iii) Developing effective mitigation strategies (or not) for the currently unresolved impacts such as fish passage, ecosystem connectivity, sediment management and nutrient flows. Further development into such mitigation measures will highlight whether these impacts can be minimised or remain to be considered as trade-offs.
(iv) Developing strategies and measures for ensuring alternative livelihoods and reducing vulnerability of the riparian communities, based on the experience of dams on the tributaries
(v) Developing mechanisms for effective benefit sharing both in country and across national boundaries, based upon the experience of dams on tributaries.
(vi) Strengthening and putting in place the necessary regulatory and monitoring institutions at national and regional levels.
(vii) Establishing financing mechanisms (e.g. a Mekong Fund) to enable continuing effective management of the Mekong and all its development (i.e. not just hydropower)

23 IMPLICATIONS OF CHOOSING STRATEGIC OPTION 1 – NO LMB MAINSTREAM DAMS

It is likely that the demand for harnessing the power potential of the Mekong mainstream will remain. There will need to be a process of active planning, consideration of alternatives and decision making based on the best available information and technologies that is encapsulated in Strategic Option 2. Should LMB countries chose to adopt Option 1, many of actions required for Option 2 would be required including:

- *Filling the energy gap*. In this case, long term alternative energy planning needs to be implemented.
- *Filling the economic gap.* The contribution of the export earnings from the mainstream hydropower proposals to the national economies of Lao PDR and Cambodia would be foregone and alternative pathways would need to be found for economic development.

- *Develop alternative designs for harnessing energy of Mekong mainstream without damming the whole channel.* Feasibility studies into use of alternative schemes that do not damage the connectivity of the Mekong would be needed.
- *Enhance the capacities of hydropower dams on the tributaries* taking into account changed hydrological regimes, climate change, improvements in sustainable hydropower design
- *Develop a plan for the Mekong mainstream.* This plan will also be required to manage the water and natural resources sustainably
    - *Improve understanding of natural, social and cultural resources and their limits to sustainable development.*
    - *Improve effectiveness of management of water and natural resources and ecosystem services.*
    - *Manage and utilise changes in flow and sediment due to Chinese and tributary dams.* Hydrological changes are occurring this will require appropriate management measures. Studies and management measures are required to feed into the plan.
- *Develop regional institutional mechanisms and capacity building of national agencies,* will also be required for sustainable management of the Mekong mainstream but without the emphasis on hydropower regulation and operation.
- *Develop livelihoods and maintaining food security for Mekong riparian communities.* Emphasis will have to be placed on ensuring that the riparian communities continue to develop and use the water and natural resources of the Mekong sustainably.

24 IMPLICATIONS OF CHOOSING STRATEGIC OPTIONS 3 OR 4 – GRADUAL & MARKET DRIVEN DEVELOPMENT

The main difference between choice of Strategic Options 3 and 4 relates to the pace, timing and scale of development of hydropower on the Mekong mainstream. *All of the recommended courses of action for option 2 are applicable except for "filling the energy and economic gap" resulting from not developing or deferring the decision on the mainstream dams.*

The main difference between Option2 and Option 3 is a decision to commit to at least some of the proposed dams of the Mekong mainstream, accepting the changes that this will involve, before a complete understanding and preparedness for these changes is in place. Implementation of all the measures suggested for option 2 should be undertaken to ensure sustainability of the plan, but within a much shorter time frame and more pressure for development than would be ideal. Especially important for Option 3 is the need to set in place a regional approach for coordination, management and regulation prior to commencement of any projects.

If Strategic Option 3 - gradual development of mainstream hydropower development - is chosen, a ***phasing and benefit sharing plan*** *for Mekong mainstream dams should be agreed by the LMB countries before any development proceeds*, incorporating:

(i) A clear policy commitment to ensure those adversely affected will receive benefits from mainstream hydropower development
(ii) A review of the sustainability of all the proposed schemes with prioritization and phasing
(iii) A coordinated programme for monitoring construction and operation of dams
(iv) Compliance enforcement
(v) Sharing of information and learning from experience in a structured and timely manner
(vi) Flexibility in implementation with ability to change the plan, cancel certain projects or develop alternatives.
(vii) Consideration of alternative hydropower systems with partial damming of mainstream channel

If Strategic Option 4 – Development of mainstream dams driven by market forces – is chosen, the proposed projects would be developed and constructed as fast as developers can finalise designs, agree on environmental and social management plans and reach agreements on tariffs. The developers would manage each project independent of an overall coordination framework. The regulators would play an important role in ensuring compliance and trying to encourage the schemes to implement comprehensive environment and social management plans. This option commits the LMB to the current proposals with minor changes in design and mitigation measures, with little opportunity to explore alternative options.

It recognises that there is no systematic plan to guide mainstream develop and no trans-boundary regulation. Nevertheless the appropriate national and regional institutions should ensure that there is in place:

a) Coordinated programme for monitoring construction and operation of dams
b) Compliance enforcement
c) Sharing of information and learning from experience in a structured and timely manner

Where possible the courses of action applicable to option 2 should be implemented, but recognizing that there may not be adequate time and capacity to apply them, and that the effectiveness of these measures may be limited.

25 SETTING PRIORITIES IN IMPLEMENTING RECOMMENDATIONS

The recommendations derived from the analysis of each of the key themes addressed by the SEA (i.e. energy and power, economics, social systems, hydrology and sediment, aquatic systems, fisheries, terrestrial systems and climate change) have been grouped by type. These include the studies that are required to make an informed decision or to improve the effectiveness and sustainability of mainstream dams, the policy changes that will be required, the institutional arrangements and capacity building, the improvements in hydropower design and mitigation measures and environmental and social safeguards required. The priorities for action for each of these recommendation types are focused on assisting the decision of whether or not to dam the Mekong mainstream.

25.1 STUDIES REQUIRED

The full list of studies required is found in Annex 2, arranged by key theme. *Priority is given to those studies that will be essential to make an informed decision on the mainstream dams.* These studies should be undertaken during the ten-year deferment period. They include:

- *Sediment/nutrient dynamics:* The comprehensive studies of the sediment/nutrient dynamics in the Mekong to complement the existing detail of the hydrological dynamics of the system. This should be extended to cover the marine sediment plume and coastal erosion, and the transport of nutrients into the floodplain.
- *Aquatic habitats:* The survey of aquatic habitats in the Mekong so that critical habitats and biodiversity hotspots can be incorporated as zones for special protection into the overall Mekong mainstream plan.
- *Fish passage:* Research and development of systems for fish passage suitable for the Mekong fish migrations, using opportunities for trialing on tributary hydropower schemes.
- *Riparian communities*: Social studies to clarify the dependence of riparian communities (especially those that might be impacted by mainstream dams) upon the natural resources of the Mekong, including fisheries, water resources, river bank gardens etc leading to development of alternative livelihood and poverty alleviation strategies.
- *Climate change:* Comprehensive climate change studies of sub-basins to define the trends and ranges of climate change and extreme events that need to be incorporated into the variety of sectoral adaptation plans, including hydropower.
- *Alternative hydropower:* Review of potential for alternative hydropower schemes that do not affect the mainstream connectivity followed by feasibility studies for selected systems throughout the LMB, including initial assessments of their environmental and social impacts.
- *Alternative energy:* Studies on alternative energy sources to “fill the gap” if mainstream dams are deferred.
- *Macro-economics:* Studies on macro-economic implications of foregoing mainstream dams
- *Mekong fund:* Feasibility study for establishing a Mekong Fund.
- *Hydropower design:* Studies to improve the performance and effectiveness of the existing proposals for mainstream dams, especially for ensuring hydrological and sediment flows, and for environmental and social safeguards.

25.2 POLICY & GUIDANCE REQUIRED

The full list of policy and guidance recommendations is shown in Annex 3, arranged by key theme. *Priority is given to those policies essential for the Deferment Option.* Many of these policy changes and guidance will depend on the findings of the studies. These include:

- *Energy balance:* The balance of alternative energy sources in national power plans if mainstream dams are not built, including conventional and renewable sources, and demand side management
- *Structural adjustment:* Economic development packages that will support other energy sources, and mitigate the economic opportunities lost if the mainstream dams are not built, including:
    - Economic support for agriculture
    - Economic support for fisheries development
- *Benefit sharing:* The development of trans-boundary and national to local benefit sharing mechanisms, using the experiences of trialling with hydropower schemes on the Mekong tributaries
- *Trans-boundary management:* Defining and addressing the gaps in policy and legislation for trans-boundary impacts and equity in application of safeguards policies, monitoring and evaluation procedures for hydropower projects, and comprehensive, transparent trans-boundary grievance procedures.
- *Climate change:* Definition of a clearly communicated set of climate change trends and ranges of risk for each sub-basin in the Mekong likely to affect development sectors, such as hydropower, fisheries and agriculture, and navigation.

25.3 INSTITUTIONAL ARRANGEMENTS AND CAPACITY BUILDING

The full list of institutional and capacity building recommendations is shown in Annex 4, arranged by key theme. The priority actions that need to be taken include:

- *Regional regulatory body:* Establish a Mekong River development regulatory body covering all forms of development that, amongst other things, sets guiding criteria for design and operation of mainstream dams, coordination of operation, dam safety, emergency management procedures, environmental flows and social safeguards, with a mandate for enforcement.
- *Mekong fund:* Establish a Mekong Fund, based upon the findings of the feasibility study mentioned above
- *Trans-boundary management:* Strengthening capacities for the management of trans-boundary risks associated with Mekong mainstream projects.
- *SEAs, ESIAs and EMPs:* Strengthen the capacities of national and provincial authorities for conducting SEAs and assessing and appraising ESIAs and EMPs, and implementing and enforcing environmental and social safeguards
- *Monitoring of environmental performance:* Strengthen the capacities of national agencies to monitor and evaluate the flows and environmental quality in the mainstream, and the performance of hydropower schemes in addressing environmental and social impacts.
- *Information sharing:* Strengthen the sharing of information, both nationally and within the basin, about the Mekong and hydropower development, including experiences of monitoring and evaluating environmental and social impacts and mitigation measures, to encourage learning and adaptive management.

25.4 IMPROVEMENTS IN HYDROPOWER DESIGN AND MITIGATION MEASURES

The list of recommended improvements in hydropower design and mitigation measures is shown in Annex 5. It is important these are investigated during the deferment period, being tried and tested on the tributaries, giving time to prove appropriate and sustainable hydropower schemes for the Mekong mainstream. Such evidence can then be used to influence the decision to build or not to build mainstream projects at the end of the ten year period. The priority actions include:

- *Apply best practice guidance:* Ensuring that all proposed projects comply with international best practice and MRC Preliminary Design Guidance and rules and regulations covering construction and operation.
- *Eliminate high impact actions:* Reconsider and prohibit high impact proposals, including locations, continuous operation strategies, reductions in operating water levels
- *Test alternatives to full dams:* Review and carry out feasibility studies for alternative designs that incorporate partial in-channel schemes, diversions and innovative designs for hydropower.

- *Test fish passage in tributaries:* Develop, build and improve fish passages on tributary dams that can allow a greater proportion of migrating fish to pass upstream and downstream of hydropower projects.
- *Reduce risks:* Review proposed projects to reduce risks of flooding and impact on irrigated land and lower numbers of people that would require resettlement
- *Apply multiple use:* Develop the procedures and mechanisms to allow multiple use of reservoirs on the Mekong mainstream
- *Improve ship locks:* Design all Mekong mainstream dams to accommodate ship locks according to the MRC Preliminary Design Guidance
- *Adjust to climate change:* Ensure that all dams being proposed have adequately addressed the risks of extreme events caused by climate change, as specified by the MRC climate change guidance

25.5 ENVIRONMENTAL & SOCIAL SAFEGUARDS

The list of recommended environmental and social safeguards arranged by key theme is shown in Annex 6. Most of these are essential elements of any hydropower scheme on the Mekong mainstream or tributary. They are especially important for the proposals for the Mekong mainstream. The practical implication of some will need to be developed during the deferment period, so that they can be applied effectively in the event of a decision to go ahead with the mainstream dams. It is important that they are tried and tested in the tributary dams before being applied in the Mekong mainstream.

