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MRC SEA FOR HYDROPOWER ON THE MEKONG MAINSTREAM

SUMMARY BASELINE ASSESSMENT REPORT

15 April 2010

The MRC SEA of Hydropower on the Mekong mainstream comprises 4 main phases: (i) scoping, (ii) baseline assessment, (iii) opportunities & risks assessment, and (iv) avoidance, enhancement and mitigation assessment.

This report formally concludes the baseline assessment phase of the SEA and documents the outcomes of the baseline consultations and SEA team analysis.

The Baseline Assessment Report has two volumes:

VOLUME I: Summary Baseline Assessment Report
VOLUME II: Baseline Assessment Working Papers

Disclaimer

This document was prepared for the Mekong River Commission Secretariat (MRCS) by a consultant team 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.

This document incorporates a record of stakeholder consultations and subsequent analysis. Whether they attended meetings or not all stakeholders have been invited to submit written contributions to the SEA exercise via the MRC website.

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 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
More than eleven hydropower dams are currently being studied by private sector developers for the mainstream of the Mekong. 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, none of the prospective developers have 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 a 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 will be considered.

CONTENTS

1 INTRODUCTION

During the SEA scoping phase, the National Mekong Committee Secretariats (MMCS) and line agencies of the four Mekong Member States participated in the SEA national workshops to identify development issues and policies for the Mekong River which might be affected by the mainstream hydropower proposals and thereby need to be considered in the SEA assessment. Those strategic priorities were consolidated into 8 themes and linked key issues which serve as the substantive backbone and analytical framework for the SEA (Table 1). The eight themes defining the SEA scope are:

1. Economic systems,
2. energy and power,
3. hydrology & sediment,
4. terrestrial systems,
5. aquatic systems,
6. fisheries,
7. social systems and
8. climate change

A scoping paper was prepared for each of the 8 strategic themes outlining the objectives, methodology and detailed coverage of the SEA.[1]

The SEA baseline assessment phase has taken the analysis of each theme a step further. It identifies and analyses the main trends associated with the themes in the past, and then projects the trends forward into a future without mainstream dams. The SEA works with a projected baseline to 2030 and beyond for some aspects of climate change – taking in the MRC Basin Development Plan Definite Future Scenario (DFS) and the LMB 20-year Probable Future (PFS) scenario without lower Mekong basin (LMB) mainstream dams. The DFS includes 40 tributary dams constructed since 2000, under construction or committed and 6 of the China mainstream dams. In the DFS, the total live or active storage of the tributary dams and of the Chinese reservoirs[2] is 21,222 MCM or 4.6% and 22,189 MCM or 4.7%

[1] The SEA scoping phase produced five reports now available on the MRC website:

VOLUME I: Main Inception Report
VOLUME II: Mainstream project profile summaries
VOLUME III: National scoping consultation summaries
VOLUME IV: SEA Theme papers and additional studies proposals
VOLUME V: The SEA Communications, Consultations and Capacity Building Plan

[2] There where originally eight mainstream dams in the Lancang-Mekong cascade in Yunnan PRC. The lower most dam (Mengsong) has been deferred indefinitely. Ganlamba is not included in the BDP DFS and PFSs though

respectively of the annual water volume leaving the Delta – making a total of 9.3% of the mean annual flow. Under the LMB 20 year "without" scenario, there are 70 tributary dams (30 additional to the DFS with a live storage of 20,185 MCM or 4.2%) and the 6 Chinese dams – with a total active storage making up 13.5% of Mekong water. The SEA projected baseline also assumes major development of the irrigation sector – with an increase from 2000 to 2015 reach 6.8 million hectares, which represents a marginal 3% increase from the baseline.

The SEA baseline trends analysis is documented in two volumes. This volume summaries eight comprehensive theme working papers which appear in full in Volume II.

Table 1: Consolidated key strategic themes and issues defining the scope of the SEA

Theme	Key issues
1. Economics	1. The broad national and regional economic implications of large scale natural resource based development in the LMB countries 2. The economic costs and benefits of sectoral development in the LMB countries 3. The distribution of economic benefits between different areas, groups and sectors
2. Energy	1. Electricity demand growth in the LMB 2. Buyer and seller motivations for cross-border power trade 3. Energy resource base in the LMB and wider GMS 4. Alternative demand-side and supply-side options
3. Hydrology & Sediment	1. Changes to the hydrological processes of the Mekong River 2. Fate and transport of sediment through the Mekong River 3. Changes to water quality
4. Terrestrial Systems (including Agriculture)	1. Habitat loss and degradation, forest cover and protected areas 2. Changes to patterns of agriculture 3. Value of paddy agriculture in each zone 4. Changes to agricultural and land use patterns along the mainstream, especially river bank gardens
5. Aquatic Systems	1. Productivity of aquatic habitats in the Mekong 2. Biodiversity of aquatic habitats in the Mekong 3. The capacity of the Mekong's ecosystem regulating services – purification and water quality 4. Value of Mekong River's cultural ecosystem services – inspiration, recreation and tourism
5. Fisheries	1. The importance of fisheries to local livelihoods and national/provincial economies 2. Changes to the unique features of the Mekong River fisheries
6. Social Systems	1. Poverty, Ethnic Groups and Natural Resource Based Livelihoods 2. Health and Nutrition 3. Resettlement and Human Trafficking
7. Climate Change	1. Changes are foreseen in climate and hydrological variability and extremes 2. Implications of those changes for natural and social systems in the basin? 3. Implications of those changes for development sectors in the basin including

remains a component in the planned cascade. The Ganlamba project has small axctive storage compared to the total cascade.

	hydropower (for example, in terms of energy generation, operations, GHG emissions and carbon financing)

2 ECONOMIC SYSTEMS

Theme and key strategic issues

Key issues (relevant to hydropower)

1. What are the broad national and regional economic implications of large scale natural resource based development in the LMB countries?
2. What are the economic costs and benefits of sectoral development in the LMB countries?
3. What is the distribution of economic benefits between different areas, groups and sectors?

2.1 PAST TRENDS AND CURRENT SITUATION

2.1.1 ISSUE: NATIONAL AND REGIONAL ECONOMIC IMPLICATIONS OF LARGE SCALE NATURAL RESOURCE BASED DEVELOPMENT IN THE LMB.

Large scale and rapidly increasing investment in natural resources (and in particular hydropower) in the region is largely funded by the foreign private sector. In many cases this represents an influx of foreign direct investment (FDI) from outside the LMB region (e.g. from China), in other cases in may represent a flow of investment from one LMB country to another (e.g. from Thailand or Vietnam to Lao PDR). Whatever the case, a large influx of investment capital is likely to have significant implications for macro-economic performance, and especially for the small economies of Lao PDR and Cambodia. Three important avenues through which macro economic impacts may be felt and have been identified as potentially significant:

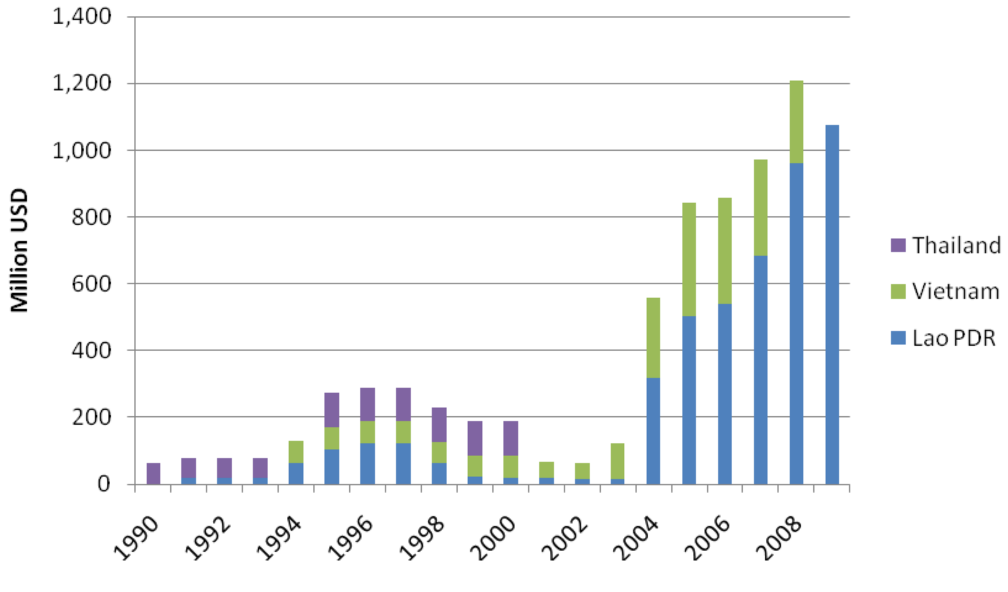
1. Multiplier effects for large scale investment – the stimulus effect on the region's economies large scale hydropower investment may imply;
2. Indirect macro-economic impacts through real exchange rate appreciation due to the in-flux of foreign exchange both as FDI and as export earnings from natural resource and hydropower projects;
3. Effects on the government debt sustainability due to expansion of state liability due to equity stakes in hydropower.

Whereas 1 is potentially relevant to all countries in the basin, in the baseline case 2 and 3 are of particular relevance to Lao PDR only.

BACKGROUND

According to available data (from IKMP at MRC) investment in hydropower over the last two decades has been expanding rapidly. In the case of the larger countries in the region these large investment amounts do not necessarily represent large in-flows of foreign exchange as in Thailand and Vietnam many of the projects have been domestically financed. Moreover, relative to the rest of the economy and other investment activities in these two countries hydropower investments are relatively small. In the case of Lao PDR however, most of the investment is from overseas. This therefore represents a massive influx of foreign funds into a relatively small economy. For example, the investment capital for NT2 alone was around 50% of Lao PDRs total GDP in 2004, when the project started (Warr 2004).

Figure 1: Estimated annual investment in LMB hydropower 1990-2009



Source: ICEM based on IKMP hydropower database, MRCS

MULTIPLIER EFFECTS DUE TO INVESTMENT STIMULUS

Large infrastructure projects can stimulate the economy and have stimulus effects on the wider economy. For example, increased spending in the construction sector due to hydropower development may increased demand for services to that sector, which will have a knock on impact to demand for inputs from the service sector to other sectors. No estimates of the significant of this stimulus effect were available and it would imply a significant modeling exercise beyond the scope of the SEA to estiamate the significance of this effect.However, any assessment should be careful about overstating the impact of hydropower development as in the counterfactual situation where these funds were not invested in hydropower they could have well been used on other investment projects in the region. For example, if hydropower resources were not available other generation capacity would have been needed which would have implied similar investments. However, it is not possible to extent to which this kind of compensating investment may have taken place in the case where hydropower projects did not go ahead. In the special case of Lao PDR, which has seen significant investment in hydropower relative to the size of the economy, the World Bank estimates that investment in large hydropower and mining projects added around 2.5 percent to GDP growth in 2007, or about USD 18 million in 2007 (World Bank 2008).

REAL EXCHANGE-RATE APPRECIATION AND ‘DUTCH DISEASE’

Over the last decade Lao PDR has experienced relatively high levels of economic growth and development. The main driver of this growth has been investment in raw materials including agro-forestry plantations, mining and hydropower. These investments have undoubtedly added to growth in GDP, and are an important source of foreign exchange and have boosted export earnings from commodities exports.

For a small economy like Lao PDR inflows of FDI during the construction stage, as well as foreign exchange earnings from hydropower during the operational phase (as well as other natural resource based investment projects) have ambiguous implications for macro-economic stability. On one hand, natural resource development is potentially an important source of investment funds bringing jobs and ancillary infrastructure as a direct result of the development. Moreover, revenues generated from government from the development of these projects are ear marked for socio-economic development purposes as laid out in socio-economic development plans. On the other hand, the implied in-flux of foreign exchange directly from the investment and earnings from these developments may lead to macro-economic imbalances. In particular, inflows into the natural resource sector could lead to rising prices for labor and inputs in that sector, bidding up prices in competing sectors and damaging their competitiveness (in the case of Lao PDR the agricultural sector). The other effect of a booming sector can be to lead to real exchange rate appreciation if the influx of foreign exchange converted to the domestic currency and used to purchase goods and services. In particular, prices of non-tradable goods can rise again leading to real exchange rate appreciation and a decline in prices of tradable relative to that of non-tradable goods in the domestic economy. The changes in the prices of traded goods reduces the competitiveness of sectors producing traded goods, both for export-oriented and import competing sectors. This effect is known as 'Dutch disease' and is well a well established if controversial notion (Mckinley 2005, Corden 1984). It is important to note that whether this effect occurs or not depends upon the extent to which the influx of investment capital and export earnings feeds through into the real economy. For enclave projects (see below) this effect may be limited. Government capacity in effectively managing the large influx of capital is central to avoiding Dutch disease, either through making investments that improve the productivity of adversely affected sectors or through controlling the influx of foreign exchange to the country.

It is difficult to show Dutch disease effects are taking place, real exchange rate appreciation can take place for a number of reasons including relative increases in productivity, changes in the terms of trade and large capirtal inflows can also be important in influencing real exchange rates. Moreover, it is difficult to show what may be causing declines in the lagging sector, Estimates relating to NT2 suggested that the real exchange rate appreciation due to FDI inflows and investment during the construction phase could amount to 1.7% per year over the construction period, and during the operating period to 0.75% per year than would otherwise have occurred (Warr 2004). NT2 only accounted for around 1/5th of the investment in hydropower in Lao PDR between 2000 and 2010 not to mention any additional government revenues from the power export earnings. Thus we may expect to see real exchange rate appreciation considerably higher than the estimates for NT2 suggested here. Indeed, recent figures on real exchange rate appreciation between2007-2009 show real effective exchange rate appreciation against the US dollar of around 20% (IMF 2009d). However, this may well be due to international pressures on the dollar – rather than real economy effects in the Lao domestic economy.

PUBLIC DEBT SUSTAINABILITY IN LAO PDR

According to a recent report by the IMF Lao PDR is regarded as a country with a high risk of debt distress both from external and internal indebtedness (IMF 2009d). The extent to which the government of Lao PDR will incur additional debt liabilities due to hydropower construction is a potential issue raised by some commentators (WCD 2001). Additional liabilities Lao PDR incurs due to its equity holdings in hydropower developments may adversely affect its credit rating and therefore its access to loans. However, it has been estimated that government deficits will be only slightly larger with the project – and that slightly higher risks need to weighed against the revenue generated for government by the project – which are expected to off-set these risks (WCD 2001). Indeed calculations by the World Bank (2005) suggest that net revenues from NT2 to the government of Laos will average around USD 30 million between 2010 and 2020, rising to an approximate average of USD 110 million in 2020 to 2034 after the commercial debt service is paid off. Moreover, the structuring of this debt, through a holding company under the Ministry of Finance, secured against PPA and underwritten in a large part by the ADB and World Bank means that government liability has been minimized. What is not clear from the structuring of this debt which is classed as commercial with a limited recourse – rather than sovereign guaranteed debt – is the indirect liability the government may hold for this debt, and therefore the short term impacts on Lao PDR's debt sustainability.

CONCLUSIONS

In summary three key conclusions can be drawn from the macro economic analysis:

- Hydropower development in the LMB represents a massive investment in the region and generation of substantial foreign exchange reserves to some countries;
- This influx of foreign exchange is likely to have profound effects on the key macro economic variables in Lao PDR, this will need to be managed carfully to avoid adverse macro-economic imapcts;
- As a country which is assessed as at a high risk of external debt default, the implications any additional debt obligations the government of Lao PDR incurs as a result of hydropower development need to be considered carefully.

2.2 PAST TRENDS AND CURRENT SITUATION

2.2.1 ISSUE: WHAT ARE THE ECONOMIC COSTS AND BENEFITS OF SECTORAL DEVELOPMENT IN THE LMB COUNTRIES

This section seeks to do broadly three establish the value of key development sectors to the basin, trends in their development and the drivers of this development. Table 1 (below) givens a summary of the finding of the economic analysis conducted in the baseline report. For greater detail on trends and sectoral drivers the relevant summary papers should be consulted.

While a breakdown of these values by ecological zone was not feasible in most cases, table 2 gives those values that were calculated on a zonal basis.

2.3 PAST TRENDS AND CURRENT SITUATION

2.3.1 ISSUE: WHAT IS THE DISTRIBUTION OF ECONOMIC BENEFITS BETWEEN DIFFERENT AREAS, GROUPS AND SECTORS?

There is a strong perception that the distribution of costs and benefits from hydropower projects is unequal, with riparian communities living in the vicinity and downstream of these projects bearing the brunt of the costs while developers, governments and power consumers reap most of the benefits. Currently, methodological approaches to assessing the distributional impacts of dams are not well defined; nevertheless the distributional analysis intends to give a better indication of how the different impacts will be distributed between different groups in the basin. To establish these impacts the analysis focuses on the distribution of population trends in the LMB, poverty, inequality and key livelihoods indicators.

DEMOGRAPHIC TRENDS IN THE LMB

There are 4 key demographic trends in the basin. Firstly, slowing population growth. 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. Vietnam and Thailand, in contrast have lower- but still slowing population growth rates (1.19% and 0.93% respectively). Secondly, increasing migration within the basin and between the basin and other areas. This consists both of an internal movement within national boundaries to usually from rural to urban areas where income earning opportunities are perceived to be greater, and international migration mainly to Thailand from surrounding countries again driven by the perception of better income earning opportunities in migrant destinations. As a consequence urban growth rates are high throughout the LMB (ranging from 6.08% in Cambodia to 1.72% in Thailand). Thirdly, higher population growth rates in rural areas, linked to higher infant mortalities and lower education levels. Finally, despite higher rural birth rates, rural populations in relative decline across the LMB countries.

Table 1: Summary of sectoral values and drivers for the LMB

Description	Indicative values	Value	Past trends and drivers
Fisheries	fish, OAA	USD 1.4-3.9 billion/year (catch value)	Growth in capture fisheries and aquaculture . Driven by increasing populations increasing commercial aquaculture in some areas.
Agriculture and forestry	Paddy production River bank garden production NTFPs Bamboo production	(river bank gardens) USD 174-574 million/year (revenue) Paddy USD 4.6 billion annual revenue	Growth due to increased irrigation, use of inputs and improving techniques, mechanisation and consolidation of fragmented land holdings. Production from river bank gard3ns relatively stable. Increasing exploitation of NTFPs and bamboo due to increased access to resources and increased access to markets.
Tourism	Tourism revenues	N/A	Rapidly increasing tourism revenues driven by global and regional growth in demand and better tourism facilities in LMB countries.
Navigation	Freight transport Passenger transport	USD 4.43-4.48 million/year (direct) USD 11.15-11.25 million/year (indirect)	Little development of sector beyond UMB. Some signs of decline due to competition from road transport.
Construction	Sand and gravel extraction output	USD 164 million	Very rapid increase in resource exploitation, driven by large infrastructure and real estate development in the region, some controls have been introduced (Vietnam and Cambodia) to preserve resource for local needs.
Mining and industry	Sink for waste products	N/A	Rapid increase in release of water from large and small scale mining and industry
Aquatic plants	Subsistence	N/A	Changes in aquatic systems and over exploitation leading to dwindling supplies in some areas
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	USD 11.2 million (2000 prices)	Largely stable
Flooding/flood control	Nutrient replenishment, wildlife habitat, damage to goods and livelihoods	N/A	Largely stable
Saline intrusion	Crop productivity	N/A	Increasing, implying declining productivity in agriculture in some areas.

Table 2: Available output values by zone

Description	Measure (Unit)	Zone 2 Chiang Saen to Vientiane	Zone 3 Vientiane to Pakse	Zone 4 Pakse to Kratie	Zone 5 Kratie to Phnom Penh and Tonle Sap	Zone 6 Phnom Penh to the sea	Total
Paddy (100km corridor centred on MMS)	Area Ha	365,509	2,291,631	162,564	1,391,025	1,981,005	6,191,735
	Output value (million USD)	146	1,604	85	723	1,981	4,539
Riverbank gardens on MMS	Area Ha	2,166	8,395	1,278	12,358	95,291	119,488
	Output value (million USD)	10	40	6	59	457	574

Source: ICEM

Table 3: Population change in mainstream riparian provinces

Country	Population		Population 2009 est		Proportion 2009 est		Growth	
	Riparian	National	Riparian	National	Of riparian	Of national	Riparian	National
Cambodia	4,323	13,389	4,358	13,605	14	32	0.8	1.6
Lao PDR	4,564	5,622	4,983	6,115	15	82	2.2	2.1
Thailand	5,666	66,148	5,701	66,679	18	9	0.6	0.8
Vietnam	17,179	85,790	17,179	85,790	53	20	0.6	1.2
Total	31,732	170,948	32,221	172,188	100	19		

Source: ICEM own calculations based on national statistics. Note: Cambodian and Thai statistics based on censuses conducted in 1998 and 2008, Lao PDR censuses conducted in 1995 and 2005 and Vietnam on censuses conducted in 1999 and 2009. Estimates are based on growth rates derived from this data.

Population changes for the riparian provinces along the Mekong mainstream are given in table 3. This shows that riparian populations are increasing their share of the population in Lao PDR, but elsewhere in the basin (excluding the Tonle river and therefore Phnom Phen) LMB are in decline relative to national populations. In fact given the difficultly of enumerating recent migrants, in some cases - such as that of north eastern Thailand and the Mekong delta in Vietnam, rural populations may be shrinking.

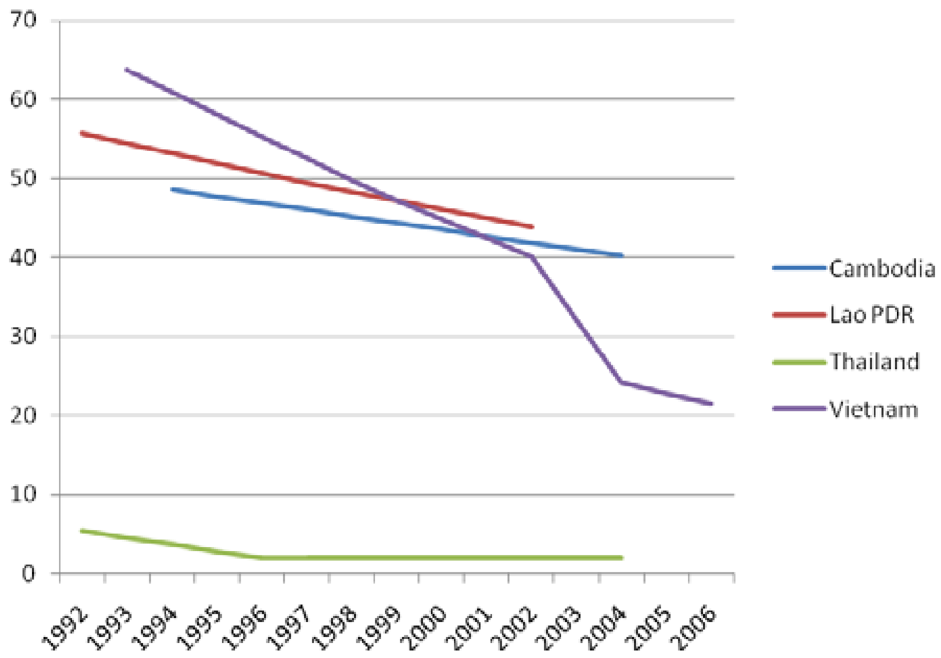
Population densities vary widely between upland and lowland areas of the LMB. Remote upland areas tend to have low population densities, in upland areas of Lao PDR, for example, population densities in some districts are as low as 0.1 pax/ha. Lowland and riparian areas tend to have higher population densities and most large urban population centres in the LMB are located close to the Mekong mainstream, for example, Vientiane, Phnom Penh, Luang Prabang and Can Tho to name a few. Population densities also increase towards the low lying down stream reaches of the basin. With district population densities in the Mekong delta in Vietnam being as high as 50 pax/ha.

2.3.1.1 POVERTY REDUCTION TRENDS

The rapid economic growth in the region has brought with it significant decreases in poverty rates across all four LMB countries (figure 2). Thailand saw its phase of rapid poverty reduction in the 1980s and early 1990s, with its current poverty rate relatively low (at 2%) and stable – suggesting that there are some portions of the population remaining in poverty untouched by economic growth. Vietnam has seen very rapid declines in poverty especially in the latter half of the 2000s, rates have declined from over 60% (the highest in the region), to a little over 20%. Lao PDR has also seen a relatively rapid decline in poverty from about 55% in 1992 to around 45% in 2004. Cambodia has also seen a decline in poverty but at a slower rate than either Vietnam or Lao PDR.

Poverty rates and densities differ widely across the basin. Remote upland areas tend to have higher poverty rates, populations have limited livelihood opportunities and access to services. While lowland areas tend to have lower poverty rates, higher overall population levels mean that the absolute number of poor (and poverty density) is higher in these areas. This is particularly the case in urban areas where poverty densities are relatively high (see social issues theme paper).

Figure 2: Poverty head count ratio (international poverty line) in LMB countries 1992-2006



Source: WDI, World Bank 2009 Note: missing values for intervening years have been interpolated.

LIVELIHOODS

Rural livelihoods in the LMB are dependent on a range of different activities including agriculture (irrigated rice, rain-fed rice and other crops, river bank gardens and swidden agricultural production to name a few), fisheries (including capture fisheries and aquaculture), raising livestock (including cattle, buffalo, pigs, ducks, chickens etc) use of non-timber forest products, trading, artisanal mining, small and household industries to name but a few (see social baseline paper). There is a high dependence of populations on natural resources and associated income opportunities (such as trading) for livelihoods, as well as the considerable household diversification of employment sources. Although in urban areas in Thailand and Cambodia wage labour in factories is an important source of income, the predominantly rural riparian populations are highly dependent upon agriculture. Moreover, fishing is likely to be an important component of livelihoods strategies in the LMB.

Table 4 gives available figures on employment in agriculture and fisheries and is illustrative of their importance in the riparian districts of Lao and Cambodia.These figures probably underestimate the importance of fisheries in particular as this is rarely a primary source of employment. It, however, often constitutes an important subsidiary source of employment. A better indication of this can be found in the importance of fish consumption in Lao PDR shown in map 1 below.

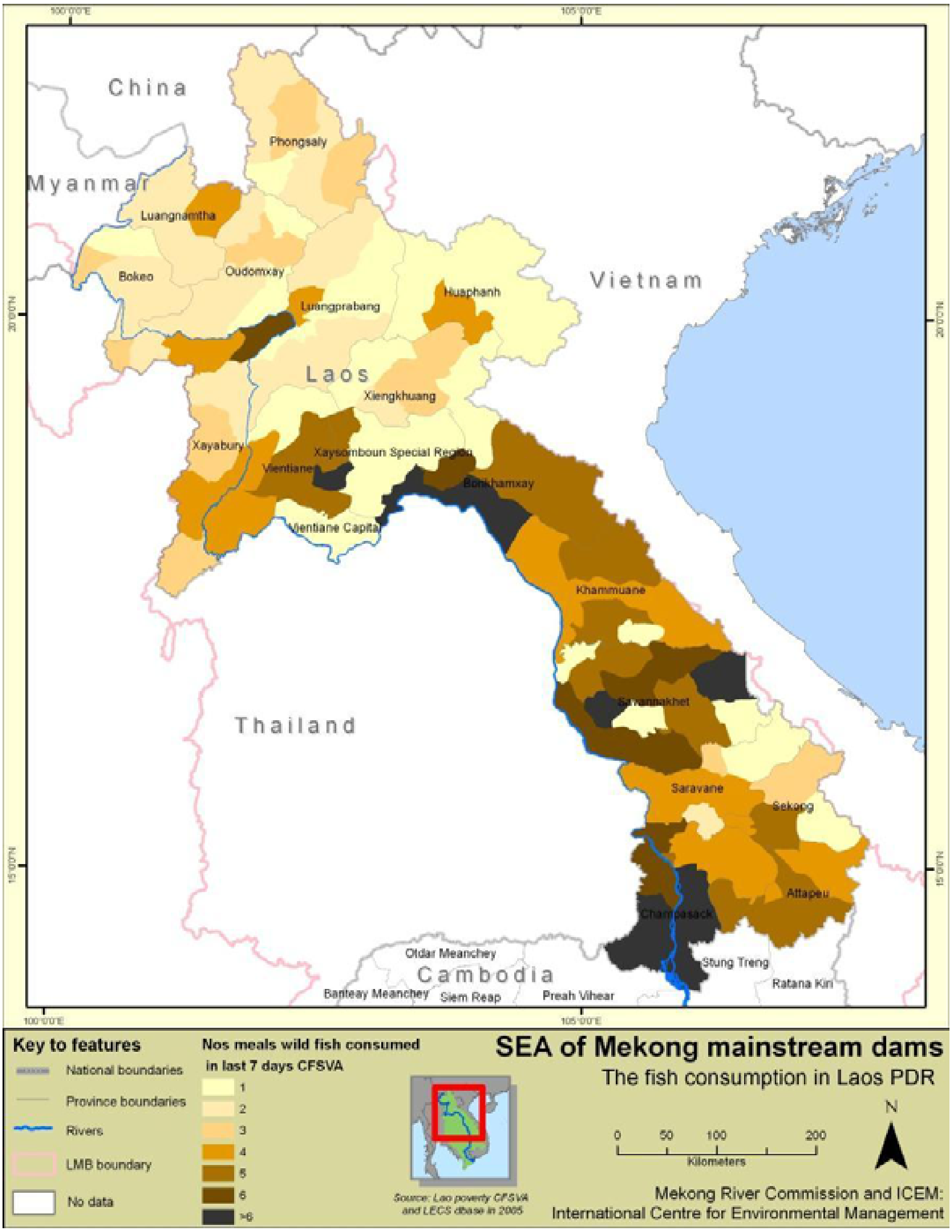
Table 4: Popultion density, and employment in agriculture and fisheries for riverine districts

Mainstream districts in	Population density (pax/ha)	Population employed in agriculture		Population employed in fisheries	
		No.	%	No.	%

Cambodia	1.14	1,486,789	29	58,937	1
Lao PDR	0.37	917,395	39	787	0
Thailand	N/A	N/A	N/A	N/A	N/A
Vietnam	12	N/A	N/A	N/A	N/A

Source: Consultants own calculations based up Lao PDR census 2005, Cambodia census 2008 and Inter-ministerial poverty mapping taskforce for Vietnam 2003.

Map 1: Weekly household fish consumption by district Lao PDR



2.3.2 SUMMARY OF CURRENT STATUS

The LMB countries are rapidly growing highly dynamic economies, going through radical and contracted period of socio-economic change. This radical change is characterized by industrial and service sector growth, rapid urbanization and in the basin, increasing consumptive pressures on the all sectors of the basin. While trends vary within the basin and between countries, three key general trends will be central to the development of the region:

- Urbanization – as continuing rural poverty and increasing income earning opportunities generated by industrial and service sector growth in and around urban areas;
- Increasing inequality – particularly 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;
- Macro –economic impacts of resource extraction, through real exchange rate appreciation, possibly compounding emerging patterns of rural-urban inequality in Lao PDR in particular.

2.4 FUTURE TRENDS WITHOUT THE LMB MAINSTREAM HYDROPOWER DEVELOPMENT

2.4.1 **ISSUE:** NATIONAL AND REGIONAL ECONOMIC IMPLICATIONS OF LARGE SCALE NATURAL RESOURCE BASED DEVELOPMENT IN THE LMB.

The analysis of past trends and current conditions established three potential macro economic trends which could have important implications for development in the basin, these were:

1. Multiplier effects for large scale investment – the stimulus effect on the region's economies large scale hydropower investment may imply;
2. Indirect macro-economic impacts through real exchange rate appreciation due to the in-flux of foreign exchange both as investment and as export earnings from natural resource and hydropower projects;
3. Effects on the government debt sustainability due to expansion of state liability due to equity stakes in hydropower.

FUTURE INVESTMENT IN HYDROPOWER

Likely future patterns of hydropower investment[3] suggest significant growth in investments in hydropower development in the basin. Figure 3 and table 4 report these trends. Expected investment into hydropower development in Lao PDR in particular stands out, based on proposed construction schedules annual investment in hydropower in the basin is expected to peak in 211-2012 at around USD 1.9 billion, with the vast majority of this investment being concentrated in Lao PDR, reaching an annual inflow of USD 1.7 billion in hydropower investment, a figure that is likely to be over half of the national GDP.

[3] based on the foreseeable futures scenario developed by the BDP

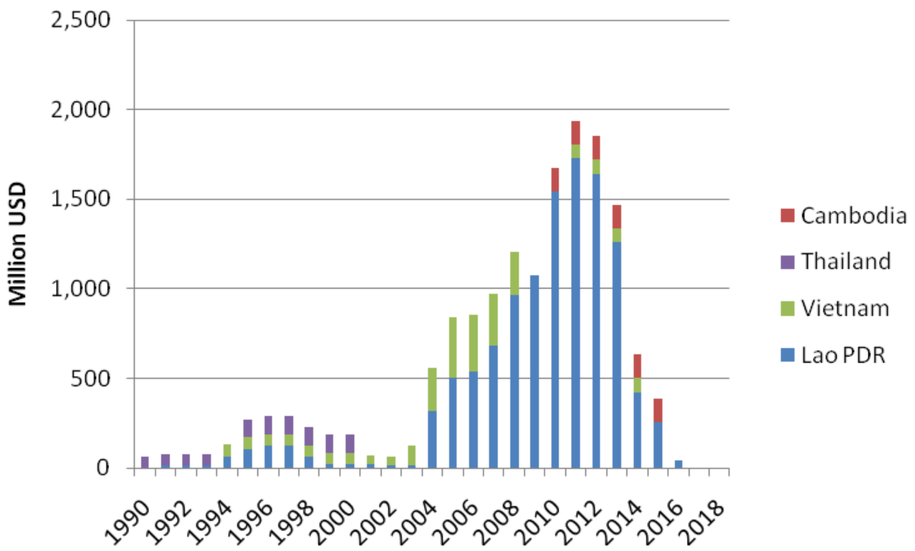
Table 4: Planned investment in LMB hydropower – average annual investment 1990-2016 (million USD)

	Lao PDR	Cambodia	Vietnam	Thailand	LMB
Average 1990-2016	400	27	83	30	540
Average 1990-2009	162	0	72	30	264
Average 2010-2016	238	27	11	0	276

Source: ICEM based on IKMP hydropower database, MRCS

This analysis is indicative of development plans and the likely scale of investment. Given the recent global downturn it is also likely that many of these projects will be delayed indefinitely with the net effect of both flattening the investment schedule - meaning investment flows in any one year are likely to be considerably lower than the current planning indicates – and shifting the years of peak investment further into the future.

Figure 3: Estimated annual investment in LMB hydropower 1990-2018



Source: ICEM based on IKMP hydropower database, MRCS

Whether or not these investments will go ahead will be dependent upon individual decisions made by hydropower investors as to the financial viability of a particular project. This in turn will depend upon PPAs and MoUs for power exports being signed between governments. World energy prices, economic performance and energy security concerns are likely to influence whether or such agreements are signed (see power baseline paper). Thus which projects or combination of projects actually go ahead is subject to a range of contingencies which are beyond the scope of this assessment. **Nevertheless, this analysis is indicative of the significance and magnitude of the proposed developments in terms of economic investment, which for a country such as Lao PDR is huge.**

EFFECTS DUE TO INVESTMENT STIMULUS

Continuing rapid development of the hydropower sector is likely in the region over the next 20 years, and especially in Lao PDR is likely to deliver considerable economic stimulus to regional economies. In the case of some of the LMB countries (such as Lao PDR) and some economic sectors (such as construction and engineering sectors in countries supplying dam components and construction service and non-tradable sectors in host countries) will certainly benefit. The extent of this stimulus effect will vary on a case to case basis but in general is likely to have an overall positive influence on economic growth.

REAL EXCHANGE-RATE APPRECIATION AND 'DUTCH DISEASE'

There are many planned large scale foreign invested natural resources development projects in Lao PDR. Real exchange rate appreciation due to the influx of foreign exchange from both FDI and revenue streams from these projects could be significant. The cumulative impact on the tradable goods sectors may become important. Whether or not this translates into increasing inequality and increases in relative poverty will depend on the extent to which the government is willing to off-set these changes through expenditures on poverty reduction.

Real exchange rate appreciation is likely to be an issue which Lao PDR will have to manage very carefully if it is to avoid the negative impacts of Dutch disease. It is unlikely to be an issue elsewhere in the basin as the role of the natural resource sector and foreign exchange earnings from it are likely to be small relative to the size of the other economies. Although in the case of Cambodia with considerable mineral exploitation and fossil fuel potential, as well as hydropower for export, if these resources are realized for export may also see upward pressure on real exchange rates.

PUBLIC DEBT SUSTAINABILITY IN LAO PDR

It is not clear to what extent LMB governments (Lao PDR and Cambodia in particular) will take on liabilities and extra debt in supporting development in the hydropower sector in the next 20 years. Nor is the extent of government revenues to be generated from such developments clear. Given the appetite of private investors for hydropower investments, and debt constraints on LMB governments it is unlikely that governments will find it necessary – or be willing - to invest heavily in these projects. Developments in the definite future scenario are therefore not likely to have significant implications for national debt sustainability.

2.5 FUTURE TRENDS WITHOUT THE LMB MAINSTREAM HYDROPOWER DEVELOPMENT

2.5.1 ISSUE: WHAT ARE THE ECONOMIC COSTS AND BENEFITS OF SECTORAL DEVELOPMENT IN THE LMB COUNTRIES

The trends in sectoral developments to 2030 are mapped out in table 5. In general all sectors are expected to show output and productivity growth compared to 2010. The exception to this is the case of environmental goods and services which are expected to see a general decline in productivity due to bio-physical changes in the basin (deforestation, increased pollution and changes in the hydrological characteristics of the river.

2.6 FUTURE TRENDS WITHOUT THE LMB MAINSTREAM HYDROPOWER DEVELOPMENT

2.6.1 ISSUE: WHAT IS THE DISTRIBUTION OF ECONOMIC BENEFITS BETWEEN DIFFERENT AREAS, GROUPS AND SECTORS?

DEMOGRAPHICS

While overall population growth rates are expected to decline for all LMB countries between 2005 and 2030, the key trend of rural-urban migration and relative decline of rural populations is expected to continue across all LMB countries. This is indicated by an urban population growth rate higher than the overall population growth rate in all LMB counties (table 6). This high urban population growth rate translates into low net population growth in rural areas. In Vietnam and Thailand rural areas are expected to see populations shrinking over the period. In Lao PDR and Cambodia rural populations are expected to see a relative decline, but to continue their slow growth. The implications for these changes for river dependant populations (derived from riparian provincial growth rates) is that the population is likely remain at roughly the same level (table 7).

POVERTY

Over the next 20 years levels of absolute poverty are likely to decline, relative poverty and geographical locations where poverty tends to persist will remain. Within this overall picture a few probable trends stand out. Firstly, urban poverty is likely to grow with urban populations, while poverty rates may be lower than in deprived rural areas the absolute number of urban poor is likely to grow substantially. Secondly, rural populations which rely on the natural resource base to support their livelihoods are likely see incomes and living standards decline as this resource base passes its carrying capacity and starts to become depleted. In the longer term this may be an additional push factor for would be rural-urban migrants and may result in larger population movements- and consequently higher poverty levels in urban areas. However, population estimates above suggest that rural populations in riparian areas are likely to remain stable, which should mean, all other things being equal, that the carrying capacity of the bio-physical systems on which these communities depend should not be exceeded.

Table 6: Population growth trends in LMB countries 2005-2030

Country	Total population			Urban population		
	2005	2030	AAGR (%) 2005-2030	2005	2030	AAGR 2005-2030 (%)
Cambodia	13,866	20,100	1.49	2,753	7,678	4.1
Lao PDR	5,880	8,854	1.64	1,551	4,322	4.1
Thailand	65,946	73,462	0.43	20,352	31,682	1.77
Viet Nam	84,074	105,447	0.91	22,454	46,123	2.88
Total LMB	169,766	207,863	0.81	47,110	89,805	2.58

Source: UN World Urbanization Prospects Database 2007, UN World Population Prospects Database 2008

Table 5: Future trend in key development sectors in the LMB 2010-2030

Description	Indicative values	Current value	Future trends
Fisheries	Fish, OAA	USD 1.4-3.9 billion/year (catch value)	Decline relative to other sectors. Absolute elves of production likely to plateau, but not decline. Aquaculture in both reservoirs and ponds is likely to increase.
Agriculture and forestry	Paddy production River bank garden production NTFPs Bamboo production	(river bank gardens) USD 174-574 million/year (revenue) Paddy USD 4.6 billion annual revenue	No change in river bank garden production is expected. Paddy production expected to grow around 81% between 2007-2030, annual increase of 3%, to output value of USD 8.2 billion. Increasing productivity driven by improved techniques, increased levels of inputs, consolidation of land, expanded irrigation and mechanisation.
Tourism	Tourism revenues	N/A	Continuing rapid growth in tourism in the LMB. Decline in certain sorts of tourism as natural resource base upon which it depends declines (e.g. Irrawaddy dolphin)
Navigation	Freight transport Passenger transport	USD 4.43-4.48 million/year (direct) USD 11.15-11.25 million/year (indirect)	Some increase in navigation downstream of Phnom Penh and in the UMB. Elsewhere decline as road infrastructure and motor vehicle ownership expands.
Construction	Sand and gravel extraction output	USD 164 million	Continuing rapid growth in exploitation, forcing increasing strict controls of extractive activities.
Mining and industry	Sink for waste products	N/A	Continuing rapid increase in pollution load, large point sources of pollution (e.g. large mines) could start to cause increased localised pollution problems.
Aquatic plants	Subsistence	N/A	Continuing decline of aquatic plans due to over exploitation and worsening environmental indicators.
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	USD 11.2 million (2000 prices)	Decline in some areas due to pollution and changes in flow regimes due to tributary and Chinese hydropower dams.
Flooding/flood control	Nutrient replenishment, wildlife habitat, damage to goods and livelihoods	N/A	Largely stable
Saline intrusion	Crop productivity	N/A	May improve due to higher dry season flows. Sea level rise and greater rainfall variability caused by climate change could result in worsening saline intrusion.

Table 7: Population growth trends for riparian LMB populations 2005-2030

No.	Ecological zone	River dependant population 2005	Growth rate (%)**	River dependant population 2030
2	Chiang Saen to Vientiane	313,939	0.18	314,505
3	Vientiane to Pakse	1,343,182	0.18	1,345,602
4	Pakse to Kratie	232,397	0.18*	232,816
5	Kratie to Phnom Penh and Tonle Sap	3,581,952	0.45	3,598,107
6	Phnom Penh to the sea	6,482,368	-0.15	6,472,652
Total		11,953,838	0.003	11,963,681

Source: ICEM based on IBFM studies Note: * assumed to be the same as for Lao PDR as similar riparian environment and population densities.** assumed to be the same as the rural growth rate.

LIVELIHOODS

There are a number of important livelihoods trends likely to emerge over the next 20 years in the LMB. Firstly, the number of people involved in the cash economy will increase both as rural-urban migration increases the amount of wage labour and as marketing agricultural goods becomes more common with improved access to markets through improved infrastructure, and expanding opportunities for wage employment in rural areas. Secondly, commercial agriculture is likely to increase, especially in Thailand and Vietnam, which will see declining rural populations and gradually increasing farm incomes. Thirdly, unless the urbanization trend in Lao PDR and Cambodia increases significantly rural livelihoods dependant on under-pressure natural resources may also come under pressure.

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3 ENERGY AND POWER

Theme and key strategic issues

Theme	*Key issues (relevant to hydropower)*
Energy and Power	1. Electricity demand growth 2. Buyer and seller motivations for cross-border power trade 3. Energy resource base 4. Alternative demand-side and supply-side options

3.1 PAST TRENDS AND CURRENT SITUATION

3.1.1 ISSUE 1: ELECTRICITY DEMAND GROWTH

This section seeks to broadly show the trends and drivers of overall electricity demand growth in the GMS region and the four lower Mekong basin countries. For greater detail and wider coverage of the status and trends on this issue, as well as the other energy and power issues in this summary, the baseline paper should be consulted.

BACKGROUND

There are several factors driving electricity demand in the Greater Mekong Sub-Region (GMS) The rapid pace of export-led economic growth in the region comes on top of efforts to improve and expand electricity access in rural areas, amid rapid trends to urbanization, diversification of regional economies and population growth. As a result, electricity demand growth rates in many Mekong countries are today among the highest in the world.

The manufacturing sector, in particular, has been a most important driver of electricity growth. Rapid urbanization and progress with electrification have also increased the proportion of the population with access to more affordable on-grid electricity. Trends to higher electricity consumption (per connection) by commercial and residential consumers are driven by higher average income levels and preference for modern conveniences, including a greater number of electrical appliances not only in urban areas, but also provincial towns and rural areas.

Nevertheless, electricity utilization in the wider GMS is low by world standards. Average per capita power consumption in the GMS is only two thirds of the developing world average (ADB 2008). Energy poverty is still a major concern in the wider Mekong region. About 20% of the GMS population (74 million people) today still has no access to electricity (ADB, 2008). Most observers suggest the lack of efficient electricity supply in rural areas could impede government policies towards effective, overall poverty reduction.

PAST TRENDS

Despite the recent global economic slowdown most countries have resumed historic demand growth rates. Viet Nam, for example, is in a phase of rapid economic growth, where power demand increased in the period of 1996 to 2007 at an average annual growth rate of about 15% per year (EVN annual report, 2007). The peak demand has also increased significantly from 3,200 MW in 1996 to become 12,636 MW in 2007.

Figure 1 below illustrates the historic electricity demand growth in Thailand correlated to GDP growth. The drop in electricity demand as a result of the last Asia economic downturn in the late 1990s can be seen. Figure 2 illustrates demand growth in the LMB as a whole, by proxy, using past trends in generation by GWh serving LMB power markets. The large proportion of thermal generation in the current supply mix is clearly evident in Figure 2.