Several recommendations stand out as priorities:

- *Trans-boundary safeguards:* Develop mechanisms for application of trans-boundary safeguards, supportive of national safeguard systems
- *Protection of natural and social system assets:* Ensure that proposed projects respect the protected river stretches, identified in the Mekong mainstream plan
- *Introduce benefit sharing arrangements* both between states and from national to local to encourage a more equitable distribution of the benefits amongst those most at risk (Box 1).

Box 1: Guidance for benefit sharing mechanisms

Guidance for benefit sharing mechanisms

Comparing Compensation and Benefit sharing

- Compensation focuses on well defined, direct and often localised impacts; Often for physical assets; Usually short term during construction period e.g. compensation payments for land, housing
- Benefit sharing focuses on enhancement and mitigation; Provides a stream of resources for the lifetime of the project (long term); Can address broader impacts e.g. livelihood support programs

Sources of funds for benefit sharing

The source of funds for benefit sharing activities of mainstream projects from:

- Directly from revenues (either on power tariff or water charges)
- Direct equity sharing (using return on project equity as an income stream)
- Host government budget transfers to affected areas/sectors/countries
- Levying property taxes on land of power facilities and reservoir
- Benefits in-kind (power, water) to affected communities (limited applicability for basin-wide and trans-boundary impacts)

Uses of funds as part of an integrated development planning approach

- Sectoral structural adjustment programs
- Area focused support for affected communities
- Broader social development programs
- Trans-boundary transfers

Benefit sharing arrangements

- Basin – wide benefit sharing fund
- Agreed principles for use of funds between all LMB countries
- Project basis VS direct budget support (targeted at national or local level)
- Monitoring system for allocation and use of funds
- Under a basin-wide authority with adequate technical capacity to manage funds

26 RECOMMENDATIONS FOR THE MEKONG RIVER COMMISSION

Most of the recommendations proposed have regional application or should be applied in each of the four countries. However, a number of recommendations are specific to a country, and these are also listed in the Annexes. Some recommendations were derived from the country group consultations at the final SEA workshop. Box 2 summarises the main recommendation concerning the strategic options of the national and international working groups. The detailed recommendations of each working group are outlined below:

Box 2: Strategic options selected by SEA working groups

Strategic options selected by working groups at the SEA Avoidance, Mitigation and Enhancement Workshop, Ho Chi Minh City, Viet Nam 29 June 2010

Over the full second day of the final regional SEA consultation workshop, country groups of the four Lower Mekong Countries plus one international group were asked to identify recommendations for each of the strategic options for each country and to indicate the preferred choice of strategic option. There were 120 people at the meeting with about 20 persons in each group with representatives of government line agencies, hydropower developers, academics, civil society and NGOs, as well as donors and international organizations. All groups called for continuing consultation and discussion on translated versions of the report prior to mainstream project decisions. Strategic options choices were:

- **Cambodia group:** A strategic option was not selected, but there was a strong request for more time for further consultation on the SEA report
- **Lao PDR group:** Preferred Option 3, but requested a wider discussion on the issues and consultation on the SEA report
- **Thailand group**: Preferred Option 1 and 2, though would not oppose if all LMB countries wanted Option 3
- **Viet Nam group**: Preferred Option 1 or 2
- **International**: Preferred Option 2 and recognised that Option 3 could be a sub-set of option 2, requiring deferment while active planning was conducted.

26.1 CAMBODIA

The specific recommendations for Cambodia include:

- Reassess power demand/supply in the next five/ten years
- Develop economic support packages for other energy sources including investigation of possible fossil fuel reserves, support for thermal plants and connection with Lao tributary hydropower generation.
- Provide donor support packages to promote the investigation of alternative energy options
- Economy-wide structural adjustment packages to mitigate the economic impacts of foregoing or delaying mainstream projects in Cambodia.
- Support for expansion of the national grid and decentralised renewable energy production to address rural energy poverty.
- Carefully weigh the pros and cons of the 460 MW vs. 2600 MW options for Sambor and revise the plans of each project to encompass environmental considerations, especially partial damming options
- Assess impact of Mekong tributaries dams on Sambor dam
- Conduct more studies:
    - Define **environmental flow requirement for the Mekong in Cambodia** (sediment load/flood plain habitat lose)
    - Reassess production and potential of **reservoir fisheries and aquaculture**
    - Reassess loss of downstream **floodplain habitats and loss of fish production**
    - **Groundwater recharge/connectivity:** address the changes to groundwater connectivity in the Cambodian floodplains with a focus on: (i) changes to the seasonal water table, (ii) impacts on arsenic levels, (ii) potential salinisation of groundwater through the elevation of the water table
    - **Tonle Sap system**: explore the changes to the seasonal flooded area of the Tonle Sap (and implications for flooded forest), the change in the hydraulic gradient driving reversal in the Tonle Sap as well as revise the sediment balance for the system.
    - **Floodplain fertility**: Establish a long-term monitoring programme to assess the potential loss of annual silt deposition on the floodplain, resulting in loss of nutrients for soil fertility
- The Ramsar Convention should be informed as soon as possible about the potential threats to Stung Treng, requesting inclusion on the Montreux Record of threatened international wetlands. In the event of a decision to go ahead with the Stung Treng dam, the Ramsar site status would have to be assessed, and may be lost. Specific compensation measures for loss of landscape amenity and aquatic biodiversity at Stung Treng Ramsar site would be required

26.2 LAO PDR

The specific recommendations for Lao PDR, developed during the final consultation workshop include:

- Reorientation of energy plans away from a dependence on mainstream hydropower.
- Accelerate and enhance production from hydropower development on the tributaries
- Develop economic support packages for other energy sources, including support for the grid and decentralised renewable energy production to address rural energy poverty.
- Economy-wide structural adjustment packages to mitigate the economic impacts of foregoing or delaying mainstream projects in Lao PDR.
- Emphasise studies and research on multiple use of reservoirs, environmental flows, a review of cultural assets, and sustainability assessments of each dam

If the decision is taken for gradual development of mainstream dams:

- Local Investment maximization: ensure use of local labor and goods by providing subsidies and training programs
- Sustain economic growth and livelihood for affected people, upstream and downstream
- Ensure and enforce fair compensation payments for affected communities.
- Develop a Benefit Sharing Fund to fund development and environmental protection activities for both tributary and mainstream projects.
- Develop mechanisms for reservoir and watershed management
- In the event of a decision to build Ban Koum dam, specific compensation measures for loss of landscape amenity and aquatic biodiversity associated with Phou Xiang Thong National Protected Area

26.3 THAILAND

During the consultation workshop, the Thai country group supported draft recommendations associated with Strategic Options 1 and 2 included in the workshop handouts. In addition the group recommended:

- Pending a decision on the Mekong mainstream dams, the Thai Power Development Plan should clearly exclude power generation from the mainstream dams, so that there is no dependence or expectation built up.
- Thailand may need to use more conventional alternatives, in addition to renewable energy and demand side management to meet incremental demand
- Conduct research on natural resources and environmental impact of hydropower development in Thailand for baseline information including compilation of past experiences, so that results can be used for considering the suitability of the project proposals
- The two governments of Thailand and Lao PDR should address the issue of loss of definition of the sovereign boundaries between the two countries associated with some mainstream projects, and come to mutually acceptable agreement
- In the event of a decision to build Ban Koum dam, specific compensation measures for loss of landscape amenity and aquatic biodiversity associated with Pha Taem National Park will be required.

26.4 VIET NAM

During the consultation workshop the Viet Nam group recommended:

- Studies and analysis to fill gaps or reduce uncertainties relating to key strategic issues would be necessary, including:
    - **Marine sediment/nutrient plume**: (i) map the changes to the extent and movement of the marine plume, and (ii) detailed hydrodynamic modelling of ocean processes with a focus on bio-geochemistry of fresh-saltwater interactions and sediment transport.
    - **Coastal erosion**: quantify the sites and rate of erosion in the context of the reduced sediment load predicted by the array of dams proposed for Lancang/Mekong and the Central Highlands.
    - **Groundwater recharge/connectivity:** address the changes to groundwater connectivity in the Cambodian floodplains and the Mekong Delta with a focus on: (i) changes to the seasonal

water table, (ii) potential salinisation of groundwater through the elevation of the water table
    - **Changes in extent of Mekong delta**, because of reduced sediment supply from the river. Expected resulting loss of stability of banks of deltaic channels and main coastline. Loss of fishpond and mangrove producing areas.
- Monitoring
    - National agencies in Viet Nam should establish a long-term monitoring programme to assess sediment changes in Mekong Delta.
    - Monitor passage of fine sediment and associated nutrients down the system, including in the Mekong Plume.
    - Monitor fish catches in the Mekong Plume
    - Monitor sediment load downstream and agricultural productivity in the Mekong Delta
- Institutional innovation at national and delta level for more effective planning of hydropower sustainability
- Laws, regulations and procedures, including scope of impacts and responsibilities for implementing & monitoring avoidance & mitigation measures

If the decision is taken for gradual development of mainstream dams, Viet Nam will have to:

- Monitor impacts carefully
- Set up institutions to carry out mitigation measures
- Secure compensation payments from developers for mitigation measures
- Shift the economy of the Mekong Delta away from agriculture and fisheries
- Develop food supply sources in other part of the countries to ensure food security
- Plan to cope with social impacts if migration away from the delta is necessary
- Secure a long-term power purchase agreement at prices lower than those of energy supply alternatives such as oil-based electricity within the country (USD 70/MWh)
- Make sure that there is no unilateral suspension of energy deliveries resulting from domestic shortages in the exporting country.[67]

27 RECOMMENDATIONS FOR THE MEKONG RIVER COMMISSION

There have been a number of recommendations arising out of whole SEA process for the Mekong River Commission. These are subdivided into four groups: i) the PNPCA process, ii) basin planning processes iii) guidance and standards and iv) a Mekong Fund.

27.1 THE PNPCA PROCESS

An important reason for initiating the SEA was to provide an overall strategic framework for the assessment of individual mainstream projects as they enter the MRC PNPCA process through LMB country notifications.

To date there has been no major developments on the LMB Mekong mainstream, e.g. mainstream dams, large irrigation schemes or river basin diversions so the PNPCA process has not yet been invoked. The PNPCA process starts when the country concerned consider that they have enough detail and information for an adequate consultation and agreement process to take place amongst all four member countries. The MRC has developed the procedures and guidance for this process of notification, consultation and agreement (posted on the MRC website).

The SEA findings and all the associated information and analysis would be taken into account as project proposals are notified. Other major sources of guidance to the PNPCA process include:

- The documents provided by the government – the feasibility studies and ESIA reports for the proposed project being considered
- The MRC's Preliminary Design Guidance for hydropower development on the Mekong mainstream

[67] In 2001 Argentina suspended gas deliveries contracted by Chile to mitigate public outcry during an energy crisis. Chile, which had become highly reliant on Argentine gas is still recuperating from the shock and the relations between the two countries were severely strained

- The BDP reports and assessments of impacts of various development scenarios, which include with and without the mainstream dams
- Any other MRCS studies and technical documents considered useful and relevant.

The full body of the SEA reports provides the **overall strategic context** for the focused project by project assessments. The SEA should be used for systematic comparison of how the proposed projects relate to the strategic concerns, and how the project designers have addressed and mitigated these concerns. The SEA does not provide a comprehensive cumulative impact assessment. *The ESIA of the proposed project should include a detailed assessment of **cumulative impacts** and its contribution to these.*

The PNPCA process specifies the **consultation** within the various MRC and NMC bodies, but does not necessarily specify consultation within the countries, e.g. at national, provincial or district level. Although this will have been done at the ESIA stage by and for the developers, some form of more independent consultation process would be appropriate to bring forward the views of line agencies, CSOs, and NGOs. The SEA provides a model for such consultations. *It is recommended that the MRC apply such a consultation process in upcoming PNPCA applications.*

Another tool which could be used to assess the sustainability of the proposed project against international best practice is the **Sustainability Assessment Protocol**, (Section II) developed by the International Hydropower Association. This review could be carried out by a team of independent assessors with the collaboration of the developers and the regulating agencies. *It is recommended that MRC consider application of the SAP to contribute to the PNPCA process*.

*It is also recommended that a **due diligence review** of proposed developers' past performance should be conducted as part of PNPCA review process* or that access be given to the government's own due diligence reports. That review would assess the developers' performance in applying national social, economic and environmental safeguards, and in preparing and implementing robust and effective dam safety procedures, including downstream release early warning systems.

The proposed mainstream dams will last for over 50 years, by which time the impacts of **climate change** will be evident. *The PNPCA process should:*

(iii) include a request for a detailed statement from the developers of how the proposed design has been adapted to take the risks of climate change into account

(iv) provide (through the MRC CCAI) a set of trends and ranges as the basic standards for climate change that developers must apply in their design proposals.

27.2 BASIN PLANNING PROCESS

27.2.1 A MEKONG MAINSTREAM PLAN

MRC should prepare a Mekong Mainstream Plan through wide consultation with LMB countries: During the course of the SEA, a fundamental gap that has become apparent is the absence of a plan for the Mekong River mainstream (as opposed to the Basin Development Plan). There is no analytical framework defining the critical stretches of the Mekong River from an ecological, cultural or social viewpoint which need special management measures and against which developments – hydropower, irrigation, water abstraction and diversion, and location of industries – can be assessed. A Mekong Mainstream Plan would identify sensitive and critical Mekong River assets, establish a framework of zones and set standards and management measures. It would establish ecologically acceptable measures for flow variation and sediment retention and discharge.

A Mekong mainstream plan contrasts with the Basin Development Plan, in that it would provide a framework against which developments can be assessed. The Basin Development Plan is based on a series of development scenarios to assess which levels of development will be acceptable. The Mekong mainstream Plan is a resource management and development proposal assessment framework, whilst the BDP is a development instrument.

27.2.2 SEDIMENT DYNAMICS OF THE MEKONG

Understanding of the dynamics of sediment and nutrient transport down the Mekong lags significantly behind the hydrology. Sediment and nutrient dynamics has emerged as a key strategic concern in the SEA, with implications for river bed and bank erosion, floodplain fertility and the maintenance of the delta and coastal

plume. *The MRC's IKMP has started a programme of work to develop capacity and understanding in sediment/nutrient transfer and this should be continued and extended as a matter of urgency.*

27.2.3 FISHERIES RESEARCH

Another gap in the basin planning process is the level of information about fisheries in the Mekong. The Mekong River Basin is acknowledged as having the largest inland fishery in the world, and yet the incomplete detail about the fishery, where the species are and the migration patterns, and the fish production has led to a very wide range of estimates by different experts, and considerable uncertainty about the impacts of the proposed mainstream dams. *A focused programme of fisheries research is needed to reduce this uncertainty and to come to a clearer picture of the fish species and the fishery production that are at risk.*

27.2.4 SOCIAL & CULTURAL KNOWLEDGE ANALYSIS

Another serious gap apparent during the SEA is the lack of social and cultural knowledge and analysis of the communities that live along and use the resources of the Mekong. A statistic that almost 60% of the people living in the basin live within 15 kilometers of the river bank underlines the need for such an analysis, without which comprehensive social development and planning for mitigating impacts cannot be undertaken, nor strategic decisions taken. *The MRC and the LMB countries should strengthen their capacity for social and cultural analysis as part of the basin planning process, including the trans-boundary social consequences of mainstream development.*

27.2.5 CLIMATE CHANGE THREAT & VULNERABILITY ASSESSMENTS

MRC should lead in defining trends and ranges of climate change for each sub-basin and in assessing their implications for livelihoods and for development sectors including hydropower. MRC is in the early stages of implementing the Mekong Climate Change Adaptation Initiative including the establishing a Mekong Panel on Climate Change and preparation of a Mekong Climate Change Action Plan. A wide range of relevant technical partners and expertise should be bought into the CCAI so that the authority and credibility of MRC's climate change projections and assessments is established.

27.2.6 SEA

MRC should draft a protocol with associated procedural guidance for conducting SEAs on a regular basis to support and advise LMB countries when faced with major development decisions having trans-boundary and international implications. This SEA of mainstream hydropower is the first use of the tool by the MRC and one of the first regional SEAs conducted in the LMB. SEAs can be used for assessment of large scale or multiple development proposals that plan to use the Mekong River and its resources, such as irrigation, water diversions, flood protection, industrial withdraws and waste emissions, urban development and hydropower. Through the consultative processes, a sharper and focused strategic analysis and recommendations can be achieved than through the wider basin development planning processes. The SEA process is particularly well suited to trans-boundary strategic impact analysis.

27.3 GUIDANCE & STANDARDS

The MRC Initiative on Sustainable Hydropower has taken significant steps in developing the Preliminary Technical Guidance on mainstream hydropower dams, a useful document that begins the set the standards required for mainstream and tributary hydropower projects. The guidance covers navigation, fish passage, sediment management and river morphology, water quality and aquatic ecology and dam safety. *The MRC should expand the guidance to cover additional issues raised during the SEA, such as environmental flows, climate change risks, reservoir management, benefit sharing, trans-boundary compensation and grievance procedures.*

27.4 A MEKONG FUND

The concept of a Mekong Fund is under consideration as a mechanism for raising and managing funds from multiple sources including revenue derived from tariffs, contributions from private developers, contributions from development partners (bi-lateral and multi-lateral IFIs) and Dialogue Partners, as well as potential new financing sources such as international carbon financing. The uses of these funds could include a range of activities such as trans-boundary mitigation and benefit sharing, heritage protection, MRC Secretariat operations, RDD and monitoring and the institutional capacity within the MRC or other body to coordinate the management of water infrastructure. *MRC should develop the concept of a Mekong fund further and put proposals forward for agreement of the four LMB countries.*

28 RECOMMENDATIONS FOR THE SEA REPORT & FOLLOW-UP CONSULTATION

Throughout the SEA, consultation meetings and the progressive SEA reports at each stage of the assessment have raised understanding and awareness on the strategic issues of concern underlying decisions on the mainstream projects. Yet, the SEA process itself has been constrained by time and resource in its reach to engage many stakeholders and senior decision makers. During the final regional consultation meeting held in Ho Chi Minh City in June 2010, experts from all four countries made strong recommendations for continuing the consultation process based on the final SEA report. In summary, those recommendations from national working groups include:

Consultation process on the final SEA should be extended to include senior decision makers in each country including its consideration by:

- **The MRC Joint Committee**
- **National Mekong Committees**
- **Line agencies**
- **National cabinets of Ministers**
- **Natural resources and environment parliamentary committees**

It is recommended that the MRC:

- Prepare a consultation and communications plan for the SEA report and ensure adequate funding at regional and national levels through the NMCs for its implementation
- Have the SEA report translated into each of the four national languages for wide circulation
- Specify the timeframe for release and distribution of the final SEA report
- Submit the SEA report to Joint Committee for endorsement and guidance
- Submit the report to National Mekong Committees for discussion and action at national level
- Circulate the SEA report to the donors and other regional stakeholders for discussion and action
- Convene a multi-stakeholder conference to discuss the report
- Establish regional technical task forces on the key strategic issues where uncertainties remain
- Integrate the SEA report into the Basin development planning process, supplementing the BDP, and providing continuity with MRC programs

It is recommended that NMCs:

- Circulated a translated version of the SEA report and summary to national line agencies
- Communicate key findings of the SEA to high-level decision makers in national languages
- Facilitate consultation and engagement with communities that would be affected

ANNEXES

ANNEX I: SALIENT FEATURES OF THE PROPOSED LMB MAINSTREAM PROJECTS

MAINSTREAM DAM		MANAGEMENT STATUS				DESIGN SPECIFICATIONS									DIMENSIONS		
	LOCATION	DEVELOPER	EARLIEST POTENTIAL COMMISSION DATE[68]	DESIGN STATUS	ENVIRONMENTAL ASSESSMENT STATUS	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 (mamsl)	Low Supply Level (Mamsl)	Live Storage (mcm)	RESERVOIR AREA (km2)	Length of dam (m)	Height (m)
Pak Beng	Lao PDR	Datang International Power Generation (China)	2016	MoU, feasibility	IEE submitted	31	7,250	1,230	1,230	5,517	4,073	340	334	442	87	943	76
Luang Prabang	Lao PDR	PetroViet Nam Power Corporation (Viet Nam)	2016	MoU, feasibility	Feasibility study,	40	3,812	1,410	1,412	5,437	4,205	310	308	734	90	1,106	68
Xayaburi	Lao PDR	SEAN & Ch. Karnchang Public Co Ltd (Thailand)	2016	MoU, feasibility	Feasibility & full ESIA submitted	24	6,018	1,260	1,260	6,035	5,139	275	270	225	49	810	32
Pak Lay	Lao PDR	CEIEC and Sino-Hydro (China)	2016	MoU, feasibility	IEE submitted	26	4,500	1,320	1,320	6,460	4,252	240	237	384	108	630	35
Sanakham	Lao PDR	Datang International Power Generation (China)	2016	MoU, feasibility	Not yet	25	5,918	700	1,200	5,015	3,978	220	215	106	81	1,144	38
Pakchom	Lao PDR Thailand	N/a	2017	MasterPlan	Not yet	22	5,720	1,079	1,079	5,318	5,052	192	190	12	74	1,200	55
Ban Koum	Lao PDR Thailand	Italian Thai Asia Corp. Holdings (Thailand)	2017	MoU, feasibility	Not yet	19	11,700	1,872	1,872	8,434	8,012	115	115	0	133	780	53
Lat Sua	Lao PDR	Charoen Energy and Water Asia Co Ltd (Thailand)	2018	MoU, pre-feasibility	Pre-feasibility study submitted	10.6	10,000	686	686	2,668	1,524	97.5	95.5	0	13	1,300	27
Don Sahong	Lao PDR	Mega First (Malaysia)	2016	PDA, detailed planning	Full EIA submitted,	17	2,400	240	240	2,375	1,989	75	72	115	290 (ha)	1820-720-2730	10.6-8.2-8.3
Thakho diversion	Lao PDR	CNR & EDL (France/Lao)	2016	MoU, pre-feasibility	IEE submitted	16	380	50	50	360		71.7	68.7	n/a	n/a	Channel 1,800m	n/a
Stung Treng	Cambodia	Song Da Construction Co. (Viet Nam)	N/a	MoU, pre-feasibility	Not yet	15	18,493	980	591	4,870	2,937	55	50	70	211	10,884	22
Sambor	Cambodia	China Southern Power Grid (China)	2020	MoU, pre-feasibility	Pre-feasibility submitted	33	17,668	2,600	2,030	11,740	9,150	40	39	465	620	18,002	56

[68] Commissioning dates as provided in MOUs signed between 2006 -2010. The first project to be notified under the PNPCA (Xayaburi in September 2010) has subsequently revised the commission date 2019