Figure 1: Thailand- growth of net electricity consumption and GDP 1982-2006

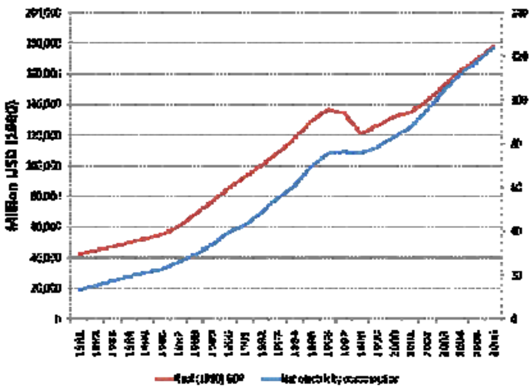
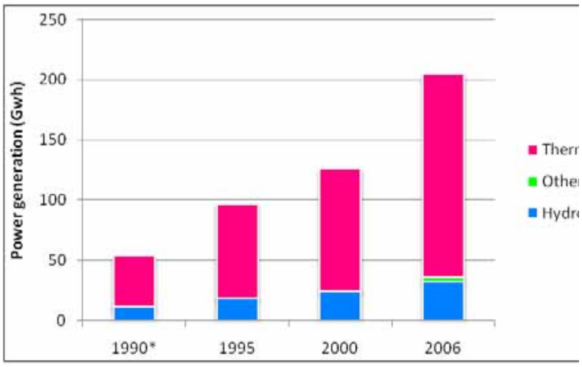


Figure 2: Power Generation Mix in LMB countries 1990-2006



Source: ADB/APERC 2009b

SUMMARY OF CURRENT STATUS AND TRENDS

Electricity demand forecasts are always contested. The baseline paper considered demand-side management as one aspect of that ongoing debate. The current status and official view of electricity demand growth trends are indicated in Table 1. This suggests that annual growth rates in electricity demand in the LMB will average up to 8.5 % in 2015, slowing to 6.5 % by 2030. The highest rates of growth in Viet Nam figure prominently.

In the consideration of markets for LMB hydropower, demand in Thailand and Vietnam are primary considerations. The reason is clear. In both 2015 and 2025, energy demand (GWh) in Vietnam and Thailand combined will represent 96 % of LMB energy demand.

- ***Thailand***: the power demand is projected to increase by a factor of 2.2 in the next 15 years, with an annual increase of peak demand of 2,600 MW per year in 2025 (equivalent to 3 new 800 MW gas-fired plants per year).

- ***Vietnam***: will catch up with Thailand demand in 2014. The power demand is projected to increase by a factor of 3.7 in the next 15 years, with an annual increase of 4,600 MW per year in 2025 (equivalent to 6 new gas-fired plants per year).

Table 1: Projected Electricity Demand Forecast in LMB Countries

		2010	2015	2020	2025
Cambodia	Peak Demand (MW)	467	1,008	1,610	2,401
	Annual Growth		16.6%	9.8%	8.3%
	Estimated Load Factor	65%	66%	67%	68%
	Energy Demand (GWh)	2,659	5,828	9,449	14,302
Laos	Peak Demand (MW)	618	1,911	2,665	2,696
	Annual Growth		25.3%	6.9%	0.2%
	Estimated Load Factor	65%	66%	67%	68%
	Energy Demand (GWh)	3,519	11,049	15,641	16,060
Thailand	Peak Demand (MW)	23,936	31,734	42,024	53,824
	Annual Growth		5.8%	5.8%	5.1%
	Estimated Load Factor	72%	72%	72%	72%
	Energy Demand (GWh)	150,969	200,153	265,054	339,479
Vietnam	Peak Demand (MW)	19,544	32,210	48,662	71,445
	Annual Growth		10.5%	8.6%	8.0%
	Estimated Load Factor	72%	72%	72%	72%
	Energy Demand (GWh)	123,268	203,155	306,921	450,618
All Countries	Peak Demand (MW)	**44,565**	**66,863**	**94,961**	**130,366**
	Annual Growth		**8.5%**	**7.3%**	**6.5%**
	Estimated Load Factor	**72%**	**72%**	**72%**	**72%**
	Energy Demand (GWh)	**280,415**	**420,184**	**597,066**	**820,458**

Source: ADB RETA (2009) based on current PDP updates of GMS countries

LMB POWER MARKET SERVED, EQUITY IN ELECTRICITY ACCESS AND SUPPLY OPTIONS

Power markets are important in understanding the role electricity in society, equity issues in addressing energy poverty, and disentangling issues about what alternative electricity supply options can be considered in different settings.

Table 2 offers a generic representation of five generic power markets in the LMB and the population, or type of customer served. These markets include (i) grid supply (ii) isolated load centers or "mini" grids (iii) household/ stand-alone systems (iv) dedicated supply to resource industries (and captive generation, or own-supply), and (v) export markets.

Table 2: LMB Power Markets and Consumers

Power Market	Population served / Types of Consumers
Grid Supply	▪ All consumers connected to national grids, (e.g. - urban centers and provincial towns (for domestic, industry, commercial, public services, etc.) - rural electrification by grid supply

Isolated load centers or mini-grids	▪ All consumers connected to isolated load canters, e.g. - Provincial towns (also domestic, industry, commercial, public services, etc in the area) - rural electrification by grid supply served
Stand-alone household supply	▪ Individual customers and homes - Primarily in rural areas, where there is no grid service - More limited applications in town/urban areas with grid service
Dedicate Industry supply and captive generation	▪ Resource based-industries / enterprise with own generation or dedicated transmission supply (not from the national grid and wheeling arrangements in the case of IPPS or utility-to-utility agreements)
Export markets	▪ Sales to national grids of neighboring countries (either by dedicated transmission or connection between the two national grids)

While LMB Countries are rapidly urbanizing, close to 70% of the 175 million people in LMB countries still live and work in rural areas. Thus, the extent to which the grid lines reach rural towns, communities and extend into remote, low population density areas is important in considering the role of large generators and alternatives to meet needs.

The situation varies considerably between LMB countries. In Thailand, for example, the grid reportedly reaches over 99% of Thai villages and electrification ratios are +95%. Similarly in Viet Nam, a large proportion of the rural population is now served by the national grid. The electrification ratio overall is +85% presently, with targets to raise this to over 95% by 2020 (mainly, but not exclusively through conventional grid extension to rural areas not yet supplied).

In Cambodia and Lao the picture is different. The absence of a national grid in Cambodia has split the power system in the country into 22 isolated systems, or mini-grids, working separately on expensive small-scale power generation (diesel generators currently dominating). As discussed in the baseline paper, this has led Cambodia to high electricity tariffs, with consequence not only for poverty alleviation, but also for economic investment.[4] Lao PDR has increased household connections from 16 % in 1995; to 44% in 2004; and to 60% in 2008. Policies are to achieve 90% household connections by 2020 through a combination of expansion of grid and off-grid supply. In Lao PDR in 2006, 93% of new rural household connections were derived from low voltage grid extensions.

Thus apart from supplying demand to urban and industrial consumers, power export projects serve rural areas to the extent the national grids feed the rural electrification lines and the local distribution systems are adequate.

3.1.2 ISSUE 2: BUYER AND SELLER MOTIVATIONS FOR CROSS-BORDER POWER TRADE

[4] From a technical perspective, small-scale generation and the absence of interconnected system partly contribute to the high unit cost of power generation as the economy of scale cannot be exploited.

This section considers the status and key drivers in cross-border power trade, under which LMB hydropower projects are advanced as export-oriented projects and a portion of the power is reserved to serve grid demand in the host country.

BACKGROUND

Growing demand for electricity is unquestionably a driver for new power generating capacity in the LMB. However, it cannot by itself be considered the direct driver of LMB hydropower development, in general, or the proposed mainstream hydropower projects in particular. The drivers are found in two broader and distinct, economic and political phenomena.

POWER SYSTEM PLANNING (IMPORTING COUNTRIES)

Power system planning determines which generation options fit within the framework of power supply policies set by governments. This essentially means a balance between power supply reliability and cost. This is discussed in detail the background paper. A related aspect in power system planning relevant to LMB hydropower is the strong interest of Thailand and Vietnam to diversify power supply sources.

EXPORT INCOME AND FUTURE GENERATION (EXPORTING COUNTRIES)

Lao PDR and Cambodia see potential revenue from electricity export to the larger neighbouring economies of Thailand and Vietnam as a primary means for lowering national debt burdens, balancing trade, boosting growth and reducing poverty. A second important aspect is the development of domestic power sector infrastructure. At present tributary dams in Lao PDR developed for export under concession agreements (CAs) between the Lao PDR government and the project entity, and the power purchase agreements (PPAs) between the project entity and EGAT, reserve a portion of output for grid supply to EdL. This is illustrated by the following:

- Theun Hinboun 1 first IPP (210 MW export) with domestic supply to Lao grid (10 MW to EdL) – about 5% of the project.
- Nam Theun 2 (1070 MW export) with domestic supply Lao grid (75 MW to EdL) – about 7% of the project.
- Theun Hinboun extension (220 MW for export) with domestic supply to Lao grid (60 MW to EdL) – about 27% of the project.

The amount of power is significant relative to the size of the power markets in Lao PDR. Continuing this trend, project-specific MOUs and feasibility studies for proposed LMB mainstream projects anticipate reserving a portion of output for domestic grids of the exporters. Assumptions in the feasibility studies indicate this may be in the order of 5-10%.

A further strategic aspect is export-oriented hydropower offers the exporting country strategic flexibility for long-term power supply and revenue earnings, based on renewable resources. For example, after the concession period, when debts are retired, Lao PDR and Cambodia will have the option of using that large amount of power domestically, or continue to sell a portion to generate revenue.

3.1.2.1 GMS MULTILATERAL POWER TRADE AGREEMENTS

The broad trend is supported by the Greater Mekong Sub-Region (the four MRC Member Countries plus Myanmar and China) Intergovernmental Agreement on Power Interconnection and Trade in 2003. Subsequently, a 'road map' to implement the agreement was prepared and regular updates are provided including a regional interconnection master plan and supporting institutional arrangements.

The GMS agreements has the objectives to, "… continue with the development of (transmission) interconnections between the respective (electricity) networks and expand capacity and energy trade to provide further opportunities to: (i) enhance the reliability of supply, (ii) coordinate the installation and operation of (electricity) generation and transmission facilities, (iii) reduce investment and operating costs, and (iv) share in other benefits resulting from the interconnected operations of their systems".

The GMS regional transmission interconnection plan is clearly long term. It builds on a series of bilateral MOUs and agreements developed by the Mekong governments over the past two decades to expand cross-border power trade between their respective countries. These bilateral MOUs authorize respective power entities in each country to negotiate a PPA for specific projects, which fit within the quantum of power under the bilateral MOU.

STATUS OF LMB BILATERAL POWER TRADE MOUS

Thailand has reportedly signed bilateral agreements to buy up to 11,500 megawatts of electricity from its neighbours, including Lao PDR to purchase 7,000 MW, with southern China for 3,000 MW and with Burma for 1,500 MW (ADB RETA 6220, 2009). In addition to the 7,000 MW MOU with Thailand, Lao has signed a bilateral MOU with Vietnam for 5,000 MW respectively. Cambodia has not signed any MOUs and proceeds with project specific arrangements only. The baseline paper goes into detail on the project-specific MOUs covering existing exports, committed and proposed projects.

While bilateral MOUs are a definite step in development of projects, their significance to the development status of any specific project should not be overstated. Bilateral MOUs are expressions of common interest in pursuing certain opportunities but they are not to be confused with firm commitments to accept or deliver power from specific projects, since they are entered before analysis of projects.

Bilateral MOUs do however indicate the level of electricity import "tolerance" in the power system of the importing country and provide basis for further consideration of any project-specific agreements and eventually power purchase agreements (PPAs) between the utility in the importing country (i.e. EGAT in Thailand and EVN in the case of Vietnam), concerning LMB power projects in neighboring LMB countries.

SUMMARY OF CURRENT STATUS AND TRENDS

Three broader strategic trends and considerations emerge with issue 2:

- There is an evolving picture with bilateral power trade MOUs, for example with Thailand and Lao PDR expanded the quantum of power under their MOU from 3,000 MW in 2003 to 5,000 MW in 2005 to the current 7,000 MW.

- The new Thailand PDP issued in January (2010), yet to go through full public hearings, expects potential imports of up to 25% of peak demand from neighbouring counties and China by 2030, along with expanding RE technologies, coal import and nuclear power, and reducing current dependence on natural gas (now 73% of generation).
- To a large extent it is not demand growth, but system planning considerations driving the initial consideration of LMB tributary hydropower, including proposed mainstream schemes. In the longer term demand growth will certainly influence the number and timing of proposed LMB mainstream hydropower schemes, if pursued.
- For Vietnam the question of power imports remains dominated by the high demand growth picture and import pricing considerations.

3.1.3 ISSUE 3: GMS AND LMB ENERGY RESOURCE BASE

This section broadly summarizes the current status of the energy resources base for power conversion technologies from micro- to large-scale, including the renewable energy (RE).

BACKGROUND

Volatility in international energy prices and concerns over climate change have all intensified the focus on developing the Mekong's indigenous renewable resources to the optimal potential including solar, biomass, wind and hydropower.

At present 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 for electricity generation (oil, coal and gas). Fossil fuel imports for power generation are set to rise. Governments are thus increasingly focused on achieving energy security by optimizing use of indigenous resources at national and regional levels.

GMS AND LMB HYDROCARBON RESOURCES

The GMS as whole has considerable hydrocarbon resources, which vary from country to country. The broader strategic picture in the LMB is that while countries do have proven hydrocarbons (i.e. coal, natural gas and oil in Vietnam, natural gas in Thailand and coal to a lesser extent), in many cases the reserves are not strategic or long term, and there is competition for use of these resources in other domestic economic sectors.

Table 3 illustrates the GMS hydrocarbon picture. What is notable is the overwhelming dominance of coal, and that most coal is not Grade 1 (i.e. it is a lower quality in terms of energy content, higher moisture content). In part, this is behind consideration of imports of higher quality thermal coal from outside the GMS region for power generation. China has the dominant share of coal and Myanmar has the dominant share of gas (proven to potential reserves).

Table 3: Energy Equivalent of GMS Hydrocarbon Resources (PJ)

	Grade 1 Energy Resources (PJ equivalence)	%	Less that Grade 1 Energy Resource (lower quality)	Total PJ	%
Coal	201,528	59.7%	1,402,061	1,603,589	88.6%
Lignite	101,641	30.1%	5,890	107,531	5.9%
Oil	18,900	5.6%	25,133	44,033	2.4%
Natural Gas	15,600	4.6%	40,061	55,661	3.1%
Total	337,669	100.0%	1,473,144	1,810,813	100.0%
Note: Assumptions on Conversions To PJ					
Hydrocarbons		Grade 1 (PJ)	Other grades (PJ)	GMS Hydro Potential - MW to	
Coal	1 MTCE	24	19.2	53,000 MW	
Lignite	1 MTCE	9.5	7.6	1,003 PJ / year	
Oil	1MTOE	42	33.6	Assumed	
Gas	1bcm	39	31.2	Plant Factor 0.6	
Conversion of Grade 1 to Other Grades			0.8		
Sources: SEA calculations adapted from ADB Sustainable Energy Futures (2009) – originally from IRM (2008). Gas reserves increased to reflect current information					

For individual LMB countries, as yet Cambodia and Lao PDR have no proven hydrocarbons, except for a limited amount of lignite coal in Lao. From Thailand's perspective, the fact that proven domestic natural gas reserves (in the Gulf of Thailand) have only 10-12 years left at current consumption is rates is increasingly important. Vietnam has higher quality anthracite coal reserves, which it exports to higher value markets (metallurgical) and other domestic sectors, as well as power generation. Suggestions are that Vietnam will import coal for power generation from international markets starting in 2012-2015 period (ADB RETA, 2009).

HYDROPOWER

The total hydropower potential of the Mekong River Basin, estimated to be 53,000 MW, with about 30,000 MW technically available in the four lower Mekong countries of Cambodia, Lao PDR, Thailand and Viet Nam - is well known.

RENEWABLE ENERGY (RE) SOURCES

The LMB countries possess a large (non-hydro) and diverse renewable energy (RE) resource base, although the utilization with advanced conversion technologies to produce electricity is still comparatively low, and some of the traditional energy resources (i.e. wood fuels and charcoal) are under multiple pressures. These RE resources can be used for grid and off-grid generation (as noted in the discussion of alternatives in issue 4).

The government of Thailand has estimated that its medium-term RE potential for conversion to power is some 14,300 MW, including: biomass (7,000 MW); solar 5,000 MW; small hydropower (700 MW) and wind (1,600 MW). Although many stakeholders argue the RE potential for solar especially in stand-alone applications is much higher, considering the potential for widely distributed solar applications that may be cost-effective.

Other LMB countries also have strategic RE potential. In Viet Nam, the RE resources are similar to Thailand, but perhaps greater potential for wind in offshore and coastal areas, and in the longer term, ocean energy conversion technologies (e.g. wave). The updated Viet Nam PDP (by the ADB RETA) anticipates generation from commercial or near-commercial RE sources to reach 2,400 MW by 2025, or close to 3% of projected installed capacity by that time.

OTHER NON-CONVENTIONAL

There is additional potential for non-conventional sources including geothermal (considered limited), municipal solid waste and a large untapped potential for co-generation linked to industrial process heating and waste processing in LMB countries.

SUMMARY OF CURRENT STATUS AND TRENDS

- Hydrocarbon fuels account for roughly 90 % of power generation in LMB countries. Imports are 22 % and set to rise, as Thailand and Vietnam increasingly consider coal imports from outside the GMS.
- While some LMB countries do have proven hydrocarbons (i.e. Vietnam and Thailand to a lesser extent), in many cases the reserves are not strategic, or long term.
- RE sources offer immediate and considerably larger longer-term potential for grid-feeding and off grid applications. Cogeneration and other non-conventional energy resources are also untapped resources.
- With regard to LMB hydropower, the status and trend is shown in Table 4. At present about 10% of LMB hydropower potential has been exploited.

3.1.4 ISSUE 4: Alternative demand-side and supply-side options

This section seeks to summarize key issues and trends with alternatives and key policy drivers and investment catalysts for RE and DSM /EE. Broader LMB energy policies increasingly promote RE options as part of a broad portfolio to serve grid and off-grid power markets.

BACKGROUND

During the scoping phase of the SEA many stakeholders felt it important to highlight the status and trends in alternatives to improve electricity access and services in power markets that LMB mainstream dams would target, in particular with (i) non-hydro indigenous, renewable energy sources (ii) further, or even accelerated hydropower development on LMB tributaries to replace or defer consideration of mainstream LMB hydropower until the full implications are better understood, and (iii) demand-side management in Thailand and Vietnam to reduce load growth.

Simply put, one set of views is alternatives do exist - this needs to be brought to the attention of political decision-makers. If Thailand and Vietnam were to pursue these alternatives, in combination with exploiting the remaining hydrocarbon resources in the GMS region (e.g. primarily natural gas and coal) supplemented by imports from outside the GMS, the LMB mainstream dams would be unnecessary from a power demand-supply import perspective.

Table 4 - 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**

A competing set of views was that all feasible supply options are needed to meet growing needs for electricity services, not only in Thailand and Viet Nam, but also in Cambodia and Lao PDR and that even aggressive demand-side management measures will only serve to moderate the rate of demand growth, but does not diminish interest on LMB hydropower.

ALTERNATIVE RE SUPPLY TECHNOLOGIES

Two broader categories useful to clarify the status and trends in the LMB concerning small and larger-scale RE options are:

1. **Decentralized generation**: meaning not connected to the national grid. It includes isolated or “mini-grids”, as well as stand-alone systems for individual customers, especially rural, low-income households engaged in subsistence agriculture distant from the grid, where rural RE electricity conversion technologies include simple (PV) home-systems and lighting, biomass conversion, micro hydro and wind generators, depending on site specific conditions

2. **Distributed generation**, captures the family of RE conversion technologies (small hydro, wind, solar biomass, etc.) as well as conventional technologies (e.g. diesel generators) and non-conventional

generation (e.g. industrial co-generation) used in a grid context with "feed in" tariffs, requiring related technical arrangements and subsidy.

While some regard distributed generation as long-term, there is interesting progress in the LMB with Thailand's very small power producer (VSPP) & Feed-in Tariff Programme and the small power producer programme (SPP), recently extended from 60 MW to 90 MW.

Drivers of RE: Each LMB country is evolving its RE policy, implementation of which is most advanced in Thailand. The Government of Thailand adopted a 15-year Alternative Energy Development Plan (AEDP) in January 2009, which aims to reach a target of 20% alternative / renewable energy in the national energy mix by 2022. The target for the power sector is to derive 11,216 MW from RE sources by 2022. The most significant policy trend is Thailand has advanced the two programmes mentioned (VSPP and SPP). SPP applications for 6,682 MW had been received by mid-2008, of which 4,151 could be supplied to the grid in a feed-in arrangement. Installed capacity via the VSPP by mid-2008 had reached 1,622 MW.

The challenges to address in RE promotion for decentralized and distributed uses in the LMB countries include the intermittent nature of energy availability of some technologies based on RE resources, high first costs - hence the need for subsidy as in the VSSP and SPP programmes in Thailand, the need for organization for their utilization, and to some extent foreign exchange implications. Each RE conversions technology also has its own complexity and institutional coordination requirements and environment and social implications.

The realistic economic potential of renewable energy sources, such as wind and solar power is circumscribed by their intermittency (i.e. with adequate wind and sun). A back-up system is required if reliable power is needed, which means investing in two systems to meet new load growth. Because of the intermittent nature of wind, fore example, most large-scale grid-connected systems around the world operate in a fuel saving mode on the grid, that is, to reduce the burning of fuel at existing thermal stations, or sell to neighbouring grids when excess RE power is available, and importing when it is not (as in the case of Denmark).

Conventional Thermal: These are well established technologies that play various roles in power supply (e.g. peak, mid-range, base load generation). At present natural gas generators in the LMB (i.e. combustion turbines (CTs) and combined cycle systems (CC)) are relatively efficient. Though there are opportunities in gas re-powering projects to improve efficiencies.

Given the level of current and potential future coal-fired generation in the LMB, one trend of primary interest is the new high-efficiency coal conversion technology called "super-critical" and "ultra-critical" clean coal. These systems use pulverised coal combustion with supercritical and ultra-supercritical boiler technology to operate at increasingly higher temperatures and pressures. They therefore achieve much higher efficiencies than conventional coal units and significant CO2 reductions. Highly efficient modern coal plants emit almost 40% less CO2 than the average coal plant currently installed globally. As noted in the baseline paper, expectations are that any new coal plant in Thailand will use these technologies.

Nuclear Power: Both Vietnam and Thailand include nuclear power in their PDPs. Five to seven nuclear reactors are proposed by 2030 in the January 2010 revision of the Thailand PDP (again yet to have Public Hearings). The Thai Government openly acknowledges the greatest challenge in proceeding with the nuclear power will be public acceptance. Vietnam more actively proposes to have 4,000 MW by 2025, with the first units possibly by 2020. It projects the nuclear power will eventually reach 20 % of grid supply in Viet Nam, beyond 2030.

Demand side-Management (DSM): At the center of the critique of hydropower (certainly LMB mainstream proposals) are what many stakeholders contend to be overly optimistic estimates of demand growth and limited attention to demand-side management (DMS) and energy efficiency (EE) potential in supply, transmission and end-use. There is ample evidence that LMB governments supported by donor partners increasingly recognize the value of DSM / EE in meeting environmental and power sector development goals. DSM is also viewed as one of the most cost-effective ways to reduce greenhouse gases such as CO_2.

Although all LMB Countries have made progress with DSM in the last decade, there is a mixed picture. Focusing on the two main power markets for LMB mainstream dams:

- **Thailand** was one of the first countries in Asia to formally adopt a nationwide demand-side management master plan in 1997. It maintains an active DSM program. As of June 2007, the DSM implementation reportedly reduced peak demand of 1,435.2 MW and energy demand by 8,148.3 GWh. As Thai Authorities note, the program also achieved CO_2 emission reduction of 5.63 million tons.
- **Viet Nam** started its first DSM Programme in 1997 with a multi-phase and multi-year programme with targets for a 120 MW reduction in peak demand and 496 GWh in 2007. Independent review suggests achievements in DSM in Viet Nam to date are very difficult to monitor because of the growth rate in demand, load shedding and the lack of monitoring data. Energy efficiency targets (or national aspiration goals) set in Vietnam in 2006 for all sectors of the economy are for a 5% reduction in overall energy consumption for 2006 to 2010, and 5 to 8% for 2011 to 2015.

The trend to higher electricity tariffs will gradually influence consumer behaviour in the medium to longer term, e.g. turning off lights and appliances when they are not needed and buying energy efficient bulbs and appliances. Except for easier measures like energy efficient lighting and conservation behaviour, current trends suggest that significant penetration of DSM is a longer-term prospect. Strategic savings through DSM require structural change and well planned investment in replacement of the existing stock of inefficient appliances, especially in the industrial and commercial sectors, and major initiatives to introduce energy-efficient appliances in the manufacture and into the supply chain for domestic appliances.

SUMMARY OF CURRENT STATUS AND TRENDS

Projecting from current trends:

- LMB countries have significant RE and non-conventional energy resource base. Small-scale REs are important to pursue and central to the energy policies and the poverty reduction policies of LMB Counties.
- A very important aspect is RE off-grid power does not compete with, but rather complements improvements in capacity to extend low-voltage grid power to Mekong people who have no electricity access. They rely on different funding sources.

- In the longer term with Thailand's feed-in tariff policies as an example, it can be expected that grid-connected RE will expand. But in all LMB countries subsidy is involved in the near term to make RE power compatible with poor consumers low incomes.
- Clean coal technologies will no doubt be of interest in LMB countries due to the high reliance on coal and of interest to the international community for emission reductions. However, these technologies imply higher investment and operating costs than and therefore cannot be expected to displace hydropower solely on economic grounds.
- Strategically, prospects for RE in the stand-alone, isolated mini grid and grid system context as well as DSM does not change drivers of mainstream power export to Thailand and Vietnam in the short to mid-term.

3.1.5 ISSUE: Trends in other issues related to regional power benefits

This section summarizes the status of other issues relevant to establishing the regional distribution of power benefits and analysis of equity issue.

GHG EMISSION REDUCTIONS FROM LMB HYDROPOWER

Global production and burning of fossil fuels today accounts for nearly two-thirds of total anthropogenic GHG emissions. Globally, thermal power generation based on coal, oil and gas alone accounts for up to one third. Applying national CO2 offset values to the annual energy produced by each hydroelectric project and targeted to each national power market the following values are obtained for the CO2 off-set by each hydropower development scenario.

LMB projects in operation by 2010:	6.1 M.Ton/year
Tributary Projects that will be operational by 2015:	22.6 M.Ton/year
Tributary Projects that could be operational by 2030:	42.0 M.Ton/year
Mainstream projects that could be operational by 2030:	51.9 M.Ton/year
All Projects that could be operational by 2030:	93.9 M.Ton/year

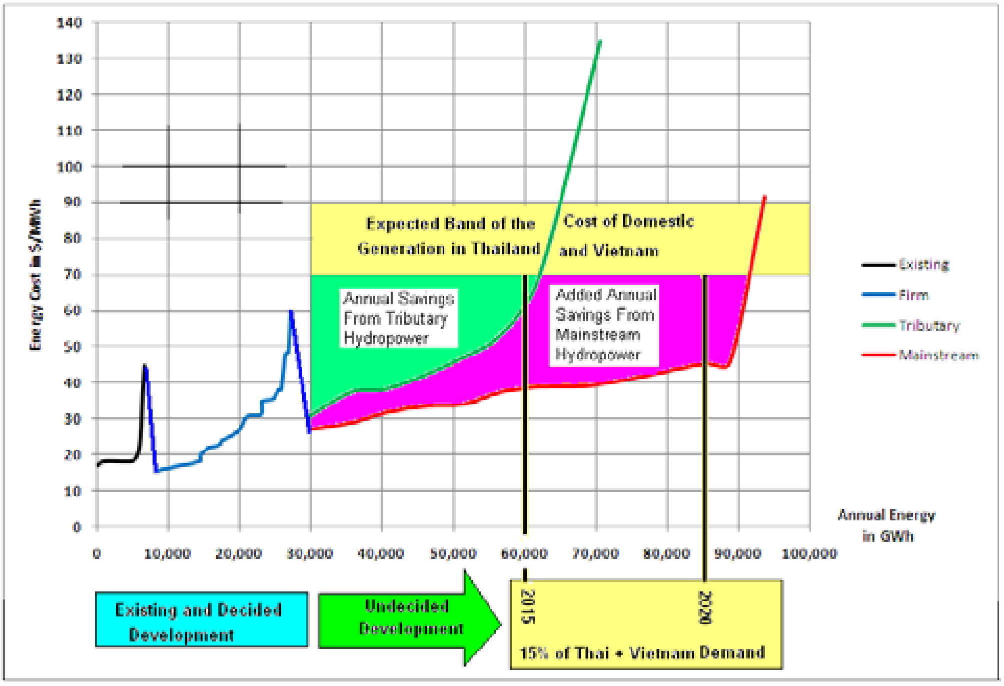
It is important to recognize these are gross offsets. Discussion on net GHG reduction accounting for potential reservoir emissions is noted in the baseline paper, but a quantitative analysis of net offsets relates to non-power considerations.

LMB HYDROPOWER INVESTMENT TRENDS AND COMPETITIVENESS

Hydropower is a highly capital intensive investment. A typical hydroelectric project today requires in the range of 1,500 to 3,000 $/kW (1.5 to 3 million US$ per installed MW) in construction budget and considerably more after accounting for the financing cost resulting from construction periods as long as 7 years. The 38 LMB hydroelectric projects in operation or under construction have an average installed capacity of around 170 MW and their unit cost is estimated at 1,250 $/kW. The remaining 97 projects identified in the LMB have an average installed capacity of 243 MW and estimated unit cost of around 2,320 $/kW.

However, there is a very wide range in the final cost of the energy (Gwh) produced by these projects. An illustration of the quantity, cost and competitiveness of the energy from existing and future LMB projects by the supply curves in Figure 1.3. The development of these supply curves is explained in baseline report.

Figure 1.3 - LMB Hydro Supply Curve and Primary Market Thermal Alternative Costs



It is important to note the environment and social mitigation costs in preparing the analysis reflect costs provided by project proponents. They have not been submitted to formal EIA / SIA scrutiny in national systems and may not reflect transboundary considerations the SEA will assess in the next phase.

GMS AND LMB EMPLOYMENT TRENDS RELATED TO HYDROPOWER

Because LMB projects are increasingly financed by private sector entities and banks from the GMS region, there will be GMS regional benefits related to contracts for civil construction, services and electrical and mechanical equipment. The trend is to increasingly manufacture hydropower equipment in China, and Thailand and Vietnam are major construction contractors. While the proposed LMB schemes represent over $US 24 billion, the distribution among GMS countries is difficult to estimate to the extent that international competitive bidding (ICB) may be used.

The labor component of LMB projects identified for development during the next 20 years is estimated at 10.8 billion US$ and approximately 40 % local labor from Laos and Cambodia. The rest will be highly skilled labor mostly from equipment producing countries in the GMS. It is likely that much of it would come from China, Thailand or Vietnam. Mainstream projects account for 55 % of the estimated labor during construction. By comparison, the labor net present value of operation and maintenance labor has been estimated as 1.1 billion US$ and 55 % of that is estimated to be local labor.

SUMMARY OF CURRENT STATUS AND TRENDS – OTHER ISSUES

The key general trends are:

- An analysis of supply curves of undecided LMB tributary and mainstream hydropower against a threshold energy price of 7 US Cents/kWh deemed to be competitive as an export price, indicates a potential of 90,000 GWh per year of which 30 % is in tributary projects and 70 % is in mainstream projects (data derived from MRCS Hydropower Data base)
- The regional distribution of benefits needs to take into account direct employment in the GMS region and locally, in view of the nature of the IPP funding sources indicated to date (i.e. from the GMS and Asia region).
- LMB hydropower has a significant potential for GHG reduction. Due to the high GHG content of the thermal power, it can be expected to displace up to 50 million tons of CO2 per year in the probable future scenario of the BDP to 2030 (excluding mainstream schemes). This is gross generation at thermal plant.

3.2 FUTURE TRENDS WITHOUT LMB DEVELOPMENT

The analysis of past trends and current conditions established a number of strategic considerations from the energy and power perspective. Those concerning the regional distribution of power benefits, distribution and equity considerations will analyzed in more detail in the next phase of the SEA:

In broader summary:

(i) Power demand will continue to grow as LMB economies diversify, and populations expand. In this context, supply-side and demand-side measures would serve to reduce the rate of demand growth, and increasingly over the medium-term defer the timing of new generation additions.

(ii) Vietnam and Thailand will seek to expand grid generation to meet demand, based on a mix of options with power economics perspectives and fuel policies of the respective governments in mind.

(iii) Lao will have a less revenue earning, beyond that generated by exports sales from tributary hydropower projects (current and proposed).

(iv) Cambodia will likely import coal, if there is no opportunity to pursue its mainstream LMB hydropower projects, either because of power system planning consideration or other reasons. To compensate for loss of foreign exchange earning potential and to realize economies of scale in energy generation, Cambodia may seek export-scale coal projects.

(v) Both Lao PDR and Cambodia would forge long-term strategic flexibility that would otherwise be presented when concession terms on the proposed LMB mainstream projects finish (e.g. 20-30 years)

(vi) RE potential has different sources of financing than LMB hydropower. Therefore no RE promotion and use will be driven by the availability of concessionary financing from donors (e.g. through rural electrification funds and programmes and funds) and in the case of Thailand national programmes. There may be increased pressure to pursue a diversified portfolio of off-grid and grid-feeding RE options to replace the power that LMB mainstream dams would otherwise offer to Cambodia and Lao PDR.

(vii) The Potential GMS and local employment as well as the potential for reduction of regional GHG emissions from thermal power generation would be lower.

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4 HYDROLOGY AND SEDIMENT

This paper summarizes the MRC SEA hydrology and sediment baseline working paper, which should be referred to for more detailed analysis of the issues presented here. The paper divides the Mekong into six hydro-ecological flow zones (Figure 1).

4.1.1 PHASING OF THE SEA HYDROLOGY AND SEDIMENT ASSESSMENT

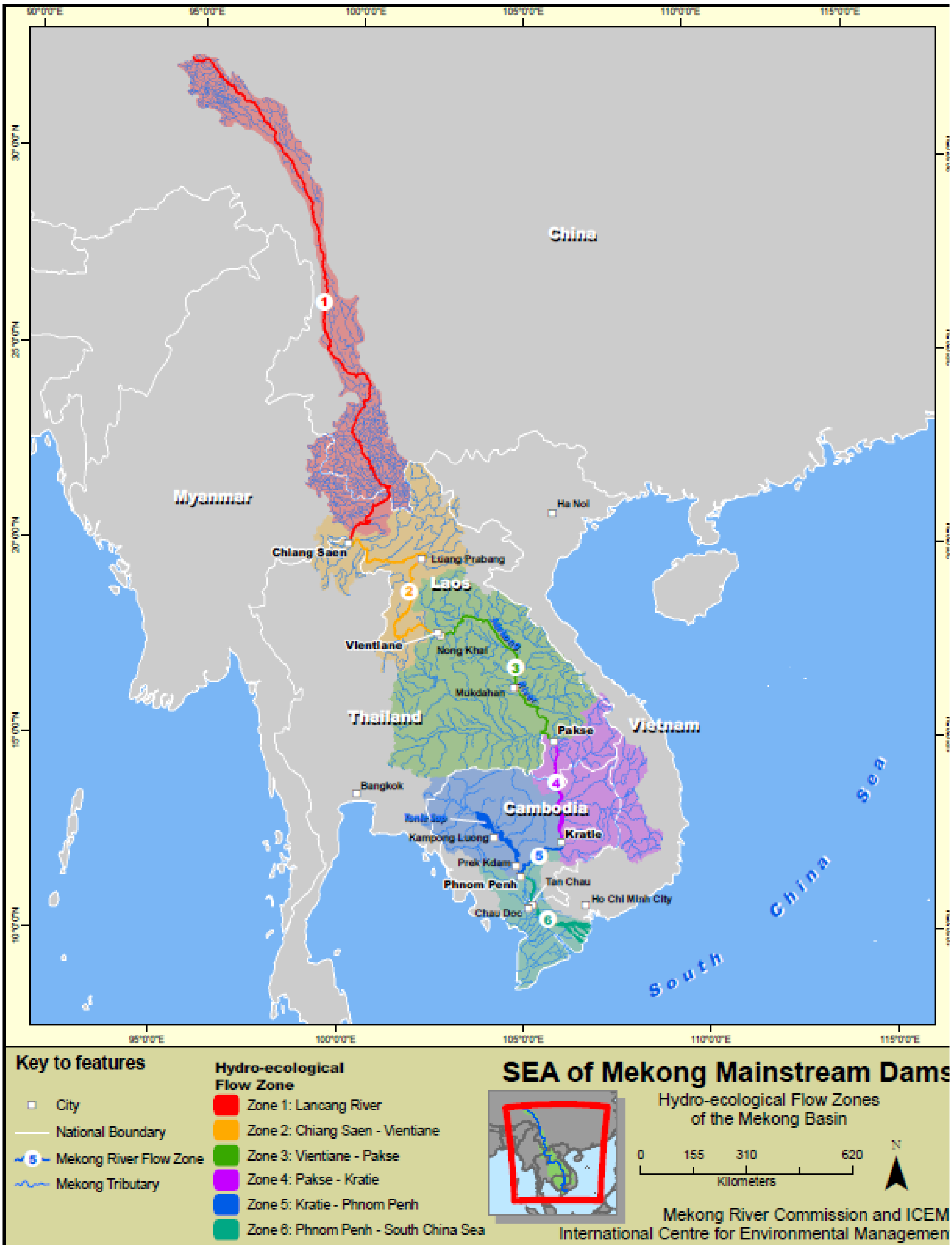
In the SEA impact assessment, the mainstream projects are assessed against a baseline of economic, social and environmental conditions. The baseline "without" the mainstream dams should represent an accurate description of the past and current situation and present a realistic projection of future conditions for a period when the mainstream dams might be constructed and operational. For the Mekong hydrological regime, the BDP Baseline has been taken as an accurate description of the past and current situation. For the projected baseline, the hydrological assessment selected two BDP scenarios – the Definite Future to 2015 and the LMB 20 Year Scenario to 2030. In this paper only the Definite Future is analysed. The LMB 20 Year baseline will be analysed during the impact assessment phase so that the mainstream project can be assessed for their effects against two sets of baseline conditions. The SEA team considers the Definite Future development scenario to be the most likely baseline conditions for the mainstream project, which if they were to proceed, would only be a reality in a post-2016-2020 Mekong basin. The LMB 20 Year scenario enables the mainstream projects to be assessed against a more extreme projected development baseline.

4.2 HYDROLOGY

4.2.1 THEMATIC CONTEXT

The Mekong River is 4,880km long with a total fall of 4,583m, area of 795,000km² and average annual flow of 505km³ (MRC, 2005; Kummu et al, in publication). 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 2). For the Lower Mekong Basin (LMB) it is the Mekong flood pulse which drives the river's high levels of aquatic and terrestrial biodiversity and system productivity (Kummu et al, 2007). The annual mainstream hydrograph for the Mekong River has three important features which are critical in establishing the current hydrological regime. First, the response of the hydrograph to the SW monsoon exhibits a single amplitude peak complemented by a highly predictable phase (MRC, 2006). Second, the onset of the flood season occurs within a consistent and small time window with a standard deviation of approximately two weeks (MRC, 2006). Third, there is a long period of low flows which facilitate the seasonal transition from aquatic to terrestrial environments. This predictability of the river hydrology has resulted in a good understanding of the natural equilibrium that is manifest throughout the 90years of sampling data. The baseline assessment uses this understanding of the Mekong hydrological regime and key aspects of the hydrograph as the platform against which future developments are assessed.

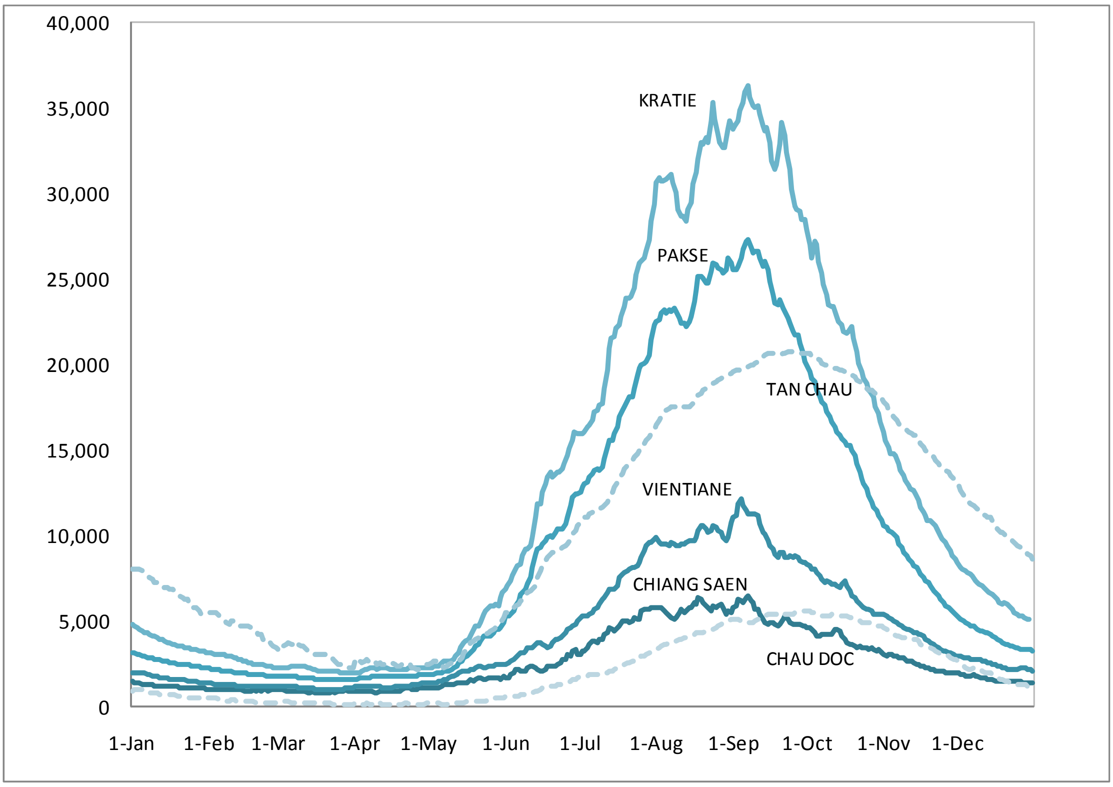
Figure 1: The hydro-ecological zones of the Mekong Basin



4.2.2 HYDROLOGICAL ISSUES

1. The Mekong hydrograph
2. Flow variation
3. Timing & duration of the hydro-biological seasons
4. Flow provenance
5. Tonle Sap flow reversal
6. Flooding in the Tonle Sap

Figure 2: Average daily flow hydrographs for the Mekong River for the MRC Baseline (1986 – 2000) (Tan Chau and Chau Doc are represented by dashed lines)



4.2.3 INFORMATION SOURCES & UNCERTAINTIES

In the Lower Mekong Basin, there is in general a good hydrological information base spanning 90years. Some tributaries remain ungauged, especially in Cambodia. Further, some information gaps exist in the delta relating to the management strategy for irrigation works. The biggest information gap concerns the Upper Mekong Basin, given the importance and interest with the Yunnan flow component any future diplomatic efforts to improve information sharing between the UMB and the LMB would be beneficial, especially regarding:

i. Operational strategies of individual projects in the Yunnan cascade & the cascade itself

ii. Flow and water level records from a number of mainstream stations spanning the last 40-50yrs
iii. Changes to land cover of the Lancang Catchment (for example the current "Green for Grain' soil conservation plan).
iv. There are significant differences between the predicted hydrological impacts of the Yunnan cascade between Chinese and LMB modelling

4.2.4 DRIVERS OF CHANGE IN THE MEKONG HYDROLOGY & SEDIMENT

Given the stability of the natural hydrological regime, change over short (human) time scales will arise from human activity in the basin. Therefore the proposed LMB mainstream hydropower projects must be considered in the development context into which they may enter. 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. These three areas are briefly summarized below:

1. **Water Availability:** human activity can affect the availability of water by: (i) altering the rainfall-run off relationship through land clearing and deforestation which has resulted in an average 15-20% reduction in forest cover since the 1960s (MRC, 2007), or (ii) by changing the timing and duration of precipitation events through long-term climate change (to be dealt with in a separate paper).

2. **Water consumption:** water consumption can be increased by: (i) increased irrigation and mainstream off-takes, for example, there have been previous plans for large-scale inter-basin transfer from the Lancang River and 'mega-irrigation' projects in Northeast Thailand, (ii) domestic consumption, and (iii) increased evaporation from agricultural or hydropower storage.

   i. *Mainstream irrigation:* under the BDP Definite Future (DF) scenario the area irrigated by the Mekong will reach 6.8 million hectares, which represents a marginal 3% increase from the baseline.

   ii. *Domestic water supply:* under the BDP DF the volume of water abstracted for domestic and industrial supply will increase from 1.78km^3 to 2.83 km^3 (59% increase), or 0.6% of the mean annual flow in the Mekong River.

   iii. *Increased evaporation:* under the DF the total mean surface area of the proposed hydropower projects will increase from 928km^2 to 1,688km^2, while the Tonle Sap Lake surface area will decrease in the order of 500k m^2 (see discussion below) which represents a nett 30-40% increase in evaporation volumes.

3. ***Water storage:*** Water storage can be natural or human induced. Surface storage is typically seasonal receiving water in the wet season and releasing back into the Mekong during the dry season. Subsurface storage can be both seasonal and nett.

   i. *Natural storage:* The majority of the natural storage results from infiltration of rainfall into the soil horizon and groundwater aquifers. Using a basin-wide mean precipitation of 1.5m/yr, a basin area of 795,000km^2 and a historic mean annual runoff of 512km^3 (MRC, 2005; Eastham et al, 2006), subsurface infiltration in the order of 1million km^3 of water infiltrates the ground surface. Looking specifically at the LMB the major groundwater aquifers are:

The Mekong River has a relatively low capacity for natural surface storage, with major storage components comprising the floodplains and Tonle Sap system (max 6-12million ha) (Hall et al, 2005). These areas provide seasonal storage holding wet season flows for release in the dry season.

ii. *Human induced storage:* Under the BDP DF the number of tributary dams will increase from 16 to 46 which corresponds to a 450% increase in active storage capacity (9.9 – 44.4km³) or a capacity to store 10% of the Mekong's mean annual flow by 2015.[5] By number almost half (20) of these projects are in Lao PDR, with 13 in the Central highlands of Vietnam, however, the 6 projects in China (known as the Yunnan cascade) collectively account for 23.7km³ of this storage (53%). Further, the Xiowan (active storage 9.9km³) and Nuo Zhadu (active storage 12.3 km³) projects each represent ~22-28% of the total storage projected for 2015 (table 3). This represents the first time when a single human activity will have the capacity to alter the hydrological regime of the entire Mekong Basin.