ANNEX II: LIST OF STAKEHOLDERS CONSULTED

	Meeting with line agencies	National Scoping Workshops	Civil Society Organization Meetings	Regional SEA Workshops
Cambodia	▪ General Department of Energy, HydroElectricity Department - Ministry of Industry Mines and Energy (MIME) ▪ Department of Hydrology and River Works - Ministry of Water Resource and Meteorology (MOWRAM) ▪ Inland Fisheries Research and Development Institute (IFReDI) & Fishery Administration (FiA) - Ministry of Agriculture Forestry and Fisheries (MAFF) ▪ Department of Environmental Impact Assessment (EIA) - Ministry of Environment (MoE) ▪ Ministry of Planning (MOP) ▪ Planning and Development department, Environmental & eco-tourism office - Ministry of Tourism (MOT) ▪ Department of Planning and public relations - Ministry of Rural Development ▪ Department of Planning & Statistics - Ministry of Agriculture Forestry and Fisheries (MAFF) ▪ Department of Waterways - Ministry of Public Works and Transportation (MPWT) ▪ Forestry Administration - Ministry of Agriculture Forestry and Fisheries (MAFF) ▪ Dolphin Conservation & Tourism Authority - Council of Ministers ▪ Department of Preventative Medicine - Ministry of Health (MoH) ▪ Environmental department of Stung Treng province ▪ Department of water resource and meteorology of Stung Treng province ▪ Department of water resource and meteorology of Stung Treng Province ▪ Fishery Diviion of Thalaboriwat district ▪ Department of agriculture of Stung Treng Province ▪ Health department of Stung Treng Province ▪ Forestry administration of Stung Treng Province ▪ Department of Planning of Stung Treng Province ▪ Department of Planning of Kratie Province	▪ General Department of Energy, HydroElectricity Department - Ministry of Industry Mines and Energy (MIME ▪ Cambodian National Mekong Committee ▪ Department of Hydrology and River Works - - Ministry of Water Resource and Meteorology (MOWRAM) ▪ Inland Fisheries Research and Development Institute (IFReDI) - Ministry of Agriculture Forestry and Fisheries (MAFF) ▪ Fisheries Administration - Ministry of Agriculture Forestry and Fisheries (MAFF) ▪ Department of Planning & Statistics - Ministry of Agriculture Forestry and Fisheries (MAFF) ▪ Department of Environmental Impact Assessment (EIA) – Ministry of Environment (MoE) ▪ Department of Waterways - Ministry of Public Works and Transportation (MPWT) ▪ Planning and Development department, Environmental & eco-tourism office - Ministry of Tourism (MOT) ▪ Department of Preventative Medicine - Ministry of Health (MoH) ▪ Department of Planning and public relations - Ministry of Rural Development (MRD)	▪ World Wildlife Fund (WWF) ▪ WCS Cambodia Program ▪ NGO Forum Cambodia ▪ Culture and Environmental Preservation Association (CEPA) ▪ CDCAM ▪ Fauna & Flora International ▪ Cambodian National Mekong Committee	▪ Cambodian National Mekong Committee ▪ Ministry of Environment ▪ Ministry of Industry, Mines and Energy, ▪ Ministry of Agriculture, Forestry & Fisheries

	▪ Fishery department of Kratie province ▪ Health department of Kratie province ▪ Department of water resource and meteorology of Kratie Province ▪ Department of Environment of Kratie Province ▪ Ministry of Tourism	▪ Dolphin Conservation & Tourism Authority ▪ Forestry Administration - Ministry of Agriculture Forestry and Fisheries (MAFF) ▪ Ministry of Tourism		
Lao PDR	▪ Department of Electricity - Ministry of Industry Mines and Energy (MIME) ▪ Department of Environment and Social Impact Assessment – WREA ▪ Department of Irrigation - Ministry of Agriculture Forestry and Fisheries (MAFF) ▪ Department of Water Resources ▪ Department of Forestry - Ministry of Agriculture Forestry and Fisheries (MAFF) ▪ Department of Livestock and Fishery - Ministry of Agriculture Forestry and Fisheries (MAFF) ▪ Governor's Office of Bokeo Province ▪ Water and Environmental Section of Bokeo Province ▪ Planning and Investment Department of Bokeo ▪ Rural Development Department of Bokeo ▪ Forestry Section of POFA of Bokeo ▪ District Governor of Paktha ▪ Culture and Information of Paktha District ▪ Governor's Office of Pakbeng ▪ Water and Environmental Office of Pakbeng District ▪ Public Health Office of Pakbeng ▪ Governor's Office of Oudomxay Province ▪ Planning and Investment of Oudomxay Province ▪ Rural Development Department ▪ Governor's Office of Luangprabang province ▪ Planning and Investment of Luanprabang Province ▪ Forestry section of PAFO of LP Province ▪ Governor's Office of Nan District ▪ Water and Environmental Office of Nan District ▪ Governor's Office of Sayaboury province ▪ Statistics of Planning and Investment department of sayaboury Province ▪ Mining and Power department of Sayaboury Province ▪ Forestry Section of PAFO of Sayaboury Province ▪ Planning Office of Sayaboury District ▪ Governor's Office of Paklay District ▪ Department of Planning and Investment of Vientiane	▪ WREO Vientiane Province ▪ WREAO Luang Prabang ▪ Department of Water Resources ▪ Department of Irrigation ▪ Department of Livestock and Fishery ▪ Department of Forestry ▪ Department of Hygiene& Preventative medicine ▪ Department of Water Ways ▪ Lao National Mekong Committee	▪ SEM II Project ▪ International Union for Conservation of Nature (IUCN) ▪ World Wildlife Fund (WWF) ▪ Wildlife Conservation Society (WCS) ▪ GTZ ▪ International Water Management Institute (IWMI)	▪ Lao National Mekong Committee ▪ WREA - Water Resources & Environment Agency ▪ Ministry of Industry Mines and Energy (MIME)

	Province ▪ Governor's Office of Med District ▪ Governor's Office of Champasack Province ▪ Planning of the Department of Planning and Investment of Champasack province ▪ Investment of the department of Planning and Investment of Champasack province ▪ International Relation of the the Department of Planning and Investment of Champasack province ▪ Forestry Section of Champasack Province ▪ Governor's Office of Pakse District ▪ Governor's Office of Khong District ▪ Planning and Investment of Khong District ▪ Water and Environmental Office of Khong District ▪ Mining and power division of Khong District			
Thai Land	▪ Royal Irrigation Department ▪ Electricity Generation Authority of Thailand ▪ Navigation & Maritime Department ▪ Department of Renewable Energy Development & Energy Efficiency Department ▪ National Economic & Social Development Board ▪ Department of Fisheries ▪ Department of Public Health ▪ Department of EIA	▪ Thai National Senate ▪ Bureau of International Cooperation (BIC)– Department of Water Resources ▪ Mekong Affairs Division - Bureau of International Cooperation (BIC) ▪ Civil Engineering Expert - Royal Irrigation Department (RIG) ▪ Water Resources and Agriculture – Office of Natural Resources and Environmental Policy and Planning (ONREPP) ▪ Electricity Generating Authority of Thailand (EGAT) ▪ Department of Alternative Energy Development and Efficiency (DAEDE) ▪ Water Planning Section – NESDB ▪ Department of Forestry (DoF) ▪ Irrigated Agriculture and Accelerated Area Group – Department of Agriculture (DoA) ▪ Department of Health ▪ Marine Department ▪ Statistical Forecasting Bureau ▪ Thai National Mekong Committee ▪	▪ TNMC, Water Resources Department ▪ Care Thailand ▪ Moon River Basin Committee ▪ Sub-Basin Network Committee ▪ Moon River Basin NGO Network ▪ Natural Resource and Environment Volunteer ▪ Community Ecology Institute ▪ Lower Moon Sub-Basin Network ▪ Subsomboon Village ▪ Esarn Cooperatives Limited ▪ Esarn Environmental Assembly ▪ of Esarn Alternative Agriculture Network ▪ Natural Resource and Environment Faculty, Mahasarakam University ▪ Water Resources Regional Office ▪ Mekong Sustainable Agriculture Extension Association ▪ Water User Network ▪ Sakolnakorn University ▪ Community Right Association ▪ Rehabilitation of Local Community Working Group ▪ Ratchapat Udonthani University ▪ Community Network Development Association ▪ Chi River Basin Farmer	▪ Thai National Senate ▪ EGAT ▪ DAEDE ▪ Department of Fisheries ▪ TNMC, Water Resources Department

			▪ Roi-Et River Sub-basin ▪ Songkram River Sub-basin ▪ WWF Thailand ▪ Khon Kaen University	
Viet Nam	▪ Department of Energy ▪ Department of Prevention & Environment ▪ IMHEN – Institute of Metrology, Hydrology and Environment ▪ Development Strategy Institute ▪ Viet Nam Inland Waterway Administration – Ministry of Transport ▪ Department of Forestry ▪ National Directorate of Aquatic Resources Exploitation and protection (NADAREP) ▪ Southern Sub-Institute of Forest Inventory and Planning (Southern FIPI) ▪ Southern Institute for Water Resources Planning ▪ Sub-National Institute of Agricultural Planning and Projection (Sub-NIAPP) ▪ Research Institute for Aquaculture No.2 ▪ Centre for monitoring of natural resources and environment – DONRE Can Tho ▪ Research Institute for Climate Change (Dragon Institute) – Can Tho UniversityDepartment of Agriculture and Rural ▪ Development of Soc Trang Province ▪ Department of Statistics of Soc Trang Province ▪ Department of Planning and Investment of Soc Trang Province ▪ Department of Labour, Invalids and Social Affairs of Soc Trang Province ▪ Department of Agriculture and Rural Development of Dong Thap Province ▪ Department of Statistics of Dong Thap Province ▪ Department of Planning and Investment of Soc Trang Province ▪ Department of Labour, Invalids and Social Affairs of Dong Thap Province	▪ Meteorology and Hydrology Institute – Ministry of Natural Resources and Environment (MONRE) ▪ Department of Environment - MONRE ▪ Appraisal and EIA/SEA Department ▪ Natural Resources and Environment Magazine – MONRE ▪ Centre for Water Resources Planning and Investigation ▪ National Centre for Hydrology and Metrology ▪ Institute for Strategic Development – Ministry of Planning and Investment (MPI) ▪ Department of Science, Education, Natural Resources and Environment – MPI ▪ Department of Agriculture & Economy ▪ Institute of Policy and Strategy for Rural and Agricultural Development – Ministry of Agriculture and Rural Development (MARD) ▪ National Institute for Agricultural Planning and Projections - MARD ▪ National Directorate of Aquatic Resource Exploitation and protection – MARD ▪ Department of Forestry - MARD ▪ Institute of Water Resource Planning – MARD ▪ Institute for Forest Planning and Investigation – MARD ▪ Viet Nam Institute for Water Resources Research – MARD ▪ Viet Nam Inland Waterways Administration – Ministry of Transport ▪ Department of Science &	▪ People and Nature Reconciliation ▪ Center for Water Resources Conservation and Development (WARECOD) ▪ Consultancy on development (CODE) ▪ Center for Biodiversity & Development ▪ Research Institute for Climate Change-Can Tho university ▪ Action Aid International ▪ Bird Life International ▪ Fauna & Flora International (FFI) ▪ Oxfam Hong Kong ▪ World Wild Fund for Nature ▪ World Vision International ▪ NGO Resources Centre ▪ East Meets West Foundation ▪ Viet Nam National Mekong Committee	▪ VNMC ▪ PetroVietnam ▪ EVN

		Technology – Ministry of Industry and Trade ▪ Department of Science, Technology & Environment – Electricity of Viet Nam (EVN) ▪ Consulting Company 1 – EVN ▪ Department of Social Welfare – Ministry of Labour, Invalid and Social Affairs ▪ Department of Health & Environment – Ministry of Health (MOH) ▪ Department of International Organisations – Ministry of Foreign Affairs ▪ Centre for Promotion of Integrated Water Resource Management ▪ Centre for Promotion of Integrated Water Resource Management ▪ Viet Nam Association of Large Dams and Water Resources Development ▪ Southern Institute for Water Resource Planning – MARD ▪ Research Institute for Aquaculture No 2. (RIA 2) ▪ Viet Nam National Mekong Committee		
China				▪ ESCIR – Ecosystem Commission for International Rivers
Private Sector developers	▪ Team Consulting Engineering Management (Xayaburi project) ▪ PetroVietnam Power Corporation (Luang Prabang project) ▪ EVN Power Engineering Consulting JSC ▪ Viet Nam Environment & Sustainable development institute (Luang Prabang Project) ▪ Charoen Energy and Water Asia Co Ltd (Thailand) (Lat Sua project) ▪ Mega First (Don Sahong project) ▪ China Southern Grid (Sambor project) ▪ CNR (Thakho project)	International Development Organisations	▪ World Bank ▪ ADB EOC – Environment Operations Centre ▪ AusAID ▪ ASEAN ▪ Finida ▪ Danida ▪ JICA ▪ KfW ▪ UNDP ▪ UNESCAP ▪ UN Women	

ANNEX III: MAINSTREAM POWER ALTERNATIVES - PARTIAL IN-CHANNEL, DIVERSION AND OTHER INNOVATIVE SYSTEMS FOR ELECTRICITY GENERATION

The proposed schemes for Mekong mainstream dams threaten its connectivity. There are alternatives that should be considered which may be less damaging. These include:

- **Partial in-channel dams.** Of the proposed dams, the one example of this is Don Sahong, in which part of the flow of the river is channeled between an island and one bank allowing electricity to be generated, while maintaining the other channel/s for ecological connectivity, navigation etc. There are a number of locations in the river where partial damming around islands could be developed. One such is an alternative to the Sambor dam. The concern with the Don Sahong dam is that, despite being a partial dam, it threatens the year-round connectivity of the mainstream for fish passage and would draw significant flows away from Khone Falls.