4.2.5 FLOW VARIATION – PAST TRENDS & CURRENT SITUATION

The LMB hydrological regime is comparatively homogenous upstream of Kratie, with comparable timing and duration of seasons in most LMB mainstream stations (see figure 2) MRC (2006). This homogeneity is driven by two main components: (i) the Southwest Monsoon which dominates the rainfall-runoff relationship in the LMB and occurs with small temporal variability (see above), and (ii) the Yunnnan flow component which is an important contribution to maintaining dry season flows through snow and glacial melt in the upper catchment. The key features of the hydrograph are:

- **Large seasonal variation in the flow regime**: reflecting the dominance of the Monsoon and typhoon events in the wet season, flow volumes peak in September approximately 4-6weeks after the peak in run-off. This results in minimum dry season flows of on average 7% of the maximum wet season flows with the seasonal variation reducing with distance downstream (Chiang Saen sees an average maximum variation of 12% with 5-6% at both Pakse and Kratie).
- **Predictable flood peak:** A flood peak which occurs with predictable regularity and is often preceded by a smaller lead peak at the beginning of the flood season. On average, the flood season at all stations between Chiang Saen and Kratie begin on the 1st of July and lasting until 4-11th of November, with a standard deviation of 2weeks (Adamson, 2005)
- **High variability at the onset of the flood season:** Comparably high variability in flow during the transition season as the first rainfall events induce a series of *spates* into the hydrograph which play an import ecological role in triggering response in biota.

Downstream of Kratie the Mekong system shifts to a complex floodplain environment and there is significant variation in the hydrograph form compared to upstream. 83% of the Mekong flooded area is located in Cambodia and Vietnam, these areas are important for regional biodiversity, as well as national

[5] *There are in total 92 hydropower dams planned for the Mekong River, if all these went ahead basin storage could increase to a potential 91.4km³ representing ~20% of the mean annual flow in the Mekong River (Kummu et al, in publication).*

agriculture and fisheries production. While, approximately 750,000ha lie along the Mekong channel in Lao and Thailand, of which 64 – 69% flood to depths greater than 3.0m. Key features of the floodplain include:

- **Reduction in the flood peak discharge:** flows become less constrained to the Mekong channel and spreads out over the flood plain with a corresponding reduction in flow and water level in the channel.
- **Lag in flood recession:** Hydrology is driven by water levels in the flood plain rather than channel flow, with the recession of overbank floodwaters and storage of floodwaters in the Tonle Sap lake prolonging the flood season into January/February. Overland flow accounts for approximately 30% of the flood flow into the Mekong Delta (SIWRP, 2006).
- **Higher daily variation in flows:** the complex hydrodynamics of receding floodwaters, reverse flow in the Tonle Sap and overland flow can cause greater fluctuation in water levels at a daily and weekly time-step (see for example average daily water levels for Chau Doc).
- **Cyclical variation in flood volumes:** Flooding is a regular occurrence south of Kratie and shows some variation in annual peak levels. Taking Tan Chau as an example, high flood water levels (>4.2m) have been exceeded 24times between 1929 – 2005 which represents an average exceedance of once every three years. Therefore, high flood levels are a frequent occurrence of the natural system. Flood related disasters do occur in the delta but are aligned with extreme events such as typhoons, severe storms.
- **Flooded depth:** The majority of Cambodian flooded areas reach depths of more than 3m during the flood season and upwards of 7m in the Tonle Sap Lake and Kratie, while Vietnamese areas reach depths of 0.5 – 3.0m.

4.2.6 TIMING AND DURATION OF THE HYDRO-BIOGICAL SEASONS – PAST TRENDS & CURRENT SITUATION

The LMB experiences four identifiable seasons which occur with regularity:

- The low flow season begins at the end of the calendar year and extends through to mid/late May. Flow is maintained by snow melt in the Mekong headwaters and the minimal natural storage of the basin in the soil horizon, groundwater and wetlands.

- The transition to flood season is characterized by the first *spates* of the Monsoon season with an increase in both flow rate and flow variability. The transition season ends in mid July

- The flood season begins when flows exceed the long term average and is characterized by the flood peak in September and sometimes a smaller leading peak. The season finishes in early to mid-November when flow drops below the long term annual average.

4.2.7 FLOW PROVENANCE – PAST TRENDS & CURRENT SITUATION

Approximately 59% of the average annual flow originates from the left bank tributaries in Lao PDR, Cambodia and Vietnam, with 24% of the total originating between Pakse and Kratie (Z4), and 22% entering between Nong Khai and Mukdahan (Z3) (figure 3). The UMB (Z1) contributes 16% to the average annual flow, while the combined contribution from the right-bank tributaries (North and Northeast Thailand and the Tonle Sap tributaries) accounts for ~25%. During the wet season flow provenance is dominated by northern Lao PDR, the central highlands and the central region of Lao PDR in direct response to the Southwest Monsoon. Precipitation peaks in august at ~500mm for the latter two areas (figure 4). During the dry season there is minimal precipitation in the LMB, while snow and glacial melt in the Lancang River mean that this zone dominates the dry season flow contributing up to 40% of the seasonal total at Kratie. The LMB tributaries are the main drivers of the peak in the flood pulse, while the Lancang River supplemented by catchment storage is critical in maintaining dry season flows.

Figure 3: Tributary contribution to Mekong annual flow (ADB, 1999)

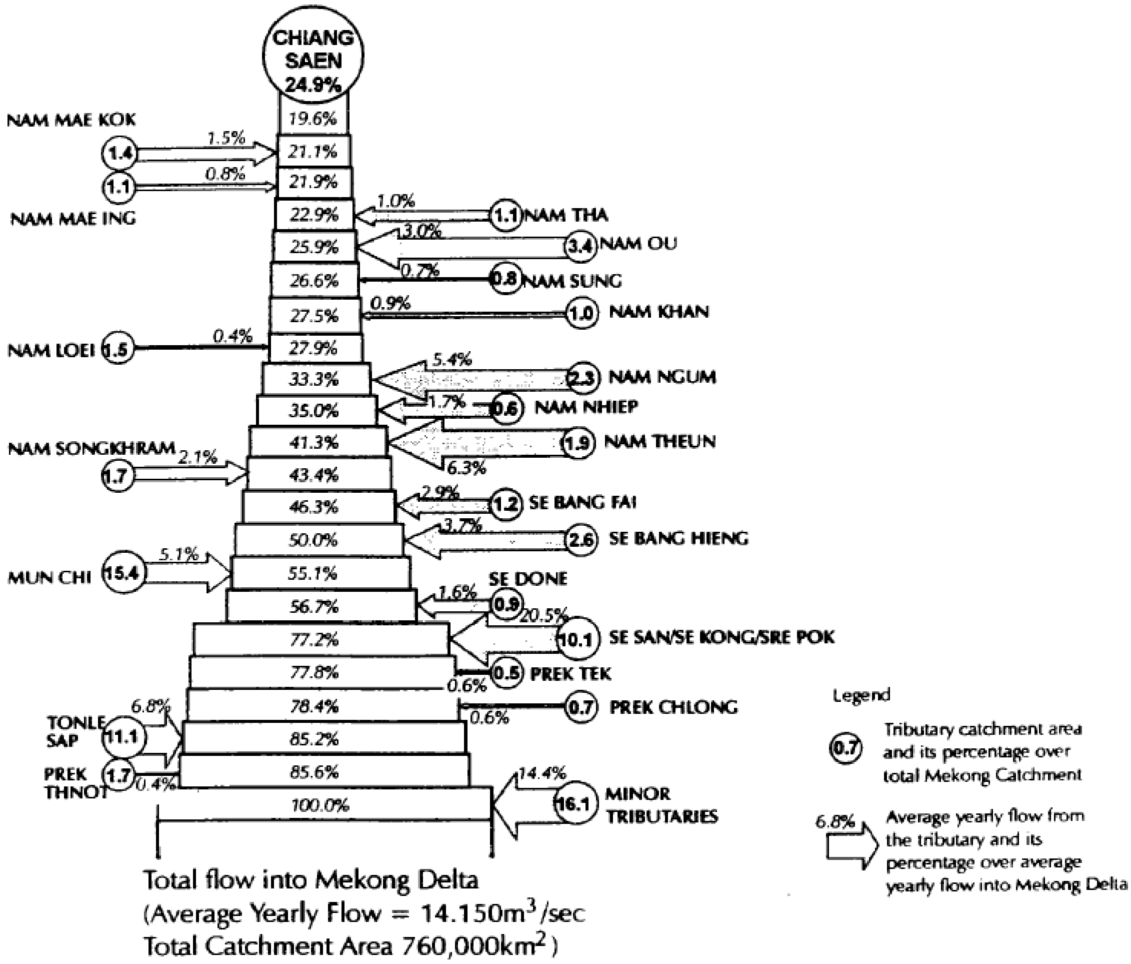
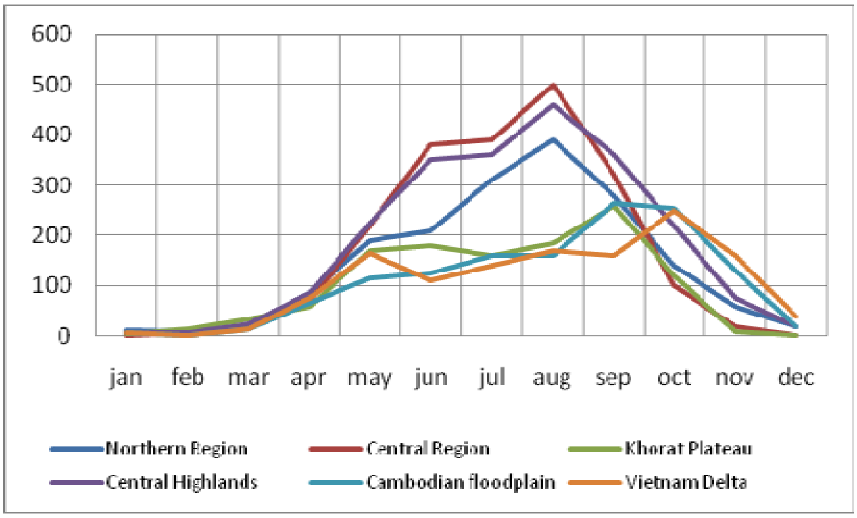


Figure 4: Mean monthly rainfall (mm) for key zones of the LMB (source: MRC, 2005)



4.2.8 TONLE SAP FLOW REVERSAL– PAST TRENDS & CURRENT SITUATION

Tonle Sap River is ~110km long with a low channel slope and an extensive floodplain (Figure 5). The low channel slope and the high variation of flow in the Mekong River induce a seasonal change in the direction of flow in the Tonle Sap River. The reversal of flow produces two distinct seasons based on the direction of flow in the Tonle Sap River. Water flows with the channel slope during the dry season and reverses direction during the wet.

- **Wet season (May – September):** water levels in the Mekong rise in response to the SW Monsoon reaching ~9m at PP and ~8m at PD, with Qin(max) ~10,000cumecs in late august = 25% of Mekong discharge at this time of the year (MRC, 2007). The elevated water levels reverses flow up the Tonle Sap River into the lake and peak inflows are reached typically three months after flow reversal. On average 45km3 flows into the Tonle Sap lake via the River and overland flow across the floodplain, representing 57% of the total lake inflows (tributaries contribute ~30% and direct precipitation the remainder) and 25% of the august flows in the Mekong(MRC, 2006).

- **Dry season (Oct/Nov – April/May):** water levels in the lake are at their highest (6-9m) and, as the Mekong floodwaters begins to recede, the hydraulic gradient reverses direction and flow resumes the natural direction reaching a flow of 10,000cumecs in just a few weeks (MRC, 2007). Peak inflow is reached 3months after the reversal in flow/start of the wet season, but return flow to the Mekong rises much faster taking just weeks to reach the same rates (i.e. four times faster). . Approximately 70km3 is conveyed back to the Mekong from the Tonle Sap Lake, which represents ~87% of the total lake outflow (the other major component is evaporation) (MRC, 2006).

Figure 5: Dry and wet season open water area of the Tonle Sap Lake (MRC, 2006)

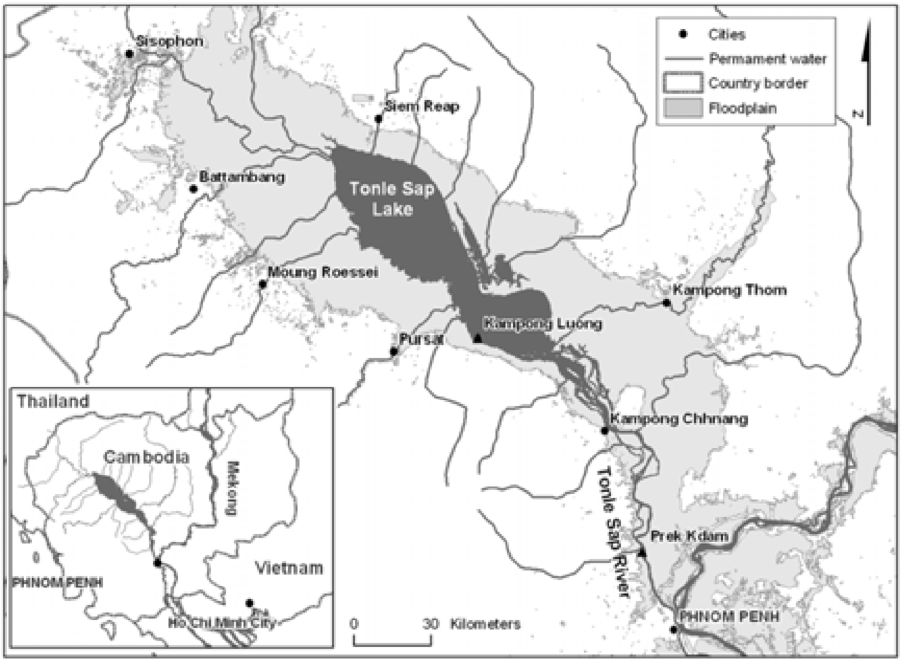


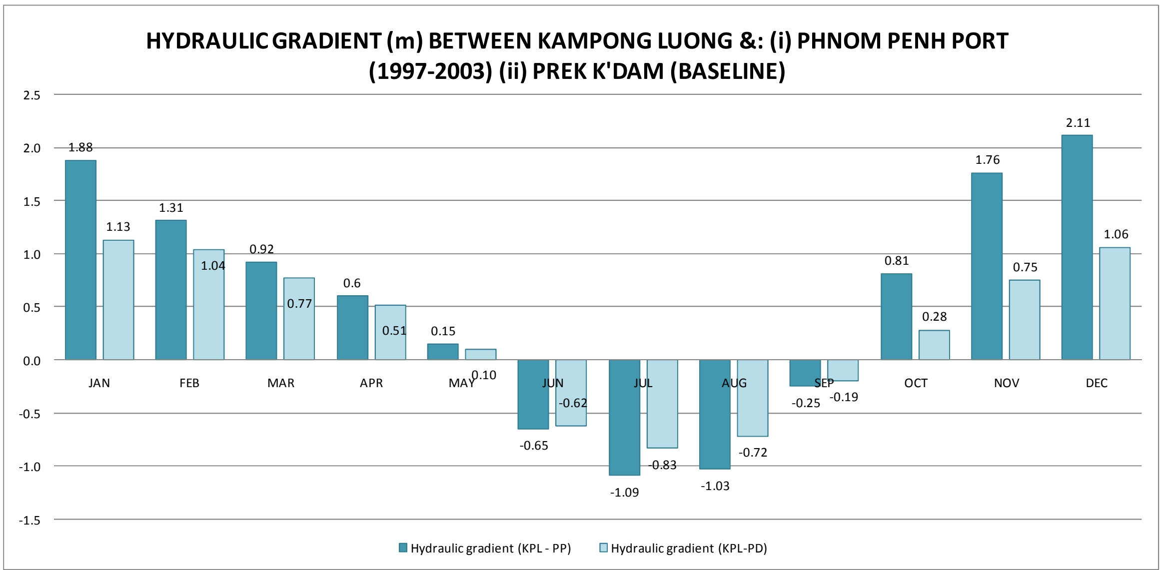
Table 1 Inter-annual variation in Tonle Sap in and out flows (1997 -2003) (based on: MRC, 2006)

	Dry Year (1998)		Average (1997-2003)	Wet Year (2000)	
	[km3]	% decrease	[km3]	[km3]	% increase
Inflow*	44.1	- 44%	79	106.5	+35%
Outflow*	43.5	- 45%	78.6	104.8	+ 33%

*Note: inflows and outflows quoted in this table relate to the total water balance of Tonle Sap Lake, including: Mekong flows, evaporation, tributary flows, & direct precipitation

Each year at the advent of the dry wet season (May) there is a reversal in the direction of flow of the Tonle Sap River for a period of 4-5months (figure 6). This flow reversal is driven by a maximum hydraulic gradient of 1.0 – 1.25m and results in the storage of 45km3 of wet season flows which are then returned to the Mekong system during the dry season. There is evidence that this magnitude of hydraulic gradient has existed since records began, and the Tonle Sap dry season contribution accounts for almost 50%% of the combined dry season flow at Tan Chau and Chau Doc with the peak contribution arriving in the dry months of December/January.

Figure 6: Comparison of the current hydraulic gradient between Phnom Penh and the Tonle Sap Lake (dark blue) and Tonle Sap River and Lake (light blue).



The gradient is greater at Phnom Penh because water levels there are directly connected to the Mekong mainstream, while Prek K'dam on the Mekong River is lies on the Tonle Sap River channel. The difference is greatest during the beginning of the dry season as water levels in the Mekong channel recede quicker than those in the smaller Tonle Sap channel.

4.2.9 FLOODING IN THE TONLE SAP – PAST TRENDS & CURRENT SITUATION

Flooding in the Mekong River and the Cambodian floodplain is the main driver behind the seasonal expansion of the Tonle Sap Lake, contributing almost 60% of the Lake's flooded volume. The total influx of floodwaters results in an average7.77m increase of lake water levels. During this time the area of the lake expands by 7,500 – 13,000km2 (average of ~11,000km2), flooding large areas of forest and expanding the highly productive littoral zone of the lake. This represents an ~ 10,000km2 fluctuation in lake surface area, with the biggest expanses of flooded area situated in the western shoreline of the dry lake bed and north of Kampong Chnhnang. Recession of the lake during the dry season also exposed a complex system of anabranching channels near Chnoc Trou and Lake Chma which currently make navigation difficult and also provide fertile seasonal habitats.

4.3 SEDIMENT

4.3.1 THEMATIC CONTEXT

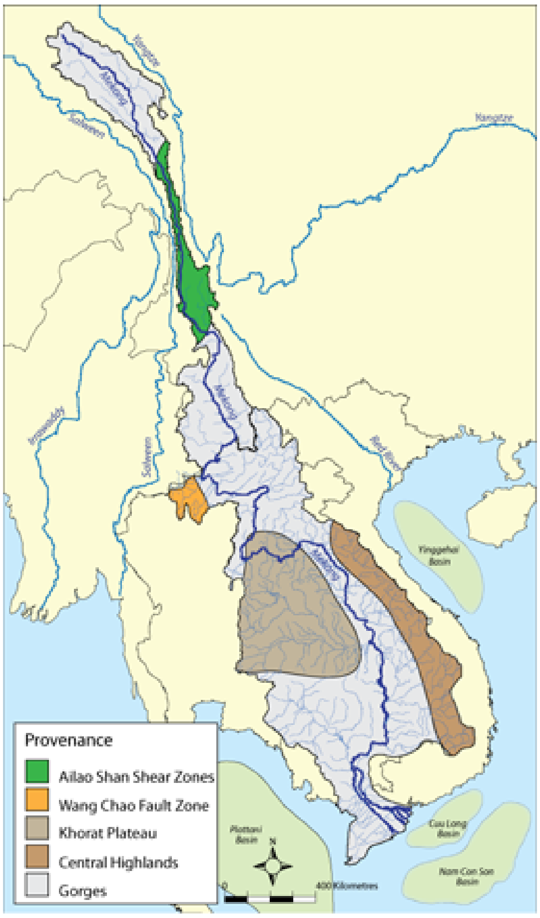
The underlying geology of the Mekong is heterogeneous and active, consequently different areas of the basin were formed by different tectonic shift millions of years apart (MRC, unpublished). This has resulted in differing sediment yields for different areas of the basin. There are five main geologic zones in the Mekong Basin: (i) Tibetan gorges, (ii) Ailao Shear Zones, (iii) Wang Chao fault zones, (iv) Khorat Plateau, (v) Central Highlands (figure 7). According to marine sedimentary deposits the Ailao Shear Zones and the

Central Highlands have dominated sediment provenance in the Mekong Basin for the past 8,000years (Clift et al, 2004).

4.3.2 SEDIMENT ISSUES

1. Sediment provenance
2. The Mekong Sediment Load
3. Sediment transport capacity
4. Bed load dynamics
5. Deep pools
6. Bed and bank erosion
7. Floodplain nutrients & sediment dynamics
8. Tonle Sap sediment dynamics
9. The Mekong Delta & marine sediment dynamics

Figure 7: Sources of sediment provenance in the Mekong Basin



Source: adapted from MRC, un published

The UMB and the central highlands dominate current sediment supply to the Mekong system

4.3.3 INFORMATION SOURCES & UNCERTAINTIES

Considerable scepticism surrounds the existing sediment data, which has been collected with inconsistent methods, measuring different parameters (SSC, and TSS) and has often yielded widely divergent estimates (see for example, Walling, 2006; Adamson, 2009b; Carling, 2009; Wang et al, 2009; Walling, 2009). Of the two data sets Suspended Sediment Concentrations are the most useful for estimating sediment loads in the Mekong, but the timing of samples has been erratic and utilised different methods (Walling, 2006). The sampling strategy of Total Suspended Solids is more consistent but samples are only taken monthly, which is not sufficient to pick up the high variability of sediment loads in the Mekong. Also, TSS is an inappropriate indicator of sediment load especially when there is more than 25% of sand size materials (USGS, 2000). Given these issues, SSC concentrations should be interpreted as having large error bars – in the order of 20-30%.

4.3.4 DRIVERS OF CHANGE IN THE MEKONG SEDIMENT

The same three drivers of change as identified in section 1.4 are relevant for Mekong Sediment. In addition, the temporal range over which data is analysed will impact on the estimate for sediment load. The main drivers and timing of variability in sediment load are summarised below for the Lancang catchment:

- **1960 – 1990 (Land clearing):** Period of population growth, intensification of land clearing, deforestation and agricultural expansion (Wang et al, 2009; Walling, 2009; MRC, 2007).
- **1990 – 2000 (hydropower development):** introduction of mainstream hydropower on the Lancang River with the construction and operation of the Manwan dam.
- **2000 – present (hydropower escalation & soil conservation):** intensification of mainstream hydropower with the addition of a second project (Daoshachsan) and the introduction of soil conservation strategies for the Lancang Catchment under the Chinese governments “Green for Grain” program (Walling, 2009)

Land clearing increases sediment yields, while soil conservation programs have been effective in many large river basins for reducing erosion and sediment yields (Walling, 2008). Hydropower typically increases sediment yields during the construction phase but then become sites of storage over their operational life. Depending on dam dimensions, the effectiveness and coordination of sediment release strategies Yunnan dams could inject spikes in sediment load during maintenance of reservoir areas.

For the LMB, the historic drivers are land clearing – particularly in Thailand (see Table 1). However, the lower population levels and development in the basin has resulted in a lower level of impact from land clearing in the LMB compared to the UMB. From a strategic point of view – the past drivers of change are centered on the UMB. Looking forward to 2015 hydropower will become the dominant driver changing sediment supply throughout the basin.

4.3.5 THE MEKONG SEDIMENT LOAD – PAST AND CURRENT TRENDS

The total Mekong sediment load displays a wide range of inter-annual variability (Walling, 2009). During wet years the LMB tributaries contribute a greater proportion of the annual load, while in dry years the dominance of the Yunnan component is increased (Sarkkula et al, 2010). On average, the annual sediment load is approximately 160Mt/yr (140 -180 Mt/yr), with approximately 50-60% originating from China. Land clearing, hydropower and soil conservation strategies have influenced the annual average sediment loads – especially in the Lancang catchment where the average load has increased to ~120Mt/yr when land clearing peaked(mid to late 80s) and reduced to ~65Mt/yr after the two existing mainstream projects came on line. The increasing sediment load witnessed during the period of land clearing and agricultural intensification in the Lancang catchment has been offset by the reductions in the sediment load caused by the two existing Yunnan dams, such that the post-2000 average is comparable to the mid-1960s average. However, in order to align the SEA with the BDP Scenarios, which do not include Manwan and Dachshaoshan in the BDP Baseline, the current sediment load from UMB is taken as 85Mt/yr.

The 'Three S' catchments in Zone 4 contribute ~ 17Mt/yr equivalent to ~10% of the total load, while the remainder of the basin is estimated to contribute 30% (Sarkkula et al, 2010). The majority of the contribution from the rest of the basin originates in the left-bank tributaries of Lao PDR – in particular from those in the southern portion of Zone 3 which drains part of the central highlands geologic complex.

4.3.6 SEDIMENT TRANSPORT CAPACITY

Sediment transport capacity is the ability of the river to move sediments from the zone of production to zone of deposition. There are two dynamic mechanisms driving sediment transport, depending on the grain size of the sediment load (Bagnold, 1979). Upward and turbulent dispersive forces are capable of keeping smaller particles in suspension allowing downstream transport in the water column, while heavier sediments rely on *saltation* to move in successive 'jumps' along the channel bed. Both transport mechanisms rely on the flow, channel slope, channel dimensions. The relevant drivers of change for transport capacity include:

- Channel discharge:
- water levels
- Channel dimensions (channel width, channel slope)
- Sediment size and load

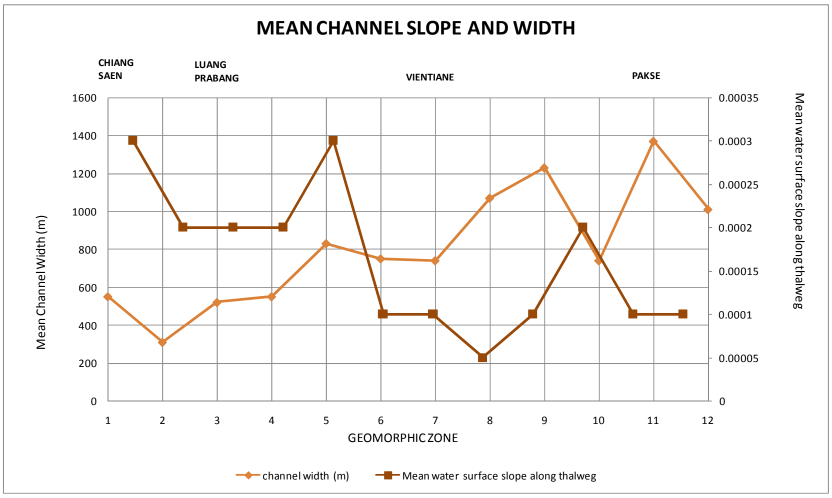
Sediment storage

The existing annual deposition-resuspension cycle is driven by the monsoon flood hydrograph and considered to be largely in balance. Important sites of natural storage are:

- **In-channel storage:** Significant proportion of LMB south of Vientiane is alluvial with a wide, near-straight channel, several hundred deep pools and extensive in-channel features interspersed with bedrock outcropping. Carling (2009) provides a very rough estimate of 14,200MCM for in-channel storage south of Vientiane, based on a lens of sediment 5-15m deep. This storage is predicted to have remained constant over the last hundred years.

  The largest reduction in channel gradient occurs in the transition from bedrock to alluvial channel ~ 40-60km north of Vientiane (see Figure 8). In this reach, the channel gradient drops by 67% and the river morphology transitions to alluvial with infrequent bed rock outcrops and large alluvial vegetated island as well as smaller sand bars and inchannel islands comprised mainly of sands and gravel (Conlan, 2008). Sediment data indicates that Chiang Saen to Nong Khai (particularly Luang Prabang to Nong Khai) has become an important zone of sediment deposition (Walling, 2009). Given that this reach has negligible floodplain area, deposition is likely to be predominantly in-channel.

Figure 8: Chiang Saen - Khone Falls: Mean channel width (m) and water surface slope along thalweg (adapted from: Conlan, 2008)



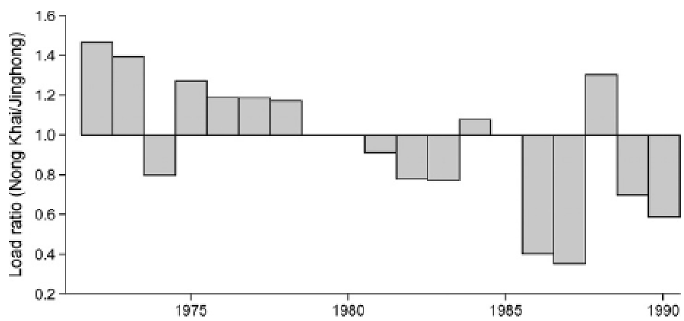
A GIS assessment of the Mekong River channel using the MRC hydrographic atlas estimated that the wet season channel in Z2 occupied ~ 460km2 dropping to 240km2 during the dry season representing a difference of 220km2 (see aquatics paper). Approximately 66km2 or 30% of this difference has been identified as sand bars or visible sediment deposits. Geomorphology work undertaken for the MRC IBFM work (2007) observed sand bars of 5-10m above bed level and siltation benches of up to 25m, assuming ~30% of Zone 2 exposed wet season channel is used for seasonal storage, then between 0.33 – 2km3 of sediment is currently stored in the Zone 2 river channel representing about 1-2% of the total sediment load for the Mekong Basin (160Mt/yr).

Sediment data indicates that Chiang Saen to Nong Khai (particularly Luang Prabang to Nong Khai) has become an important zone of sediment deposition. Walling (2009) illustrates that since the 1980s there has been a lower sediment load at Nong Khai than at Jinghong (see Figure 9). This is confirmed by Wang (2009) for Chiang Saen to Nong Khai (Figure 10). Given that this reach has negligible floodplain area, deposition is likely to be predominantly in-channel. Before 1980 the sediment load at Jinghong was consistently higher than at Nong Khai, which would suggest that deposition in Zone 2 is a new phenomena perhaps caused by changes to the sediment load at Nong Khai.

- **Floodplain storage:** the floodplains of Cambodian floodplains are likely to store 15-25% of the sediment load at Kratie. Estimating the Kratie sediment load at 160Mt/yr, this could range between 12-40Mt/yr, of which approximately 30% enters the Tonle Sap system. Estimates of storage in the delta are difficult to predict because of the intensive control of the hydrological regime with irrigation canals and sluices. No sediment depth profiles are available to indicate the total volume of sediment stored within the floodplain.

- **Delta building:** Lastly a significant but unmeasured proportion of Mekong sediments discharge into the South China Sea, where tides migrate sediments south along the Ca Mau peninsula until competing tides in the Gulf of Thailand and the South China Sea induce deposition on the coast line of the peninsula particular on the western face (discussed in further detail below). No solid estimates are available but delta building is likely to have maximums in the order of meters for some areas. There are also sections of the delta's eastern coastline which are subject to erosion

Figure 9: Ratio of Average Annual SL at Nong Khai over Jinghong for 1972-1990



(Source: Walling, 2009)

Deposition is likely to occur when the load ratio is less than 1. This has been a regular occurrence since 1980.

All periods show a decrease in sediment load between Luang Prabang and Nong Khai contrary to the increased discharge and Basin area. Wang et al (2009) interpret this by identifying the Luang Prabang – Nong Khai reach as an important zone of sediment deposition

The sediment transport capacity of the Mekong River has remained constant over the history of monitoring based on the stability of the annual hydrograph. The sediment load of the Mekong shows large inter-annual variability, but there is a long term trend of sediment deposition in the Cambodian floodplain and the Mekong Delta, and a more recent (post-1980) trend of sediment deposition between Jinghong and Nong Khai. Excluding the Mekong delta, because of insufficient information, annual sediment storage in the Mekong Basin is currently concentrated in Z5 with maximum total annual storage likely to be in the range of 25 -40Mt.

4.3.7 BEDLOAD DYNAMICS

There is very limited information available on bed load and bed material, concentrations and transport in the Mekong River (Kummu, in publication; Carling, 2009). Typically bed load accounts for less than 10% of the sediment load in major rivers. Below is a summary of current estimates in the literature.

Bedload is an important but poorly understood component of the sediment dynamics of the LMB, in particular for the meandering bedrock reaches north of Nong Khai. This area is likely to be the main zone of bedload deposition, with sands and gravels accumulating in sand bars, in-channel islands, and siltation banks in the up and downstream vicinity of channel constrictions or at bends in the river planform. It is difficult to estimate the proportion of bed material in the sediment load. Most bedload in Zone 2 is likely to be stored in the river channel, with current sand bar storage approximated as ~30% of the exposed wet season channel area with a further component of bedload likely to be stored in the channel bed, especially at tributary confluences. The movement of bed load is likely to be in the order of ~10km per year (or one pool crossing) hampered by the presence of deep pools which accumulate material during the onset of the flood season before the high flows of the flood peak pass the material into the downstream storage areas.

Figure 10: Comparison of sediment load and discharge in the Mekong Basin

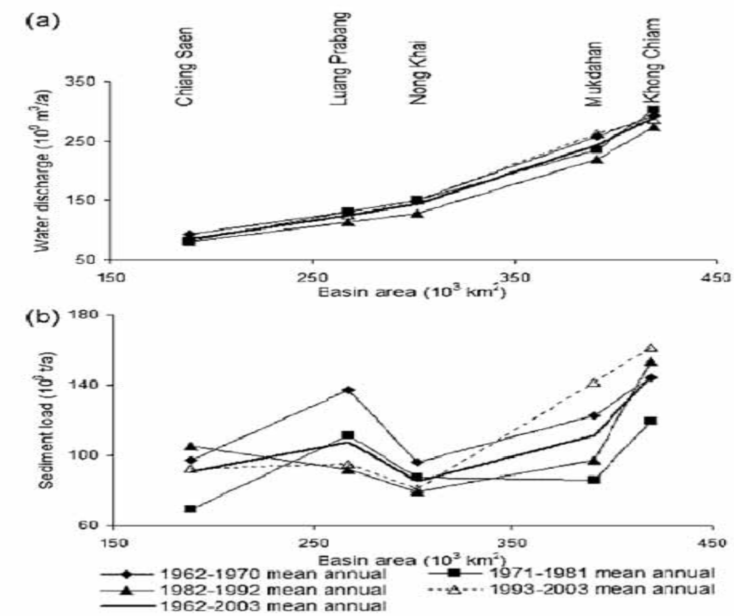


Figure 8. Variations of the (a) water discharge and (b) sediment load along the Lower Mekong River. The five stations are Chiang Saen, Luang Prabang, Nong Khai, Mukdahan and Khong Chiam from left to right. Note that the solid and empty symbols represent the pre-dam and post-dam periods, respectively

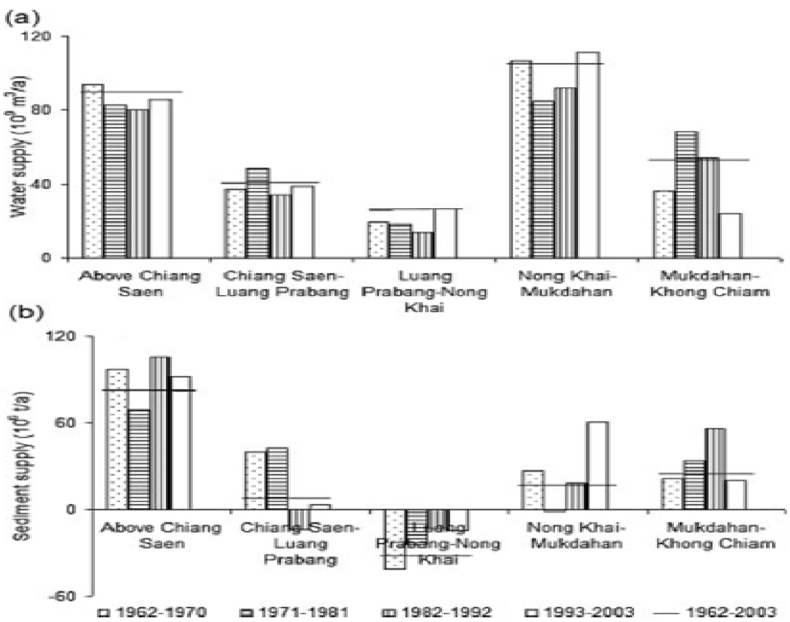


Figure 9. The water and sediment supplies of the Mekong River sections during the entire period of 1962–2003 and the four sub-periods

Source: Wang et al, 2009

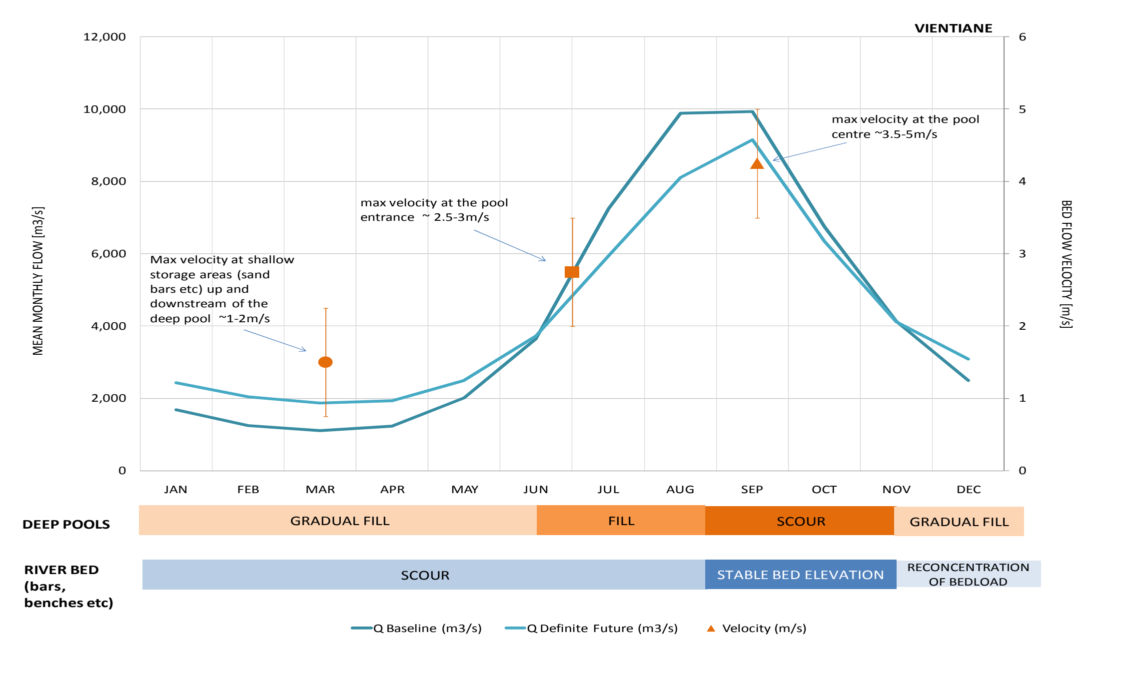
4.3.8 DEEP POOLS

There are at least 335 deep pools along the thalweg of the Mekong mainstream. These pools are dynamic features of the river channel consolidating sediment movement into a pulse-like wave which transports sediment between adjacent zones of sediment storage over the monsoon flood cycle. The deep pools play an important role in regulating the downstream progression of sediment and building in-channel features such as islands and sand bars, which are important for the river's biodiversity. No information is available on the past trends in either the location or number of deep pools.

Figure 11 below summarises the main phases in the migration of a sediment wave through a bedrock confined pool from Conlan (2008). The graph overlays the mean monthly flow at Vientiane for the baseline (current) and Definite Future (2015) conditions, with the estimated maximum velocities at the pool entrance, pool centre and pool exit. During the dry season velocity is greatest in the river bed (Conlan refers to these as 'crossings'), which results in the gradual scour of these areas and gradual infilling of deep pools. Then during the onset of the flood season, velocities peak at the entrance to the deep pool initiating a ~2month period of rapid pool infilling. At the peak of the flood season, the river bed maintains a stable elevation as the flows peak in the pool centre translating the sediment wave through the deep pool. By the end of the flood season the sediment wave has passed through the pool and begins to break up and deposit on the 'crossing' downstream. Then during the dry season the bed load in the crossing reconcentrates, consolidating into in-channel formations such as sand bars and siltation benches.

The translation for the sediment wave from crossing – deep pool – crossing (~10km) typically takes a full monsoon flood cycle (Conlan, 2008). This has important implications for the fate of sediment in the Mekong system. Suspended sediments are likely to move approximately at the same velocity as the flow as they remain entrained during the rising limb of the flood peak and reach downstream deposition sites in Zone 3-6. However, sediment moving close to the channel bottom tends to aggregate in a wave which moves under saltation and travels in the order of one pool crossing (~10km) per year. This means that though the pools are not sites of storage themselves, they act as buffers in the system regulating the downstream transport of coarser sediments and bedload, which produces the complex of in-channel features, which are themselves important habitats contributing to the productivity of the Mekong system. This is in agreement with Conlan's (2008) conclusion that deep pools do not store sediments during the dry season, rather, they act as conduits for sediment transport between storage zones ("crossings") and for the conveyance of wet season sediment loads.

Figure 11: Timing of the sediment wave translation through Deep pools of Z2.



Source: adapted from; Conlan, 2008 & BDP modeling results

4.3.9 BED AND BANK EROSION

From Kummu's (2007) study the following past trends include:

- Since 1992, erosion has increased on the left bank, while accretion has increased on the right bank. This is part of the natural balance between erosion and deposition
- Both erosion and deposition have increased for in-channel islands, suggesting the rate of migration of channel islands may have increased since 1992.
- The banks of channel islands are more unstable than the river bank (Kummu et al, 2007). Therefore any changes to channel morphology due to increased erosion and accretion is likely to be experienced first by the channel islands.

4.3.10 FLOODPLAIN NUTRIENTS AND SEDIMENT DYNAMICS

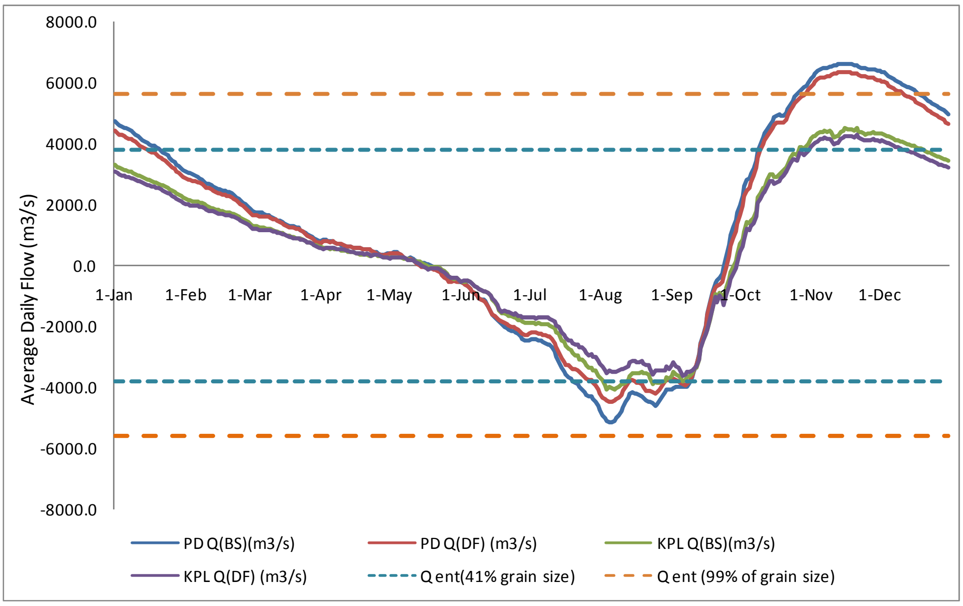
- **Cambodian flood plain:** Sarkkula (2010) provide a summary of the fate of nutrients in the Mekong system. The high productivity of the Mekong floodplains is based on the load of cohesive sediments from upstream areas and on the nutrient loading associated with the sediment flux. Phosphorous is often the limiting nutrient and is locked into the geology of the upland areas until run-off and erosional processes transport it to the zones of deposition where conditions are favourable for deposition. Detailed studies of phosphorous in the Cambodian floodplain indicate that 31-42% of the bioavailable Phosphorous is transported into the floodplain with the sediment influx (Sarkkula et al, 2010). This equates to 21,500t/yr of bioavailable P, which is capable of fertilising 5,400-16,500km2 of rice paddy area (Sarkkula et al, 2010).

- **The Tonle Sap Lake:** The previous section demonstrated that sediment deposition in the Tonle Sap Lake is concentrated around Lake Chma, the braided Tonle Sap river channel north of Kampong Chnhang and the broad floodplains on the western extent of the lake's floodplain. During the flood season these are the shallowest areas of the lake and therefore encourage sediment deposition,

4.3.11 TONLE SAP SEDIMENTATION

Historic sediment balances for the Tonle Sap indicate that the lake is a net importer of sediment from the Mekong with 4.5-6million tons of washload entering the Tonle Sap, and 3 – 6.7 million tones exiting per year. Though the sediment yields and loads in the Mekong River are not likely to have changed significantly between the 1950s and the present, there is some question whether the sediment storage capacity of the Tonle Sap has decreased. One study in particular hypothesizes that the northern extent of the Tonle Sap is reaching storage capacity which is slowing down the deposition rate, other studies indicate that sediment deposition remains at 80% of inflow yields with the TSL storing 4-7% of the Mekong sediment load at Kratie (MRC, unpublished 2; Kummu et al, 2008b).

Figure 12: Exceedance of the entrainment flow for coarse sands and fine gravels at Prek K'dam and Kampong Luong.