- **Out-of channel diversion hydropower schemes.** Of the proposed schemes, Thakho HPP is the only one which offers a non-damming option. This scheme diverts water round a large drop in head (Khone-Phapheng Falls) and generates electricity without threatening the connectivity of the mainstream. There may be other locations where such diversion schemes would be possible, although the drop in head at Khone Falls provides the best opportunity. Such locations have not been fully assessed.

- **Bend cut-off diversions**. These typically use the winding nature of a river to develop a reasonable difference in head over a short straight line distance. Typically a fraction of the river flow around a major bend, or series of bends, is sent by a diversion tunnel, and delivered back to the river several kilometers downstream. A power house is installed at the outlet end of the tunnel, and power is developed in proportion to the difference in head, and the flow rate diverted through the tunnel. Peak power from the turbines of 50 to 100 megawatts may be developed in this way, using only a fraction of the flow in the Mekong River. Advantages of this system include absence of a dam/reservoir system, the fact that only a fraction of the flow in the river is utilised, with the remaining flow left in the river channel, and the fact that the majority of the sediment is passed downstream in the river channel. Disadvantages include the cost of tunneling (which may be offset by the savings from not requiring a dam). This strategy was utilised at Avuong dam in Quang nam-Da Nang province, Viet Nam, where flow was diverted from the Song Avuong to the Song Bung via a 7 km long tunnel, (in this case a dam was also constructed on the Avuong River to raise the river level and maximise the head developed).

  Sites that are suitable for bend cut-off diversions need to be investigated further, and the cost effectiveness examined as part of a pre-feasibility study. Possibilities on the Mekong mainstream downstream of China include:

  1. Xieng Kok cut-off, north to south alignment, 5 km long tunnel (within Myanmar), about 10 m head difference
  2. Chiang Saen cut-off, west to east alignment, 14 km long tunnel (within Lao PDR), about 10 m head difference
  3. Luang Prabang cut-off, north-west to south-east alignment, 21 km long tunnel (within Lao PDR), about 20 m head difference.

- **Other innovative systems for electricity generation.** A number of concepts are being developed in other parts of the world for generating electricity, e.g. drawing upon experiences with hydrokinetic systems. These have not yet been proven, but could have the advantage of allowing the development of hydropower without threatening the connectivity of the Mekong mainstream. The USA Federal Energy Regulatory Commission lists a number of preliminary permits for inland hydrokinetic systems on rivers such as the Columbia, Tennessee and St Clair rivers up to 20MW.[69] All these hydrokinetic units have smaller output per unit; however there is the potential for their installation in large numbers amounting to a significant level of generation for a given river reach. Systems include:

  (i) **The Anaconda system**[70] designed to capture coastal wave energy. It uses a distensible rubber tube anchored to the river bed and floating just beneath the surface, in which bulge waves are “squeezed” by passing waves. It is not possible to conceive that this would produce any significant amount of energy from the Mekong River, or from mainstream reservoirs on the Mekong, on account of the low wave energy (orders of magnitude lower than sea waves.

  (ii) **The Schauberger vortex**,[71] which is based upon the velocity of the flow of water and a system might be envisaged in which the already swiftly flowing water is channelled into a round pipe or jet funnel to concentrate its velocity and designed to induce a vortex in the funnel.

69 http://www.ferc.gov/industries/hydropower/indus-act/hydrokinetics.asp

70 http://www.checkmateuk.com/seaenergy/index.html

71 http://www.frank.germano.com/theschaubergerpage.htm

(iii) **Inflow turbines:** a number of kinetic hydropower generation systems exist which operate` by submerging axial and cross-flow turbines in the water column. These have primarily been developed for marine environments but can be applied to rivers with strong currents. Efficiency can be enhanced with the addition of venturi shrouds which increase the cross-sectional area channelled into river-bed mounted turbines. The Belgian company, Rutten Electromecanique is actively completing some projects in RDC (Congo) with **floating power generators**. They have already made contact with MRCS. These may be suitable on the Mekong mainstream, but would provide lower power outputs, because the size of rotor is limited, and the velocity in the river is modest. There would be significant problems with anchoring and damage in the Mekong, on account of the high floating debris load. Likely peak power output would be two to three orders of magnitude smaller than the present projects.

ANNEX IV: RECOMMENDED STUDIES

ENERGY AND POWER

Strategic Options 1 and 2

- Assessment of what "no mainstream dams" or "deferment" means to power sectors in each country and implications for investor/FDI investment in LMB power development
- Study to confirm the impact of operation of upstream Lancang-Mekong dams on LMB power generation and operation of dams and level of other potential risks and benefits – e.g. understanding opportunities for revenue generation and synergies with impact mitigation / enhancement in other sectors in dry season flows.
- Review of alternative schemes for harnessing Mekong mainstream hydropower and feasibility studies for their application.

Strategic Option 3 and 4

- Develop a hydrological model for operation of mainstream dams in hourly detail and with different configurations of plants in place
- All project developers and regulators should apply the model under guidelines of flow modification to determine the performance of their proposed projects under different flow and states of development

ECONOMICS

Strategic Options 1 and 2

- Study of the macro-economic implications of foregoing mainstream hydropower development, including lost opportunity costs at the national and regional level
- Studies into the feasibility of establishing a Mekong Fund

Strategic Options 3 and 4

- Economic studies on mainstream hydropower development must:
  - Incorporate realistic accounting for all direct and indirect costs and benefits
  - Depend upon detailed studies undertaken in other sectors (fisheries and hydrology in particular)
  - Address uncertainty through comprehensive sensitivity analysis

HYDROLOGY AND SEDIMENT

Hydrology is one of the best studied features of the Mekong. Sediment and nutrients are among the least understood components. Recommendations for further studies cover:

- Field work and monitoring
- Data management
- Information sharing (within LMB national monitoring programs & with China)

MRC is well positioned to coordinate many of these activities and already is setting up a sediment program under IKMP.

Ongoing hydrological monitoring:

Strategic Options 1 and 2: Continue to develop and maintain hydrological and sediment monitoring and analysis
Strategic Options 3 and 4 Provide funding and technical input to MRCS to recalibrate, relocate and rebuild gauging stations that would be seriously impacted by the proposed projects, either by inundation, or by very significant deposition or erosion of bed material/bed level.

Technical studies include:

Strategic Options 2, 3 and 4

- **Comprehensive studies on sediment dynamics**, including
  - Profiling of the sediment grain size distribution: (i) a comprehensive and ongoing monitoring program of suspended sediments, and (ii) for bed load, assessment should prioritise bed composition, size distribution of sediment and bed load transport, in the mainstream particularly in the Zone 3 reach, and in major tributaries. (iii) In addition, improved definition of time scale for projects causing serious bed erosion problems near Vientiane.

  - Consolidation of sediment data: Resolution of why there is an apparent drop-out of the suspended sediment load at Nong Kai. (Lao PDRand Thailand)
  - Role of cohesive sediments: (i) characterise the presence of cohesive sediments in all zones of the Mekong, (ii) assess their eco-morphological importance for processes of siltation, fertilisation, nutrient transport and aquatic productivity Floodplain deposition: The cumulative impacts of mainstream projects on floodplain deposition based on 3D hydrodynamic modeling of the floodplain with reduced sediment loads.
  - Fate and transport of nutrients: extend existing IKMP basin-scale sediment modeling undertaken to quantify the impacts on primary production and explore the longitudinal connectivity of the production cycle from the headwaters to the river mouth. With focus on: (i) floodplains, (ii) off shore delta, (iii) nutrient loading from major city sewage outfalls
- **Morphological changes**: bed and bank erosion, lateral migration of the channel and changes to connectivity between the floodplains and the main stem. In the bed rock and confined reaches, the focus would be on sand bars and deep pools, as well as the fate and transport of bed load and non-cohesive sediments.
- **Marine sediment plume**: (i) map the changes to the extent and movement of the marine plume, and (ii) detailed hydrodynamic modelling of ocean processes with a focus on bio-geochemistry of fresh-saltwater interactions and sediment transport. (Viet Nam)
- **Coastal erosion**: quantify the sites and rate of erosion in the context of the reduced sediment load predicted by the array of dams proposed for Lancang/Mekong and the Central Highlands. (Viet Nam)
- **Groundwater recharge/connectivity**: address the changes to groundwater connectivity in the Cambodian floodplains and the Mekong Delta with a focus on: (i) changes to the seasonal water table, (ii) impacts on arsenic levels, (ii) potential salinisation of groundwater through the elevation of the water table (Cambodia and Viet Nam)
- **Tonle Sap system**: explore the changes to the seasonal flooded area of the Tonle Sap (and implications for flooded forest), the change in the hydraulic gradient driving reversal in the Tonle Sap as well as revise the sediment balance for the system under a the 20Y scenario with reduced inputs. (Cambodia)
- **Hydro-dynamics of fish migration**: Analysis of capability of migratory fish species to move upstream against an opposing river current, including the burst speed that fish are capable of sustaining. Design and hydraulic testing of a scale model fish ladder suitable for Mekong migratory fish, installation of a full scale fish ladder at a test site (e.g. at a dam somewhere on the lower Mekong tributary system), and observations to see the effectiveness of the ladder, and its limitations.

Strategic Option 3 and 4

Studies to improve mainstream dam operations:

- **Reservoir sedimentation dynamics & flushing effectiveness:** Deposition and erosion of sediment in example reservoirs
- **Downstream implications of peaking & continuous operation & ramping rates**: operational strategies, ramping rates & size of downstream wave propagation
- **Seasonal reservoir simulation**: timing of water release ahead of the flood arrival & effects on timing of the downstream hydrograph.
- **Sensitivity analysis of annual energy generation to operating water levels**: to understand the sensitivity of annual energy generation totals (GWh per year) at each site, to lowering the operating levels of the reservoirs
- **Thermal plume**: explore the downstream changes to water temperature which could be induced by the Yunnan cascade
- **Mekong River Cumulative Trapping Efficiency rule curves for mainstream projects**: sensitivity analysis to assess the implications of different groupings of the 11 LMB mainstream projects: (i) Northern Lao cascade (Chiang Saen - Vientiane), (ii) Lao-Thai projects (Vientiane – Khone Falls), (iii) Cambodian floodplain projects (Cambodian floodplain projects)
- **Emergency management**: Time and motion study to simulate the operation of turbines and spillway gates following a breakdown of the electrical system, e.g. the transmission line or the transformers. Analysis of the speed of load shedding, and the ability of the spillway gates to open sufficiently quickly to keep reservoir levels at or below the design full pool level. Analysis of the resulting scenarios, and the propagation of a change of flow wave downstream, resulting from the breakdown
- **UMB daily water level harmonics**: historic observed water levels before and after Manwan dam to statistically explore the fluctuations in water levels at daily and hourly time steps.