The window for sediment efflux from the TSL is on average mid-October to mid-January, with larger material capable of being transported from late October to mid December, and a one month smaller window at the Lake than in the Tonle Sap River. The window for sediment influx entering the TSL is currently mid July to early September, and larger materials are not likely to currently enter the system. This indicates that the complex hydrodynamics of the TSL system and flow reversal act as a 'sieve' preferentially passing smaller sized sediments into the Tonle Sap and accumulating at a rate of ~0.2mm/yr over the entire inundation plain of the TSL. However, the comparatively lower flows at Kampong Luong suggest that transport capacity is not uniform throughout the system with preferential zones of deposition at Lake Chma, the 'delta' north of Kampong Chnhnang and the western shore line of the dry season lake area and amongst the lowest sedimentation rates in the dry season lake bed.

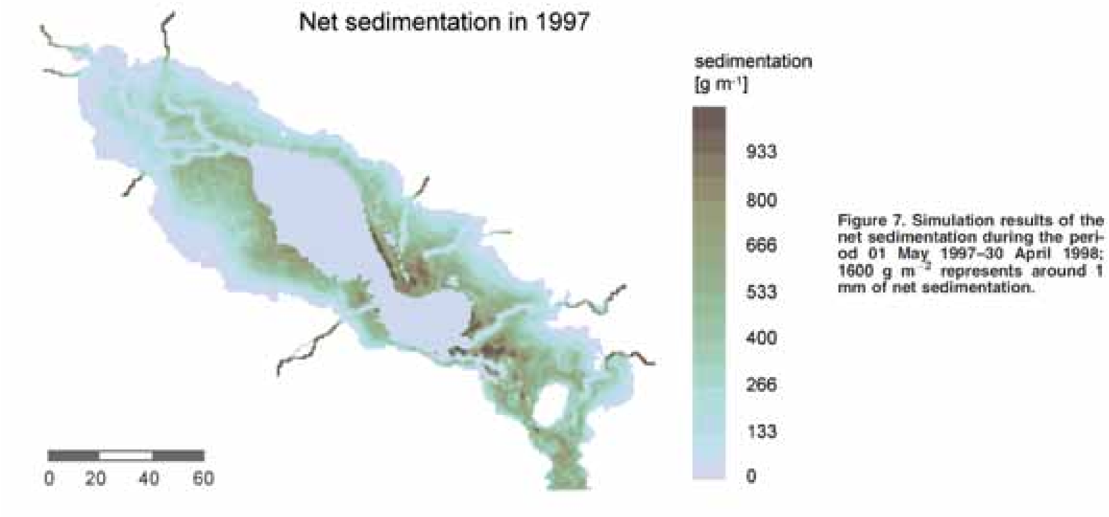
Max sedimentation rates (up to ~0.5mm/yr) were observed at the extremity of the dry season lake area, particularly in Lake Chma, the braided reach north of kampong Chnhang and on the Western edge. Mekong River sediments are an important contribution to all three of these zones, particularly Lake Chma and Kampong Chnhnang.

4.3.12 THE MEKONG DELTA MARINE AND SEDIMENT DYNAMICS

Flooding, saline intrusion and acidic flows from acid sulphate soils are a regular and seasonal occurrence for the Mekong Delta. All of which have undergone change in the past due to human management of the detlai environment:

- **Flooding:** in the order of 30,000km of primary, secondary and tertiary canals have divided the Mekong delta into a largely homogenous but highly productive region. This system of canals and sluice gates have escalated during the 1990s and allow local authorities to drain the larger floodplains of the Mekong Delta (the plain of reeds and the Long Xuyen Quadrangle) and provide suitable conditions for three rice crops per year in many areas of the delta. At present flooding affects 1.9million ha.
- **Saline intrusion:** the extent of saline intrusion is measured by the 4g/l isobar which represents the threshold between brackish and freshwater. An extensive network of dikes has been built – particularly on the western coastline to control saline intrusion. On average 1.4 – 1.9 million ha are affected for a period of 3-5months during the year.
- **Acid sulphate soils:** has emerged as an issue of the past 20-30years during a period of agricultural intensification. The draining of large areas of wetland exposed acid sulphate soils to the air and oxidation. After which the first flushes of the flood season would become acidic as the encountered acdic soils. Currently, 1.6million ha (40% of the delta) is seasonally affected by acid sulphate soils.

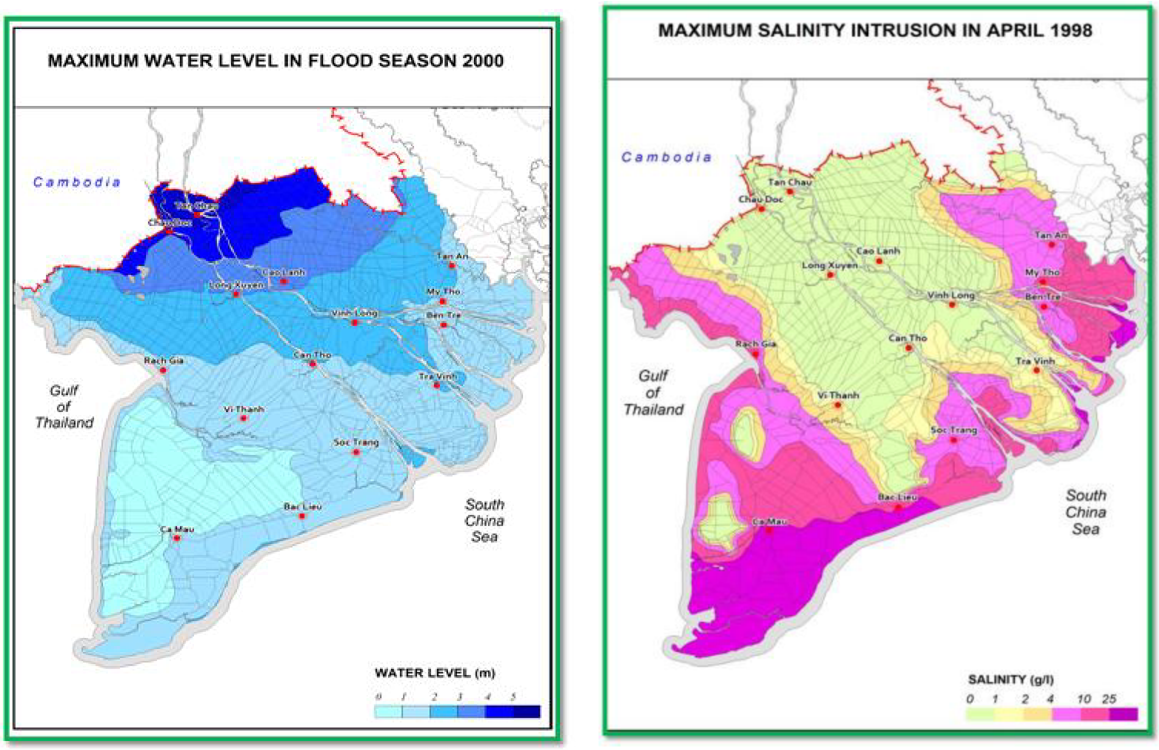
Figure 13: Net sedimentation in Tonle Sap Lake (1997)



Source: Kummu et al, 2008b

- **Marine sediment plume:** A significant proportion of the sediment load enters the marine environment, where tidal forcing drifts the sediment plume southward loosely tracking the eastern coastline of the delta. The youngest region of the delta is the Ca Mau Pennisula and sediment deposition is concentrated on the eastern and western face of the tip. Very little is known about the trends in the fate and size of the Mekong sediment plume, but it plays two important functions for the delta:
    - The plume introduces nutrient rich silt into the marine environment which plays an important role in the highly productive marine fisheries of the Mekong delta. Trash fish from marine fisheries are also an important source of food-pellets used extensively in the Mekong Delta to support its large aquaculture industry.
    - The plume is also responsible for delta building and the preservation of mangrove coastlines – particularly in Ca Mau province.

Figure 14: Key features of the Mekong Delta hydrological regime



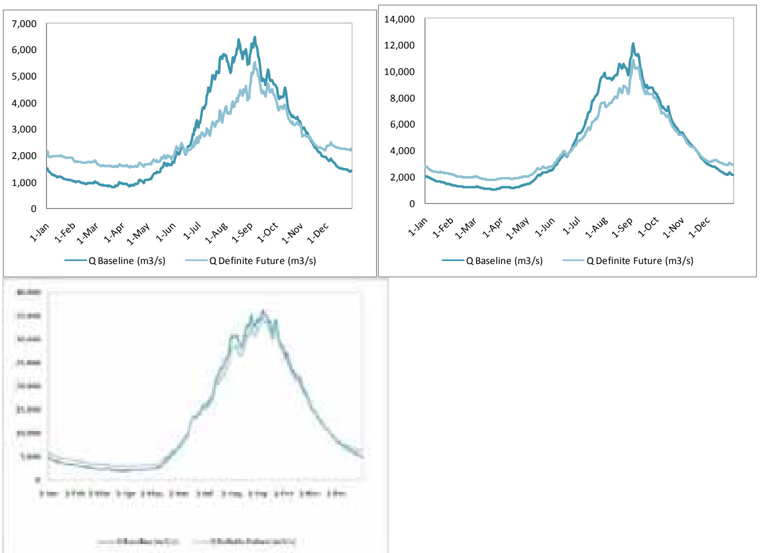
Source: SIWRP, 2009: (left) max flood depths during a wet year, (right) maximum saline intrusion during a dry year.

4.4 HYDROLOGY - FUTURE TRENDS TO 2015

4.4.1 FLOW VARIATION – FUTURE TRENDS TO 2015

The best indication of the hydrological changes to be expected from the Yunnan cascade can be extrapolated by comparing the current and future mean daily and monthly hydrographs for the LMB (see figures 15 as an example and table 4 below).

Figure 15: changes to the hydrograph between the Baseline and Definite Future scenario



Source: Adapted from BDP modelling: (left) Chiang Saen, (middle) Vientiane, (right) Kratie

- **Average annual flow:** under the BDP DF there is no significant increase in average annual flow
- **Average seasonal flow:** Dry season flows will increase by ~690 m^3/s, while wet season flows will be reduced by ~700m^3/s. These results differ from the modeling results presented by ESCIR at the 2nd BDP Regional Stakeholder Consultation, in which the increase in dry season flow was almost double (1,200 m^3/s) while the reduction in wet season flow was 1,200 - 1,400 m^3/s (Pimpan, 2009). As mentioned above, this significant discrepancy is yet to be resolved but could be the result of differing reservoir operational strategies defined in the model and is a critical issue for the SEA(discussed further below). Table 5 presents the average, min and max flows and water levels for each station Chiang Saen to Kratie for both the BDP baseline and definite future.

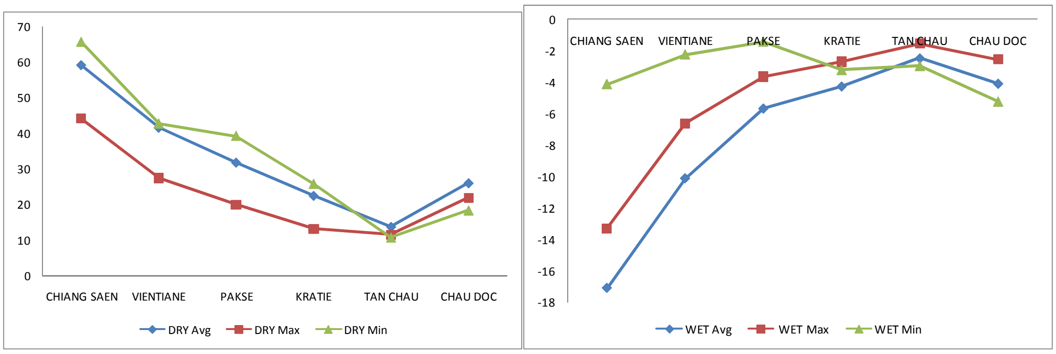
Table 2: Changes to seasonal flow based on the MRC and ESCIR modelling

Seasonal flow	MRC	ESCIR
Increase flow in dry season (m^3/s)	690	1,200
Decrease flow in wet season (m^3/s)	700	1,400

- **Peak flood flow:** The peak flow is decreased reflecting lower annual flood volumes.
- **Seasonal flow:** The changes in seasonal flows broadly reflect the importance of the Yunnan flow contribution to the stations of the Mekong. There is a greater percentage increase in dry season flows for all stations because at this time the Yunnan component makes up 40% or more of the natural flows down to Kratie – this results in a 10-70% increase in dry season flow for the 6 LMB mainstream stations. While during the wet season, flows from the Lao tributaries dominant the seasonal flow,

consequently, the changes to the wet season flow volume is of the order of -18% to -2% (See figure 16). In absolute terms the seasonal increases and decreases are of comparable magnitude.

Figure 16: : (left)) percentage increase in average dry season flows and (right) percentage decrease in average wet season flows



- **Flood-related disaster:** The Yunnan cascade will not directly reduce flood risk because flood risk attributed to Lancang flows is not as significant as the flood risk from Lao tributaries. This is because flood risk is not driven by seasonal flow fluctuations but by the occurrence of extreme events. An historical assessment of storm and cyclone events indicates that major storm events track further south than the Yunnan cascade and so reduce their ability to directly mitigate storm consequences by buffering flows. Conceivably, dam releases could be altered to reduce the Yunnan flow contribution and provide additional downstream capacity to absorb extreme events, however, this would require intensive transboundary coordination with potential impacts on energy production.
- **Flooded area:** The Definite Future will see a typical reduction of ~250,000ha in flooded area, the majority of which will affect areas with flood depths greater than 3m. This will affect more than 15% of the flooded areas in Thailand and Lao PDR, and less than 5% of the area in Cambodia and Vietnam.

Table 3: Average, Max and Min Flows for the Mekong mainstream under existing and predicted 2015 scenarios

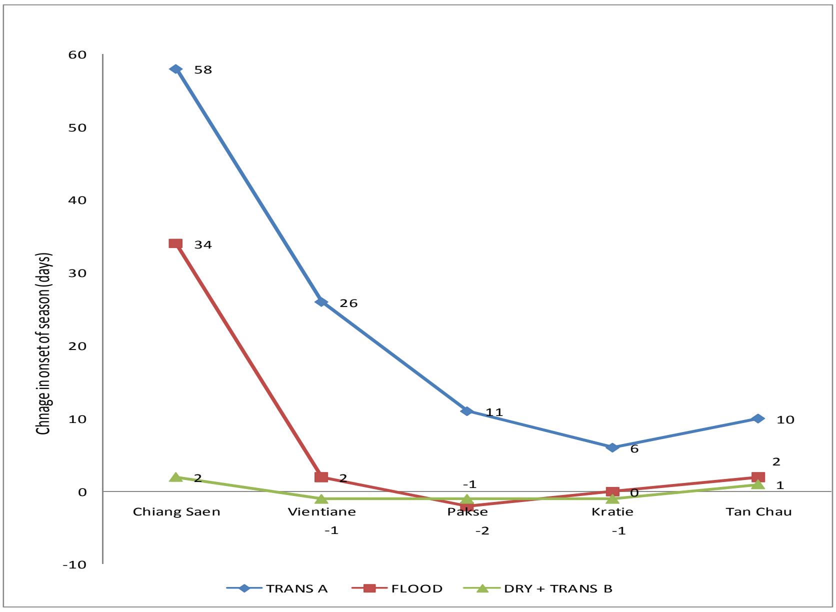
	CHIANG SAEN	VIENTIANE	PAKSE	KRATIE	TAN CHAU	CHAU DOC
BASELINE						
AVERAGE Flow (m3/s)	2,622	4,299	9,390	12,869	10,488	2,121
MAX Flow (m3/s)	6,476	12,121	27,333	36,297	20,764	5,605
MIN Flow (m3/s)	791	1,012	1,532	2,001	2,160	139
DEFINITE FUTURE						
AVERAGE Flow (m3/s)	2,615	4,282	9,319	12,798	10,633	2,126
MAX Flow (m3/s)	5,512	10,848	25,919	34,793	20,236	5,406
MIN Flow (m3/s)	1,557	1,786	2,407	2,953	2,972	248

4.4.2 TIMING AND DURATION OF THE HYDRO-BIOLOGICAL SEASONS – FUTURE TRENDS TO 2015

The onset of the four hydrobiological seasons occurs with a standard deviation of ~2weeks (Table 7). This remains consistent from Chiang Saen to Kratie. By 2015 the following changes can be expected under the BDP Definite Future:

- ***Onset (figure 17):*** changes to the timing of the seasons is greatest in the upper reaches of the LMB where the Lancang flows contribute a greater proportion. The timing of Transition A from the dry to the flood season will be most affected, starting ~7- 8weeks earlier at Chiang Saen and ~1 week at Kratie. This season is important in triggering seasonal patterns in the river's ecology (for example fish migrations). Upstream of Vientiane will also see an earlier onset of the flood season, though tributary flows from the left bank will reduce this to negligible variation downstream of Vientiane.

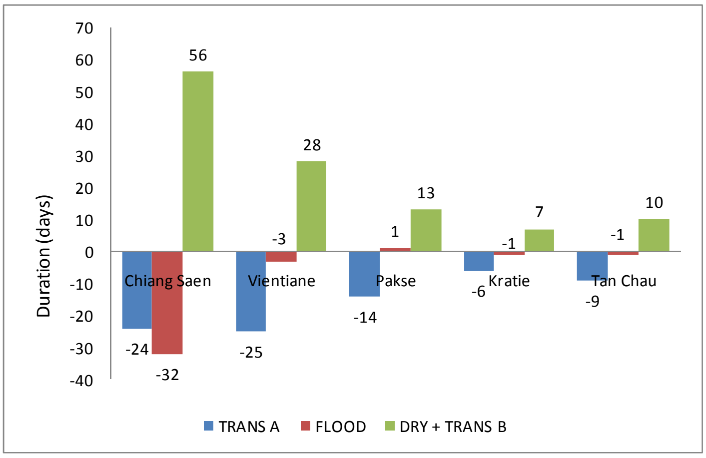
Figure 17: Variation in the start date of the Mekong hydro-biological seasons.



Positive values show a delay (in days) in the onset of the season, negative values show the early arrival of the season

- ***Duration (figures 18):*** Upstream of Pakse will experience a 2-4week reduction in 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. These cumulative reductions will see an increase in the duration of the combined Transition + dry season.

Figure 18: Change in the Duration of the Mekong seasons between the Baseline and the Definite Future.



- ***Magnitude :*** dry seasonal flows will increase by 70% at upstream stations decreasing to a 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.

- ***Cumulative:*** The cumulative effects of the changes to the hydro-biological seasons is a reduction in duration of the two transitions seasons combined with a reduced variability between the wet and dry seasons. These two factors serve to homogenize the Mekong hydrograph and subdue the prevalence of the flood pulse. This is most pronounced in the upper reaches of the LMB reducing downstream as the left bank tributaries begin to influence the hydrograph.

Table 4: Changes to the timing and duration of the Mekong Hydro-biological seasons

		END OF DRY	END TRANS. A	END OF FLOOD
STATION	SCENARIO	2*Q(min)	Q>Q(ave)	Q<Q(ave)
CS	BS	20-May	24-Jul	11-Nov
	DF	17-Jul	28-Jul	13-Nov
VTE	BS	14-May	25-Jun	14-Nov
	DF	10-Jun	27-Jun	13-Nov
PK	BS	18-May	16-Jun	8-Nov
	DF	29-May	14-Jun	7-Nov
KT	BS	17-May	17-Jun	12-Nov
	DF	23-May	17-Jun	11-Nov
TC*	BS	*25-May*	*30-Jun*	*17-Dec*
	DF	*4-Jun*	*2-Jul*	*18-Dec*
CD*	BS	-	*15-Jul*	*11-Dec*
	DF	-	*16-Jul*	*11-Dec*

**timings for transitions have been calculated for Tan Chau and Chau Doc, however, it should be noted that for these stations these values are o*

4.4.3 FLOW PROVENANCE – FUTURE TRENDS TO 2015

The dominant impact of the BDP DF is the changes to flows in the Lancang River. The mean annual flow contribution from Zone 1 is 56km³, which means that the Yunnan cascade can retain in active storage approximately 42% of the mean annual flow. The operational strategy for the Yunnan cascade is not known, but if project owners intend to maximize power production it is likely that the majority of reservoir storage will be utilized during the wet season. BDP modeling suggests a 17% reduction in wet season flow or storage of ~11km³/yr. While the modeling presented by ESCIR suggest approximately a 30% reduction in wet season flows which would approximate the maximum storage capacity of the Yunnan cascade (22-23km³). This presents a reasonable range over which changes to the Yunnan component can be considered.

The total storage capacity of all tributary projects in the LMB DF is 20.3 km³, with LMB tributaries contributing approximately 300 km³ to average annual flows. Given that most tributary flow eventuates during the wet season and the assumption that tributary projects will seek to maximize power production, it is estimated that tributary projects have the capacity to store 5-7% of the tributary contribution.

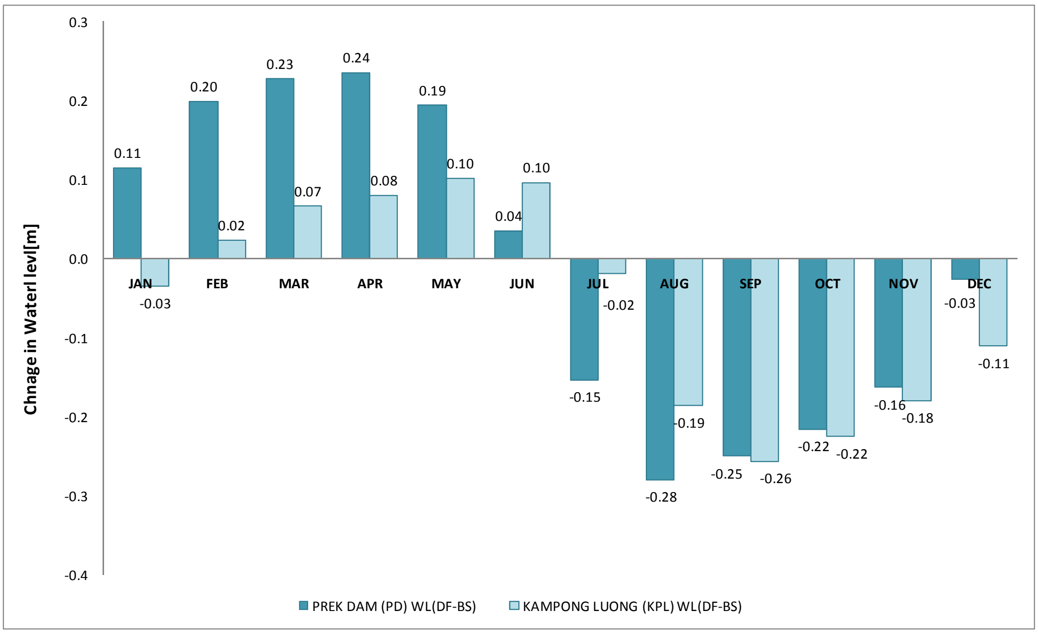
Therefore, the reduction in wet season flow and increase in dry season flows evident in the modeling is driven by the Yunnan cascade. Variation in this driver (as witnessed in the two modeling results of table 4) reflects both the importance of the reservoir operational strategies to the downstream hydrograph, and the need for closer collaboration between the Mekong countries. The implications of the Yunnan cascade on the LMB hydrograph could be severely exacerbated if optimal power generation is adopted and full storage capcity is utilized.

The BDP Definite Future scenario is a lower range estimate as to what the variation in flow induced by the Yunnan cascade is likely to be. The ECSIR prediction represent close to the upper range of the change in flow would escalate the magnitude of change experienced by the hydrological regime.

4.4.4 TONLE SAP FLOW REVERSAL – FUTURE TRENDS TO 2015

- ***No change to the timing/phasing of the hydrographs in the Tonle Sap system:*** The predicted 2015 flow regime will see lower variation between the wet and the dry season flows and water levels in Zone 5 due to regulatory effects of hydropower in China (see hydrographs for Kratie). Figure 19 compares the current and 2015 hydrograph for KPL and PP based on 13 years of monitoring and 13 years of simulated model results. The hydrographs demonstrate that there is not a significant change in the timing of water level maxima/minima, nor in the length of the transition phases, however, there is a reduction in the amplitude of the seasonal water level extrema.

Figure 19: Change in WLs at Kampong Luong & Prek K'dam expected by 2015



- ***Decrease in amplitude of seasonal WL extrema:*** Figure 19 indicates that during January – June water levels will increase by 0.1-0.25m at PD and 0.1m or less at KPL. The peak increase in PD water levels occurs in April, just before the end of the dry season and the traditional reversal of flow in the Tonle Sap. Water levels at KPL during this period are not as vulnerable to changes in the Mekong mainstream water levels because the lake surface is higher than the river level and so the incremental increase of 0.02-0.1m results in increased backwater effects delaying the return flow of water to the Mekong system.

  From July – December, there is a larger decrease in water levels at both stations. PD levels are reduced by a maximum of 0.28m in August/September which corresponds to the flood peak and the beginning of flood water recession. KPL water levels are reduced by up to 0.26m in September. The biggest changes in water levels will occur at the time of the flow reversal in the Tonle Sap River.

Table 5: Change in Water Levels of the Tonle Sap system

	CHANGE IN WATER LEVELS BY 2015 (m)	
	JAN - JUNE	JULY - DEC
Prek K'dam (PD)	0.04 to 0.24m	-0.03 to -0.28m
Kampong Luong (KPL)	-0.03 to 0.1m	-0.02 to -0.26m

- ***Change in the timing and magnitude of the Tonle Sap hydraulic gradient:*** These changes in water levels will impact on the magnitude of the hydraulic gradient driving the reversal of flow. Figure 21 identifies that the timing of all major phases in the average hydrograph remain the same (peak inflow and outflow gradients, Sept/Oct reversal of flow), with the exception of the May reversal of flow. The start of Mekong inflows into the Tonle Sap Lake is likely to be delayed by up to 1 week on average.

Figure 20: (top) Daily fluctuation in the hydraulic gradient of the Tonle Sap River (PD - KPL) for both BDP baseline and Definite Future Scenarios, (bottom) Decrease in the hydraulic gradient (PD-KPL) between the BDP Baseline & Definite Future scenarios

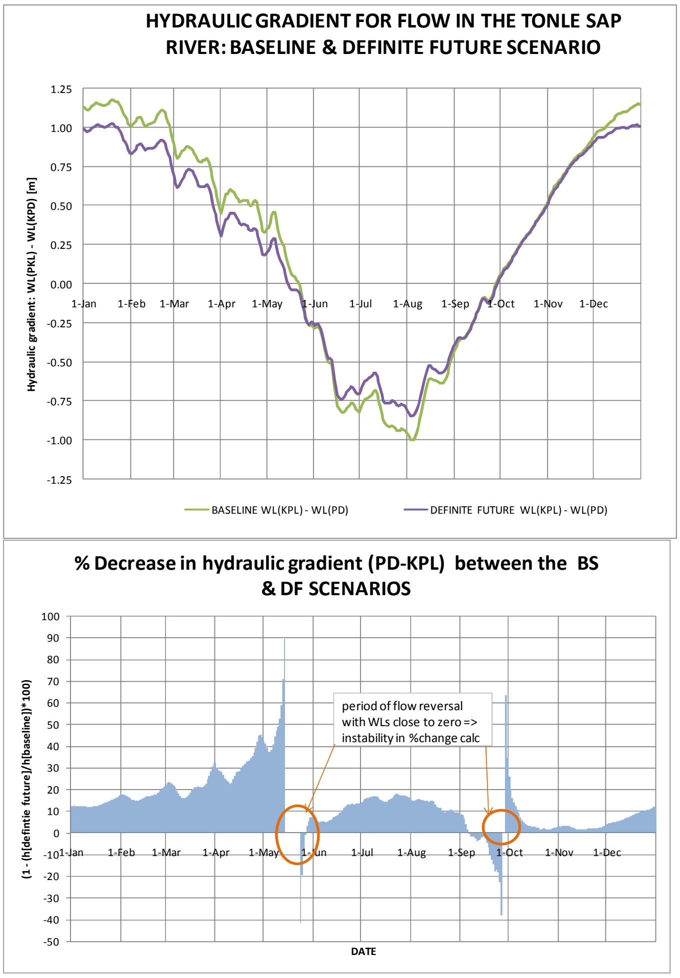


Figure 20 illustrates the computed decrease in hydraulic gradient PD-KPL., from which three main conclusions can be drawn:

(i) during the infilling season (May – September) there is a 10-15% decrease in the hydraulic gradient driving flow into the Tonle Sap Lake

(ii) The falling limb of the flood season (October to December) experiences the smallest change in hydraulic gradient with typically 5% or less reduction

(iii) The biggest reduction in hydraulic gradient occurs during the heart of the dry season (January – May) with a 10-40% reduction in gradient.

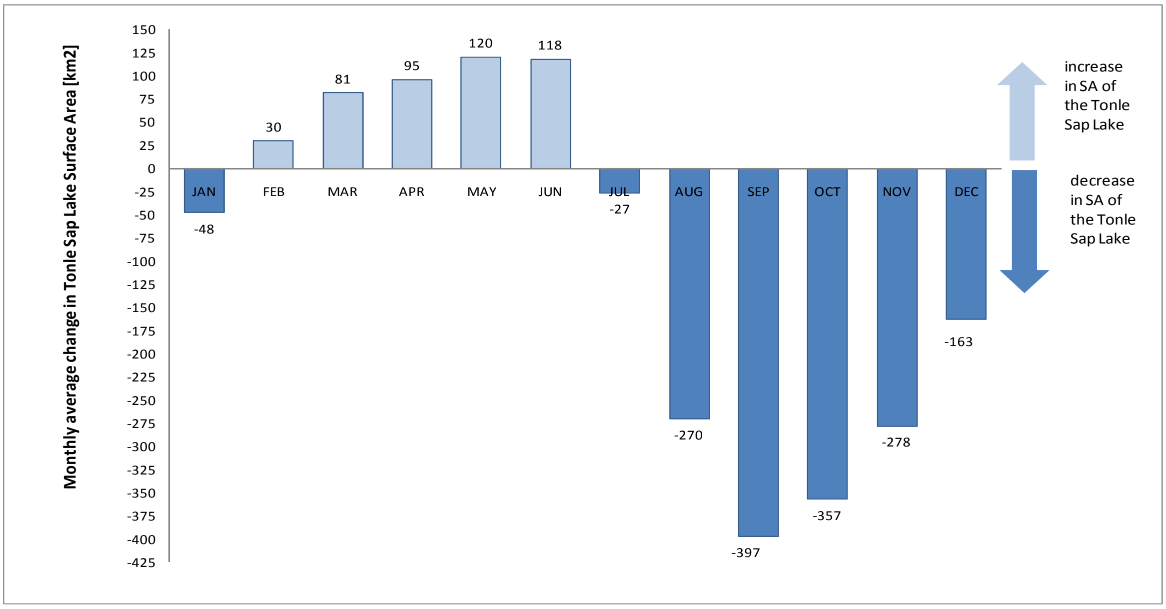
This suggests that the hydraulic gradient behind the reversal of flow in the Tonle Sap is more vulnerable to elevated dry season water levels rather than decreases in peak flood levels.

Developments by 2015 will result in a maximum 0.28m reduction in wet season water levels in the Tonle Sap River with a 0.1-0.25m increase in dry season level. This correlates to a 5-40% reduction in the hydraulic gradient driving the reversal of flows. These changes will not stop the seasonal reversal of flows but they are likely to delay the onset of the reversal by the order of a week as well as reduce the amount of water transferred between the Mekong and Tonle Sap systems.

4.4.5 FLOODING IN THE TONLE SAP BASIN

- ***Changes to water levels at Kampong Luong:*** BDP modeling indicates WLs at Kampong Luong will (figure 19):
    1. increase by a max of 0.1m between March – June,
    2. remain unchanged between January – February
    3. decrease by a max of 0.28m between July - November
- ***changes to lake surface area:*** based on the empirical ratings curve developed by Kummu (2008b), this will result in the following changes to the lake surface area (fig 21):
    1. a decrease in SA between July – January, with a maximum 3-5% (~400km2) decrease during peak September flooding in the Tonle Sap Lake
    2. an increase in SA between February – June, with a maximum 5-8% (~120km2) during the dry season
    3. this represents a 500-600km2 reduction in the inundation areas as the combination of increased dry season and reduced wet season compound one another

Figure 21: Decrease in Tonle Sap Lake Area based on 2015 changes to average monthly WLs at Kampong Luong.



Lake areas were calculated using the above rating curves. The peak decrease in lake area occurs during the flood peak and just before the reversal of flow, similarly the peak increase in area occurs at the time of the dry season flow reversal.

- ***Implications of the changes to lake area:*** the change in lake area lies within the observed range between wet and dry years for the lake, however the consistent change in lake area over the years will have significant impacts, including: permanently flooding much of the gallery forest around the riparian zone of the dry lake area, isolating other flooded forest areas from inundation at the extent of the TSL floodplain, and reducing the lake littoral zone since the reduction in wet season area will be most pronounced for shallow flooded areas - the north western flood plain (near Battambeng) and the north east area (near Kampong Chnhnag) (see bathymetry map)
- This analysis is indicative of the scale of change to be expected in 2015. It is recommended that detailed 3D hydrodynamic modeling is required to provide further detail.

CONCLUSION

By 2015, upstream regulation will seasonally alter water levels in the Tonle Sap Lake by +0.1m/-0.3m, which will decrease the maximum extent of flooding in the Lake by 3-5%, and increase dry season lake area by 5-8%. The decrease in wet season lake area will reduce the area of fringing forest flooded and reduce the littoral zone of the lake both of which are critical aspects of the lake's high productivity. The increase in dry season lake area will further exacerbate the reduction in the Tonle Sap floodplain by permanently inundating some areas. Together these effects will induce a 500-600km2 reduction in floodplain subject to the seasonal flood pulse and oscillation between terrestrial and aquatic environments – which represents 5-10% reduction in the floodplain area. This will reduce the productivity of the Tonle Sap System, but further study is required to quantify the magnitude of this reduction.

4.5 SEDIMENT - FUTURE TRENDS TO 2015

4.5.1 THE MEKONG SEDIMENT LOAD – FUTURE TRENDS TO 2015

- ***Sediment trapping in the Yunnan Cascade:*** The eight mainstream hydropower projects which make up the Yunnan cascade will dominate change to the Mekong sediment load because: (i) the Lancang catchment supplies the majority of the load, and (ii) the reservoir has a large storage capacity capable of retaining 42% of the mean annual flow in the Lancang River. The individual reservoir trapping efficiencies reach 90-98% while the cumulative effect of the entire cascade will be to trap 71-81% of the Yunnan load (Kummu et al, in publication). This will result in ~70Mt/yr being trapped in the Yunnan cascade and an annual sediment load entering Chiang Saen of 15-17Mt/yr.
- **Sediment trapping in the Three S basins:** less sediment data is available for the Three S basin, though current best estimates suggest ~17Mt/yr. An estimated 16 dams will exist in the Three S basin by 2015, with cascades of 5 or more dams in the headwaters of the Sesan and Srepok. Some of these reservoirs have trapping efficiencies of up to 90%, however, substantial sub-areas of the catchment will remain free-flowing by 2015, such that the best current estimate if the Three S trapping efficiency is 37% (Carling, 2009). Based on this estimate the future Three S

sediment contribution is likely to drop to 11Mt/yr with on average 6Mt/yr trapped behind the 15 reservoirs. Further work is needed in setting up a better sediment monitoring program in these basins, given their importance to the Mekong River and also the number of projects planned in the future.

- **Sediment trapping in the rest of the basin:** Most of the remaining tributaries have mean annual sediment loads in the order of 0.1 -1 Mt/yr, except for the Nam Ou (~6.2Mt/yr) and Se Bang Hieng (3.2Mt/yr), both of which are not expected to be dammed by 2015 (Kummu et al in publication). Based on an analysis of the sediment load and trapping efficiency the existing LMB tributary projects currently trap 1-2% of the sediment load and future sediment trapping in the remaining LMB tributaries is likely to be a smaller impact on the future sediment balance than projects on the Lancang and Three S rivers.

Indicative 2015 sediment budget: It is not possible to undertake a comprehensive sediment balance given the problems and gaps in the data record, however, a quick back-of-the-envelope calcultation suggests that the Yunnan contribution will be reduced to 17Mt/yr, the Three S to 11Mt/yr so that the total sediment load at Kratie will drop from ~165Mt/yr to ~ 25-30Mt/yr with the deficit supplied from existing in-channel storage.

4.5.2 SEDIMENT TRANSPORT CAPACITY – FUTURE TRENDS TO 2015

Under the Definite Future scenario the transport capacity will reduce marginally (<3%) due to a reduction in the peak flow, however this is not expected to affect the transport of 99% of the Mekong Sediment Load for almost all mainstream reaches in the LMB (Carling, 2009). The only exception is Chiang Saen, where Lancang flows still dominate the flood peak and the reduction in the flood peak may reduce the capacity for larger than sand-size materials to be suspended and transported downstream.

Based on estimates of sediment trapping in the Definite Future reservoirs, an 135Mt/yr deficit will arise in the sediment load of the Mekong River. Consequently, the constant transport capacity is likely to induce re-suspension of sediment currently stored in the Mekong channel. The largest deposits are in the wide alluvial reaches downstream of Vientiane, which are likely to contain ~14,200MCM, with smaller storage in Z2. Annually, in the order of 1% of the total stored channel sediment is likely to be entrained. The resuspension process is likely to be a complex combination of scour and deposition determined by the channel geology with impacts first noticed in the vicinity of Vientiane – Nong khai and at current bed erosion hot-spots. Over the long term, this will result in a reduction of in-channel features such as islands, sand bars and siltation benches and potential incision of the channel within alluvial reaches (Carling, 2009). Carling (2009) concludes that in terms of changes to channel morphology, this uptake will result in localised impacts within 10 years and regional impacts within 20years, based on a rapid order of magnitude assessment of the gross depletion of channel deposits.

The reduction in sediment load from China and the increased entrainment of channel deposits may also induce a shift in the grain size profile of the suspended sediments. Further information on the grain size distribution of both the current washload and the channel bed is required to draw concrete conclusions, however, the following points are raise as indicative of the types of changes which may occur:

- **Nutrient loading:** One of the main pathways nutrients (especially Phosphorus) are introduced to freshwater systems is via erosion of headwater geology and suspended transport downstream to zones of deposition. This transport relies on bonding between nutrient and cohesive sediments which represent the clay size or finer. A shift in grain size distribution of the Mekong sediments will reduce the ability for the sediment load to transport nutrients which cannot be supported by larger or non-cohesive sediments (see nutrients section below).

- **Transport mechanism:** Conlan's (2008) study on deep pools reveal that transport of sand sized materials is governed by the interaction of a several transport mechanisms. With little bed load and most bed material being gravel size or smaller there is likely to be a complex process of suspension, deposition, saltation and resuspension moving sand through the water column and along the channel bed. Given the presence of at least 335 deep pools, this is likely to slow the downstream migration of sand size sediments (see deep pools section) as the sediment wave through the deep pool moves in the order of 1 pool crossing (~10km) per monsoonal cycle (Conlan, 2008).Further coarse sand movement is often aided by the presence of finer materials in the water column which help to induce and maintain suspension.
- **Flood plain transport:** One of the key features of the Cambodian foodplain is sediment deposition. As floodwaters rise and overtop the river banks they begin to deposit sediment in a process known as overbank siltation. This elevates the channel bank and slows the return drainage of floodplain waters back into the channel. The floodwaters then deposit nutrient-rich fine sediments over wide a wide expanse of floodplain. If the system shifts to larger size sediments then deposition will occur closer to the river bank and potentially within the channel itself.

4.5.3 BEDLOAD DYNAMICS – FUTURE TRENDS TO 2015

The Yunnan hydropower cascade will trap up to 80-90% of the sediment entering Zone 2 (Adamson, 2009b, Kummu et al, in publication). Given the properties of bed load grain size and weight it is likely that bed load trapping efficiencies will be greater than this with close to all bed load being trapped. Therefore, the bed load supply to the Zone 2 will be cut and given that there will not be a significant reduction in transport capacity (Carling, 2009), there will be a progressive downstream conveyance of bed load and erosion of in- channel storages zones (sand bars etc). However, the large number of deep pools will slow the rate of bed load conveyance so that effects will be begin to be seen within a few water seasons at the uppermost reaches of Zone 2, but will take a number of decades before effects are seen at Vientiane.

4.5.4 DEEP POOLS – FUTURE TRENDS TO 2015

Under the Definite Future scenario both the peak flows and sediment load will be reduced, however the reduction in peak flow is not expected to reduce the in-pool velocity enough to prevent entrainment. At Chiang Saen the duration of the flood season will be shortened by ~4weeks (25% of historic flood duration), this will affect the time over which scour velocities are reached resulting in only partial scouring of the deeper pools and increasing the time-step over which the sediment wave completely passes through the pool. The reduction in sediment load because of the reservoirs in the Definite Future is not likely to induce any changes in the functioning of the deep pool as their buffering effect on sediment movement has resulted in a significant volume of sediment stored within the channel banks. Therefore, in the short term the pools will continue to function naturally (with a potential reduced scouring efficiency) as 'crossings' continue to migrate downstream. In the long term, upstream crossings will disappear as they translate downstream and are not replaced, such that the deep pools eventually become static 'holes' and no longer dynamic components in the translation and storage of sediment and bed load.

4.5.5 BED AND BANK EROSION – FUTURE TRENDS TO 2015

Under the Definite Future scenario there is not likely to be an increase in the rate of erosion (Carling, 2009), however there will be an increase in nett erosion downstream of Vientiane as the river compensates for the reduced supply resulting from the hydropower developments (Sarkkula et al, 2010). Based on past erosion potential, this sediment uptake is likely to first affect channel islands and channel bed deposits, followed by river banks. In terms of channel geomorphology and using current estimates of in-channel storage, it would take many decades for the alluvial reaches to be completely eroded (Carling, 2009). However, local effects will be seen within 10years and regional effects within 20years (Carling, 2009). The uptake of sand sized particles from the river channel will also alter the particle distribution of the sediment load increasing the fraction of sand-sized materials, which will alter the downstream deposition dynamics in the Cambodian floodplain and the Mekong delta.

4.5.6 FLOODPLAIN NUTRIENTS AND SEDIMENT DYNAMICS – FUTURE TRENDS TO 2015

- **Extent of flooding:** The Cambodian floodplain will reduced by 4.8% (~1,034km2) due to the reduction in water levels predicted for the Definite Future.

- **Cambodian flood plain:** The trapping of sediment behind the Yunnan dams and the Three S dams proposed for the Definite Future will have a more immediate impact on finer sediment (Sarkkula et al, 2010). This is because the sustained transport energy of the Mekong will induce short and long term resuspension of coarse and non-cohesive sand-sized particles into the water column. Approximately 10,000 – 18,000t/yr of bioavilable P will be lost from the Mekong system (Sarkkula et al, 2010).
- **Tonle Sap Lake:** Productivity is reduced by 4 – 40% across the lake area. The western perimeter of the dry season lake area is likely to face productivity reductions of up to 40% (Sarkkula et al, 2010).

The impact of the Yunnan cascade and other tributary developments is explored in the top and bottom right plots (figure 22).

- **Reduction in the nett load:** there will be a significant reduction of the majority of sediment sizes associated with the Yunnan cascade and other tributary projects.
- **No change in medium sand transport**: at Kratie there will be little reduction in medium sand transport because this will continue to be supplied by the erosion of upstream bed materials
- **Coarsening of the load at Kratie:** there will be a slight, but difficult to measure coarsening of the load at Kratie.
- **No coarsening of the load at Tan Chau/Chau Doc:** This coarsening of the sediment load will not arise at Tan Chau/Chau Doc, because it is not likely that medium sand is currently transported this far downstream.

4.5.7 SEDIMENT DYNAMICS IN THE TONLE SAP LAKE (TSL) – FUTURE TRENDS TO 2015

There are two drivers of change for 2015 sediment dynamics in the Tonle Sap:

1. Changes to inflows and outflows on the Tonle Sap system
2. Changes to the sediment load in the Mekong River

The biggest change in sediment flux between the Baseline and Definite Future will occur during the infilling of the Tonle Sap Lake. During this time, flows up the Tonle Sap River will not be sufficient to entrain coarser materials, and there will be a reduction of 2-4 weeks of the 9week period in which finer materials consisting of 41% of the sediment profile will be passed. This will have significant implications for the volume of sediment entering the Tonle Sap Lake because the 2015 scenario will see an increase in the particulate size of sediments as hydropower developments trap sediments and more bed and bank material from Zone 3 is resuspended to compensate for reduced supply. Further, the period of sediment transport out of the Lake will be reduced by 1-2weeks reducing the connectivity of sediment transfer between the Tonle Sap and Mekong. From a geomorpological point of view this is likely to see increased sedimentation in the Tonle Sap River and the southern extent of the dry season lake area, which will build up in-channel features (e.g. at Chnoc Trou and the ‘delta’ area north of Kampong Chnhnang) and increase braiding near the outlet of the lake. The changes to the sediment flux will also reduce the proportion of sediment reaching the littoral zone of the TSL floodplain affecting the productivity of the flooded forests.

Figure 22: : Indicative changes to the sediment load composition for Kratie and Tan Chau/Chau Doc..The left hand figure represent the current and past situation, while the right hand figures present the best estimate of the 2015 situation.