TERRESTRIAL ECOSYSTEMS AND AGRICULTURE

For Strategic Option 2, 3 and 4

- **Study to update understanding of biodiversity status and distribution**, including endangered species habitat requirements and agricultural biodiversity and traditional races

- **Research on values of nutrients** attached to sediments and increased of agriculture production cost due to loss of natural nutrients. (see above fate and transport of nutrients)

AQUATIC ECOSYSTEMS

Strategic Options 1 and 2, 3 and 4

- **Review, survey and classify aquatic habitats** in whole Lower Mekong (biodiversity and ecological importance)
  - Identify key biodiversity hotspots on Mekong mainstream
  - Prioritise key tributaries for ecosystem integrity and health of the Mekong, highlighting those affected by proposed mainstream dams
  - Leading to identification of a system for protection of key stretches of the river and its tributaries
- **Assessment of the ecological importance and productivity of the seasonally exposed in-channel wetlands**

Strategic Option 3 and 4

- **Research into enhancement of multiple use in reservoirs**, including irrigation, navigation, fisheries and potential downstream consequences of water diversion.
- **Cultural ecosystem services**: Systematic review of all cultural assets associated with Mekong and with specific sites of proposed dams
- **River based tourism**: Carry out market assessments and feasibility studies for enhancing the diversity of river-based tourism attractions and recreational facilities of dams and reservoirs when constructed

FISHERIES

Strategic Options 2, 3 and 4

- **Research and development of systems for fish passage**, suitable for Mekong conditions, to improve effectiveness.
- **Systematic assessment of Mekong fish species** that can survive in hydropower reservoirs, and those that will not.
- **Assessment of habitat improvements in reservoirs** to encourage fish diversity production

SOCIAL SYSTEMS

Strategic Options 2, 3 and 4

- **Studies into distribution of impacts on subsistence and livelihood dependence on fisheries** at different sections of the Mekong mainstream
- **Assessment of loss of Tonle Sap floating homes** due to increased and rapid water flow changes
- **Assessment of cumulative downstream impacts in Viet Nam due to altered river flows and sediments reduction** leading to incremental reduced agricultural productivity, rise in agricultural costs, reduced fresh and saltwater fisheries production

NAVIGATION

Strategic Options 2, 3 and 4

- **Study on small users:** Studies to determine the numbers of small users within 15 kilometres of the proposed mainstream hydropower projects and how the construction and operation of the dam will impact on their activities.

CLIMATE CHANGE

Strategic Options 2, 3 and 4

- **Risks to food security:** Comprehensive collaborative study (MRC, CSIRO and other international partners) of climate change risks on agricultural and fisheries by sub-basin and overall food security
- **Increased tributary power potential:** Potential for increased power production from tributaries through retrofitting for greater efficiency and capacity in existing and new projects
- **Design for extreme events:** Assessment of design implications for mainstream projects of risk of increased range in flow and incidents of extreme events
- **Potential for emissions reduction** through hydropower in Lao PDR and Cambodia

ANNEX V: POLICY AND GUIDANCE RECOMMENDATIONS

The following recommendations cover the policies, guidance and economic support required under the different strategic options. They are arranged by theme, although inevitably there is some overlap. They include filling the energy and economic development gaps if the mainstream dams are cancelled or deferred, and the social policies and practices which need to be rationalised between the LMB countries if Options 3 or 4 are chosen.

ENERGY AND POWER

Strategic Options 1 and 2

- **Alternatives to bulk supply**: Clarify and rationalise LMB national policies and strategies relating to alternatives for bulk supply from potential mainstream dams
- **Alternative sources of energy** must be factored into the national power development planning to supply of 65,000 GWh per year foregone from proposed mainstream dams (65,000 GWh = 10 x Nam Theun 2's)
- **Use more conventional alternatives** to meet incremental demand (e.g. from coal imports for Thailand, Viet Nam and possibly Cambodia; Cambodia may also choose Lao hydro imports).
- **Accelerate consideration of Renewable Energy supply + Demand Side Management** in all countries (see box)

Option 3 and 4

- Develop policies for addressing issues of **international energy exchanges** particularly in the event of electricity being exported from a country which is experiencing electricity shortage
- Establish rules and regulations under which mainstream projects are developed and operated, covering especially **scheduling and operation**. This should include application of the model of operation (see under studies)
- Enhance aspects of **trans-boundary cooperation related impacts of power generation on other sectors** (e.g. as under 1995 Agreement and project-specific PNPCA trans-boundary agreements) including LMB cooperation with China e.g. scope to optimise operation considering non-power impacts & power production.

ECONOMICS

Option 1 and 2

- **Develop alternatives to replace forgone export revenue** (in economic terms USD US1.2 billon for Cambodia and USD 4.6 billion for Lao PDR annually by 2030 – less debt repayment + other cost during concession period).
- **Develop economic support packages** for other energy sources
  - Cambodia - investigation of possible fossil fuel reserves, support for thermal plants
  - Lao PDR - potential for accelerated tributary development
  - Donor support packages to promote the investigation of alternative energy options
  - In both cases, support for the grid and decentralised Renewable Energy production to address rural energy poverty.
  - Integration of these options into existing and planned regional programs
- **Develop economy-wide structural adjustment packages** in order to mitigate the opportunity cost of foregoing or delaying mainstream projects in Cambodia and Lao PDR
  - Reorientate SEDPs away from a dependence on mainstream hydropower
  - Donor support for development of key sectors in Cambodia and Lao PDR
  - Sectoral support (for agriculture, mining and manufacturing industry)
  - Social development (health and education)
- **Develop the Mekong Fund**, based upon feasibility study

Strategic Options 3 and 4

- **To enhance the investment stimulus** from the mainstream hydropower plants, each country should aim to:
- Maximise local input requirements (labour and other inputs) in projects
- Provide support for developing ancillary industries such as hydro-engineering (subsidies, training programs etc)
- Support for tradable goods sector
- Support for improving productivity of agriculture and manufacturing
- Support for improving productivity to address service sector bottle-necks
- Provide training and skills programs, infrastructure, subsidies
- **Broad interventions aimed at improving national productivity (health, education , import of capital** goods)
- Broader social development programmes (education, health ,rural infrastructure) – integrated with national target programs

- Possible area focused support for badly affected locations (e.g. Tonle Sap)
- Likely to require large scale trans-boundary reallocation of resources
- **Equitable financing of mitigation measures and enhancement**
  Hydropower development is likely to imply the generation of significant economic rents, including economic benefits (for power consumers), profits (for developers) and revenues (for host governments). These benefit streams will last the life-time of the projects. In principle, all mitigation and enhancement measures should be financed through these benefit streams. Benefits sharing may be used to redistribute some of the benefit of hydropower for mitigation and enhancement measures (see box on benefit sharing).
- **Benefit sharing - Distribution of costs and benefits:** Benefit sharing mechanisms should be developed for all LMB hydropower schemes, including proposed mainstream dams and tributaries. The risk of costs and opportunities for benefits relating to mainstream hydropower developments in the LMB are likely to be unevenly distributed

- Opportunities
  - Power consumers (urban dwellers, industry)
  - Host country governments (Cambodia and Lao PDR)
  - Private sector developers and financiers
- Risks
  - Poor and vulnerable communities (riparian areas and basin-wide)
  - Local administrative areas(provinces, districts etc), particularly near dam sites
  - Country economies that are more dependent upon natural systems (Cambodia, Viet Nam)

Economic support for agriculture

Strategic Options 1 and 2

- **Intensified support for agricultural systems** along the Mekong, taking advantage of increased dry season water availability because of Chinese and tributary dams

Strategic Options 3 and 4

- **Increases in irrigable areas (enhancement)**
  - New irrigation pumps/machinery and O&M support
  - Extension services to support sustainable and efficient use of improved irrigation infrastructure coordination with hydro power uses
- **Localised loss of land (mitigation)**
  - Suitable replacement land (including provision for loss of river bank gardens)
  - Provision of extension services
  - Livelihood diversification support (training, provision of capital for small business, small scale local infrastructure and amenity provision etc)
  - Transitional income support packages
  - **Structural adjustment package for agriculture**
  - Large scale loss of sediment and associated nutrients is likely to require mitigation in the medium term
  - On-going monitoring of nutrient levels (soil and water testing)and production levels in affected areas
  - If and when required support for purchase of replacement fertilisers[72]
  - Extension support in use of fertilisers
  - Structural adjustment packages (for all sectors) need to be fully integrated with sectoral development planning and broader SEDPs

Fisheries economic sector mitigation and enhancement

Strategic Options 1 and 2

- Intensified support for enhancing and more effective management of fisheries resources in Mekong mainstream

Strategic Options 3 and 4

- Support for alternative fisheries production where possible
- Reservoir and aquaculture production – extension services, stock and equipment, re-training, concessional funding
- Support for alternative livelihoods
- Livelihood diversification program, including skills training, extension services, micro finance and concession lending, support for rural SMEs
- Emphasis on animal husbandry
- Support for ancillary and processing industries
- Payments for retiring capital equipment

[72] Given the emerging world wide shortage of rock phosphates the cost of any such provision is likely increase significantly in the future

- Soft loans and micro credit for SME and household production diversification
- Re-training programs for households/employees

SOCIAL SYSTEMS

Strategic Options 3 and 4

- Independent external monitoring needed to ensure that safeguards standards are complied with
- Trans-boundary and trans-provincial revenue sharing agreements specifically for poverty alleviation
- Define and address gaps in policy and legislation concerning trans-boundary impacts and equity in safeguard applications by developers
- LMB countries to agree common standards for monitoring and evaluation procedures
- LMB countries to agree comprehensive and transparent trans-boundary grievance procedures

CLIMATE CHANGE

All options

- Following a collaborative study, MRC should issue a clearly communicated set of climate change trends and ranges of risk linked to (a) the development sectors of strategic importance such as fisheries, agriculture and hydropower and (b) by sub basin
- The study findings and framework of climate change risk ranges and safeguards for the LMB should be submitted to the MRC Joint Committee for review and adoption as a regional guidance for development within the basin.
- The MRC climate change risk ranges and safeguards by sub-basin should be included within the framework of the PNPCA
- All hydropower development in the region – including the current 12 LMB mainstream projects – should be required to take the MRC projected risk ranges into account in the feasibility analysis, design and operation of their projects.
- The Mekong Panel on Climate Change should be established quickly with priorities being guidance on climate change implications for hydropower, agriculture and fisheries in the LMB.

ANNEX VI: INSTITUTIONAL AND CAPACITY BUILDING RECOMMENDATIONS

The following recommendations cover the necessary new institutions that will be required to manage hydropower development on the Mekong mainstream and the capacity building for existing institutions at national and local levels. These will definitely be required for Options 3 and 4, and preparations should be made for a decision to go ahead with mainstream dams at the end of the deferment period of Option 2.

ENERGY & POWER

Institutional requirements

- Reinforce Institutional Arrangements and Capacities for cooperation in the management of the trans-boundary risks associated with the LMB mainstream projects
  - Ensuring clarity in assignment of responsibilities / accountability
  - Ensuring participation in impact monitoring, assessment and collective responses to unforeseen impacts + to seize development opportunities
- Enhance regional power planning with linkage to BDP process covering institutional mechanisms, coordination of operation
- Develop Benefit sharing mechanisms (regional > national and in national systems (national > local)
- Introduce cooperative monitoring of hydropower plants covering compliance + adaptive management and sharing of information
- Improve licensing mechanisms covering temporary, construction and operating licenses
- Provide rules and regulations for operational oversight and emergency management
- Allow flexibility in concession agreements and PPAs to allow for adaptive management
- Establish framework for managing joint public-private mainstream project on borders between two countries
- **Form a Mekong River Authority** that sets guiding criteria for operation of mainstream dams
  - with specialised institutional structures to make fast decisions that can have international consequences, e.g. for operating multiple projects under unusual flow conditions
  - with joint operation body to set specific rules for hourly flow modification and perform optimised operation planning to derive maximum flow from the cascade
- Develop the institutional arrangements for the management of the proposed Mekong Fund

Capacity building

- Build the capacity of the local power operating companies
- At the national level, reinforce the capacity and scope of national regulatory / safeguard systems (environment, social, safety of dams)

HYDROLOGY & SEDIMENTS

Institutional requirements

- **Establish a Mekong River Authority** to take responsibility for the satisfactory design and operation of the hydropower facilities, and of navigation and fisheries issues
  - Potential for increasing the mandate of the MRC
  - Experience can be drawn from organizations such as Central African Power Corporation (operating the Kariba project, Zambia/Zimbabwe) and from the background and contents of the Columbia River Treaty.