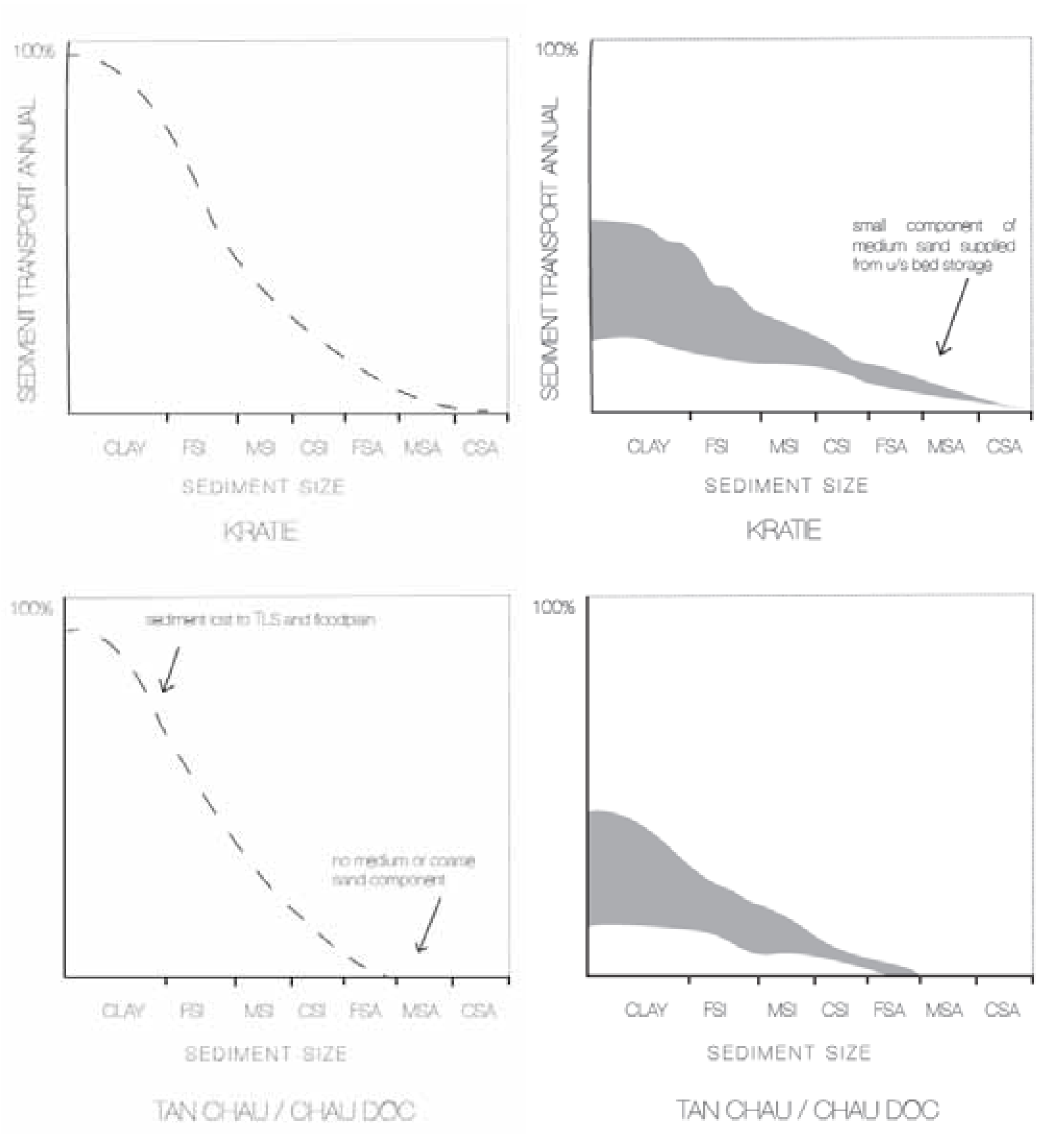


Figure 23: Sediment dynamics of the Cambodian floodplain (source: Kummu et al, 2008). There is some uncertainty of the sediment load at Kratie however, there is reasonable confidence that between 15-25% of sediments deposit on the floodplain (4-7% in the Tonle Sap system). The remaining 75-85% enters the Mekong Delta

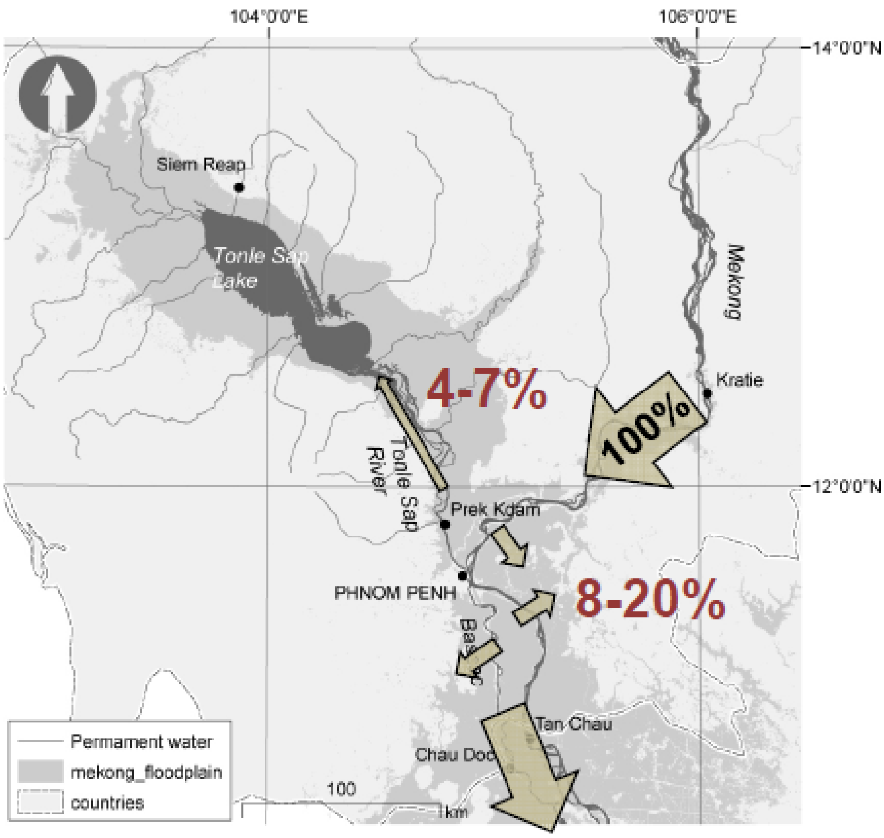


Table 6 Comparison of Baseline and Definite Future days in exceedance of required entrainment flow for 99% and 41% of Mekong sediments (based on Carling, 2009 and BDP modeling).

Q(ent)	STATION	SCENARIO	PERIOD EXCEEDING Q(ent)	TOTAL DAYS	REDUCTION IN TIME EXCEEDING Q(ent) (weeks)
OUTFLOW: TONLE SAP – MEKONG					
5,600	Prek K'Dam	BS	26 OCT - 18 DEC	54	
5,600	Prek K'Dam	DF	29 OCT - 12 DEC	45	1.3
5,600	Kampong Luong	BS	*does not exceed*		
5,600	Kampong Luong	DF	*does not exceed*		
3,800	Prek K'Dam	BS	10 OCT - 20 JAN	103	
3,800	Prek K'Dam	DF	11 OCT - 15 JAN	97	0.9

3,800	Kampong Luong	BS	27 OCT - 19 DEC	54	
3,800	Kampong Luong	DF	1 NOV - 11 DEC	41	1.9
INFLOW: MEKONG TO TONLE SAP					
5,600	Prek K'Dam	BS	*does not exceed*		
5,600	Prek K'Dam	DF	*does not exceed*		
5,600	Kampong Luong	BS	*does not exceed*		
5,600	Kampong Luong	DF	*does not exceed*		
3,800	Prek K'Dam	BS	20 JUL - 9 SEP	52	
3,800	Prek K'Dam	DF	29 JUL - 9 SEP*	35	2.4
3,800	Kampong Luong	BS	3 - 12 AUG, 24 - 29 AUG*	15	
3,800	Kampong Luong	DF	*does not exceed*		

* exceedance is intermittent during this period with up to 1 week of non-exceedance

4.5.8 MEKONG DELTA & MARINE SEDIMENT DYNAMICS – FUTURE TRENDS TO 2015

- **Flood area:** The Definite Future will see a typical reduction of 20,000ha in the flooded area of the Mekong Delta (table below).
- **Flood depth:** Water regulation will also shift the distribution of flooded depths in the delta, with an increase of ~90,000 – 100,000ha experience lower water level (<1.0m) during the flood season.
- **Flood duration:** As discussed in the analysis of hydro-biological seasons, there will be a reduction in the duration of the flood season and also the transitions seasons, with an increase in dry season. Specifcally, the border area of the Mekong Delta (Kieng Giang, An Giang, Dong Thap provinces) will experience 2-4week shortening of the flood season. A significant proportion of flood volumes for these areas (~20-30% of total flood volume) is generated by overland flow from Cambodia.

Table 7: Change to flooded areas of the Mekong Delta (adapted from: Piman, 2010)

Flood depth	BDP Baseline ('000ha)	BDP Definite Future ('000 ha)
< 0.5m	307	374
0.5 – 1.0m	668	712
2.0 – 3.0m	795	666
> 3.0m	5	3
Totals	**1,773**	**1,756**

- **Saline intrusion:** BDP modeling suggests that they are affected by saline intrusion would reduce by ~15% because increased dry season flows will reduce the effectiveness of the hydraulic gradient driving saltwater into the delta (Piman, 2010). In principle this is likely to be the case, however further study is needed to understand the morphological implications of the reduced sediment load arriving in the delta to better understand the future saline intrusion dynamics. The current delta river channels lie close to and even below sea level and are cut through 3-5km of sedimentary material. Changes to the nett erosion from Z6 channel reaches may cause incision of the channel which may enhance saline intrusion. Detailed hydrodynamic modeling is required to better understand the implications of the Definite Future on saline intrusion.

- **Marine sediment plume:** there is likely to be an 80% reduction in the supply of fines to the Mekong delta – based on the trapping efficiencies of the Yunnan and Three S projects. It is unlikely that larger sand-sized particles will remain in suspension through the Cambodian floodplain. Therefore, although the reduction in sediment load will undergo a lag of several decades before it becomes a problem in the upstream areas. The Delta's reliance on clays and fine silts suggest that the impact of an 80% reduction in load will begin to manifest changes in the marine sediment plume over shorter time scales. Based on an indicative assessment of the changed sediment load (Figure 22) , some likely changes are:
    - **Reduction in the size:** the sediment plume will be supplied with significantly less material and will therefore disperse quicker with a reduced range of littoral migration.
    - **Reduction in delta building:** the reduce load and range of marine transport will stunt delta building on the Ca Mau Pennisula, and increase coastal erosion along the entire eastern coastline of the delta.
    - **Collapse of nutrient transport:** there is likely to be a collapse in the nutrient transport pathway connecting the Upper Mekong Basin to the marine environment. Modelling on Tonle Sap suggested that a 4-40% reduction in primary productivity will be experienced in the lake with an 80% reduction in sediment load (Sarkkula, et al, 2010). While the hydrodynamics are completely different the reduced washload in the marine environment will also see a reduction in primary productivity, which will have major implications for the Delta's marine fisheries, as well as the aquaculture industry which uses marine trash-fish to produce fish pellets.

Figure 24: Satellite image of the Mekong Sediment plume taken in September. There are two main discharge sites: (i) the delta fan near the mainstream outlet which discharges into the South China Sea and transported along the delta coast in littoral drift before depositing at on the tip of the Ca Mau Penninsula, (ii) small bay in Kien Giang province near the Cambodian border

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5 TERRESTRIAL ECOSYSTEMS AND AGRICULTURE

Themes and key strategic issues

Theme	*Key issues (relevant to hydropower)*
Terrestrial ecosystems and agriculture	• Habitat loss and degradation, forest cover and protected areas • Changes to patterns of agriculture • Value of paddy agriculture in each zone • Changes to agricultural and land use patterns along the mainstream, especially river bank gardens

Analysis of the impacts of the mainstream dams under this theme follows the recognized hydro-ecological zones of the Mekong as described in the aquatic ecosystems section.

5.1 PAST TRENDS AND CURRENT SITUATION

Issues:

- Habitat loss and degradation, forest cover and protected areas
- Changes to patterns of agriculture
- Value of paddy agriculture in each zone
- Changes to agricultural and land use patterns along the mainstream, especially river bank gardens

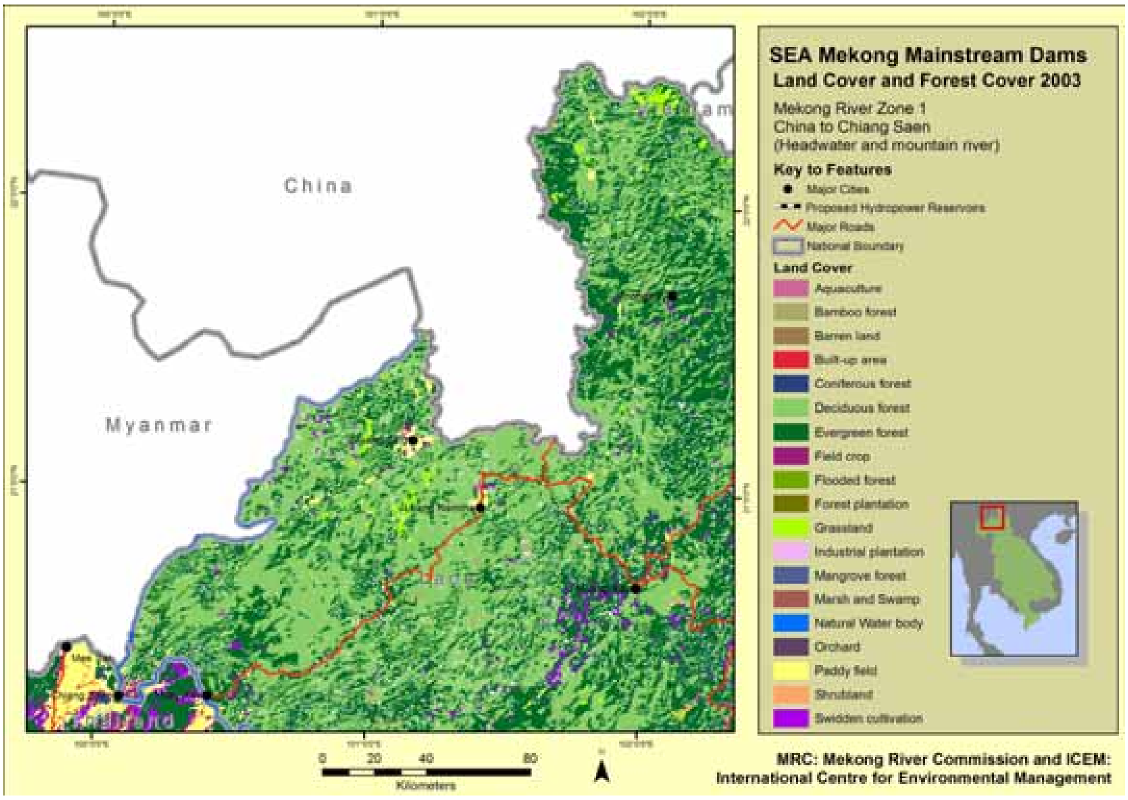
5.1.1 ZONE 1

In Zone 1, the river flows through a narrow, steep-sided valley, which is generally forested with secondary mixed deciduous forest (Figure 1). Only a very small proportion of primary forest remains, and the rest having been heavily logged along the river valley, with some slash and burn agriculture, and replacement growth of bamboo. There are some isolated stands of planted teak. River bank vegetation is generally intact, and small shrubs grow on the more stable sandbars and rocky outcrops. The aggressively invasive plant, *Mimosa pigra*, is spread by water, and has established itself even far upstream in Zone 1 taking over areas of river bank and sandbars. Around the Golden Triangle up to Chiang Saen and downstream the valley is wider and flatter with some permanent agriculture especially on the Thai side. Riparian communities tend to be small and scattered, but with development of resorts in the Golden Triangle, and the large port town of Chiang Saen.

There is one small national protected area in Myanmar (Pasar) in the Golden Triangle, and the Nong Bong Khai non-hunting area (Ramsar site) just south of Chiang Saen, which is part of the Chiang Saen Important

Bird Area (IBA)[6]. The Mekong channel from the confluence with the Nam Pha is considered as part of the Upper Lao Mekong Channel IBA.

Figure 1: Landcover and forest cover map of Zone 1



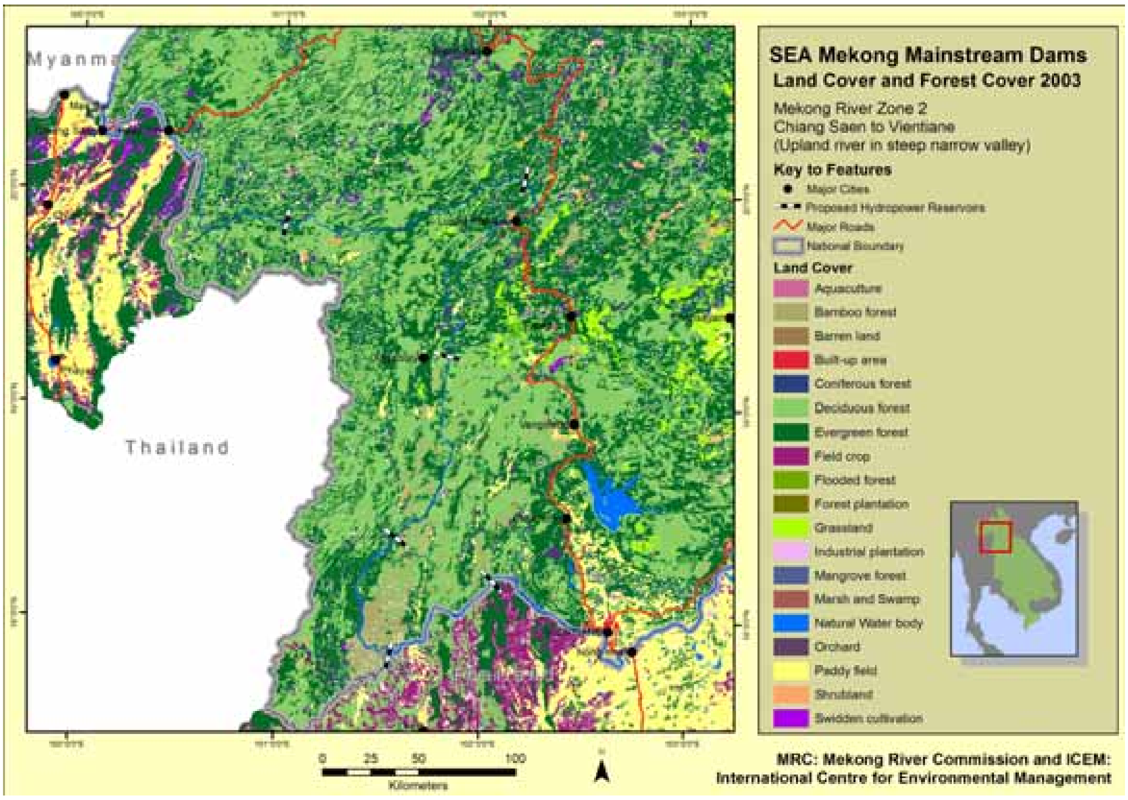
5.1.2 ZONE 2

After a flatter, more cultivated area downstream of Chiang Saen, the river valley narrows again, especially after Houay Xay/Chiang Khong. The area along the Mekong River is dominated by mountainous landscapes of exceptional beauty. The vegetation on the hillsides of the valley throughout this zone are generally quite densely forested, usually secondary forests (mixed deciduous and evergreen) which have been logged or cleared for slash and burn cultivation. Bamboo forests cover an estimated 40% of the surrounding landscape in the upper section (Figure 2). The area is sparsely populated with small hamlets/villages, which practice various agricultural activities. The livelihoods of riparian people are unique and almost strictly based on agriculture. There are some small areas of teak plantation near some of the riparian communities. The riparian vegetation, which may not be very wide, has usually been cleared near these communities, The riparian areas, which are seasonally flooded, provide rich soils for river bank gardens, and there is some use of the sand banks for cultivation of maize, groundnuts and vegetables. Many fruit trees grow on the banks of the river.

[6] Important Bird Areas are a designation of BirdLife International to indicate the importance of an area for bird biodiversity. Because birds are one of the most studied taxonomic groups, they are used as an indicator for areas of high biodiversity and conservation value. It does not indicate any level of protection.

After the junction with the Nam Ou and down to the junction with the Nam Khan at Louangprabang, the valley is wider with some floodplain, which is cultivated (as can be seen from the pink areas on the maps). After Louangprabang the valley closes in again, and a similar landscape of steep sided, forested, hillsides with isolated riparian communities continues down to the town of Pak Lay and down to Sanakham and the border with Thailand. There are occasional flatter areas where the valley widens, or tributaries meet the Mekong, and these are often locations where communities have become established. As the Mekong flows between Thailand and Laos down to Vientiane, the landscape gradually flattens and becomes more cultivated.

Figure 2: Landcover and forest cover map of Zone 2

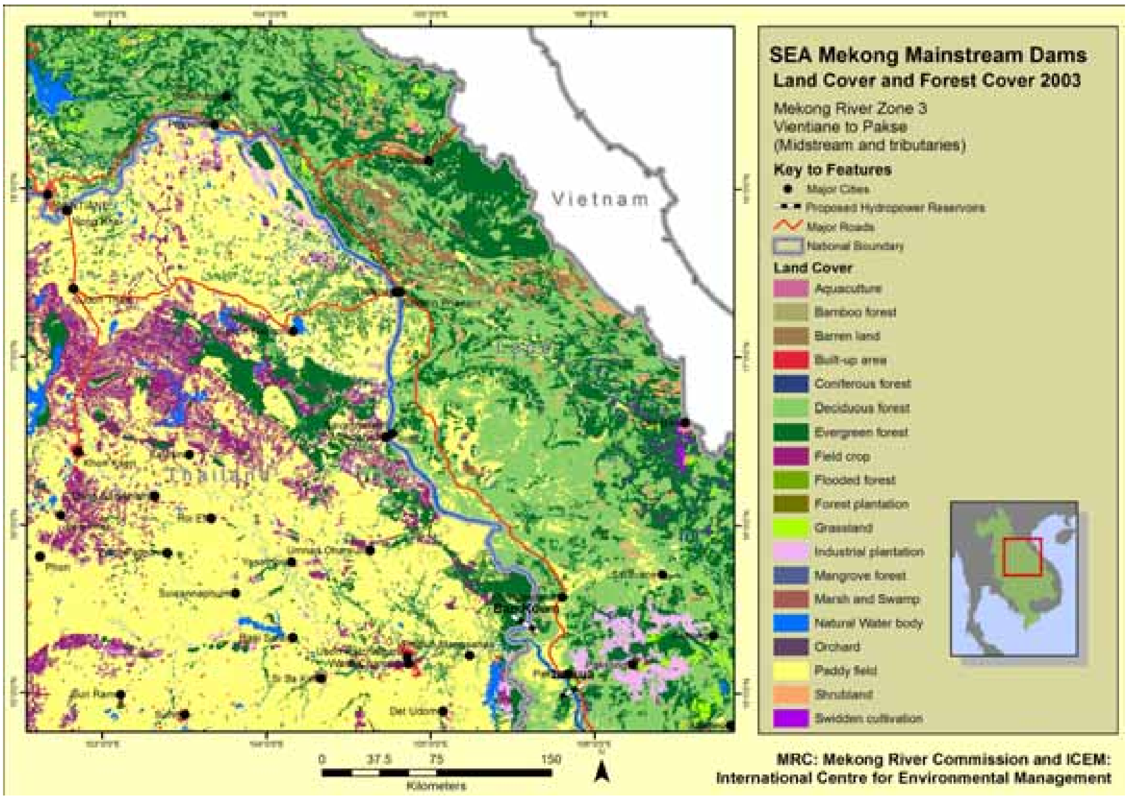


The rich and diverse ecosystems along the Mekong provide habitats - open sand bars and mudflats, tall grass/reed beds, and exposed bedrock and vertical earth banks for many bird species. Three Important Bird Areas (IBAs) have been identified in this zone – Upper Lao Mekong (the river channel in Bokeo, Oudomxay and Xainabury provinces), Mekong Channel at Pak Chom, and the Mekong channel upstream of Vientiane. All are considered important for congregatory water birds, the River Lapwing and Small Pratincole. The forested hills away from the Mekong are important areas for terrestrial biodiversity. There are two protected areas in Laos, one in Xayabury Province on the west side on the border with Thailand (Nam Phui NPA) and one on the east side in Vientiane Province (Phou Phanang). Nam Phui NPA is connected with an extensive series of National Parks to the wets on the Thai side. These NPAs are generally mixed deciduous forest on sandstone escarpments, with some patches of evergreen forest. There are no protected areas covering the Mekong channel.

5.1.3 ZONE 3

In Zone 3, the river flows through a wide valley, flanked by steep hillsides on the Laos side to the north after Vientiane and as it turns south, on the east bank forming the foothills of the Annamite mountains. On the Thai side the landscape is a much flatter agricultural landscape, consisting of the Songkhram river and its floodplains. Figure 3 clearly shows the extensive agricultural land on the Thai side. After Mukdahan/Savannakhet, however, a steep sandstone escarpment on both sides of the river forms an impressive landscape. These hills are generally forested with dry deciduous dipterocarp forest, with some communities and cultivation in the relatively narrow valley bottom.

Figure 3: Landcover and forest cover map of Zone 3



River bank vegetation is largely modified for communities and agriculture. River bank gardens are also a significant feature along this zone, associated with such riparian communities, including in the major towns along the river. Seasonally inundated floodplains occur in places behind the levees and more extensive floodplains where major tributaries enter the Mekong. The inner banks of the levees support soft-stemmed, fast-growing plants such as *Phragmites*, and scattered woody plants may occur on their tops. The actual mix of species depends on the slope of the river bank, with shallower slopes supporting species such as *Xanthium*, *Melilotus* and *Phylla*. The floodplains behind the levees receive annual doses of fertile sediments and flood water, and comprise very productive landscapes. The rice lands on these floodplains contain scattered remnants of a short-tree forest with species endemic to this area, and wetland plants such as sedges, reeds and water lilies. Tree species on higher areas include *Dipterocarpus*, *Hopea* and *Croton*, with many introduced species, among cultivated areas of papaya, cassava, banana and tobacco. On some of the rocky islets upstream of the Mun river confluence, the scattered, rheophytic trees - *Anogeissus rivularis*, can be found. These are trees of the channel woodland typical of braided channels found in Siphandone and Stung Treng.

There are three protected areas in Zone 3, which come down to the Mekong – two in Thailand (Pha Taem and Kaeng Tana NPs) and one in Laos (Phou Xiang Thong). The focus for both these protected areas is the biodiversity of the dipterocarp forests, the eroded sandstone landscape and the 3000 year old rock paintings on the Thai cliffs overlooking the Mekong above Ban Koum. There are two Thai Ramsar sites in Nong Khai Province (Kud Ting and Bung Khong Long). These are a short distance from the Mekong and linked to it through the Songkhram river and are important for wintering migrant birds and for several endemic species of fish.

5.1.4 ZONE 4

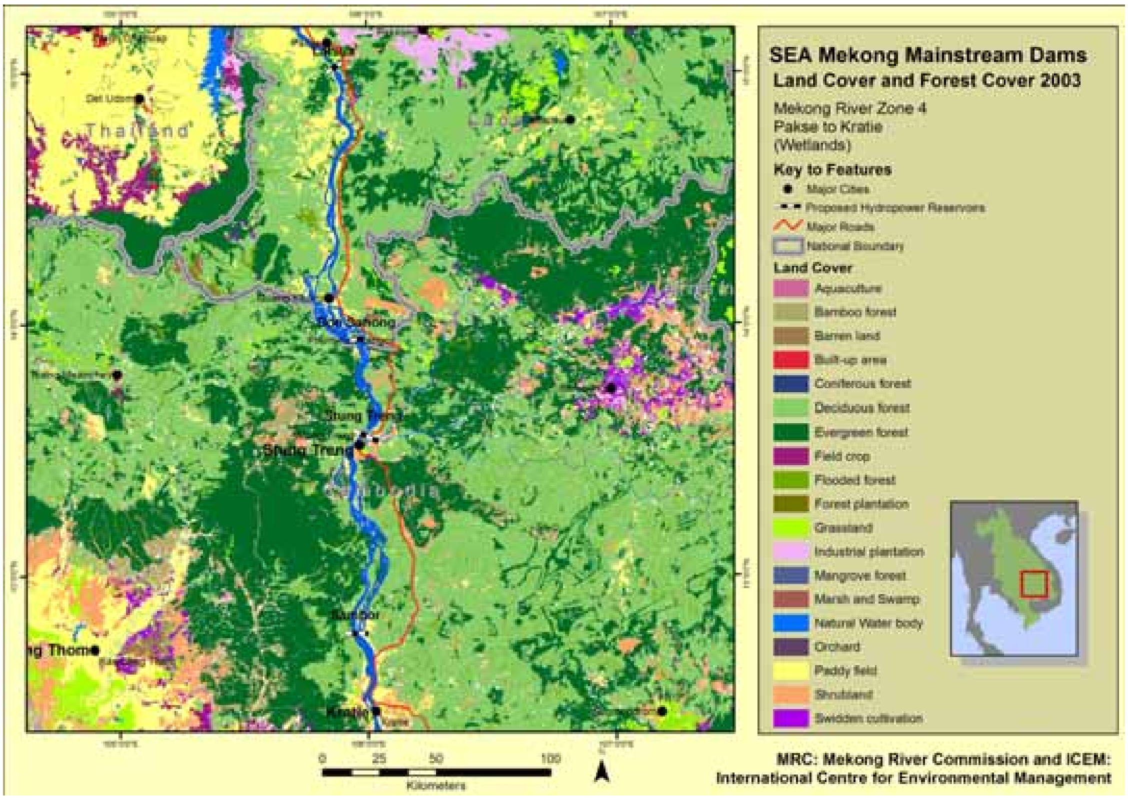
From Pakse the river flows through a wider valley, with distant views of the Bolevan Plateau and the hills on the west side of the river in the triangle between Laos, Thailand and Cambodia. The Khone-Phapheng Falls area occurs at a major geological fault line, with a drop of some 15 m to Into Cambodia, where the landscape bordering the river rises slowly on both sides, widening around Stung Treng confluence with the 3S rivers and around Kratie (Figure 4).

The Siphandone area is a zone of wide slow-flowing water dotted with countless islets. Distinct plant communities occur on sandy, rocky or silty substrata, with that on the rocky islets being endemic to the area. The emergent shrubby rheophytes on the rocky islets, including Homonia, *Telectadium* and *Rotula,* are highly valued by the Lao people. Islands with silty deposits over bedrock cores support a variety of pioneer species including lianas and the invasive alien species, *Mimosa pigra*. Stout trees, including *Anogeissus, Acacia, Eugenia* and *Gymnosporia* occur in succession from water level up the banks of the river. Vegetation classifications found in Stung Treng Ramsar site include unique seasonally flooded forest - channel woodland (*Anogeissus, Acacia*); channel bushland (*Phyllanthus, Telactadium*) sand and grass on sand bars, riparian forest, tall grassland on floodplains, and agriculture. The terrestrial habitats include mixed deciduous, dry dipterocarp and semi-evergreen forests.

In Cambodia, the mixed dry deciduous dipterocarp and semi-evergreen forests of the Northern Plain Dry Forests, extend westwards from the river, and are considered a priority landscape for conservation by WWF. Chhep District in Preah Vihear province of Cambodia, and the southwestern part of Dong Khanthung proposed protected area in Laos contains a high density of pools and seasonally inundated grasslands, which are especially important for the conservation of large water birds, white-winged duck and Siamese Fireback, with small numbers of Asian elephant, gaur and banteng. WWF (2006), Allen et al (2008). Similar vegetation for the reach between Stung Treng and Kratie described in detail in Bezjuin et al (2008).

A typical feature of Siphandone and its extensive alluvial deposits is their seasonal utilisation for cultivation of river banks, sand dunes and islets, which are rapidly cleared of vegetation when the water level starts receding. It has been estimated that, within the 45 km-long reach of river between Done San and the border with Cambodia, and accounting only outer river banks and islands with permanent human settlements that the total length available for river bank gardens is in the order of 700 km (Daconto, 2001). Other agriculture mostly consists of rainfed paddy with some small-scale irrigated plots near the river.

Figure 4: Landcover and forest cover map of Zone 4.

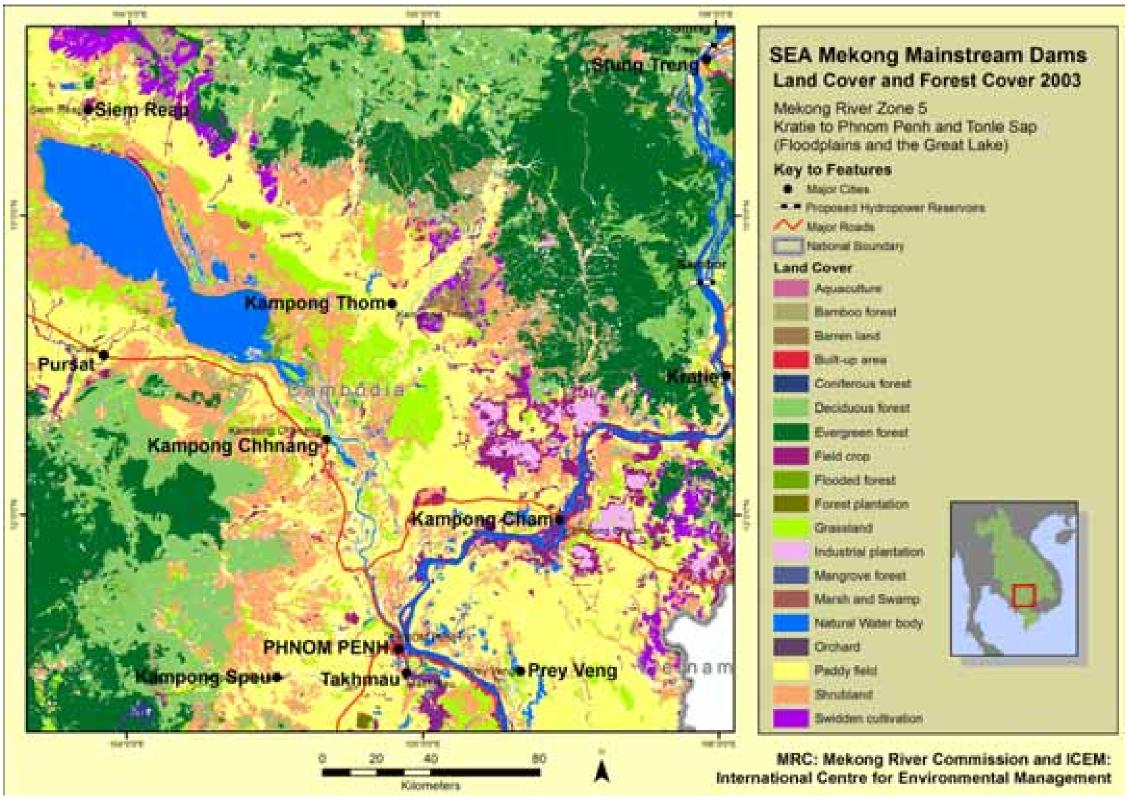


Whilst the whole stretch of the river between Siphandone and Kratie is recognized as a series of Key Biodiversity Areas, reflecting the high value of this area for conservation, there are no protected areas along the river. The Stung Treng area is designated as a Ramsar site, but is not a National park and does not have protected area status. There is a proposed NPA at Dong Kanthung in the triangle between Laos, Cambodia and Thailand, and Don Kalo IBA is a part of the adjacent Xe Pian NPA, but these are both some distance from the River. Chhep IBA in the Northern Plain Dry Forests to the west of Stung Treng is important for many rare and endangered bird species.

5.1.5 ZONE 5

After Kratie, the river enters the main Mekong floodplain areas of Cambodia (Figure 5). Natural levees up to 10 m tall retain river water within the main channel at the onset of the monsoon season but also trap flood water on the floodplains at the end of the dry season. Historically, the floods covered a vast mosaic of grasslands, scrub and tall forests for several months each year, but most of this is now converted to rice fields and drained urban areas. Agricultural land (as shown in pale yellow in Figure 5) predominates from Kratie to Phnom Penh and around the Tonle Sap. The seasonally inundated areas around the Tonle Sap are clearly indicated, together with the flooded forest. Although the general water bird populations along the Mekong mainstream are quite depleted, the floodplains and the flooded forests carry significant diversity and populations of water birds.

Figure 5: Landcover and forest cover map of Zone 5



There are a number of Important Bird Areas including Stung Sen /Santuk/Baray (IBA 021) which is one of the largest remaining tracts of seasonally inundated grassland within the Tonle Sap floodplain and an important breeding ground for the Bengal Florican. Prek Toal (IBA`003) is a protected area of flooded forests at the north western end of the Great Lake containing some spectacular congregations of waterbirds. The Tonle Sap Biosphere Reserve (TSBR) covers an area of 14,812 km^2 consisting of 3 core areas: Prek Toal Core Area (21,341 ha) in Battambang province, Boeng Tonle Chhmar Core Area (14,560 ha), also a designated Ramsar site, and Stung Sen Core Area (6,355 ha) associated with Stung Sen River/Tributary in Kampong Thom.

The zone as a whole supports the largest global colony of Spot-billed Pelican and the largest South-east Asian colonies of Darter, Black-headed Ibis, Painted Stork, and Greater Adjutant stork, the largest mainland colony of Milky Storks, the largest colony of Asian Openbill stork in Indochina, the only breeding colony of Glossy Ibis in Cambodia, and large colonies of Lesser Adjutant stork and Little Egret. Nevertheless, the IBFM ornithological specialists considered that this zone was “largely modified with room for improvement”.

5.1.6 ZONE 6

The Mekong delta has now been largely converted from a wetland of very high biodiversity and productivity to very productive agricultural lands, often with three crops of rice per year (Figure 6). Lacking the high levees of Zone 5, the entire delta was probably originally a continuous floodplain, from upstream marshlands supporting submerged or floating plants such as *Hydrilla* and *Najas*, to downstream mangrove systems dominated by *Melaleuca*. Large areas of the invasive alien species *Mimosa pigra* cover river and canal banks, with seeds spread by flood waters. The Tram Chim National Park gives some idea of the former character of the wider area known as the Plain of Reeds, a wetland depression of about 13,000 km^2 with large areas of acid-sulphate soils in the northern part of the delta in Cambodia and Vietnam. The Plain lies in a flat lowland region subject to seasonal flooding (July - December) which at the flood peak (September - October), effectively becomes a vast lake with some areas flooded to a depth of nearly 4 m. Except for scattered ponds and swamps, the Plain dries out during the dry season. Most parts of the Plain have been converted to rice production over the past 40 years.

Of the total land use in the Vietnamese part of the Delta, 63.1% of the land is agricultural, 8.3% is forestry, about 5% special use (e.g. protected areas) and about 5% residential. Between 1995 and 2005, the delta production of rice increased steadily to about 18,000 tonnes per year, and has remained relatively steady since then. With three crops a year in many of these agricultural lands, and with limited land for expansion, it is likely that rice production in the Delta has reached its full potential.

Agriculture in the delta is constrained by soil suitability. The extent of the rich alluvial soils is limited to the floodplain on each side of the river a shown in Figure xx which shows the extent of acid sulphate and high saline soils. Acid sulphate soils have been drained and made suitable for agriculture through regular flushing with flood waters by the extensive network of canals and drains throughout the Delta. It is anticipated that problems of acid sulphate soils may remain localized, as long as river flows are maintained to continue the flushing process.

The high saline soils are found on the seaward edge of the delta, and this is the area that has been developed for aquaculture (Figure 7a) The extent of saline intrusion is largely controlled by the flows of freshwater coming down the river, especially in the dry season. Saline water intrusion normally affects 2 million ha of land during the dry season, when saline water may extend 50 kms inland. Drought conditions, can extend the high salinity inland for longer periods as shown by the zones of raised salinity during the 1998 drought. Figure 7(b) shows the duration of salinity levels greater than 1 gram per litre during the dry season drought of 1998. The area affected exceeded half of the total 55,000 km2 that defines the main delta.

Figure 6: Landcover and forest cover map of Zone 6

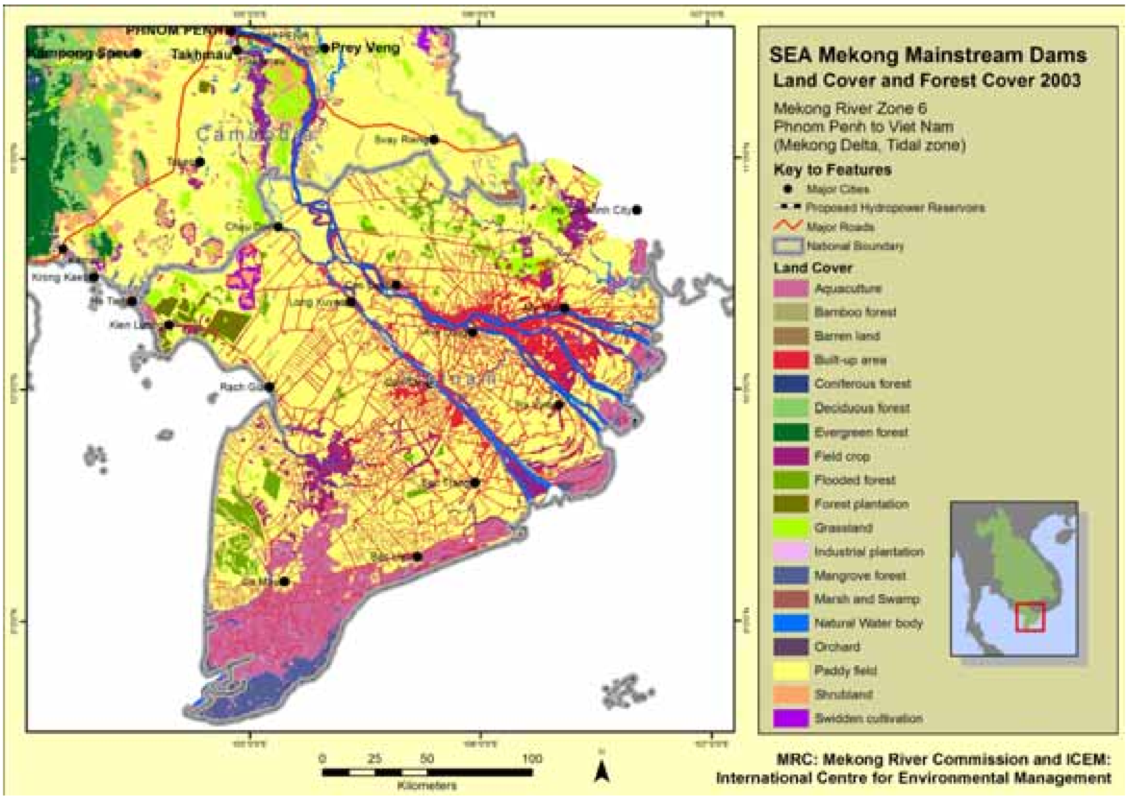


Figure 7: a) Distribution of soil status in the Mekong Delta; b) Simulation of saline intrusion during the dry season drought conditions of 1998.

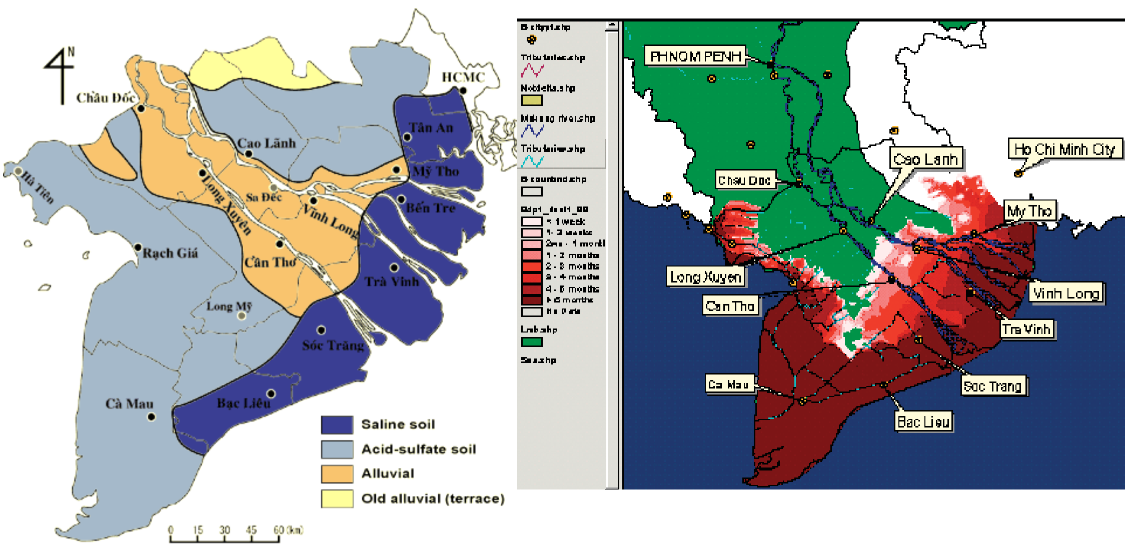


Fig. Distrubution of soil status in Mekong Delta

(Source: MRC 2003, State of the Basin Report)

In Cambodia, there three Important Bird Areas – Basset Marsh, Boeung Veal Samnap and Bassac March lying in the floodplains adjacent to the river and are important for Spot-billed pelicans. In Vietnam, there are five IBAs, and several wildlife sanctuaries. These include Tram Chim National Park and Lang Sen Provincial protected area, which are representative of the original Plain of Reeds ecosystem and important for dry season roosting and feeding of the Sarus Crane and migratory waterfowl. The wetland habitats in the Plain of Reeds include: seasonally inundated grasslands, inundated semi-natural Melaleuca forests and Lotus swamps. The Plain of Reeds supports the only known Indochinese population of Grass Owl, which is dependant on undisturbed grassland. There are two protected areas in the Delta - the Tram Chim National Park, in Dong Thap Province, and Lang Sen provincial nature reserve, in Long An Province, to the north east of Tram Chim which is the only remaining area of natural Melaleuca forest, and thus has important biodiversity value. Along the coast in Tra Vinh Province there are several small IBAs including Chua Hang, Tra Cu and Bac Lieu.

5.1.7 KEY BIODIVERSITY AND PROTECTED AREAS

The Mekong River lies within the Indo-Burma biodiversity hotspot and is considered one of the most ecologically rich regions of the world. It is therefore surprising that the number and area of protected areas along the Mekong from the Chinese border to the Delta is very low. There is one national protected area in Zone 1 in Myanmar, three small Ramsar sites in Thailand in Zones 2 and 3, and two national parks in Thailand and one in Laos in zone 3 (Pha Taem and Keang Tana, and Phou Xiang Thong respectively); the Stung Treng Ramsar site in Cambodia in zone 4 (which has little legal protection), and the Tonle Sap Biosphere Reserve in Zone 5 and one National Park (Tram Chim) in the Delta in Zone 6. Effectively this means that the Mekong mainstream only has protected area status for about 100 km upstream of the Mun river confluence.

However, much of the river channel and some areas adjacent to it, within a 50 km corridor on each side of the Mekong are considered as Key Biodiversity Areas (KBA). These are shown in Figures 8 and 9, and listed in Table 7 (at end of section). An analysis of KBAs from IBAT (www.ibatforbusiness.org) is shown in Table 1, and this indicates that all zones have significant coverage of key biodiversity areas. The Mekong Channel is considered a KBA for at least 100 km in Zone 1, 280 kms and 215 kms at the top and bottom ends of Zone 2, 150 kms in zone 3, the 310 km or the whole of zone 4, the whole of the Tonle Sap system in Zone 5 and a number of smaller wetland areas in the Delta.

Thus for the zones 1 to 4, a total of 1,005 km out of 2040 km or about half the length of the river from Chinese border to Kratie are considered to be KBAs. Probably this would be more if further biodiversity assessments were carried out, e.g. between Pak Lay and Louangprabang. Much of the KBAs are based upon assessments for Important Bird Areas by BirdLife, but since birds are usually the most studied of taxa, they are considered to be indicative of high biodiversity values. Certainly the biodiversity of Zone 4 is outstanding, mirrored also by the fish species diversity (see Aquatic systems baseline)

Table 1: 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+

5.1.8 FOREST COVER

With little protection afforded to the terrestrial landscapes along the 50 km corridor on each side of the Mekong mainstream it is not surprising that the forest cover is quite degraded even in Zones 1 and 2. Ease of access to the hillsides along the Mekong in these zones, have resulted in logging and swidden agriculture, so that much of the remaining forest cover is all secondary growth. In Zone 3, the river passes through mostly agricultural landscapes, especially on the Thai side, and most of the forest cover has been lost, except for the reach above the Mun river confluence which retains some good forest cover, mainly deciduous dipterocarp; this is the length of the mainstream where protection on both sides of the river has been established. In Zone 4, whilst the areas of flooded forests in Stung Treng and Kratie remain, the riparian forest cover has been modified significantly, especially in Siphandone, and increasingly in Stung Treng and Kratie being removed by both communities and economic land concessions, which sometimes extend to the river bank. In Zone 5, although mainly floodplain, agricultural areas, the main forested areas of concern are the flooded forests around Tonle Sap, e.g. at Prek Toal, which are susceptible to changes in the extent and depth of flooding.

Table 2 shows an estimate of the different landuses (cultivated land, forest cover, open land, wetlands and built-up areas) for each of the zones within a 50 km corridor on each side of the Mekong made for this SEA from the 2003 landuse data available from MRC. This shows the preponderance of forest cover in Zones 1 and 2, and 4 (about 80 – 90%); the increasing importance of agricultural land in Zones 3, 5 and 6 (ranging from 41 to 67%); and increasing areas of wetland with progression down the zones, with nearly 10% of landcover in Zone 6. The built-up, urban areas are quite extensive in the Delta, especially along the eastern channels of the Mekong in Ben Tre province.

5.1.9 LAND USE - AGRICULTURE

Throughout its length, the land along the Mekong is used in different ways for agricultural purposes. In Zones 1 and 2, one of the main agricultural practices is swidden – slash and burn – along the hillsides. Where there are lower-lying flat areas beside the river, or at the confluences with tributaries, more permanent forms of cultivation have been established. Table 8 (at end of the section) shows the land use areas in key selected districts in Laos bordering on the Mekong, featuring the agricultural and forest areas. It is clear that the districts in Zone 2 have a very much higher extent of forest cover, between 50 – 70%, which decreases at Pak Lay, Vientiane and in Champassak, though Khong District has a high proportion of protected forests. Upland rice areas are highest in Xayaboury and Paklay, Lowland paddy high in Louangprabang, Pakse and Khong districts. There are large concession areas in Pakbeng (Oudomxay). Table 3 shows the less detailed distribution of agriculture and forestry and other land uses in key provinces in Thailand, Cambodia and Vietnam.

Table 2: Landuse and forest cover by zone in 50km corridor of the Mekong

Zone	1	2	3	4	5	6
	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
	sq.km	sq.km	sq.km	sq.km	sq.km	sq.km
Paddy field	500.22	3,655.09	22,916.31	1,625.64	13,910.25	19,810.05
Orchard	13.88	420.83	94.53	0.00	4.63	0.00
Field crop	123.48	3,418.93	2,467.25	91.59	2,317.79	1,518.06
Swidden cultivation	177.07	1,000.27	37.61	64.94	1,264.64	130.04
Total cultivated land	***814.65***	***8,495.12***	***25,515.70***	***1,782.17***	***17,497.32***	***21,458.14***
% cultivated land	***8.91***	***15.88***	***41.80***	***5.73***	***41.24***	***67.50***
Industrial plantation	0.00	51.49	1,329.19	537.23	693.20	0.00
Forest plantation	0.00	0.00	0.00	0.00	0.00	74.11
Bamboo forest	17.51	1,869.33	105.00	932.07	1,388.53	2.81
Coniferous forest	0.00	0.00	8.54	2.60	0.00	0.00
Deciduous forest	4,993.43	16,800.19	13,801.33	13,022.97	2,548.89	2.55
Evergreen forest	3,116.75	24,566.91	15,932.43	11,527.22	3,338.99	2.57
Total forest cover	***8,127.69***	***43,287.91***	***31,176.50***	***26,022.09***	***7,969.62***	***82.03***
% forest	***88.91***	***80.90***	***51.07***	***83.73***	***18.79***	***0.26***
Barren land	0.00	5.53	1,342.46	12.79	103.31	54.26
Grassland	123.03	575.19	242.91	222.68	4,067.18	1,565.94
Shrubland	0.00	299.10	588.57	998.65	9,046.38	906.61
Total open land	***123.03***	***879.81***	***2,173.93***	***1,234.12***	***13,216.87***	***2,526.82***
% open land	***1.35***	***1.64***	***3.56***	***3.97***	***31.15***	***7.95***
Flooded forest	0.00	0.00	15.75	1,016.22	305.16	388.36
Mangrove forest	0.00	0.00	0.00	0.00	0.00	146.99
Marsh and Swamp	0.00	26.61	344.39	156.37	26.39	2.70
Natural Water body	46.13	521.08	1,419.15	844.33	3,382.24	1,765.57
Aquaculture	0.00	3.82	7.18	0.00	0.00	765.84
Total wetlands	***46.13***	***551.51***	***1,786.46***	***2,016.92***	***3,713.79***	***3,069.46***
% wetlands	***0.50***	***1.03***	***2.93***	***6.49***	***8.75***	***9.66***
Built-up area	30.16	295.95	395.55	22.68	25.69	4,654.41
% Built-up	***0.33***	***0.55***	***0.65***	***0.07***	***0.06***	***14.64***
TOTAL	**9,141.66**	**53,510.29**	**61,048.14**	**31,077.98**	**42,423.28**	**31,790.85**

Source: GIS analysis of 2003 landuse data, MRC

Table 3: Areas of forest and agriculture land uses in NE Thailand, Cambodia and Vietnam

	Forest	Agriculture	Residential & Roads		Water body	Others
	ha	ha	ha	ha	ha	ha
NE Thailand	36,047	111,786	8,164		5,244	7629.0608
%	21.35	66.2	4.83		3.11	4.51
- Chiang Rai	43.70%	27.50%				
- Phayao	50.30%	26.20%				
- Loei	37.50%	32.10%				
- Nong Khai	9.10%	57.50%				
- Nakhon Phanom	24%	43.00%				
- Ubon Ratchatani	17.20%	63.10%				
	Forest	**Agriculture**	**Residential**	**Roads**	**Water body**	**Plantation**
Cambodia	**ha**	**ha**	**ha**	**ha**	**ha**	**ha**
Stung Treng	928,000	126,836	103217	2496	41,094	9,750
%	76.61	10.47	8.52	0.21	3.39	0.80
Kratie	926349	88752			88752	
%	83.50	8.00			8.00	
	Forest	**Agriculture**				
	%	**%**				
Vietnam Delta	8.30%	63.10%				

5.1.10 VALUE OF PADDY AGRICULTURE IN THE DIFFERENT ZONES

Based upon the area of agricultural land used for paddy rice production in each of the zones, taken from Table 2 above, and applying the average yields of rice in tones per hectare per year appropriate for each zone, and using a value of rice at 0.2 USD per kg, the current value of rice production in the 50 km corridor on each side of the Mekong mainstream has been estimated. These calculations are shown in Table 4. A comparison of the different zones, shows a relatively small value of rice production in Zone 1, increasing through Zone 2, to the very high annual values for Zone 3, which illustrates particularly the intensity of rice production in NE Thailand. Zone 4 has a relatively low value of rice production, largely because of the less appropriate topography around the river and low levels of agricultural development and irrigation in Stung Treng and Kratie. This is highlighted by a comparison of the areas and rice yields for the Cambodian Mekong mainstream provinces shown in Table 5. The highest value of rice production occurs in the Delta in Zone 6, where production is focused on the productive strip of alluvial soils on either side of the Mekong distributary channels.

Table 4: Zone estimates of the annual value of paddy rice production in 50 km corridor of the Mekong mainstream

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	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 $US/kg	**US$ million**	**10.00**	**146.20**	**1,604.14**	**84.53**	**723.33**	**1,981.00**

(Yields and values taken from MRC, 2009)

Table 5: Areas and yields of wet season and dry season (rainfed and irrigated) rice paddy in Mekong mainstream provinces in Cambodia.

Zone	Province	Wet season	Yield	Dry season	Yield
		ha	t rice/ha/a	ha	t rice/ha/a
4	Stung Treng	23,045	2.5	0	
	Kratie	29,778	2.58	13,979	2.518
5	Kampong Cham	166,285	3.01	52993	3.78
	Kampong Chhnang	105,222	2.584	22914	3.827
	Kampong Thom	164,279	2.186	20,468	3.749
6	Kandal	43,507	2.926	57170	4.145
	Prey Veng	250,339	2.754	72654	4.2

National rice yields throughout the four LMB countries have been increasing at a rate of about 3% per year, largely due to improvements in technology, and to some extent an increase in the proportion of land under irrigation. It is projected that by 2030, yields in Cambodia, Laos and Thailand will have reached 4.4, 5.9 and 5.1 t/ha (MRC, BDP technical note on Agriculture, 2009). For Vietnam it is not expected that rice yields in the Delta will increase significantly more than the present levels of 5.2 t/ha.

5.1.11 RIVER BANK GARDENS

There has been very little definitive study on the importance of river bank gardens along the Mekong, although they are widely recognized as contributing significantly both to income and subsistence provision of fresh vegetables, maize, and crops such as tobacco. River bank gardens are cultivated within the river channel as the water levels start to recede from October/November. They benefit from the nutrients deposited during the wet season, and easy access to the river for watering the gardens. River bank gardens are cultivated near communities wherever the banks and exposed sandbars are suitable, i.e. not too steep and eroding. Most of the information used here comes from estimates of impacts made by EIAs of mainstream dams (Pak Beng, Pak Lay, Xayaburi, and Pak Chom) as well as studies in Siphandone (Daconto, 2001) and Stung Treng (Allen et al, 2008).

The size of river bank gardens varies from very small plots of less than 0.1 ha per household through an average of about 0.25 ha/hh (e.g. at Pak Beng) to an average of 0.8 ha/hh in Loei, Thailand, around Pak Chom, and up to 0.5 ha/hh in Stung Treng. A first estimate of the areas and production of vegetables in river bank gardens in each zone has been attempted using the river dependent populations living within a 15 km distance of the river. (MRC IBFM Social assessment 2007). A recent assessment of vulnerability of river dependent populations shows the proportions of households in this corridor using river bank gardens, which ranges from 7% in Cambodia, 11% in Thailand and 14% in Laos, up to 29% in Vietnam. (MRC, SIMVA report 2010) The case of Vietnam is different from the other countries because many of these gardens are cultivated on canal banks away from the river, so potentially covers a much larger area.

Calculations on the yield and value of vegetable production from river bank gardens in each of the zones shown in Table 6, indicate that the total area of river bank gardens in Zones 1 and 2 would be 2,166 ha, in Zone 3 the area would be 7,320 ha, in Zone 4 the area would be 1,278 ha, and in Zone 5, 12.358 ha. These areas could yield mixed vegetable crops with values USD 10.4 million per year for Zone 1, USD 40.3 million per year for Zone 2, and USD 6.14 million per year for Zone 3. For maize and beans the value in USD/year is about one third of the value of mixed vegetables. It should be noted that most of these crops are used for household consumption, with usually surpluses being sold. Most households grow a variety of crops, which makes estimates of yield and value complicated. (Blake 2004)

Table 6: Estimates of size and value of river bank gardens in each zone

No.	Ecological Zone	River dependent rural population (2005)	River dependent HH within 15 km	% of HH using RBGs	Number of HH per zone with RBGs	Average area of RBG per HH	Total area of RBG	Yield of Vegetables	Total value per year
								@0.6 kg/sq.m	@$0.8/kg
						ha	ha	Tonnes	US $ million
1	China to Chiang Saen	NA							
2	Chiang Saen to Vientiane	313,939	62,788	14	8,665	0.25	2,166	12,997	10.40
3	Vientiane to Pakse	1,343,182	268,636	13	33,580	0.25	8,395	50,369	40.30
4	Pakse to Kratie	232,397	46,479	11	5,113	0.25	1,278	7,669	6.14
5	Kratie to Phnom Penh and Tonle Sap	3,581,952	716,390	7	49,431	0.25	12,358	74,146	59.32
6	Phnom Penh to the sea	6,482,368	1,296,474	29	381,163	0.25	95,291	571,745	457.40

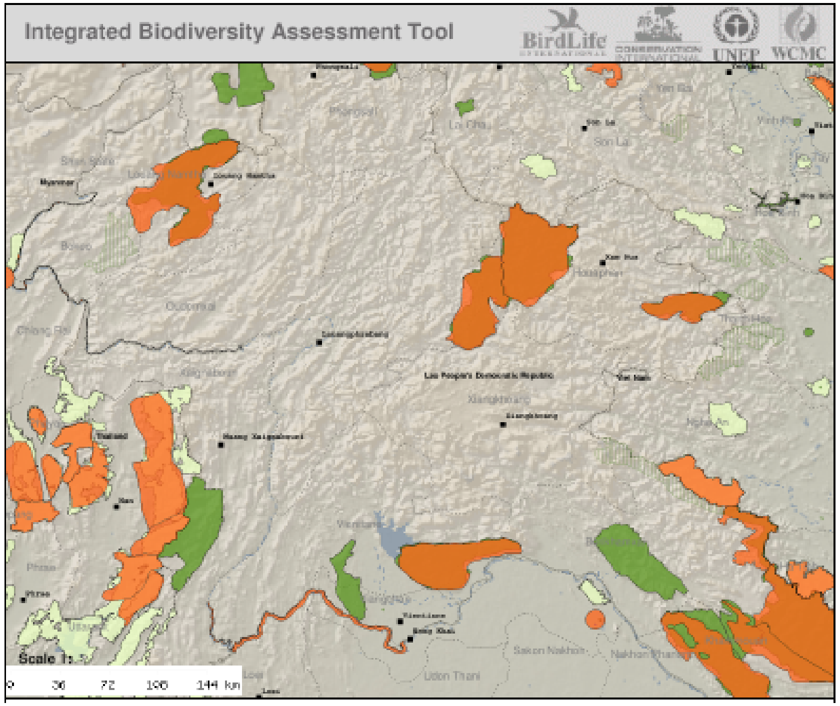
Notes:
1. River dependent population within 15 km corridor as estimated by IBFM Social report, MRC 2005
2. Assuming 5 persons per household
3. % of HH using RBGs from estimates of MRC 2010, SIMVA report
4. % of HH in zone 3 is average between Thailand and Laos; in zone 4 is average between Laso and Cambodia
5. Estimates of yield and value of vegetables taken as a composite of provincial and market values

5.1.12 SUMMARY

The terrestrial ecosystems surrounding the Mekong as represented by the landuse and forest cover, start from extensive forest cover in Zones 1 and 2, which decreases markedly as the river passes through zones 3, 4, 5 and 6; agricultural land use becomes progressively higher percentage, especially in NE Thailand, southern Laos, and below Kratie in Zone 5 and in the Delta. Government policies tend to be towards intensification of agriculture, with increased irrigation in Laos and Cambodia. In NE Thailand water for further irrigation is a limiting factor, and availability of suitable land is a limiting factor in the Vietnam Delta. There are very few protected areas along the Mekong, but much of the Mekong corridor has been recognized as a series of Key Biodiversity Areas, albeit with little effective protection. River bank gardens have been recognized as an important contributor to the livelihoods of riparian communities, and although these have not been systematically studied, their contribution in each zone has been estimated of the order of 10 – 60 million US per year.

Figure 8: Key Biodiversity areas (red) & Protected Areas (green or white areas) in Zones 1 & 2, 3

a) Zones 1 & 2



b) Zone 3

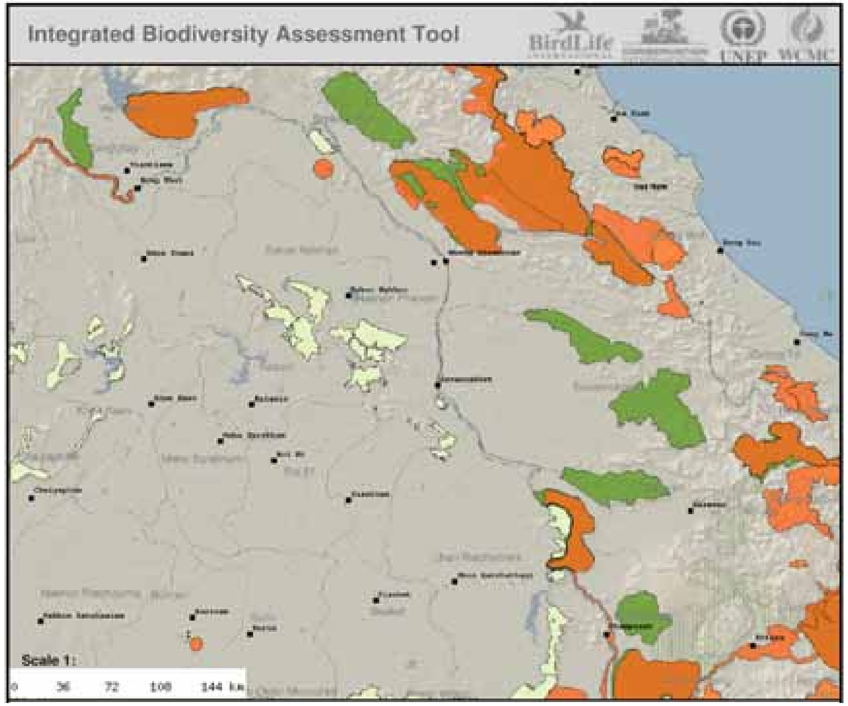
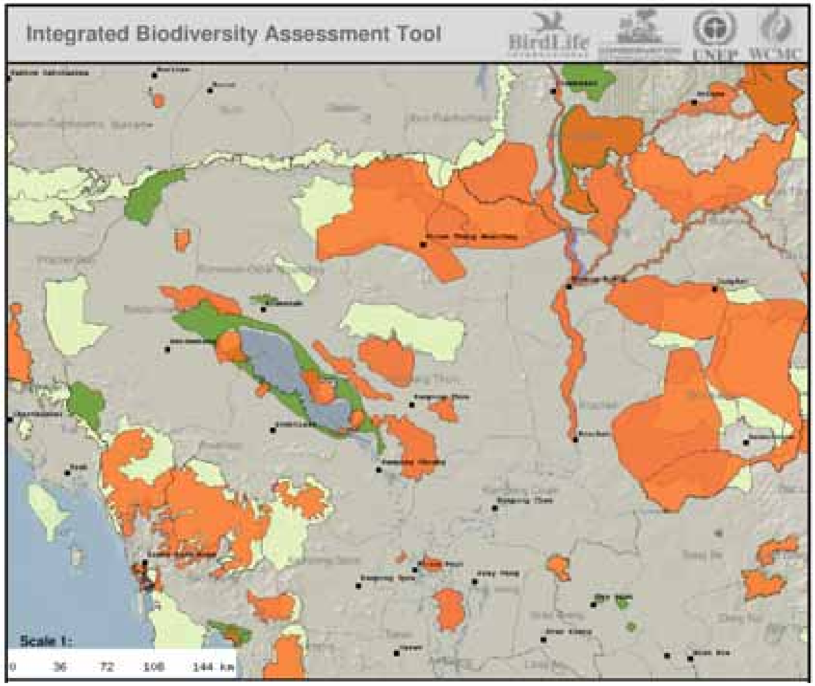


Figure 9: Key Biodiversity areas (red) & Protected Areas (green or white areas) in Zones 4, 5 & 6

a) Zones 4 and 5



b) Zone 6

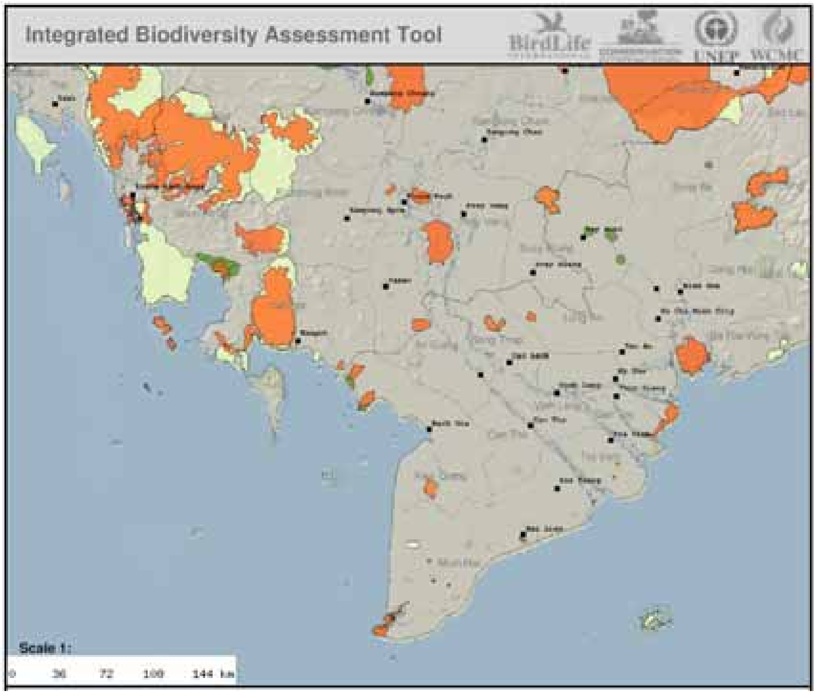


Table 7: List of Key Biodiversity Areas and Protected Areas adjacent to the Mekong by Zone						
Zone	**Country**	**Name**	**IBA number**	**Protection status**	**Area (ha)**	**Mekong connection and importance**
1	Laos	Upper Lao Mekong	IBA La027	None	10,980	Mekong channel and valley in Province of Bokeo, from the Nam Pha confluence to Chiang Saen. Important for congregatory waterbirds, esp. Small Pratincole, River Lapwing
	Myanmar	Parsar		Protected Area	7770	Golden triangle just upstream of Chiang Saen, along right bank of Mekong
2	Thailand	Chiang Saen Basin/ Nong Bong Kai Non Hunting Area	IBA Th007	Partly protected/ Ramsar site	6240/ 433.8	Wetland associated with tributary of Mekong. Major habitat for local and migratory water birds and congregatory species, esp Spotted Redshank and Small Pratincole
	Laos	Upper Lao Mekong	IBA La027	None	10,980	as above Mekong channel and valley in Provinces of Bokeo, Oudomxai and Xaignabouli. From Chiang Saen to 80 km below Pak Beng. Important for congregatory waterbirds, esp. Small Pratincole, River Lapwing
	Laos	Mekong channel upstream of Vientiane	IBA La006	None	18,230	Mekong channel and valley in Provinces of Vientiane and Xaignabouli. From Pak Lay to Vientiane. Important for congregatory waterbirds, esp. Small Pratincole, River Lapwing
	Laos	Nam Phui		Protected Area	191,200	National protected area about 20 - 30 km west of Mekong between Xayabouri - PakLay road to east, westwards to Thai border. Mixed deciduous forests on sandstone ridges
	Laos	Phou Phanang		Protected Area	70,000	National protected area in watershed between Nam Thon & Nam Ngum watersheds. North of Mekong, southern tip touches river c. 30 km west of Vientiane. Degraded forest with semi-evergreen forest patches

Table 7: List of Key Biodiversity Areas and Protected Areas adjacent to the Mekong by Zone						
Zone	**Country**	**Name**	**IBA number**	**Protection status**	**Area (ha)**	**Mekong connection and importance**
	Thailand	Mekong Channel near Pakchom	IBA Th022	None	18,890	Provinces of Loei and Nong Khai, Important for congregatory waterbirds, esp. Small Pratincole, River Lapwing
3	Thailand	Kud Ting, Nong Khai		Ramsar site		New Thai Ramsar site.(details to be provided)
	Thailand	Bung Khong Long Non-hunting area	IBA Th021	Ramsar site	2,214	Nong Khai province, wetland important for migratory wildfowl, esp. Baer's Pochard. N. of Songkhram floodplain, 15 km from Mekong
	Thailand	Songkhram River basin		Proposed Ramsar site		Proposed Thai Ramsar site covering Songkhram river floodplain in Nakhon Phanom and Sakhon Nakhon (details to be provided)
	Laos	Phou Xiang Thong / Houay-Kok-Houay Phalaphang IBA	IBA La014	Protected Area	120,000 / 36,650	Sandstone escarpment, similar to opposite Pha Taem in Thailand. Dry deciduous dipterocarp forest. Plateau drains to Mekong. Extends along Mekong for about 100 km. seasonally exposed sandbanks, small alluvial fans and rocks in river
	Thailand	Pha Taem		National Park	34,000	Sandstone cliffs overlooking Mekong, with exotic rock formations. Deciduous dipterocarp forests. 3000 yr old rock paintings. Extends along Mekong from Khong Chiam, Si Muang Mai and Pho Sai districts
	Thailand	Kaeng Tana		National Park	8,000	South of Mun and Sirindhorn river confluence, south of Pha Taem NP, downstream of Pak Mun dam. Dry dipterocarp forests. Numerous cataracts on Mun River
	Laos	Mekong channel (Phou Xiang Thong – Siphandone)	IBA La007	None	34,200	Extends from Phou Xiang Thong along Mekong down to Siphandone. Important for congregatory water birds, especially Small pratincole. Part of endemic bird area for Lower mekong River basin, especially Mekong Wagtail

Table 7: List of Key Biodiversity Areas and Protected Areas adjacent to the Mekong by Zone						
Zone	**Country**	**Name**	**IBA number**	**Protection status**	**Area (ha)**	**Mekong connection and importance**
4	Laos	Siphandone	IBA La022	None	37,320	Champasak province, braided river channels and islands of Mekong, forests, grasslands, wetlands. Threatened species - White rumped vulture, Congregatory water birds, small pratincole. Lower Mekong basin endemic bird area.
	Laos	Dong Khanthung	IBA La005	PA (proposed)	191,560	SW corner of Champasak province, forest and wetlands between 90 - 500 m asl, west of Mekong, adjacent to Siphandone. Important for White winged duck, Giant Ibis, White rumped vulture and red headed vulture
	Laos	Xe Pian / Dong Kalo	IBA La021	Protected area	240,000 / 41460	Xe Pian east of Mekong to Sekong and Bolevan. IBA is wetlands part of Xe Pian. Important for Giant Ibis and Greater adjutant.
	Cambodia	Mekong River (Kratie - Lao PDR border)	IBA Kh023	None	83,501	Riverine forests and wetlands, islands in main channel. Lower Mekong Endemic bird area. Important for White shouldered ibis, white rumped vulture. River dolphins in deep pools
	Cambodia	Stung Treng		Ramsar site with no protection status		Ramsar site, 40 km of Mekong channel. River tern, River Lapwing, Mekong wagtail, Masked finfoot, Elds deer, Hog deer, Siamese crocodile, softshell turtles
	Cambodia	Chhep	IBA Kh 007	None	243,661	Preah Vihar and Stung treng Provinces, west of Mekong adjacent to Stung Treng Ramsar site. Grassland,shrubland and wetlands, important for Adjutants, Giant ibia White winged duck, Sarus Crane, vultures
	Cambodia	Dolphin Special management zone		Proposed	33,808	Special management zone proposed by WWF between Sambor and Siembok and deep pool at Kampi, with specified dolphin conservation area

Table 7: List of Key Biodiversity Areas and Protected Areas adjacent to the Mekong by Zone						
Zone	**Country**	**Name**	**IBA number**	**Protection status**	**Area (ha)**	**Mekong connection and importance**
	Cambodia	Kratie Hog Deer protected area		Proposed	51,848	Proposed by WWF for protection of Hog Deer, floodplain west bank of Mekong between Sambor and Kratie.
	Cambodia	Tonle Sap		Biosphere Reserve		Whole of the Great Lake is considered as multiple use UNESCO Biosphere reserve. Contains seven fish sanctuaries
	Cambodia	Prek Toal	IBA Kh003	Protected area	39,873	Battambang province, Flooded forests, shrublands, wetlands to north west end of Tonle Sap lake. Important for breeding colonies of congregatory waterbirds, Pelicans, Painted stork, adjutants, masked finfoot, darter
	Cambodia	Boeung Chhmar	IBA Kh015	Ramsar site	39405 / 28,000	Forest and wetlands at lower end (north side) of Tonle Sap floodplain. Important for congreagtory waterbirds, Pelicans, Adjutants, Masked finfoot, Darter.
	Cambodia	Stung Sen/Santuk/Baray	IBA Kh021	None	109,081	Kampong Cham, K. Chhnang, K. Thom. Grasslands, shrublands and wetlands in floodplains between Mekong and Tonle sap river. Important for Sarus crane, bengal florican, Greater Adjutant, white shouldered ibis.
	Cambodia	Basset Marsh	IBA Kh036	None	2,270	North of Phnom Penh, west side of Tonle Sap river. Important for pelicans
5	Cambodia	Boeung Veal Samnap	IBA Kh037	None	11,286	in Kandal province, floodplain shrublands and wetlands on east side of Mekong, opposite Phnom Penh. Important for pelicans
	Cambodia	Bassac Marsh	IBA Kh038	None	52,316	in Kandal province, floodplain shrublands and wetlands between Mekong and Bassac rivers. Important for pelicans and Whiskered tern

Table 7: List of Key Biodiversity Areas and Protected Areas adjacent to the Mekong by Zone						
Zone	**Country**	**Name**	**IBA number**	**Protection status**	**Area (ha)**	**Mekong connection and importance**
6	Cambodia	Boeung Prek Lapouv	IBA Kh039	None	9,276	Takeo province, on Cambodia/Vietnamese border near Chau Doc. Bassac river floodplain, grasslands and wetlands. Important for Pelicans, Sarus crane, Bengal florican
	Vietnam[7]	Tra Su		Nature reserve, Special use forest	2,200	An Giang Province. Grassland and swamps and Melaleuca forest, important for breeding colonies of water birds, including purple heron, night heron, Oriental darter
	Vietnam	Nui Cam		Nature reserve	1,500	An Giang Province. 710 m high mountain area of secondary and plantation forest surrounded by rice fields.
	Vietnam	Tram Chim	IBA Vn006	National Park	7,588	Remnant of Plain of Reeds in Dong Thap province to east side of Mekong. Floodplain grasslands, wetlands, melaleuca forest. Water birds, Sarus crane, painted stork
	Vietnam	Lang Sen	IBA Vn007	Provincial reserve	5,500	Remnant of Plain of Reeds in Long An province to east side of Mekong. Floodplain grasslands, wetlands, natural melaleuca forest. Water birds, Sarus crane
	Vietnam	Lung Nuoc Hoang		Nature reserve	6,000	Can Tho Province. Melaleuca forest with small patches of open water and grassland. Wetland bird species.
	Vietnam	Thanh Phu		Nature reserve	4,510	Ben Tre Province coastal landscape consists of sandy belts, tidal mudflats, saline tidal swamps and toxic acid-sulphate swamps, mangroves. Important for shorebirds and breeding for commercial fish, prawn
	Vietnam	Tra Cu	IBA Vn009	None	2	Tra Vinh province, 20 km from Dinh An mouth of Mekong. Agricultural landscape, Black crowned night heron

[7] The Key Biodiversity and Protected Areas in the Delta listed lie within 50 kms of the 9 channels of the Mekong Delta.

Table 7: List of Key Biodiversity Areas and Protected Areas adjacent to the Mekong by Zone						
Zone	**Country**	**Name**	**IBA number**	**Protection status**	**Area (ha)**	**Mekong connection and importance**
	Vietnam	Chua Hang	IBA Vn010	None	2	Tra Vinh province, 20 km from Cung Hau mouth of Mekong. Agricultural landscape, Black crowned night heron
	Vietnam	Bac Lieu Bird Sanctuary		Nature reserve	127	Bac Lieu Province. Remnant elevated mangrove forest. Important as one of largest breeding colonies of water birds in Delta

Table 8: Land use categories in selected Mekong districts in Laos

Province	Bokeo		Oudomxay		Louangprabang		Xayabury				Vientiane		Champassak			
District	Paktha		Pakbeng		Nan		Sayaboury		PakLay		Med		Pakse		Khong	
Land use	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Total area	**75,550**		**81,712**		**189,515**		**391,600**		**219,648**		**117,600**		**12,507**		**171,824**	
Garden	28,858	38.20	4,463	5.46	0	0.00	19,256	4.92	20,795	9.47	1,447	1.23	3,498	27.97	506	0.29
Lowland paddy	1,448	1.92	314	0.38	47,919	25.29	17,350	4.43	1,558	0.71	1,743	1.48	1,523	12.18	28,570	16.63
Upland rice	2,985	3.95	1,556	1.90	5,135	2.71	35,800	9.14	109,130	49.68	2,105	1.79	0	0.00	0	0.00
Orchard	3,553	4.70	0	0.00	0	0.00	1,263	0.32	1,840	0.84	500	0.43	0	0.00	200	0.12
Grazing	100	0.13	704	0.86	9,455	4.99	1,600	0.41	13,508	6.15	320	0.27	0	0.00	4,074	2.37
Concession	150	0.20	23,856	29.20	81	0.04	0	0.00	20,000	9.11	3,846	3.27	0	0.00	0	0.00
Total agriculture	37,094	49.10	30,893	37.81	62,590	33.03	75,268	19.22	166,831	75.95	9,961	8.47	5,021	40.15	33,350	19.41
NBCA	10,009	13.25	11,532	14.11	8,780	4.63	211,529	54.02	12,225	5.57	0	0.00	0	0.00	46,000	26.77
Regeneration forest	2,136	2.83	1,563	1.91	11,500	6.07	13,700	3.50	2,821	1.28	2,500	2.13	0	0.00	0	0.00
Production forest	200	0.26	4,583	5.61	50,959	26.89	8,300	2.12	5,125	2.33	0	0.00	0	0.00	0	0.00
Protection forest	22,500	29.78	10,575	12.94	33,800	17.84	11,200	2.86	13,165	5.99	0	0.00	0	0.00	76,500	44.52
Spirit forest	36	0.05	200	0.24	0	0.00	250	0.06	150	0.07	70	0.06	0	0.00	114	0.07
Cemetary/burial forest	36	0.05	150	0.18	0	0.00	350	0.09	225	0.10	120	0.10	2	0.02	228	0.13
Others	250	0.33	22,021	26.95	0	0.00	30,000	7.66	5,000	2.28	102,163	86.87	0	0.00	14,358	8.36
Total forest	35,167	46.55	50,624	61.95	105,039	55.43	275,329	70.31	38,711	17.62	104,853	89.16	2	0.02	137,200	79.85
Residential	2,929	3.88	95	0.12	21,886	11.55	37,503	9.58	11,976	5.45	2,386	2.03	5,588	44.68	1,174	0.68
Public buildings	360	0.48	100	0.12	0	0.00	3,500	0.89	2,130	0.97	400	0.34	1,896	15.16	100	0.06
Total buildings	3,289	4.35	195	0.24	21,886	11.55	41,003	10.47	14,106	6.42	2,786	2.37	7,484	59.84	1,274	0.74

5.2 FUTURE TRENDS WITHOUT THE LMB MAINSTREAM HYDROPOWER DEVELOPMENT

5.2.1 ZONE 1

In Zone 1, increased access to the corridor surrounding the Mekong, resulting from road construction and improved navigation will continue to put pressure upon the terrestrial ecosystem, increasing illegal logging, hunting and the wildlife trade. Whilst the Laos official policy is to reduce swidden agriculture throughout the country, the pressures are such that it will be difficult to reduce swidden agriculture significantly in Zone 1. Population growth, shortage of suitable land for other forms of agriculture will lead to reducing rotation times and increased degradation of the hillsides surrounding the Mekong.

In summary: Pressure on terrestrial environment of Zone 1 will be increased due to increased access and growth of populations using swidden agriculture, with continued degradation

5.2.2 ZONE 2

The generally forested hillsides In Zone 2 that make up much of the terrestrial ecosystems, are under pressure from logging, especially in Nan District, Louangbrabang, which has a very high proportion of production forests. The presence of forest industries along the riverbank in zone 2 points to the importance of the production forests and navigation for transport of timber. Other Mekong districts have a higher proportion of protected forests (NPAs, regeneration forests and protection forests) may be under pressure from illegal logging, hunting and the wildlife trade. Swidden agriculture also predominates in Xayabury and Paklay districts (nearly 10% and 49% upland rice production). Growing populations and shortage of available land for other agriculture will make conversion from swidden agriculture difficult. However, the extent of lowland paddy is much higher in Louangprabang, but the availability of flat land limited, so additional growth is not expected. River bank gardens throughout the zone are important for local livelihoods, but under the changing patterns of dry season flows and lower transport of sediments expected from the Chinese dams over the next 20 years, there will be changes in productivity of the river bank gardens, and some of the planting on sandbars may be lost. The extent of the gardens on the riverbanks should remain the same. Concessions in for agroforestry in the zone are growing and are high in Oudomxay, giving rise to changes in the natural ecosystem. There are no plans for extending the protected area system in Zone 2, although about 500 km of the river channel out of 800 km in Zone 2 has been identified as Key Biodiversity Areas.

In summary: Pressures upon natural forests in Zone 2 will continue over the next 20 years, with limited room for expansion of permanent areas of agriculture. River bank gardens will continue to provide important livelihood contributions for riparian communities. No additional protection or conservation measures are expected.

5.2.3 ZONE 3

In Zone 3, there will be a tendency for agriculture on the Laos side to intensify, whilst agriculture on the Thai side may be expected to benefit from increased water availability in the Mekong in the dry season as a result of the higher levels of water being released from the Chinese and tributary dams in Laos. The raised dry season water levels (increased by 1 – 2 m) will not significantly affect the extent of river bank gardens, since most riverbank cultivation is carried out on the top 8m of river bank. In terms of forest cover and protection, about 100 km of the 715 km of the river channel is protected, and whilst on the Thai side in Pha Taem NP, public access is already relatively good, and used extensively by tourists, on the Laos side in Phou Xiang Tong NPA, public access is currently being improved through road construction to the southern end of the protected area (near to proposed Ban Kum dam site). It is to be expected that pressure on this protected area will increase as a result. (see Figure 8)

By 2030, Laos is planning to have extended its total irrigable area from 166, 476 ha to 451,296 ha – an increase of about 2.5 times. Thailand is projected to have almost doubled its irrigable area from 1.412 million ha to 2.718 million ha. Most of these increases will occur in Zone 3. (MRC, BDP Technical note 2009).

In summary: Potentially increased agriculture production from new irrigated areas in Laos and increased availability of water in the dry season in Thailand. Some degradation of the protected areas in Laos due to improved access.

5.2.4 ZONE 4

In Zone 4, the potential for dry season irrigation will be increased as a result of the raised dry season water levels in the river, especially in Champassak province in Laos. River bank gardens are expected to remain more or less the same over the next 20 years. Pressure on natural terrestrial systems, especially from illegal logging, hunting and the wildlife trade in Siphandone, Stung Treng and Kratie provinces in Cambodia are expected to continue.

Large-scale urban and tourism resort developments are being planned around the Khone Falls area, capitalizing on the tourism attractiveness of the area. Changes in land use surrounding the river has also been responsible for loss of gallery forest and riverine vegetation, conversion into agricultural areas and concessions that are reported to have damaged local fisheries.

Landuse in Stung Treng and Kratie is also experiencing rapid change, especially through the allocation of economic land concessions and mining concessions. In 1997, the landuse maps of showed no plantations in zone 4. By 2003, there were 57,300 ha of industrial plantation in Zone 4 and 69,300 ha in Zone 5. The most recent information indicates that currently there are over 80 economic land concessions in the two provinces of Zone 4, covering a total of over 530,000 ha. (Table 9). These are mainly for development of agroforestry. This trend in growth of economic land use concessions is expected to continue.

Table 9: Extent of economic land use and mining concessions in Stung Treng and Kratie

Provinces	No of Companies	Total land allocation

Kratie	46 Economic land concession	298,071 Ha
	>1000 ha: 25 companies	281,604 Ha
	< 1000 ha: 21 companies	16,467 Ha
	21 economic land concession in Sambo district	140,192 ha
Stung Treng	13 Economic land concession	195,105 ha
	> 1,000 ha : 12 companies	194,236 ha
	<1,000 ha: 1 companies	869 ha
	13 mining companies	203,400ha

WWF reports that there is a high risk of extirpation of most of the large mammal species in the Stung Treng to Kratie area, and population declines of over 23 bird species, 6 turtle species, large lizards and snakes, and population decline of Cantor's Giant softshell turtle due to egg collection and capture, Bezuijen (2008). Additional legal protection for the Stung Treng Ramsar site is unlikely to be approved whilst decisions on the proposed Stung Treng HEP are outstanding. The proposals for the Dolphin special management zone and the Kratie Hog Deer protection area require funding and approval, and so their future is uncertain. (see Figure 9).

In summary: In Zone 4, the rapid rate of development with land use change resulting from commercial and tourism development, agriculture and economic concessions will continue to put pressure on natural terrestrial ecosystems, with risk of loss of vegetation cover and biodiversity.

5.2.5 ZONE 5

The changes in the flow patterns in both wet season and dry season resulting from the Chinese dams and tributary storage dams in Laos, will influence the patterns of the annual flood around the Tonle Sap in terms of extent, depth and duration, and this will have an effect upon the survival of the flooded forests and seasonally inundated grasslands. Agriculture in the Mekong provinces is expected to intensify with additional irrigation schemes being developed. River bank gardens will continue as before.

By 2030, Cambodia is projected to have increased its irrigable area from 504,000 ha to 778,000 ha. The total cropped area, taking into account wet, dry and third season cropping, is projected to increase from 563,000 ha to 877,000 ha by 2030. Much of this increase will take place in Zone 5 and the upper part of Zone 6.

In summary: Pressure on land use and terrestrial natural resources in Zone 5 will result from changing patterns of seasonal flooding. Agriculture is expected to intensify in the zone with increased irrigation, taking advantage of increased dry season flows.

5.2.6 ZONE 6

In Zone 6, Cambodia is planning large scale irrigation & flood protection schemes in the southern part of the country, which will affect the flows and flooding patterns. The changes in hydrology resulting from the

Chinese dams and tributary storage dams, which will tend to increase the dry season flows, may serve to push back the effects of saline intrusion, and to maintain the flushing of the acid sulphate soils in the Delta. Conversely, increased irrigation abstraction of water during the dry season upstream, may have the opposite effect.

The reduction in sediment loads being discharged from the delta as a result of sediment trapping in dams in China and in the Mekong tributaries, over the next 20 years, could have potentially a very serious impact upon the Delta, leading over the years to regression or loss of the leading edges of the Delta; it would no longer continue to grow out, as has happened in other major deltas of the world. When combined with sea level rise as a result of climate change, the implications for the extent and quality of the soils in the Delta are significant.

Nutrients associated with the fine sediments coming down the river contribute to the overall fertility of the floodplain. Reductions in the levels of sediments can be expected to reduce this contribution.

By 2030, Vietnam is projected to have increased its irrigable area in the Delta from 1.92 million ha to 2.045 million ha. Taking into account the wet, dry and third season cropping, the total cropped area is expected to increase from 4.22 million ha to 4.40 million ha. This relatively small increase illustrates the limitation of suitable land in the Delta. (MRC, BDP Technical Note on agriculture, 2009)

With increasing populations and growing scarcity of suitable land, there is continued pressure to convert the remaining natural wetland areas to agricultural land e.g. in the Plain of Reeds, and mangrove areas to aquaculture. This would result in loss of the characteristic biodiversity of the Delta.

It is expected that over the next 20 years, urban areas in the Delta will expand, especially around the major centres of Can Tho and My Tho and in Ben Tre province, with resulting loss of agricultural land.

In summary: Agricultural production in the Delta will not increase significantly over the next 20 years, and soil conditions will be affected by changing conditions of saline intrusion, flushing of acid-sulphate soils and erosion of the delta.