  The Authority must:
  - be independent (politically & financially),
  - Have a mandate for enforcement
  - Strong engineering capacity
  - A formula for assigning a mil rate to the electrical energy production at the proposed projects would provide part of the annual funding, and this would be paid annually to the River Authority for supporting its work

  Responsibilities would include:
  - **Design guidance**: ensuring uniformity of design, with particular reference to dam safety and safe operating procedures. Assuring uniformity of guidelines for construction, construction management, and work/environmental safety during construction.
  - **Coordination of dam operations**: ensuring good communications between completed projects, to coordinate electricity supply to national grids, and in the way that water is released from one project to the next one downstream

- **Emergency management protocols**: organizing water releases that are coordinated between projects in emergency situations, e.g. resulting from major floods or from equipment failure/breakdowns
- **Navigation:** ensuring that navigation is coordinated, to facilitate the best possible transit times through each of the dams, with the arrival of boats from upstream or downstream, and the coordination of dredging of the navigation channel to ensure minimal disturbance to boat traffic.
- **Stakeholder notification and consultation**: provide effective communication of dam operation activities and events to directly affected communities and ongoing consultation with these communities in relation to livelihood implications of dam operations
- **Coordinated reservoir flushing & maintenance schedule**: Co-ordinate reservoir flushing activities so that downstream residents are minimally disturbed, and to fit in with navigation channel dredging activities.
- **Dam safety reviews & enforcement**: Ensuring that comprehensive dam safety reviews are carried out in a sufficiently thorough way, and at sufficient repeat periods to ensure that the very best advice is provided to the dam owners in a timely way. Ensure that the advice given to the dam owners is acted upon.
- **Independent turbine efficiency testing**: Providing a standardised service for turbine efficiency testing, to assess periodically whether the power delivered for given water flows measures up to the manufacturer's specified efficiency. This will be important, as the turbines will be operating in a highly abrasive environment (large ingestion of sand load), and rapid deterioration of efficiency should be anticipated.
- **Standardised water licensing & enforcement**: Developing a standardised structure for water licenses/agreements, specifying the limits of storage (full pool level, flood level, volume stored), the maximum diversion flow amounts through the turbines, the required fisheries/environmental flow diversion (in m3/s), and navigation requirements, if applicable.
- **Independent control & enforcement of environmental flows**: Providing an independent assessment of the magnitude of the environmental and fisheries flow releases, checked from time to time to ensure that the flows are no smaller than the values agreed to when the government(s) issued the storage and diversion flow license.
- **Turbine control guidelines**: Providing guidelines for ramping rates for the turbines and the spillway gates at each of the projects, computed to provide sufficiency slow rates of change of the water surface at key downstream locations. Making sure that there is future compliance with these guideline values

TERRESTRIAL SYSTEMS

Institutional requirements

- **Establish Reservoir and Watershed Management Boards or Authority for each hydropower project.** The reservoir and the land surrounding them should be managed more sustainably and productively. This can NOT be the sole responsibility of the dam operators. Each dam or cascade of dams should have a reservoir and watershed management board, which should be established before construction starts with activities should be financed from dam operational budget.
  - Membership should include representation of dam operators, ministries or provincial departments of forestry, agriculture, fisheries, water resources, riparian communities, fishermen and farmers organisations
  - Responsible for management of watershed, recreation of wetlands and improvement of habitat and biodiversity in reservoir.

AQUATIC SYSTEMS

Institutional requirements

MRC has key role in:

- Carrying out research and surveys on key components of the aquatic and terrestrial ecosystem
- Development of frameworks for protection of key habitats of the river
- Guidance for flows and sediment flushing of dams
- Analysing and publishing results of monitoring impacts of all dams on Mekong – especially ecosystem health, fisheries, agriculture on annual basis
- Sustainability assessment of dams for PNPCA process
- Culture and tourism protection and development

Ministries of water, environment, natural resources, agriculture, forestry and fisheries have responsibilities for:

- Ensuring the quality of EIAs and EMPs and management
- Application of the frameworks standards and guidelines developed by MRC
- Ensuring compliance of dam developers, contractors and operators with regulations, standards and agreements

Capacity building

- Improve the quality of EIAs to include comprehensive habitat, biodiversity and ecosystem assessments (not just fish)
- Improve capacity of regulating agencies to appraise biodiversity and ecosystem assessments
- Establish standards for monitoring of aquatic ecosystem and biodiversity and ensure that these are carried out to establish a baseline at least one year (or more) before construction starts
- Compile and assess all ecosystem and biodiversity monitoring records from all hydropower schemes on an annual basis – MRC to analyse and publish the results
- EIAs to include assessment of river-based cultural assets, sites and festivals
- Build capacities of regulatory authorities for monitoring and enforcement of environmental quality, flows and operation of hydropower dams

SOCIAL SYSTEMS

Institutional requirements

- Local provincial & district authorities must be involved in development of mainstream dams to integrate poverty alleviation strategies
- All health programmes should include provincial and district health authorities, and support to capacity strengthening provided
- Monitoring of social impacts and poverty alleviation must be linked to national MDG goals and targets
- Fear of compensation claims preventing local authorities from undertaking IEC with local communities; regular changes of administrative staff mean notification procedures may not be transferred to new staff.
- Annual programmes for emergency preparedness training and run-through
- Development of water user groups

Capacity building

- Capacity strengthening of provincial & district authorities to address social, livelihood and health implications of direct & indirect impacts, and to link national poverty alleviation strategies with ensuring livelihood security of indirectly affected communities
- Capacity of district and provincial authorities to enforce watershed protection (e.g. logging, mining, slash/burn) requires strengthening
- Capacity of local authorities to prevent outsiders from accessing fisheries opportunities requires strengthening
- Raise awareness for local administrations on gaps between national practice and international safeguards compliance requirements
- Provide training for district and provincial administrations on national and international social and environmental safeguards standards

ANNEX VII: HYDROPOWER DESIGN AND MITIGATION RECOMMENDATIONS

All these recommendations should be considered in the design of the proposed hydropower schemes on the Mekong mainstream if Options 3 and 4 are followed. Some may have to be considered and developed during the deferment period of Option 2.

ENERGY AND POWER

- Ensure that all proposed projects comply with the MRC Preliminary Design Guidance
- Develop rules and regulations covering
  - Operating rules
  - Backwater effects
  - Unified flow management
  - Emergency procedures

HYDROLOGY AND SEDIMENT

Avoidance – reconsidering proposed projects

- **Exclude high impact projects**: Not all the projects have the same scale of impact on the hydro-sediment regime and the omission of some projects could avoid some impacts in localised areas of the basin
  - predicted reductions in the transport and arrival of medium and coarse-sized sediments to Zone 5 could be delayed by the order of decades if the Zone 3 and Zone 4 projects (Ban Koum, Lat Sua, Stung Treng, and Sambor) do not proceed
- **Enforce a continuous operating strategy** for all mainstream projects in order avoid rapid fluctuations in water surface levels (e.g. at the hourly, daily and weekly time-step).
  - This is most critical for projects with: (i) large communities downstream, and/or (ii) substantial downstream irrigation (Luang Prabang, Pak Lay, Pak Chom, Ban Koum, Lat Sua, Stung Treng, Kratie)
- **Reduce operating water levels:** At present LMB mainstream projects maintain reservoir water levels 5-10m above the Q1000 level for significant stretches of the reservoir (10- 100km).
  - e.g. CNR Optimisation study has already reduced operating water levels & avoided: (i) trans-boundary disputes at Pak Beng, (ii) operator disputes within the Lao Cascade
  - redesign of some projects to reduce the water levels in the reservoir to remain below or comparable to a less extreme event (e.g. the Q20 flood event) would avoid the permanent inundation of some wetlands, floodplains and communities in Zone 2 and 3

Mitigation

1. **Impact:** Streampower reduction in the reservoirs causes deposition of sediment.
   Mitigation:
   - Sluicing to remove sediment will be undertaken at the dams, but the effect of sluicing will influence only the reservoir bed within a short distance (100 to 200 m) upstream of the dams. The majority of the reservoir bottom will accumulate sediment.

   Recommendation: Developers and operators must comply with sediment flushing and sluicing requirements for mainstream dams (e.g. MRC Technical Guidance).

2. **Impact:** Permanent inundation of riverside areas associated with high water levels in reservoirs
   Mitigation:
   - Control project operating levels: Re-design of projects so that proposed maximum reservoir levels are lower than high water levels that residents are accustomed to, e.g. <20 year return period flood levels. An energy generation penalty in the forecast electricity production will be a likely outcome. This could even avoid some inundation impacts
   - Protect directly affected communities: Local dykes with pumping facilities inside dykes to protect villages, tourist and cultural sites from inundation.
   - Clear arrangements for both responsibility and funding for maintaining and operating the dykes/pumps will be needed.

   Recommendation: Developers should consider risks and impacts and take appropriate measures. Regulating agencies should carefully assess proposed mitigation measures

3. **Impact**: Large hourly changes in water surface level, associated with turbine operation to match peaks and troughs in daily loads

Mitigation:

- Control mode of operation: Projects to be operated in steady-load mode, or in reduced peaking mode with only minor fluctuations from hour to hour. The magnitude of permissible fluctuations will need to be set and enforced by an independent authority
- Re-regulating dams are not recommended for dampening dam-induced changes to hydrology (e.g. the Lancang cascade). For LMB, Re-regulation dams are not suitable because of the very large daily water volumes involved in the mainstream projects. They would need to be about half the reservoir length (~50+km) and would need to be placed downstream of a project or a cascade. They would multiply negative impacts from the dams

Recommendation - Governments must regulate prior to project start-up, to ensure that satisfactory guidelines/rules are in place for operations, and then establish an independent technical authority which can enforce guidelines and monitor operations

4. **Impact:** Unexpected large changes in turbine flow, arising from unforeseen breakdowns in powerhouse plant, substations, or transmission facilities. Rapid load shedding causing water flow via turbines to cease, and rapid resumption of generation/flow.
   Mitigation: Early warning system for riverbank inhabitants, following shut downs and start-ups of powerhouse turbines.
   Recommendation – Governments must decide on guidelines for satisfactory rates of ramping, and on arrangements for early warning

5. **Impact:** Flood releases and catastrophic damage to dam facilities, resulting from mechanical/electrical failure of spillway gate hoist mechanisms
   Mitigation:
   - Design of flood gate facilities with multiple back-up mechanical/electrical controls, to ensure operation of gates without fail when needed
   - Comprehensive dam safety reviews, undertaken regularly, by a team of independent international and local experts, with rapid follow-up on their recommendations
   - Early warning by rapid communications, between dam operators in the proposed series of mainstream dams.
   - Early warning of problems to downstream riverside inhabitants

   Recommendation: MRC and Regulating agencies should establish common guidelines for dam safety, including provision for independent review for all dams, and early warning systems.

6. **Impact:** Irrigation pump station infrastructure rendered inoperable. Associated with very high water levels in the river associated with reservoir maximum operating levels and changes to the deposition/scour areas for sediment
   Mitigation:
   - Pump station facilities to be raised to prevent inundation, or stations to be moved in the events of persistent siltation of intakes.
   - New infrastructure may be required, e.g. re-regulating ponds
   - Pumps to be changed if needed, and replaced with pumps whose flow/head characteristics provide better matches to the water levels in the proposed reservoirs.
   - Some floating pumps will need bank protection works or relocation to avoid being rendered inoperable

   Recommendation: Developers should assess risks to irrigation infrastructure (upstream and downstream) and provide appropriate mitigation measures

7. **Impact:** Depletion of bed material deposits in reaches downstream of dams, with erosion of the banks and bed of the river
   Mitigation: Stabilisation of river banks and mid-channel islands in localised areas by using bank protection such as rip-rap. Not feasible for erosion protection of extensive reaches, because of high cost for materials and construction.
   Recommendation: Developers should assess risks of downstream bed and bank erosion as part of ESIAs with appropriate mitigation measures. Regulating agencies must appraise adequacy and approve provisions.

8. **Impact:** Siltation (all sizes of sediment) at headwater reaches of reservoirs, associated with loss of energy in flowing waters. Difficulties with navigation, and instability of river channel
   Mitigation: Dredging and trucking of sediment deposits, particularly to ensure that a navigable channel is maintained
   Recommendation: Developers should monitor and report on siltation in reservoirs, and dredge to appropriate depths if necessary to maintain navigability

9. **Impact:** Loss of annual silt deposition on the floodplain, resulting in loss of nutrients for soil fertility

Mitigation: enhanced fertiliser use, particularly in areas subject to large siltation rates, e.g. within about 1 km of the major channels ~25,000km2 in Cambodia & Viet Nam.
Recommendation: No adequate direct compensation. National agencies in Cambodia and Viet Nam should establish long-term monitoring programme to assess loss in soil fertility

10. **Impact:** Changes in extent of submerged Mekong delta, because of reduced sediment supply from the river. Expected resulting loss of stability of banks of deltaic channels and main coastline. Loss of fishpond and mangrove producing areas.
Mitigation: Rip-rapping with or without dykes, but applicable in localised areas only because of high cost, and difficulty of maintenance.
Recommendation: No adequate direct compensation. National agencies in Viet Nam should establish long-term monitoring programme to assess sediment changes in Mekong Delta.