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6 AQUATIC ECOSYSTEMS

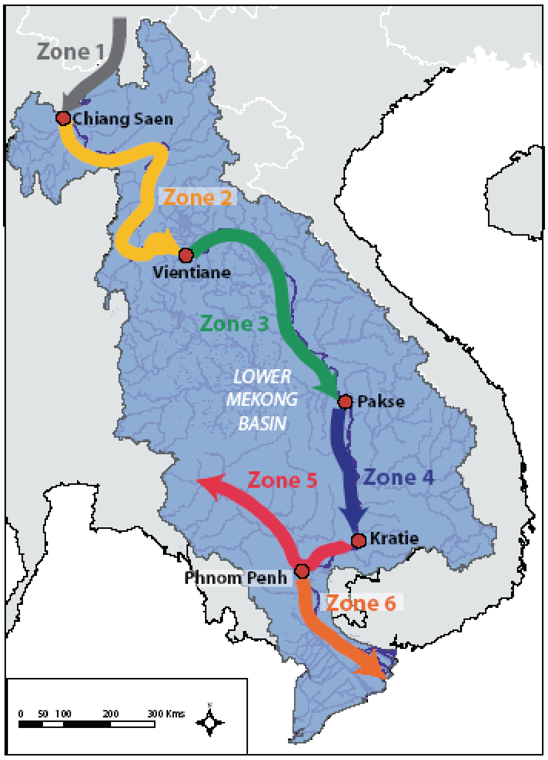
Themes and issues

Theme	*Key issues (relevant to hydropower)*
Aquatic ecosystems	• Productivity of aquatic habitats in the Mekong • Biodiversity of aquatic habitats in the Mekong • The capacity of the Mekong's ecosystem regulating services – purification and water quality • Value of Mekong River's cultural ecosystem services – inspiration, recreation and tourism

6.1 HYDRO-ECOLOGICAL ZONES

Analysis of the impacts of the mainstream dams under this theme is arranged into the recognized hydro-ecological zones of the Mekong as shown in the diagram, Figure 1, followed by a discussion of the key issues. Maps of the topography and landcover in each zone are shown in the Terrestrial ecosystems baseline, taken from the MRC's Land and Forest cover data sets, 1997. The character of the river channel in the different zones is illustrated by more detailed maps of the proposed mainstream dam sites in zones, 2, 3 and 4.

Figure 25: Main aquatic ecological zones of the Mekong



Hydro-**ecological zones considered**:

- **Zone 1** – China to Chiang Saen – headwaters and mountain river
- **Zone 2** – Chiang Saen to Vientiane – upland river in steep narrow valley
- **Zone 3** – Vientiane to Pakse – the Thai/Lao midstream section
- **Zone 4** – Pakse to Kratie, including wetlands of Siphandone, Khone Falls, Stung Treng and Kratie,
- **Zone 5** – Kratie to Phnom Penh and the Tonle Sap - Floodplains and the Great Lake
- **Zone 6** – Phnom Penh to the sea – Mekong delta, tidal zone

6.2 PAST TRENDS AND CURRENT SITUATION

6.2.1 ZONE 1

This zone covers the headwaters and mountain river section in China (over 1900 km), flowing between Myanmar and Laos to the Golden Triangle, reaching Chiang Saen after 2260 km from the source, (2240 km from the mouth). It is a steep mountain river, flowing through narrow gorges with a very small catchment and relying heavily upon snow meltwaters. Flowing between Laos and Myanmar, the river continues through a series of massive rocky outcrops and rapids alternating with deep pools and exposed sandbars in the low flow season. Approaching Chiang Saen it widens and slows in a more meandering course, with associated wetlands and reedbeds to the south of Chiang Saen. The water quality is generally overall excellent, with high Total Suspended Solids, but with some evidence of toxicity (arsenic, chromium and mercury) in the sediments at the Chinese border, possibly as a result of industrial and urban pollution upstream, which underlies the poor ecological health of the river at Ban Xieng Kok. A number of major rapids have been removed to improve navigation. Aquatic invertebrates are typical of such fast flowing rivers. 162 species of fish recorded in the Lancang river, of which at least 61 species are common with fish species in the Lower Mekong Basin. At least 157 species of fish recorded in surveys in 2003 and 2004 for the stretch between Xieng Kok and Louangprabang. Fishing activities tend to be focused around the small communities for local livelihoods, using deep pools and rocky and shoal areas. A total of 87 species of river dependent birds reported. No information available on reptiles and amphibians or river dependent mammals, but it is probable that the river corridor remains good, largely natural. (Meynell et al, 2003 and Dubeau et al, 2004)

6.2.2 ZONE 2

Zone 2 extends for some 800 km (km 2380 and km 1585 from mouth). An upland river in steep narrow valley, down a single-thread, bedrock confined channel, spreading out in local floodplains e.g. downstream of Chiang Saen, and from Nam Ou confluence to Louangprabang, and then into Vientiane plain in south of zone. The largely natural river morphology consists of alternating rocky outcrops, rapids and deep pools, shoals, riffles and sandbars. The river bank is generally steep and rocky, with some large sandbars being exposed as the water recedes at the end of the wet season. There are major areas of deep pools around the Nam Ou confluence and near Chiang Kong / HouayXai, in Xaiyabouly and at Chiang Khan.

Figure 2: Zone 2 River channel around proposed dam site at Pak Beng

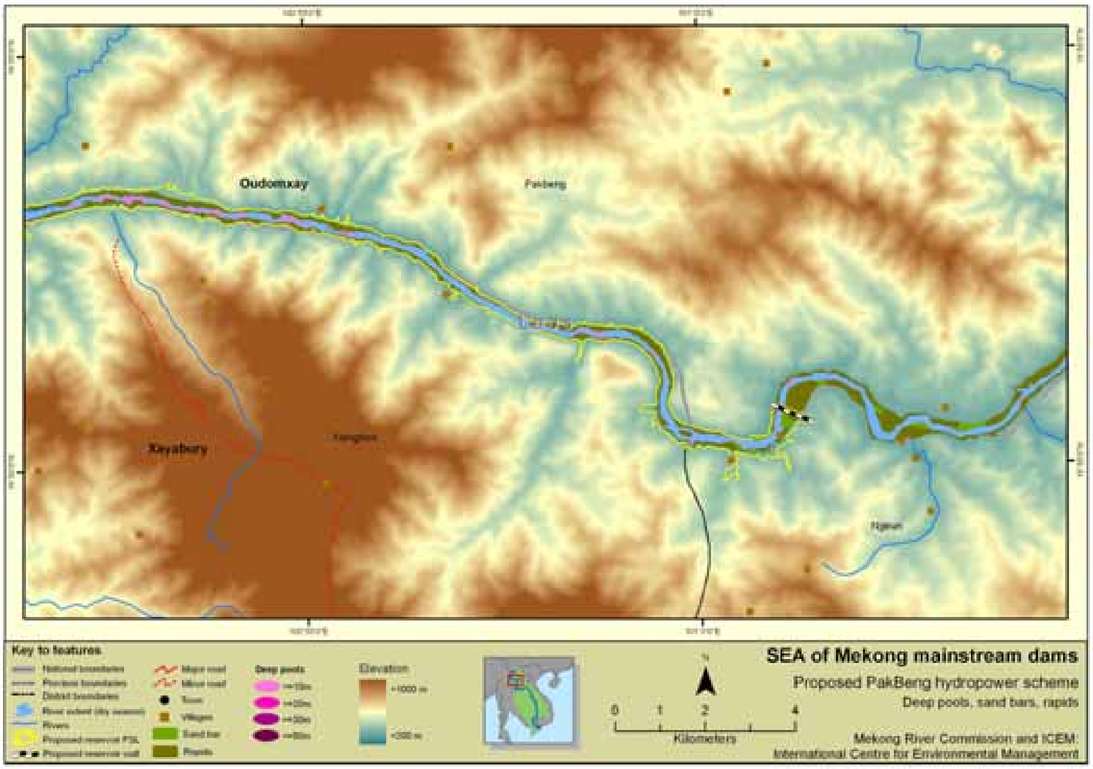


Figure 3: Zone 2 River channel around proposed Louangprabang dam site

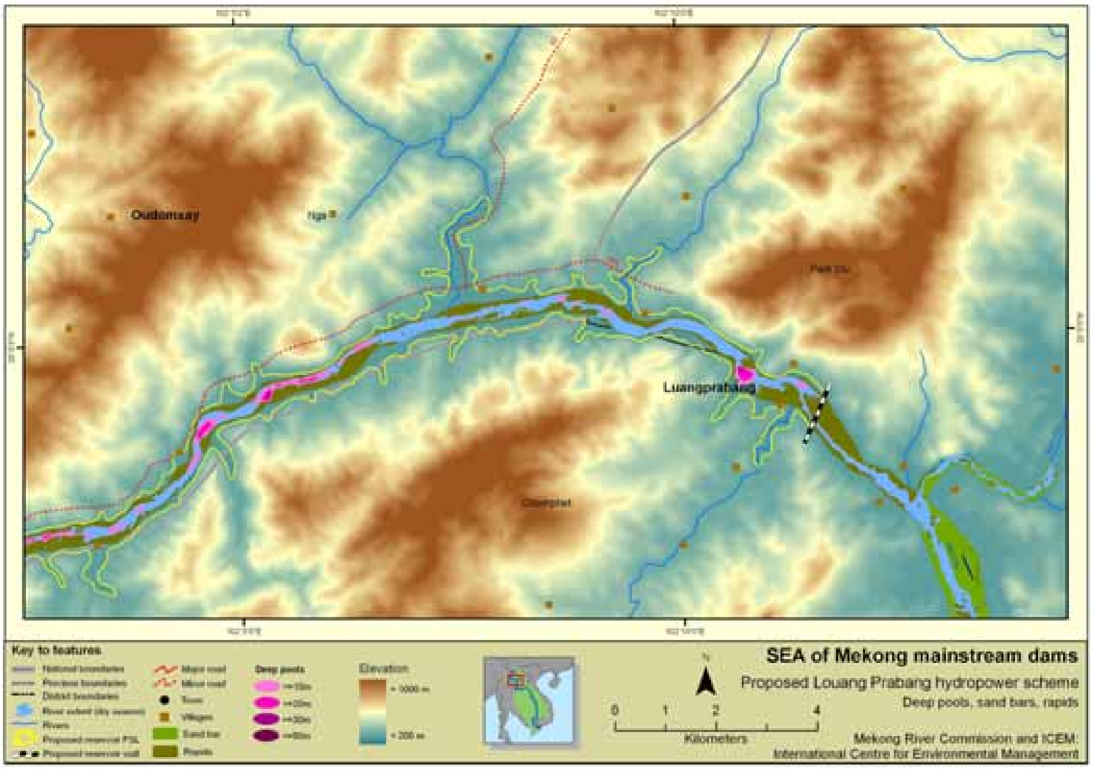
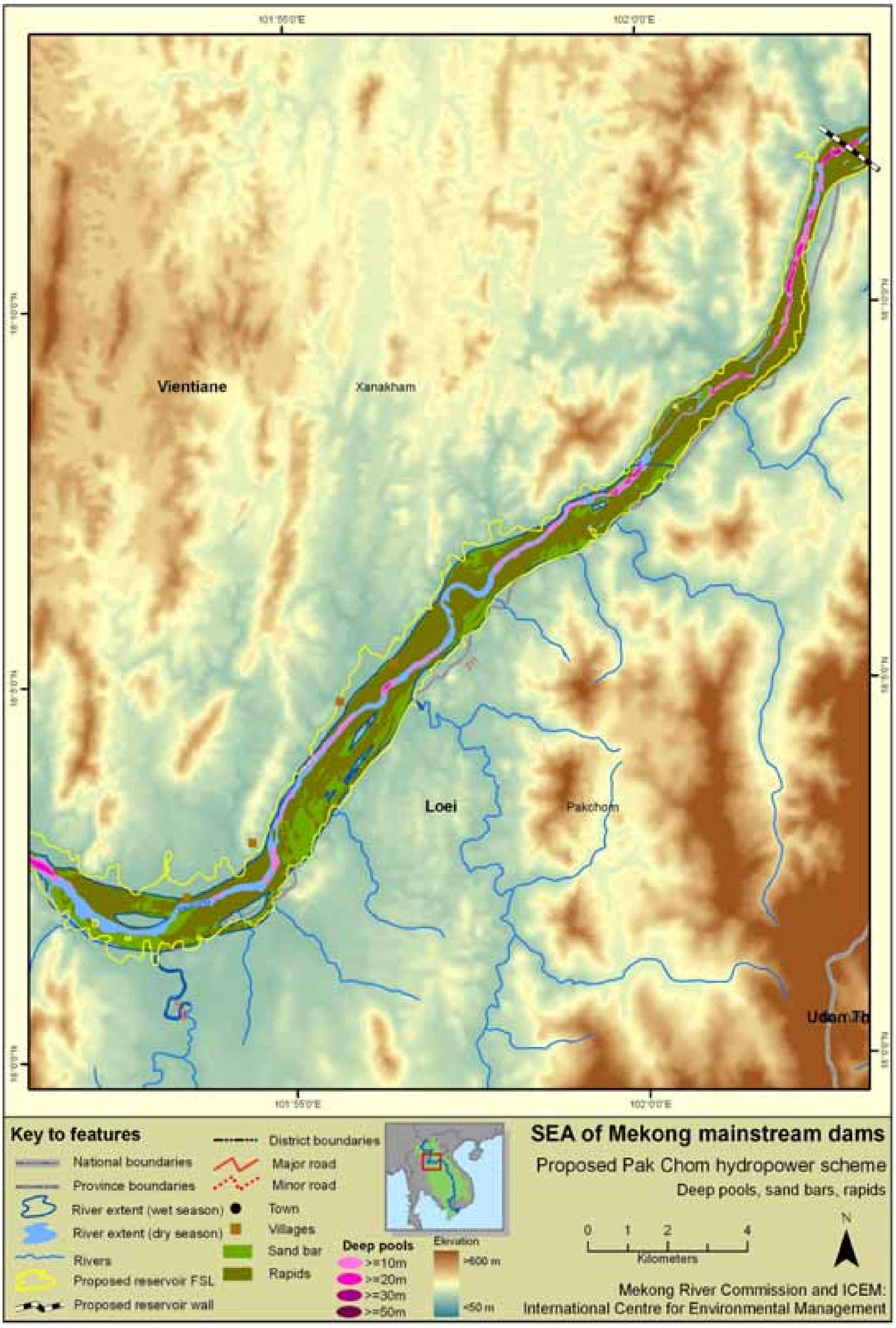


Figure 4: Zone 2 River channel around proposed Pak Chom dam site


101°55'0"E
102°0'0"E
Vientiane
Xanakham
Loei
Pakchom
Key to features
National boundaries
Province boundaries
River extent (wet season)
River extent (dry season)
Rivers
Proposed reservoir FSL
Proposed reservoir wall
District boundaries
Major road
Minor road
Town
Villages
Sand bar
Rapids
Deep pools
>=10m
>=20m
>=30m
>=50m
Elevation
>600 m
<50 m
SEA of Mekong mainstream dams
Proposed Pak Chom hydropower scheme
Deep pools, sand bars, rapids
0
1
2
4
Kilometers
N
Mekong River Commission and ICEM:
International Centre for Environmental Management

Water quality is very good, with low N nutrients, until Vientiane where water quality shows a raised organic matter, mineralization and acidification. Louangprabang and Vientiane both have slightly raised heavy metal content due to high tourist boat traffic and high urban populations. MRC ecological health card report shows conditions to be deteriorating at Louangprabang from excellent in 2004 and 2005 to good in 2008. In Vientiane ecological health is rated as moderate to good. In some reaches, there are extensive in channel wetland areas exposed during low flows. These may be unvegetated, or vegetated with *Homonia* sp, large grasses and *Phragmites*. These habitats are important fish breeding and feeding; fishing activities are often focused around these. The growth and collection of "river weed" in the shallows during low flows depends upon seasonal changes in water level, and has decreased in Northern Laos due to hydrological changes (Lazarus, 2006). Invertebrates are rated as good, largely natural and are representative of the wide variety of habitats in the river channel. There are 140 species of fish in 30 families represented in this zone. Migratory species use this stretch of river, most notably the Mekong Giant catfish, which supports a culturally important fishery around Chiang Khong, and which is known to breed nearby. The gravel beds and riffles, and vegetation in the in-channel wetlands are favoured places for fish breeding. At least 17 species of amphibians and 25 species of reptiles reported, including regular reports of Softshell turtles (*Amyda cartilaginea*) caught by fishermen. The IBFM ratings for the biological component of this area are "satisfactory, moderately modified".

6.2.3 ZONE 3

Zone 3 covers the stretch of river between Vientiane and Pakse, the Thai/Lao midstream section, extending some 700 km (km 1585 to km 870 from the mouth). The river is generally broad, slower flowing in a single-thread alluvial channel with a local propensity to develop isolated lozenge-shaped islands. The river channel is mostly sand and finer sediments, with bedrock becoming increasingly scarce downstream until after Mukdahan, especially around the Mun confluence. Between Mukdahan and Pakse, the river cuts through some impressive sandstone escarpments on both Thai and Laos sides, where it again passes through a narrow channel between rocky outcrops, rapids and shoals. There are six localities where deep pools are found – often associated near the confluences with major tributaries. Water quality is generally good, but with raised organic matter (pollution from urban areas of Vientiane, Nakhon Phanom and Khong Chiam, and with increased acidification with passage downstream. High salt concentrations draining from the Khorat plateau, via the Songkhram and Mun/Chi Rivers, are largely diluted by the larger flows in the Mekong. The ecological health of the river downstream of Vientiane appears generally excellent, with spots, e.g. around Nakhon Phanom where the ecological health indicators decline. The major habitats for aquatic invertebrates include sandy deposits, especially for large palengeiid mayflies. A number of snail, shrimp and mussel species are eaten by local people. No surveys of fish species have been undertaken, although high biodiversity is probable. No surveys of birds have been reported in this stretch, though the presence of sandbars and fine sediments make good feeding grounds for birds, and the high cut river banks make good nesting sites. No surveys of amphibians and reptiles, and water dependent mammals. The IBFM specialists rated.

Figure 5: Zone 3 River channel around proposed Ban Koum dam site

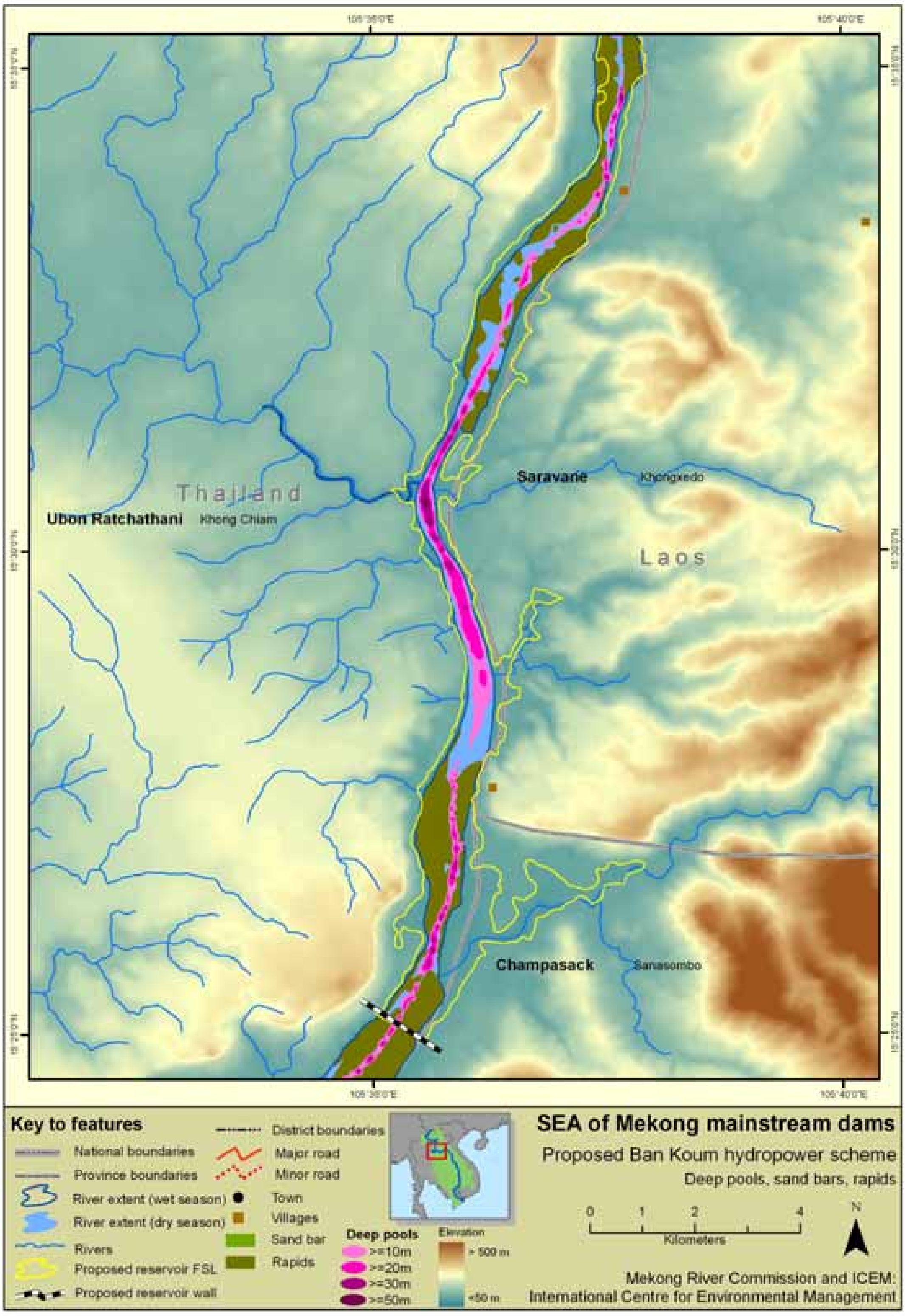
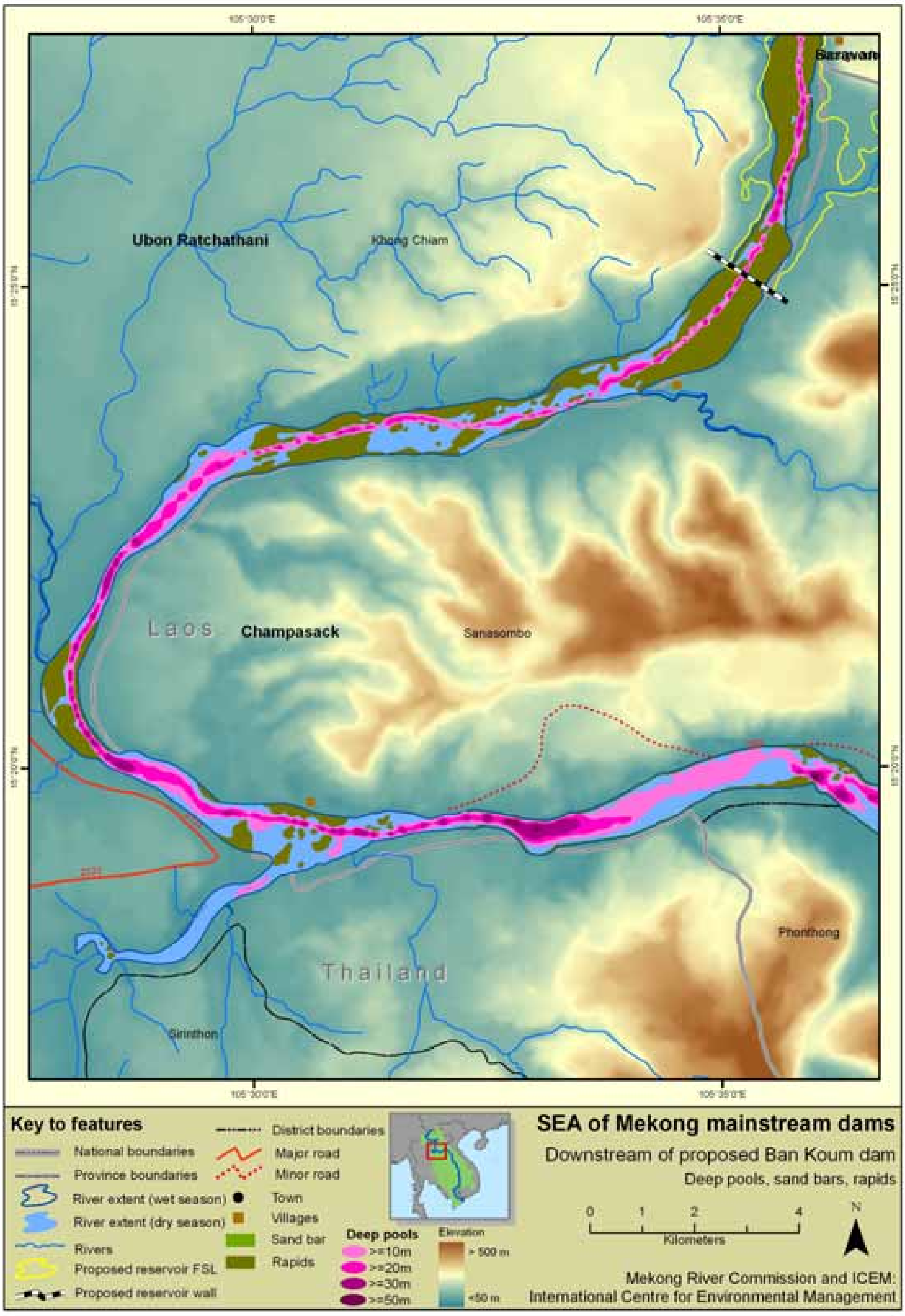


Figure 6: Zone 3 River channel downstream of proposed Ban Koum dam site, including confluence with Mun river



6.2.4 ZONE 4

Zone 4 covers the most spectacular reaches between Pakse in the South of Laos to Kratie in Cambodia. It extends from 870 km to 560 km upstream of the mouth of the river, with the Cambodia/Laos border lying at 722 km. It includes Siphandone, Khone-Phapheng Falls, Stung Treng Ramsar site, and the reach from Stung Treng town to Kratie. The river starts as a single-thread channel with local development of multiple channels developing into wide multiple-channel, braided, bedrock-confined reaches upstream of Khone Falls, where the river drops some 15 m. This continues below the Falls to Stung Treng and Kratie. The river width varies from a single channel of about 700m at Pakse, to over 10 km with multiple channels in Siphandone, and down to Stung Treng. There are a wide variety of different channel morphologies determined by the underlying bedrock and seasonal distribution of sediments in sandbars. This is an area of significant deep pools. A survey of 30 deep pools showed the deepest was 77 m at about 10 km upstream of Stung Treng town (MRC Technical Paper No 11, 2006). The IBFM specialists considered this as the “most natural, least modified” part of the river channel.

From Pakse through to Kratie the water quality is generally good, although one bioassay test (2003) carried out by MRC at Kratie indicated toxicity. Studies on the causes of mortality of the Irrawaddy dolphins in the area found raised tissue levels of POPs such as DDT and PCBs and mercury, indicating bioaccumulation, that may contribute to their high mortality WWF (2009). The MRC bioassessment shows generally good to excellent health of the zone based upon plankton and macroinvertebrates. Recent reports by fishermen of excessive growths of filamentous algae may indicate eutrophication (Allen et al 2008).

Biodiversity is greatest in this zone, recognized in the designation of the Stung Treng Ramsar site. This part of the river is recognised internationally as a biodiversity hotspot for freshwater snails, with around 120 species having been described from the area. Other common invertebrates are baetid mayflies and shrimps. Dry-season emergence of mature aquatic flies form an important food for fish. Khone Falls and the 3S rivers are major migration routes for fish at all seasons. The IBFM specialists considered that the fisheries status of the area was “satisfactory, moderately modified”. Very small, isolated populations of the critically endangered Siamese Crocodile still exist in the Stung Treng Ramsar site. At least 7 of the 44 species of Cambodian amphibians have been found in Stung Treng, (Allen et al. 2008) and 12 amphibian species between Kratie and Stung Treng (Bezuijen et al 2008). Hard and soft-shell turtles are also found in the river, using the sandy banks as nesting areas. The critically endangered Irrawaddy Dolphin lives in deep pools in the dry season from the Laos border below Khone Falls to Kratie. Beasley et al (2003) estimated that there were between 100 and 140 individuals of the dolphin in this zone of the Mekong, and WWF (2009) estimates that there have been 88 recorded dolphin deaths since 2003, with the current population between 66- 86. Other water dependent mammals include otters (Smooth-coated and Hairy-nosed otter), but these have suffered heavily throughout the region due to a lucrative trade in live animals and body parts.

Figure 7: Zone 4 River channel around proposed Latsua dam site

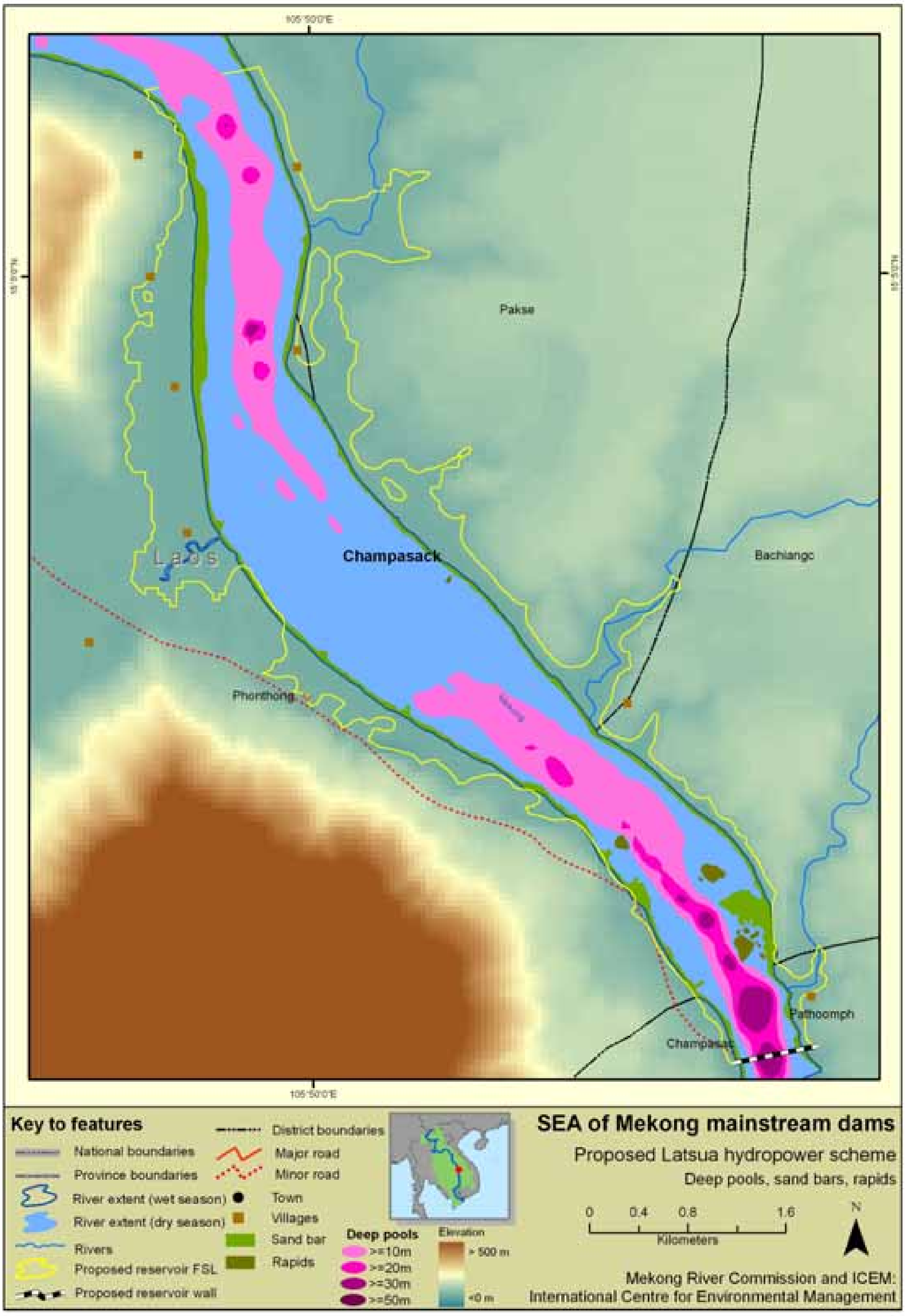


Figure 8: Zone 4 River channel around the proposed Don Sahong dam site – Siphandone and Khone Falls

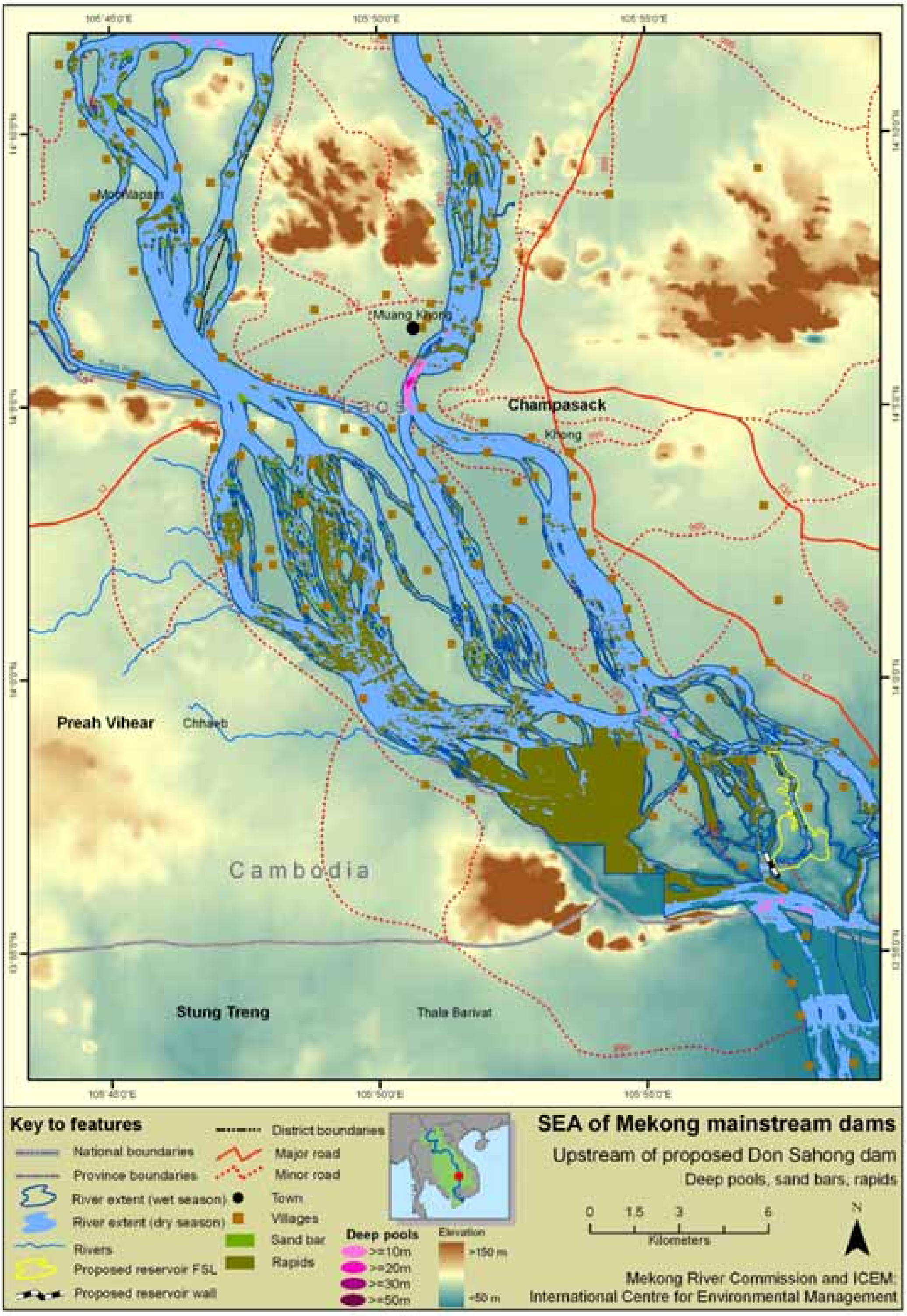


Figure 9: Zone 4 River channel around the proposed Stung Treng dam site

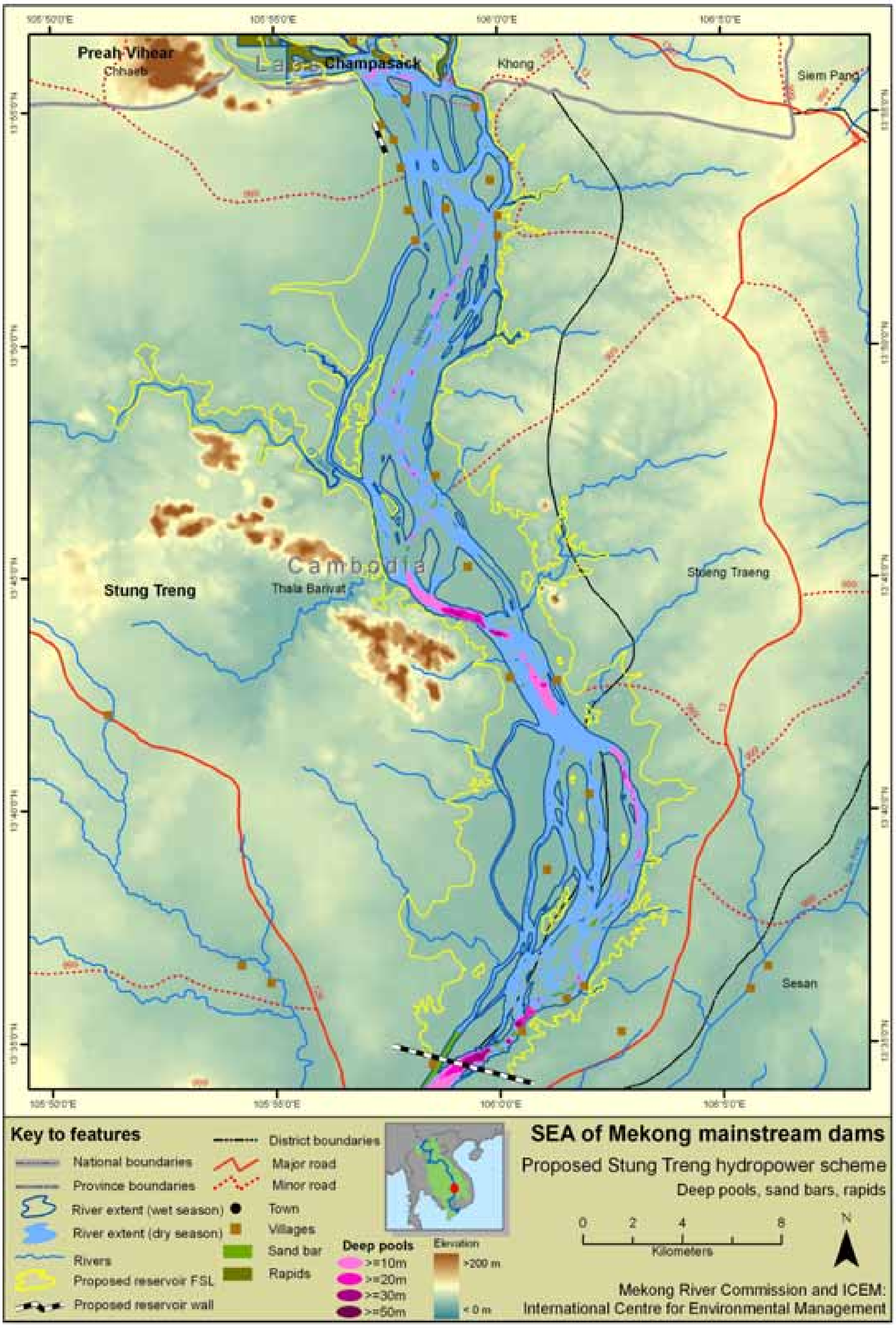
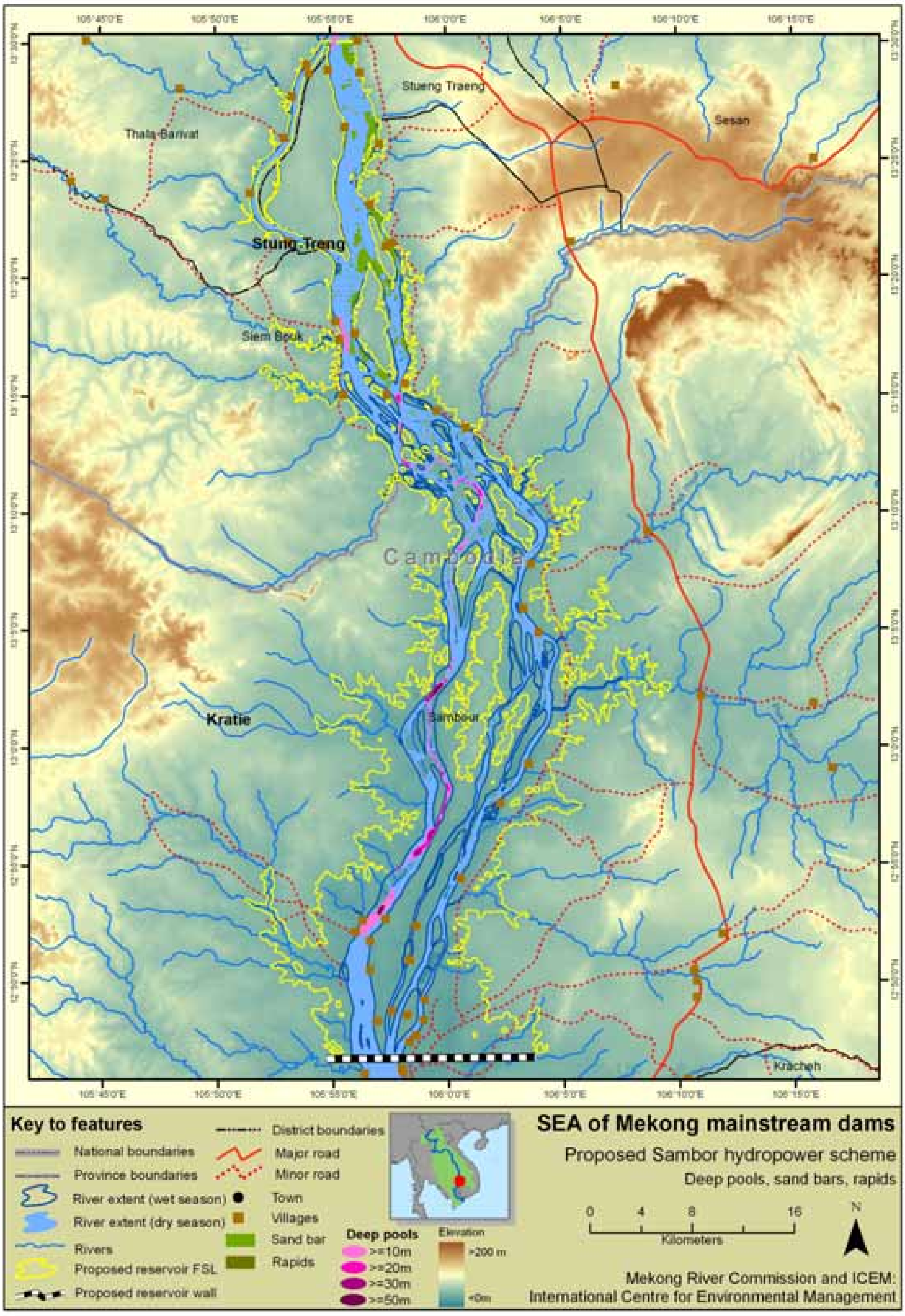


Figure 10: Zone 4 River channel around the proposed Sambor dam site



6.2.5 ZONE 5

Zone 5 covers the lowland river section between Kratie and Phnom Penh – km 560 to km 225 from the mouth of the river, and the Tonle Sap system – the Great Lake and Tonle Sap river. At Kratie the hydrology and hydrodynamics of the Mekong change significantly and is extremely complex because of the very low gradients focusing upon water levels, over-bank storage and flooding and the hydrodynamics that determine the timing, duration and volume of the seasonal flow reversal into and out of the Great Lake. The Mekong floodplains extend from Kampong Cham southwards to the Delta. The river consists of a meandering alluvial channel developing multiple channel networks. Only one minor area of deep pools exist, upstream of Kampong Cham as the river emerges on to the floodplain. The IBFM geomorphology and water quality specialists considered that this reach was “good, largely natural”.

Water quality assessments at Kampong Cham and downstream indicate excellent water quality for protection of aquatic life. (MRC Water Quality Report Card, 2008). However, water quality in the Tonle Sap river may not be as good relative to the Mekong. At Prek Kdam, elevated levels of total heavy metals in the sediments are attributed to boat traffic and some industrial activities, esp. arsenic, chromium, lead and mercury, which were well above the threshold requiring specific attention (MRC Technical Paper no 15, 2007). When bioassessment was carried out at Prek Toal at the northern end of the Great Lake, the ecological health was considered “moderate to good”. Kampong Cham marks the northerly limit of a vast natural floodplain that once stretched from central Cambodia to the Mekong delta. The macro-invertebrate species in this reach are predominately mussels, snails, shrimps and large numbers of chironomid midges. The fish biodiversity in this zone is very high, with 282 species being recorded in the Tonle Sap of which 160 species are the same as in the Stung Treng to Kratie reach. There are 31 endemic species found here. The fish migrations from the Tonle Sap in the early part of the year may be a response to declining water quality conditions in the Great Lake as the water level drops. The reptiles and amphibians are considered “largely modified”. One of the features of the Tonle Sap system is the large number of water snake species, mostly homalopsids. Over 6.9 million snakes are removed annually, the largest harvest of an assemblage of snakes in the world, and reports from hunters indicate that the harvest has declined by 74 – 84% in the period between 2000 and 2005. (Brooks et al 2006). There are many crocodile farms on the Tonle Sap, mostly hybrids of the Siamese Crocodile, with some escapees, but no wild individuals.

6.2.6 ZONE 6

At Phnom Penh (km 225 from the sea) the mainstream divides into two distributaries – the Mekong and the Bassac. Passing into Vietnam it sub-divides into a complex system of branches and canals. By the time the river reaches the sea, there are nine distributary channels in the Delta. The key features of this zone are tidal influences and salt-water intrusion. Every year, 35 to 50 per cent of this zone is flooded during the rainy season. Geomorphologically the river has been “significantly modified” by the creation of a system of canals and embankments, especially in the Vietnamese Delta. The IBFM specialist studies considered that water quality ranged from being good, e.g. in protected areas such as Tram Chim National Park to being “seriously to critically modified”. The MRC water quality report card for 2008 indicates that generally the water is good to excellent for protection of aquatic life in many parts of the Delta, however, the concentrations of organic matter (COD) and nutrients, e.g. total phosphorus is highest in the Delta. Toxic contamination indicated by bioassay tests are highest at Neak Loung in Cambodia, Tan Chau and

Chau Doc in Vietnam especially copper, nickel and arsenic. The Delta sampling stations tend to have a higher than usual TEQ values for dioxins and furans. The ecological health indicators show that the Bassac River is in better health compared to the Mekong which is only moderate. The macro-invertebrate fauna are snails, shrimps, polychaete worms, odonates (dragon flies) and chironomid midges that live in the silt or clay riverbanks and silty riverbed. Tram Chim National Park, representative of the Plain of Reeds, is a freshwater wetland with regulated water levels and a high abundance of fish, amphibian, reptile and waterbird species. The fish diversity in the Delta is the highest in the Mekong river system with over 481 species and 73 families. 210 of these species are also found in the Tonle Sap system of Zone 4. Many fish are also tolerant of the brackish water, or come in from the sea. Aquaculture is a characteristic feature - in floating cages, especially for catfish in the upper delta, and extensive shrimp ponds nearer the sea.