11. **Impact:** River thalweg that presently defines international boundary will move in some locations. Loss of river channel features which define international boundary line, e.g Thailand-Lao PDR boundary.
Mitigation: Negotiations if needed, to reach agreement and confirm latitude/longitude of break points in boundary line.
Recommendation: Where there is a risk of change in alignment of international boundaries due to reservoirs and channels downstream of dams, studies on the predicted changes will be needed, followed by negotiations and agreements between the two countries.

Enhancement

- Reservoirs should be developed and managed as multi-use projects to improve the overall balance between opportunities and risks
  - Enhancement of power production through peaking operations
    - LMB mainstream projects could theoretically be brought on & off-line with very short ramping rates (order of minutes)
    - Profitability of the projects would increase substantially if electricity generation was timed to match peak demand times
  - Enhancement of multipurpose water use through:
    - Installation of new pumping infrastructure
    - Water licensing & allocation of quantities for irrigation and/or domestic use
  - Trade off between power production and Multipurpose use
    - Avoiding/mitigating impacts on the natural system
  - If peaking operation is chosen then most negative impacts will be exacerbated and potential benefits for irrigation would be significantly reduced

AQUATIC ECOSYSTEMS

Construction

- Establish clear guidance for good environmental management of construction activities,
- Monitor the performance of contractors and developers and ensure compliance
- Ensure that contractors and developers have emergency response plans in place, equipped and staff trained.
- Monitor fish catches and aquatic ecosystem health upstream and downstream of dam sites before and during construction, compile and publish results for all dams
- Phase construction activities to minimise disruption to river-based tourism activities
- Provide alternative river based transport around the dam sites
- Assess and develop measures for compensation of loss of tourism incomes during construction phase, including for small-scale tourism service providers

Operation

- Monitor performance of dam operators and ensure compliance with agreements and regulations in flow variability and sediment flushing
- Monitor passage of fine sediment and associated nutrients down the system, including in the Mekong Plume.
- Monitor fish catches and aquatic ecosystem health upstream and downstream of dams and in reservoirs, compile and publish results for all dams
- Monitor fish catches in the Mekong Plume
- Enhance the ecological diversity of habitats in reservoirs,
- Assess discharges of effluents that may affect reservoir water quality and develop treatment
- Establish and maintain measures for protection of river-based cultural assets, sites and festivals

FISHERIES

Design improvements

- **Reassessing dam location** - Dams upstream are biologically less damaging than those downstream. But In order to sustain reservoir productivity, tributaries upstream of existing dams should not be dammed. It is critical to maintain at least one intact migration system for fish, from the sea to breeding sites in upstream tributaries. An integrated system including fisheries considerations for the selection of dam location is possible, bearing in mind species migration ranges, dam locations, possible habitat loss, and local fishery studies.
- **Diversions and integrated projects** - Diversion canals can utilise only a fraction of river volume for hydropower – leaving the natural river intact for fish migrations, E.g.: 18 plants on the Rhone River between Switzerland and France produce ~3000 MW without blocking the river; Integrated projects can combine hydropower with several other uses
- **Offtake management** - Using multiple levels of offtake from the reservoir can reduce the anoxic condition of water downstream, and increase water quality
- **Spillway design and downstream aeration** - Spillways can improve improved water quality downstream (re-oxygenation and release of methane)
- **Vegetation clearing -** Partial clearing of vegetation is the best option for reservoir fisheries and water quality –
    - Remove 'soft' material gives less decay and improved water quality
    - Leave some 'hard' material for fish habitats/sanctuaries in the reservoir
- **Filling schedule** - Reservoir filling schedules which block too much of the natural flow devastate river ecology. It is best to mimic pre-project seasonal flows and not reduce downstream flow by more than 10%
- **Fish passes able to cope with Migrations**:

    ~50 species of commercial long-distance migrants; 8 pulses/year in Khone Falls; 30 tonnes/hour in Tonle Sap

    1. **Natural bypass channels** - Made via excavation of one of the river banks; Can mimic a 'real' stream; Common in Europe and North America; Only possible in certain areas and for very low dams. Mekong Mainstream Dams (MMD): possible for Don Sahong.
    2. **Pool fish passes** - Divides the height of the dam via a series of staggered pools (steps of 15-40 cm); Common throughout North America and Europe; Appropriate for passes that must accommodate numerous species; best for low dams (<10m). MMD: not suitable given the height of mainstream dams
    3. **Vertical slot fish passes** - Vertical slots in the baffles allow fish to swim at any preferred depth through each slot; Good for migrations involving multiple species; No proven efficacy beyond 30m high dams. MMD: cannot accommodate the size and diversity of mainstream migrations
    4. **Weir-type passes** - Notches and orifices modulate flow and provide different kinds of passages to fishes; Generally small in size, and often used for salmon in North America. MMD: cannot accommodate the size and diversity of Mekong mainstream migrations
    5. **Denil-type passes** - Use spaced baffles on the sidewall and the floor so that current speed does not exceed swimming capability of target species; Useful for large fish species; Mainly used in N. America and W. Europe; Best suited for a maximum height of 30; can tolerate only moderate variations in upstream water level. MMD: too specific, cannot accommodate size of migrations and variabililty in reservoirs
    6. **Fish locks** - When fish enter the lock, the lower gates close and the upper gates open; Can be used for dams up to 60m high; The locks have low capacity and depend on the ability to attract fishes. MMD: cannot accommodate the size of mainstream Mekong migrations
    7. **Fish lifts** - Literally lift fish from tailwater up to reservoir; Can be used for very high dams; Suitable only for large fish species; need to attract fish; only a few dozen individuals are moved at a time. MMD: totally inappropriate given the size and diversity of Mekong migrations

After dam construction

- **Reservoir aerators** - Improved aeration means improved conditions for fish (↓ contaminants, ↑ food production) in reservoir & downstream; Reservoir aeration can become expensive for large reservoirs
- **Mitigation of downstream effects** - Concept: mimic pre-dam 'natural' flow conditions. Maintain environmental flows of (minimum) 20-50% of pre-project levels. Very complex, requires case-by-case studies to determine appropriate management scheme

SOCIAL SYSTEMS

Design

- Review technical design to provide embankments or lower risk design, to avoid additional relocation; provision of higher irrigated land if land lost is more than 10% of productive assets
- Undertake comprehensive watershed management programmes in tandem with project activities

Operation

- Maintain regular water level monitoring; stop dam operations when agreed levels reached; O&M procedures must include downstream warning in case of sudden water release, especially in densely populated areas, e.g. Pakse

NAVIGATION

Design improvements

- Ship locks must be appropriate dimensions and operational. MRC has proposed the preliminarily design specifications for Mekong navigation locks.
- Minimum requirements, standards and guidelines should be adopted for the design, construction, maintenance and operation of ship locks prior to the construction of mainstream hydropower dams.

Enhancement

- Investments in trade facilitation, port services, and maintaining the improving navigation channel will be required by member countries and development partners.
- Proposed International cruises will require further investment in fleet, port and customs services to ensure safe and sustainable navigation on the Mekong River.

CLIMATE CHANGE

- All proposed projects should incorporate findings from design reviews taking the increased risks of extreme events – droughts and floods – based upon MRC climate change guidance

ANNEX VIII: ENVIRONMENTAL AND SOCIAL SAFEGUARDS RECOMMENDATIONS

The following measures would all be applicable for Options 3 and 4, but may require development during Option 2. In general, there is a requirement to strengthen and improve environmental and social safeguards, and to build the national and provincial level capacities for enforcement.

ENVIRONMENTAL SAFEGUARDS

Energy and Power

- Develop mechanisms in the MRC for application of trans-boundary safeguards which support national systems E.g. expanding Preliminary Design Guidance for mainstream schemes

Terrestrial

- Compensate for loss of forest land, by replacement planting on degraded land near the lost land
- Review lost wetland types and attempt to re-create lost wetlands adjacent to the reservoirs
- Specific compensation measures for loss of landscape amenity and aquatic biodiversity (Pha Taem and Phou Xiang Thong protected areas (Ban Koum) (Thailand and Lao PDRLao PDR)
- Specific compensation measures for loss of landscape amenity and aquatic biodiversity at Stung Treng Ramsar site. The Ramsar Convention should be informed as soon as possible about the potential threats to Stung Treng, requesting inclusion on the Montreux Record. (Cambodia)
- Monitor sediment load downstream and agricultural productivity in the Mekong Delta

Aquatic

- National governments to establish protected reaches of the Mekong River system.
- Consider multiple use of the reservoirs, in full knowledge of consequences of diversions of water on downstream areas (saline intrusion, acidification in the dry season)

Fisheries

- Fish passage systems should always be installed, even if not currently very effective,
- Provision of training in new fisheries techniques, annual stocking of reservoir and tributary fisheries

SOCIAL SAFEGUARDS

Energy and Power

- **Introduce benefit sharing arrangements** (see box on benefit sharing), between States as part of 1995 Agreement and additionally from Regional > National > Local. This should be part of tariff mechanism with consumers based on the user pays principle

Terrestrial

- Provide adequate compensation for loss of agricultural land (dam site, inundation, access roads and transmission lines)
- Develop standards for fair compensation and/or alternative measures for replacement of river bank gardens applicable throughout the LMB
- Ensure compliance with standards for compensation/replacement for river bank gardens
- Develop compensation measures for the loss of agricultural and fishery productivities in the Delta.

Social systems

- Replacement land for directly affected households to include irrigation options
- Ensure relocated communities are settled as discrete villages to maintain socio-cultural ties
- Ensure relocated communities are settled in areas not at risk of erosion. Ensure project-related infrastructure (roads, etc.) are well-protected from flow changes by embankments
- Well planned health, water supply, drainage & sanitation programmes implemented well in advance of impacts. Risks are lowered by competent and timely health programmes in place.
- Contractor to implement effective health & safety programme for labour force
- Effective flood preparedness and emergency contingency planning needed, based on comprehensive knowledge base (e.g. GIS based inundation maps, catalogue of economic assets at risk, village locations, contact persons, safe areas, communications methodology
- Comprehensive and separate package of mitigation measures for directly & indirectly affected people, with special measures for poor & vulnerable groups, particularly ethnic minorities and fisheries-dependent households
- Put mitigation measures into place well before construction impacts are felt

- Programme of community awareness about safe water and sanitation use. Apply programme of parasitic infection eradication among adults and children.
- Programme of registering and health tracking of local sex workers, and of labour force when returning from home leave
- Implement programme of parasitic infection eradication among adults and children. Implement nutrition awareness programmes for APs
- IEC programme undertaken with communities in impact areas; emergency preparedness plans in place and dam operators & local authorities know what these are & how to implement them
- Revenue-sharing by developers with affected provinces and countries for poverty alleviation measures particularly for indirectly affected households losing fisheries
- Earmarked jobs with contractors and developers; fish ladders, training in new fisheries techniques; annual stocking of reservoir and tributary fisheries
- Special provision to restore AP livelihoods, and to provide facilities needed to help districts & provinces to meet MDGs (e.g. provision of clean water supply, sanitation, good quality housing, etc.)
- Provision of replacement small riverboats suitable for rapid flows and/or reservoirs where appropriate
- Ensure that APs and long-established riparian communities have sole rights to reservoir fisheries
- Prohibition on concessions awards on land provided to affected people. Secure and permanent land tenure rights allocated.
- Ensure that small but powerful interest groups do not have the opportunity to grab benefits for themselves, but that any benefits are distributed to those directly and indirectly affected
- Land allocation and secure tenure rights to affected households, particularly those fisheries dependent

Navigation

- Channel improvement, aids to navigation and more investment in vessel and port services to significantly improve the effectiveness of inland waterway transport and provide economic opportunities for riparian communities.

ANNEX IX: REFERENCE LIST

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