6.2.7 ANALYSIS OF PRIMARY PRODUCTIVITY OF THE MEKONG CHANNEL

Estimating of the net primary productivity (NPP) of wetlands is difficult, but Mitsch and Gosselink (1993) indicate that for riparian wetlands the NPP ranges from 0.6 – 1.4 KgC/m2/yr. Swamps and marshes have very high net primary productivity of 2.0 KgC/m2/yr, comparable to tropical grasslands and cultivated land (see table below) while streams and lakes have NPPs at about 0.5 KgC/m2/yr. The Mekong mainstream is probably lower than this because it is very turbid (reducing light penetration) and fast flowing – a NPP of 0.3 KgC/m2/yr is used here. Riparian wetlands are generally more productive than their adjacent uplands because flooding provides adequate water supplies; nutrients are supplied and favorable alteration of soil chemistry results from the periodic flooding (nitrification, sulfate reduction, nutrient mineralization, all of which make the nutrients more available to the plants) and flowing water offers a more oxygenated root zone than if the water were stagnant. This range (0.6 – 1.4 KgC/m2/yr) is taken as a first estimate of the primary production of the in-channel wetland areas exposed during the dry season (including the mosaic of rocky outcrops, sand bars, river banks, in channel grasslands and shrublands). This seasonal exposure and flooding of in-channel wetland areas is largely responsible for the high productivity of the Mekong River.

	Net primary productivity	
Vegetation unit	**Range (kgC m^{-2}/yr)**	**Aproximate mean (kgC $m^{-2/}$yr)**
Tropical grassland	0.2 - 2.9	0.8
Cultivated land	0.1 - 4.0	0.65
Swamp and marsh	0.8 - 4.0	2
Lake and stream	0.1 - 1.5	0.5
Riparian wetland	0.6 – 1.4	

Source: Helmut Leith in http://www.fao.org/docrep/k1100e/k1100e04.htm and Mitsch and Gosselink 1993

Lamberts and Koponen (2008) whilst modeling changes in productivity in the flood pulse system of the Tonle Sap, noted that primary productivity depends upon the periphyton (plants growing on plants and substrates) with an average of 86.5 mgC/m^2/hr; upon the phytoplankton with productivities ranging from 0.03 to 747.4 mgC/m^2/hr; upon rooted macrophytes which may produce 8 – 12 tonnes of biomass /ha/yr; and upon floating macrophytes, which are probably of lesser importance in the Tonle Sap. It is difficult develop a composite figure from these different sources of primary productivity, but the model illustrates how productivity of the Tonle Sap depends upon the flood pulse, and how changes in timing, extent and depth of flooding in the Great Lake can significantly alter this productivity, e.g. for an increase of 10 cm in the permanent water level of the lake, the loss of annual biomass production in rooted macrophytes (flooded forest) of up to 8%, which corresponds to a total loss of 1.2 million tonnes of biomass production per year. The same arguments can be used for other parts of the Mekong system that depend upon seasonal flooding and recession, even in the upper parts of the river channel.

Calculations based on the NPP in the areas of dry season and wet season channels (see Table 6) and the area exposed during the dry season in each zone, indicate that the % contribution to total NPP due to the exposure in dry season ranges from 15 - 33% at the lower rate (0.6 KgC/m2/yr) and 39 - 64% at the higher rate (1.4 KgC/m2/yr) in the different zones (see Table 7).

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.

6.2.8 MEKONG RIVER BIODIVERSITY

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. Many of these species are endemic and are found only in some of the tributaries, but nearly 500 species are found at different points in the mainstream. In Siphandone alone there are reported to be around 120 species of freshwater mollusks (Daconto, 2001), and the MRC's IBFM specialist studies (2005) also reported on the rich macro-invertebrate biodiversity. Analysis of fish species carried out for this SEA (Baran, 2010) has shown that the different zones of the Mekong contain the following numbers of families and fish species. (Table 1). This shows that the Mekong Delta has the highest number and proportion of fish species (62%), largely as a result of movement of estuarine and marine species into the delta. As is to be expected there is a decrease in fish biodiversity with distance upstream, although both Zone 5 and Zone 4 have very rich biodiversity. The numbers of endemic species is also a good indicator, and it is interesting that Zone 2 has the highest proportion of endemicity, closely followed by Zone 4. It is probable that Zone 2 marks a transition zone between the more lowland river species and the upland river species found in Zone 1.

Table 1: 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

(note: Zone 3: was not assessed because of lack of fish survey data, but will probably be intermediate between Zones 2 and 4).

There are a number of Endangered fish species, listed by the IUCN Red-listing process, which include the Critically Endangered, Giant Mekong Catfish, *Pangasianodon gigas, Pangasius sanitwongsei,* the Endagered Long-nosed marbled Whip ray, *Himantura oxyryncha,* and Mekong freshwater stingray, *Dasyatis laoensis.* The range of these species extends through all zones. Also considered Endangered are the shad *Tenualosa thibaudeaui, Probarbus jullieni,* the Giant Carp, *Catlocarpio siamensis.* There are 15 other Vulnerable fish species, but systematic assessments of Mekong fish species have not been undertaken, so this is not a good indicator of biodiversity at risk. The Siamese Crocodile, found in very small numbers around Stung Treng is considered to be Critically Endangered. Of the turtles, Yellow headed Temple turtle, *Hieremys grandis,* Elongated tortoise*, Indotestudo elongata,* and Cantor's Giant softshell turtle*, Pelochelys cantorii,* are all considered Endangered and have been recorded in Zone 4. (Bezuijen,et al 2008) and in Laos. Of the river dependent mammals, the Mekong sub-population of the Irrawaddy Dolphin is classified as Critically Endangered and the Hairy-nosed otter, *Lutra sumatrana,* is Endangered.

6.2.9 WATER QUALITY AND ECOLOGICAL HEALTH

The MRC work on the water quality and ecological health provides a systematic assessment of the zones at selected sites. Results for the Mekong mainstream showed the status of selected sites as shown in Table 2:

Table 2: Assessments of Water quality characteristics at selected sites on Mekong mainstream

Zone	Locality	Organic Matter	Nitrogenous matter	Nitrates	Phosphorous matter	Mineralisation	Acidification
Zone 1	Chiang Saen	Green	Green	Green	Green	Yellow	Blue
Zone 2	Louangprabang	Green	Blue	Green	Green	Green	Green
Zone 3	Vientiane	Yellow	Green	Green	Green	Yellow	Yellow
	Nakhon Phanom	Yellow	Green	Green	Green	Green	Yellow
	Khong Chiam	Yellow	Green	Green	Green	Green	Yellow
Zone 4	Pakse	Green	Green	Green	Blue	Green	Yellow

(based upon the French water quality classification system. Blue = very good, Green = good, Yellow = fair, Red = bad) (Source: MRC, 2007)

The MRC Report Cards on Aquatic Ecological Health, assesses the proportion of littoral macroinvertebrates, benthic macroinvertebrates, benthic diatoms and zooplankton at different sites in Mekong mainstream and tributaries and compares them to reference sites. It grades the ecological health of the river at those sites and has been conducted progressively since 2004, and most comprehensively in 2008. The results are shown in Table 3:

Table 3: Ecological health assessment at selected sites down the Mekong mainstream

Ecological Health from Card	Sample site	2004	2005	2006	2007	2008
Zone 1 - China to Chiang Saen	Xieng kok	C				D
	Chiang Saen					B
Zone 2 - to Vientiane	Louangprabang	A	A			B
	Vientiane	C			B	C
Zone 3 - to Pakse	Songkhram				C	A
	Nakhon Phanom					C
Zone 4 - to Kratie	Siphandone				A	A
	Stung Treng		B	A	B	B
	Kratie	A		A		A
Zone 5 - Phnom Penh and Tonle Sap	Tonle Sap			C		B
Zone 6 Bassac	Koh Khel			B		C
	VKB					B
	VDP					C
	VLX			C		B
	Can Tho			C		B
Zone 6 Mekong	VTP					C
	VTT					C
	VCL			C		C
	Vinh Long					C

Excellent	A
Good	B
Moderate	C
Poor	D

(Source: MRC Report Card December 2009)

The IBFM specialist studies and overview made an assessment of the ecological status of different zones based upon the different character and organisms found in that zone. The results of their assessments are shown in Table 4.

The key feature about water quality issues in the Mekong is the River's capacity for diluting pollutants, sediments and higher salt concentrations. The result of this is that poor water quality is often rather localized, and quickly diluted, with rapid improvement in water quality e.g. after high polluting loads from urban areas.

Table 4: Results of the IBFM specialist assessments of ecological status of different river zones

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* D#	B* C#	D* B-E#	C-D
Invertebrates	B	B	B+	B-	C
Fish	C	C	C	C	D
Water Birds	C	C	D+	D+	D+
Frogs/Reptiles	C B-	C B-	D+ C+	D+ C+	D+ C+

A Excellent. ***Unmodified, natural***. Close to the probable condition in the absence of human intervention in the catchment.
B Good. ***Largely natural***. Modified from the original natural condition but not sufficiently to have produced measurable change in the nature and functioning of the ecosystem.
C Satisfactory. ***Moderately modified***. Changed from the original condition sufficiently to have measurably altered the nature and functioning of the ecosystem, although the difference may not be obvious to a casual observer. Efforts should be made to ensure that no further deterioration occurs.
D Room for Improvement. ***Largely modified***. Sufficiently altered from natural for obvious impacts on ecosystem nature and functioning to have occurred. Management agencies should be developing strategies to improve the conditions.
E Improvement Necessary. ***Seriously to critically modified***. Important aspects of the original nature and functioning of the ecosystem are no longer present. The area is heavily impacted by human interventions.

(Source: MRC 2005. IBFM report 5 and 7)

6.2.10 CULTURAL ECOSYSTEM SERVICES OF THE MEKONG RIVER

The cultural ecosystem services provided by the Mekong river are shown in Table 8 by zone, separated into spiritual and inspirational, festivals associated with the river, recreational and tourism. This shows the depth of the cultural association with the river. Hydrological, morphological and biological changes in the river will alter these associations, sometimes with loss of cultural heritage and indeed the tourism attraction and revenue.

In both Laos and Thailand, the Mekong river is said to be home to the Phaya Naga, mythical serpent-like creatures who live in the stretch between Vientiane and Ubon Ratchathani. The Naga is particularly important to Lao iconography, and features prominently in the culture of all Lao. Traditionally it has been the spirit protector of Vientiane, and by extension, of the Lao state.

The value of river tourism is huge, with the Mekong River itself having an almost iconic status, representing the region as a whole. ADB's GMS tourism strategy clearly identifies the Mekong River Tourism Corridor, (see Fig 13). Figure 11 shows the trends in tourist arrivals into the GMS (ADB, 2005), and Table 5 shows the expected value of tourism services to the six countries of the GMS as a whole. River-based tourism, relying to a large extent upon the integrity and landscape value of the river is obviously only a fraction of these large sums, but some of the examples taken from different zones show how important the river is.

Figure 11. Trends in tourism arrivals to the GMS

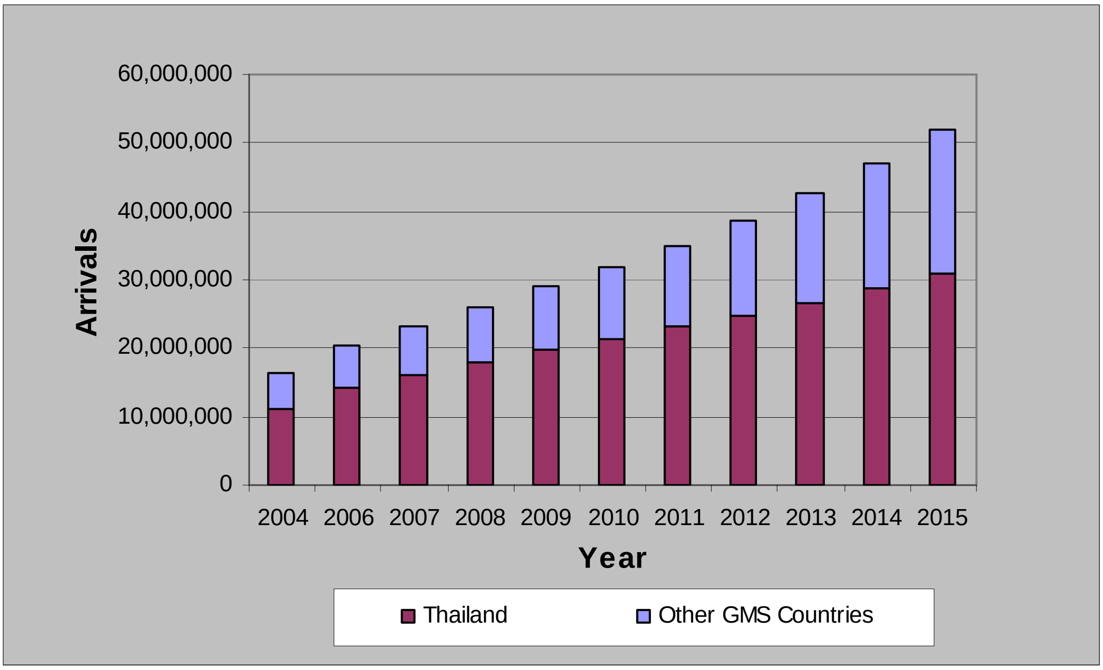


Table 5: Estimated value of tourism expenditure in 6 countries of GMS

	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**

(Source: ADB 2005. GMS Tourism strategy)

In Laos, projections indicate that international arrivals may develop from 1.6 million visitors in 2007 to 3.5 million visitors by 2015, with tourism revenue rising from $ 233 million to $ 399 million. (National Tourism Administration).

An estimate of the value of tourism in each zone of the River in Laos has been made by taking the percentage of all tourists visiting Laos going to the different provinces between 2003 and 2007, factoring in the interests in "nature" as an indication of interest in the Mekong, and assuming that they visit the province for one day spending the average US $ per person for the year. This gives a conservative value of tourism in each zone. It does not include the visitors to Vientiane Capital and Louangprabang, although many of these would also have an interest in the integrity of the Mekong. Table 5 shows the steady increase in tourism since 2003, with Zone 1 and 2 bringing in 18.5 million in 2007, Zone 3 bringing in 10.2 million and the Laos part of Zone 4 bringing in 11.2 million.

Table 5: Value of Mekong-interest tourism for the different zones in Laos

	2003	2004	2005	2006	2007
	US $ income from tourism per year				
Zone 1& 2					
Bokeo	1,870,901	1,425,426	3,833,603	2,824,393	7,832,277
Oudomsay	1,603,630	1,425,426	2,683,522	2,636,100	4,475,587
Xayabouli	534,543	285,085	383,360	527,220	671,338
Vientiane Province	267,272	285,085	383,360	376,586	5,594,484
TOTAL Zone 1 & 2	**4,276,346**	**3,421,022**	**7,283,845**	**6,364,299**	**18,573,686**
Zone 3					
Khammouane	1,069,086	570,170	1,533,441	1,242,733	3,356,690
Savannakhet	3,741,803	2,280,682	3,833,603	3,652,881	6,153,932
Saravanh	801,815	570,170	766,721	979,123	727,283
ToTAL Zone 3	**5,612,704**	**3,421,022**	**6,133,764**	**5,874,737**	**10,237,905**
Zone 4 (Laos)					
Champassak	4,543,618	3,421,022	6,133,764	4,217,760	11,188,967
Total Zone 4 Laos	**4,543,618**	**3,421,022**	**6,133,764**	**4,217,760**	**11,188,967**

(Source: ICEM calculated from Lao National Tourism Administration)

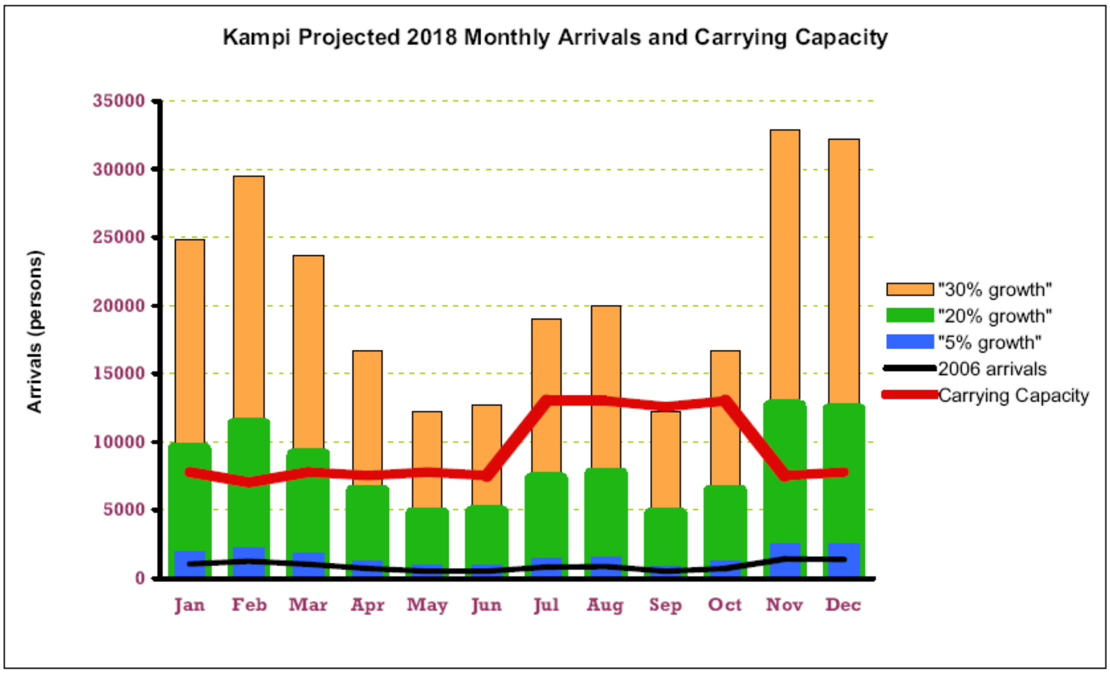
Whilst most of the districts along the Mekong in Laos, have relatively low dependence upon tourism for their livelihoods, with Pak Beng and Xayaboury recognizing that between 2 – 3% of the population having tourism as the primary source of livelihood, in Khong District in Champassak 20% of the population have tourism as the primary livelihood source.

In Cambodia, quite apart from the association of the Mekong and Tonle Sap with Angkor Wat, the river dolphins are considered an item of national heritage and in Kratie attracted:

- 2005: 75,000 domestic and 7,612 foreigners.
- 2006: 82,000 domestic and 10,844 foreigners.

In Stung Treng: there were 29,968 domestic tourists and 50,910 International arrivals in 2005/2006. (Cambodia, Annual report on tourism statistics) Most visitors to Stung Treng visit Ramsar Site which provides potential value for both conservation and ecotourism purposes. Under the GMS tourism strategy, the Mekong Discovery Trail has been developed and marketed for the area between Kratie and the Lao border. The SEA on Tourism sector in Cambodia estimated that even with 20% growth of visitor numbers, the carrying capacity of the Dolphin pool at Kampi, a major tourist attraction, would not be exceeded for most months of the year. (Figure 12)

Figure 12: Projections for visitor numbers and carrying capacity at Kampi Dolphin pool



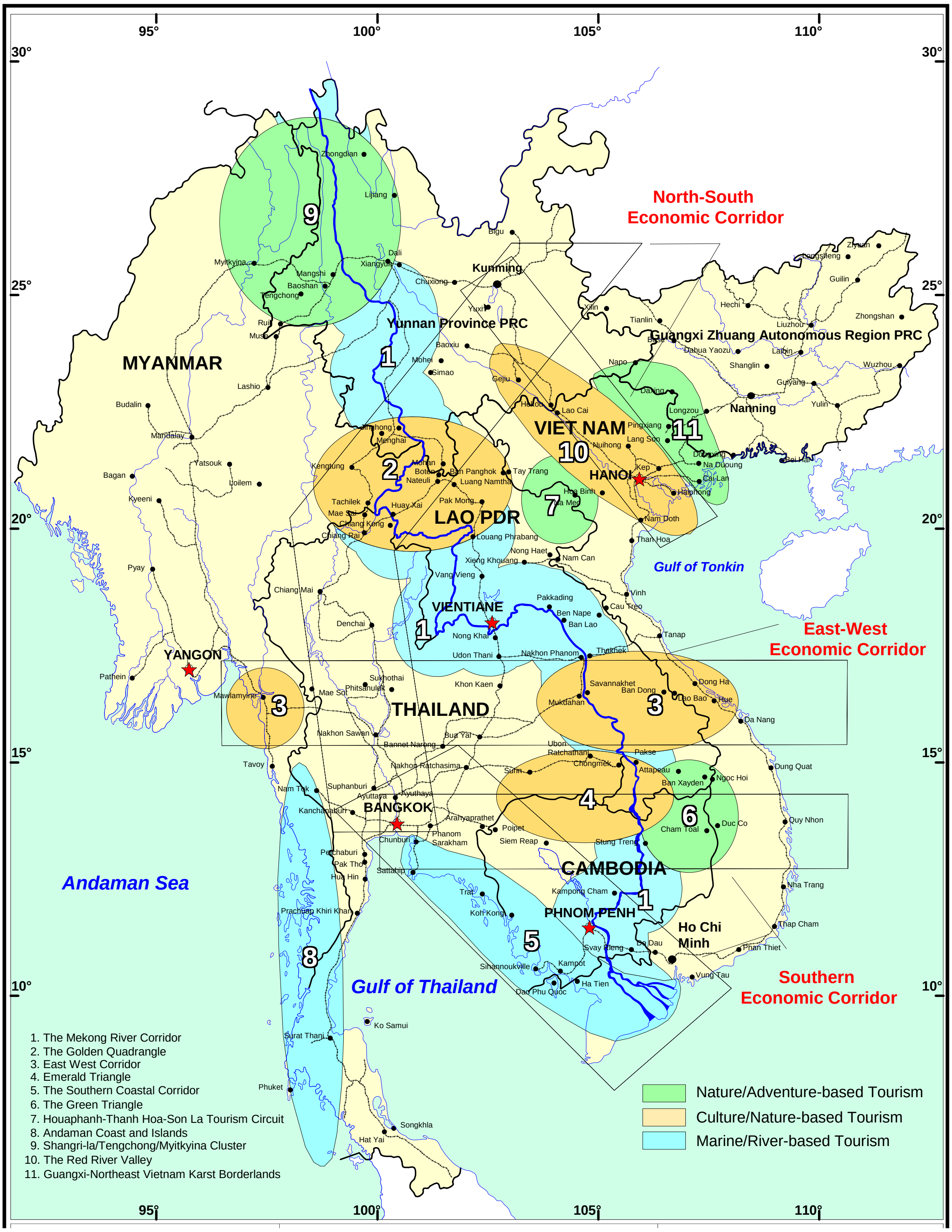
Source: SEA of tourism sector in Cambodia, 2008

In 2008, 1.2 million international tourists and 8 million domestic ones arrived in the Mekong Delta, and there are 250,000 people employed full-time in the tourism sector. For Can Tho alone, the total number of tourists was 850,000, with a revenue of USD 24.6 million. In 2009, Can Tho received 1.1 million tourists, of which 200,000 were internationals, with a revenue from rural and river tourism of USD 31.6 million; and the plan for 2010 is to receive 1.4 million tourists including 300,000 internationals.

6.2.11 SUMMARY OF CURRENT STATUS

The aquatic systems of the Mekong River are extremely diverse and productive, and dependent upon the seasonal pattern of hydrologic and sediment flows down the river. The diversity of habitats, biodiversity as shown by fish species, increases with passage down the river, making it one of the most biodiverse rivers of the world. The water quality and ecological health of the river is generally good, although there are areas of raised contamination levels, especially near urban areas, but the dilution afforded by the river, maintains conditions suitable for aquatic life throughout. The cultural heritage of the river, its provision of recreational opportunities and aesthetic appreciation of the Mekong's natural landscapes, contribute to the region's attractiveness as a tourism destination.

Figure 13. Map of GMS highlighting the Mekong River Tourism Corridor (1)



Source: ADB 2005: GMS Tourism Strategy

Table 6: Profile of the Mekong River channel in the different zones, featuring the areas occupied by the proposed mainstream dams

No.	Ecological Zone	Characteristic	Dams	Length of River section	Average width of river section	Area of channel		No of deep pools > 10 m deep in dry season	Area of deep pools				Habitat features (Area	
						Dry season	Wet season		>=10 m	>=20 m	>=30 m	>= 50 m	Rocks and Rapids	Plain Sand bars
				km	m	sq km	sq km		sq m	sq m	sq m	sq m	sq km	sq km
1	China to Chiang Saen	Headwaters and mountain river		2,120										
			Chinese dams											
2	Chiang Saen to Vientiane	Upland river in steep narrow valley		795	914.64	238.37	459.73	598	21.74	3.35	0.17	0.00	161.74	66.35
			Pak Beng	160	500.00	43.72	67.36	98	1.47	0.02	0.00	0.00	14.28	9.35
			Louangprabang	147	400.00	25.46	46.21	146	3.86	0.36	0.01	0.00	19.84	0.91
			Xayaburi	95	500.00	30.11	67.17	96	3.38	0.55	0.00	0.00	31.11	6.14
			Pak Lay	110	510.00	23.43	49.93	112	3.51	0.52	0.01	0.00	26.32	0.19
			Sanakham	97	695.00	38.99	66.82	67	2.47	0.13	0.00	0.00	26.15	8.22
			Pak Chom	85	900.00	24.56	71.17	52	3.81	0.80	0.01	0.00	33.90	12.72
			TOTAL Zone 2 dams	694		186.27	368.66	571	18.50	2.38	0.04	0.00	151.60	37.53
3	Vientiane to Pakse	Thai/Lao midstream and tributaries		713	950.00	575.67	696.98	172	28.56	8.45	2.16	0.19	66.25	55.26
			Ban Koum	149	950.00	71.73	121.67	110	13.35	4.66	1.19	0.15	49.64	0.30
			Latsua	10	800.00	8.14	9.07	6	2.68	0.47	0.13	0.00	0.06	0.87
			TOTAL Zone 3 dams	159		655.55	827.72	288	44.59	13.58	3.48	0.35	49.70	1.17
4	Pakse to Kratie	Wetlands of Siphandone, Khone Falls, Stung Treng and Kratie, including significant tributaries		330	1,500.00	529.98	805.77	181	25.34	4.44	1.41	0.36	41.75	72.74
			Don Sahong	5	150.00	0.81	0.63	0	0.00	0.00	0.00	0.00	0.18	0.00
			Thakho	N/A										
			Stung Treng	52	1,800.00	39.35	104.82	64	4.44	1.15	0.39	0.02	2.88	0.74
			Sambor	86	2,200.00	159.02	253.94	47	8.98	2.02	0.75	0.34	0.00	12.32
			TOTAL Zone 4 dams	143		199.17	359.39	111	13.42	3.18	1.13	0.36	3.06	13.06
5	Kratie to Phnom Penh and Tonle Sap	Floodplains and the Great Lake		364	1,100.00	413.32	550.09	121	51.89	7.47	0.54	0.00	0.00	136.77
6	Phnom Penh to the sea	Mekong Delta, Tidal zone		225				28						

(Source: ICEM, GIS analysis of Mekong hydrographic atlas, MRC)

Table 7: Estimates of primary production due to seasonally exposed wetlands in the Mekong River channel by hydro-ecological zone

Zone	Ecological Zone	Length of zone	Average width of wet season channel	Area of channel			Primary productivity - NPP				Total NPP (NPP in dry season Channel + NPP in area exposed in dry season)	NPP due to exposure in dry season (Total NPP - NPP in wet season channel)	Total NPP (NPP in dry season Channel + NPP in area exposed in dry season)	NPP due to exposure in dry season (Total NPP - NPP in wet season channel)	% contribution to NPP due to exposure	
				dry season	wet season	area exposed in dry season	due to dry season channel - 0.3 KgC/m2/yr	due to wet season channel - 0.3 KgC/m2/yr	due to area exposed in dry season - 0.6 KgC/m2/yr	due to area exposed in dry season - 1.4 KgC/m2/yr	0.6 KgC/m2/yr		1.4 KgC/m2/yr		lower rate	higher rate
		km	m	sq km	sq km	sq km	TonsC/Yr	TonsC/Yr	TonsC/Yr	TonsC/Yr	TonsC/Yr	TonsC/Yr	TonsC/Yr	TonsC/Yr		
1	**China to Chiang Saen**	2,120														
2	**Chiang Saen to Vientiane**	795	914.64	238.37	459.73	221.35	71,512	137,918	132,810	309,891	204,323	66,405	381,403	243,485	33	64
3	**Vientiane to Pakse**	713	950.00	575.67	696.98	121.31	172,702	209,094	72,784	169,828	245,486	36,392	342,531	133,437	15	39
4	**Pakse to Kratie**	330	1,500.00	529.98	805.77	275.78	158,995	241,730	165,470	386,098	324,465	82,735	545,093	303,362	25	56
5	**Kratie to Phnom Penh and Tonle Sap**	364	1,100.00	413.32	550.09	136.77	123,996	165,026	82,060	191,474	206,056	41,030	315,470	150,444	20	48
6	**Phnom Penh to the sea**	225														

Table 8: Cultural services provided by the Mekong River

	Ecological Zone	Spiritual and inspirational	Key festivals	Recreational	Mekong Tourism features
1	**China to Chiang Saen**	Naga myths		Swimming, picnicing, walking along banks and on sandbars during dry season	Boat trips to China, River adventure, riverside ethnic villages
2	**Chiang Saen to Vientiane**	Riverside temples, naga myths	Boat racing festivals at every town Giant Mekong Catfish fishing festival at Chiang Kong/Houai Xai -	Swimming, picnicing, walking along banks and on sandbars during dry season, angling	Slow and fast boat trips from Chiang Kong/Houay Xai to Pak Beng to Louangprabang, riverside ethnic villages
3	**Vientiane to Pakse**	Riverside temples, naga myths	Boat racing festivals at every town Naga and fireball festivals (Nam Ngum confluence)	Swimming, picnicing, walking along banks and on sandbars during dry season, angling	Riverside at Vientiane/Nong Khai, Thakek/Nakhon Phanom, Savannakhet/Mukdahan and at Pakse. Bicoloured river, Pha Taem and Kaeng Tana National Parks in Thailand, Phou Xiang Thong PA in Laos
4	**Pakse to Kratie**	Riverside temples, Dolphin myths, naga myths	Boat racing festivals at every town	Swimming, picnicing, walking along banks and on sandbars during dry season, angling	Khone Falls, Siphandone boating and island stays, Irrawaddy Dolphin viewing on Cambodia/Loa border and at Kampi, Cambodia. Stung Treng Ramsar site. "Mekong Discovery Trail"
5	**Kratie to Phnom Penh and Tonle Sap**	Riverside temples, naga myths	Boat racing festivals at every town	Swimming, picnicing, walking along banks and on sandbars during dry season, angling	Riverside at Kratie, Kampong Cham and Phnom Penh, boat trips on Tonle Sap, crocodile farms, floating villages, Prek Toal ecotours
6	**Phnom Penh to the sea**	Riverside temples, crane myths, fishers worship fishing deity	Khmer's Seeing Water Off Festival at the end of the flood season and Welcoming Water Festival at the beginning of the flood season; Okombok Festival of Khmer group that includes racing of elongated boats.	Swimming, picnicking, boating, angling, fruit picking	Boat trips to delta towns, floating markets, floating aquaculture, rural and orchard tourism, tropical fruits, traditional riparian handicraft-making villages, bird sanctuaries, national parks and nature reserves, historical battle grounds, mangrove forests, fisheries festivals, riverine isles, fruit festival

6.3 FUTURE TRENDS WITHOUT THE LMB MAINSTREAM HYDROPOWER DEVELOPMENT

6.3.1 ZONE 1

There have been a number of changes to the river system in Zone 1. Three hydropower dams in China have now been completed (Manwan 1996, Dachaoshan 2003, Jinghong, and Xiaowan is now reported to be filling). In 1992, when Manwan was being built, there was a significant drop in TSS reported at Chiang Saen and Luangprabang, with wide fluctuations in TSS load over 2,000 mg/l before 1992, and with smaller fluctuations up to 1,000 mg/l since then. (MRC, 2007). Thelowest Chinese dam, Mengsong, has been cancelled due to the impact that it would have on fish migrations. (Kang et al 2008). Navigation has increased significantly since 2003, with ships up to 150 tonnes regularly moving between Chiang Saen and China (in 2004-5, there were a total of 2,160 commercial boat trips in this zone). The river channel modifications removing 11 major rapids and shoals and 10 scattered reefs was completed by 2004, under the Lancang-Mekong Navigation Channel Improvement project. There has been an increase in the risks of water pollution (organic matter, oil spills etc) as a result of this navigation traffic, and the construction of a port in Chiang Saen and river embankment schemes. There are also reports of increased river bank erosion, disturbance of fishing craft and nets as a result of this increased traffic (Lazarus et al, 2006). Other pressures on the natural resources of the river come with increased access – both navigation and roads – and include increased hunting and fishing for both subsistence and wildlife trade. The dams in China will have an increasing impact upon the hydrology of this zone, with over 75% of the flow at Chiang Saen being derived in China. There will be an increasing tendency for markedly increased dry season flows and lower wet season flows, which will have an impact upon all aspects of the river morphology and ecology.

The increased dry season flows will benefit navigation and this is likely to be further enhanced by further removal of 51 rapids and shoals to make the waterway navigable by vessels up to 300 DWT for at least 95% of the year - Phase 2 of the Lancang-Mekong Navigation Improvement Project. In Phase 3 it is proposed that canalisation of the river would enable ships of up to 500 DWT to pass up the river. The navigation channel would be extended from Chiang Saen to Louangprabang. With increased navigation traffic both in size and frequency there will be additional pressures on the ecological health of this zone, from the increased water pollution, river bank erosion, increased access and disturbance both of biological resources and local river users. (Lazarus et al, 2006)

Prediction - River morphology and aquatic ecology in Zone 1 will change significantly over next 20 years

6.3.2 ZONE 2

No major river channel modification has taken place yet under the Lancang-Mekong Navigation project, although this remains one of its objectives. There are no major schemes abstracting water for irrigation, but there are plans for a cascade of seven dams on the Nam Ou being developed. Various pressures include the disturbance (especially noise from the speedboats) and pollution caused by tourist boats operating between Houay Xai and Louangprabang. There is some limited navigation with 30 DWT boats between Vientiane and Louangprabang in the high flow season. There are a number of logging operations and riverbank sawmills along the stretch between Louangprabang and Sanakham, which may cause some pollution or organic matter and chemicals. Pollution pressures from the urban centres of Vientiane and Louangprabang persist and will increase as urban populations grow.

Generally this zone is one of the most dramatic and unspoilt landscapes of the Mekong, appreciated by an increasing number of tourists. The hydrological changes caused by the Chinese dams will continue to be significant in this zone, since the contribution of the Yunnan component is just under 50% of the total annual flow at Vientiane. The flows below Louangprabang will also be affected by the cascade of changed hydrology of the Nam Ou when the cascade of dams is completed. This will mean higher dry season water levels – possibly by as much as 1 metre, which will change the distribution and appearance of deposited sandbars, reduce the areas of in-channel wetlands that dry out and become vegetated in the low flow season. There will also be less sediment coming down the river as more is trapped behind the Chinese dams.

Prediction: Continued gradual degradation of the river in Zone 2, with loss of fish diversity and production and reduction in river weed

6.3.3 ZONE 3

The hydrological influence of the Chinese dams will be becoming less significant in this zone, as about 40% of the total flow in the Mekong comes from tributaries along this stretch of the river. Thus the contribution of the Yunnan component is only 22% at Pakse. However, there are some large hydropower developments on the tributaries for example six dams in the Nam Ngum basin, the Theun-Hinboun hydropower complex, and Nam Theun 2, and the flows in the Mun/Chi rivers modified by irrigation reservoirs and hydropower dams. With all the hydropower development in Yunnan and in the Lao tributaries the Nam Theun 2 CIA predicted that the dry season flows at Savannakhet might increase by 135% corresponding to a water level increase of 1.2 m and during floods the discharge might be decreased by 20%, corresponding to a lowered water level of 1.6 m. The localized impact of Nam Theun 2 will be to reduce the flows in the Mekong between Pak Hinboun and Xe Bang Fai by about 2 cm in the dry season and 23 – 29 cm in the wet season. These general increases in water level will tend to reduce the diversity of habitats and productivity, with less exposure of the sandbars and river banks in the dry season. (Norplan, ADB. Nam Theun 2 CIA, 2004)

There are regular pumped offtakes of water from the river on both Thai and Laos sides for irrigation. There is less navigation or tourist traffic in this zone, and ferry crossings between Nakhon Phanom and Thakek, Mukdahan and Savannakhet have been much reduced by the construction of new bridges across the Mekong. Unless otherwise treated, pollution from urban areas may increase, extending the polluted zones further downstream and agricultural run-off may increase nutrients in the river, especially phosphate. Fishing pressure and use of illegal fishing methods may increase with increasing populations.

Prediction: General further degradation of the habitat and biodiversity in Zone 3

6.3.4 ZONE 4

Whilst there has to date been little infrastructure development on the river in this zone, and habitats have remained largely intact, pressures from increasing use of natural resources, such as fish other aquatic animals, are showing a trend in terms of reduced populations, if not loss of some species. The SIMVA study (MRC 2010) indicated that 37.6% of households consulted on the Mekong mainstream considered that fish species were disappearing from their catches over the last 5 years; in contrast 23% of households in the Tonle Sap and only 11 % of households in the tributaries reported such loss of species. Use of illegal methods, hunting and the trade in wildlife has also taken its toll in many species populations. Mortality due to disease and accidental capture in fishing nets of Irrawaddy Dolphin is extremely serious, and is likely to lead to their local extirpation in the next decade. There is an expanding tourism interest in the Dolphin, both in Cambodia and Laos, and disturbance from boat engines and pollution may add pressure on the declining population. Weed invasion by *Mimosa pigra* and the excessive blooms of filamentous algae, both point to a stressed environment.

The construction of hydropower dams on the 3S rivers, especially the recently approved Lower Sesan 2 HPP at the confluence between the Sesan and the Sre Pok rivers will effectively block fish migration and the overall connectivity of the river system. Dams upstream on the 3S rivers will trap a large majority of the sediment coming down the river.

Whilst measures have been suggested for conservation in Siphandone, Stung Treng Ramsar site and the reach between Kratie and Stung Treng (Allen et al 2008) and Bezuijen et al (2008), little effective conservation management measures have been put in place. A protection zone for the Irrawaddy Dolphins has been proposed by WWF focused around the key deep pools inhabited by the dolphins, e.g. at Kampi. Government measures to prohibit use of nets in certain deep pools are also in place.

The pressures on the zone from developments and land use change in this area are increasing and without adequate planning and management controls will continue to degrade the riparian and riverine ecosystem. Whilst it will continue to be the most biodiverse area of the Mekong, there will inevitably be losses of both fish and river dependent species. The fish resources will continue to decline with changes in habitat, overfishing and use of illegal methods. The potential changes in water quality, indicated by the bioaccumulation of POPs and mercury in dolphins, and the blooms of filamentous algae will need to be monitored and analysed more closely.

Prediction: 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.

6.3.5 ZONE 5

Some industrial and municipal wastes as well as storm water run-off discharge directly into the Tonle Sap river near Phnom Penh. Domestic wastes are also released from river bank and floating communities in the Great Lake. Agricultural run-off with higher nutrient loads and other agricultural chemicals contribute to the pollution in this zone. There are pressures on the fisheries and water snake harvest from over-exploitation and illegal methods of fishing. Lamberts (2006) suggests that current natural resource use of the Tonle Sap has exceeded the optimum supported by its ecosystem productivity base.

Changes in the hydrology of the flood pulse as a result of the Chinese dams, will alter the dynamic in the Tonle Sap system, but it is difficult to quantify how this will show in terms of its aquatic biodiversity and productivity. Lamberts and Koponen (2008) show that flood pulse alterations affect ecosystem productivity by altering the euphotic volumes in which aquatic photosynthesis is possible and by limiting transfer of organic matter from rooted macrophytes to the aquatic phase. The pressures of fishing and hunting will continue to reduce the fish populations. The water quality in the Tonle Sap near the floating fishing villages and in the river near Phnom Penh will continue to give cause for concern.

Prediction: 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

6.3.6 ZONE 6

The city of Phnom Penh, with almost 2 million inhabitants discharges much of its sewage that drains into the Bassac River. Pollution is also derived from sewage and industrial wastes from the many urban areas in the Delta, from the floating fish farms and the nutrients and agrochemicals in agricultural run-off from the extensive paddy fields in the Delta. Boat traffic is very intense giving rise to oil and grease contamination. The impact of road embankments and similar infrastructure developments on the movement of flood water is increasingly important**.** Nearer the coast, saline intrusion threatens agricultural productivity. Shrimp farms have caused loss of extensive areas of natural coastal habitats, especially mangroves and coastal wetlands.

Increasing population pressure will continue to add to the pollution load from urban waste waters, and agricultural run-off. Climate change and sea-level rise is considered a very serious threat to the integrity of the delta, and this will be exacerbated by hydrological changes resulting from Chinese dams and dams in the tributaries. The trapping of sediments behind dams in China and from the Central Highlands in the long term will cause the delta to erode.

Prediction: 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.

Changing ecosystem services
Overall the current importance and predicted direction of change in the ecosystem services provided by the different zones of the Mekong over the next 20 years is shown in Table 9. This covers Provisioning, Regulating, Cultural and Supporting services.

Productivity of aquatic habitats in the Mekong
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.

Biodiversity of aquatic habitats in the Mekong
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. The passage of migratory fish species up and down the Mekong mainstream will be maintained.

The capacity of the Mekong's ecosystem regulating services – purification and water quality
In the absence of adequate waste water treatment, increasing populations and urbanization over the next 20 years will lead to expanding zones of higher water pollution from domestic and industrial wastes. This

may be offset by the probable increased water flows during the dry season may allow for greater dilution of these wastes at critical times of year. The effects of increased nutrients from agricultural run-off will increase the risks of eutrophication and growth of filamentous algae. Industrial and mining wastes will give rise to accumulation of heavy metals and toxic chemicals in sediments and the food chain.

Value of Mekong River's cultural ecosystem services – inspiration, recreation and tourism

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 reduce the appearance of sandbars and beaches. This will significantly reduce access to 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.

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Table 9: Importance of ecosystem services and future trends in each zone of the Mekong

Ecosystem services	Zone 1		Zone 2		Zone 3		Zone 4		Zone 5		Zone 6	
Provisioning	**Present**	**Future**	**Present**	**Future**	**Present**	**Future**	**Present**	**Future**	**Present**	**Future**	**Present**	**Future**
Food production of fish, wild game, fruits, and grains	Low	↓	Medium	↓	High	↓	High	↓	High	↓	High	↓
Fresh water storage and retention of water for domestic, industrial, and agricultural use	Low	↑	Low	↑	Medium	↑	High	↑	High	↓	High	↑
Fiber and fuel production of logs, fuelwood, peat, fodder	Low	→	Low	→	Low	→	Low	→	Low	→	Low	→
Biochemical extraction of medicines and other materials from biota	Low	→	Low	→	Low	→	Low	→	Low	→	Low	→
Genetic materials genes for resistance to plant pathogens, ornamental species, and so on	Low	→	Low	→	Low	→	Low	→	Low	→	Low	→
Regulating												
Climate regulation source of and sink for greenhouse gases; influence local and regional temperature, precipitation, and other climatic processes	High	→	High	→	High	→	High	→	High	→	High	→
Water regulation (hydrological flows) groundwater recharge/discharge,	High	↓	High	↑	High	↑	High	↑	High	↑	High	↑
Water purification and waste treatment retention, recovery, and removal of excess nutrients and other pollutants	High	↓	High	↓	High	↓	High	↓	High	↓	High	↓
Erosion protection and retention of soils and sediments	High	↓	High	↓	High	→	High	→	High	→	High	→
Natural hazard regulation, flood control, storm protection	High	↑	High	↑	High	↑	High	↑	High	↑	High	↑
Cultural												
Spiritual and inspirational source of inspiration; many religions attach spiritual and religious values to aspects of wetland ecosystems	High	↓	High	↓	High	↓	High	↓	High	↓	High	↓
Recreational opportunities for recreational activities	Low	→	High	→	High	→	High	→	High	→	High	→
Aesthetic - appreciation of natural features	High	→	High	→	High	→	High	→	High	→	High	→
Educational opportunities for formal and informal education and training	Low	→	Medium	→	Low	→	Medium	→	Medium	→	Low	→
Supporting												
Biodiversity - habitats for resident or transient species	High	↓	High	↓	High	↓	High	↓	High	↓	High	↓
Fish spawning and nursery areas	Medium	↓	Medium	↓	Medium	↓	High	↓	High	↓	Medium	↓
Soil formation sediment retention and accumulation of organic matter	High	↓	Medium	↓	Medium	↓	High	↓	Medium	↓	High	↓
Nutrient cycling storage, recycling, processing, and acquisition of nutrients	High	↓	Medium	↓	Medium	↓	High	↓	Medium	↓	High	↓
Pollination habitat for pollinators	Low	→	Low	→	Low	→	Medium	→	Medium	→	Low	→

7 FISHERIES

Past trends and current situation	
Theme:	**Fisheries**
Issues:	1. The importance of fisheries to local livelihoods and national/provincial economies 2. Changes to the unique features of the Mekong River fisheries

7.1 MEKONG FISH BIODIVERSITY

The Mekong River is the second river in the world, after the Amazon, for its fish species richness, and the Tonle Sap is the lake having the highest fish biodiversity after the East African Great Lakes. Lao PDR, Thailand and Vietnam are among the top 5% countries for their number of freshwater fish species and number of threatened fish species.

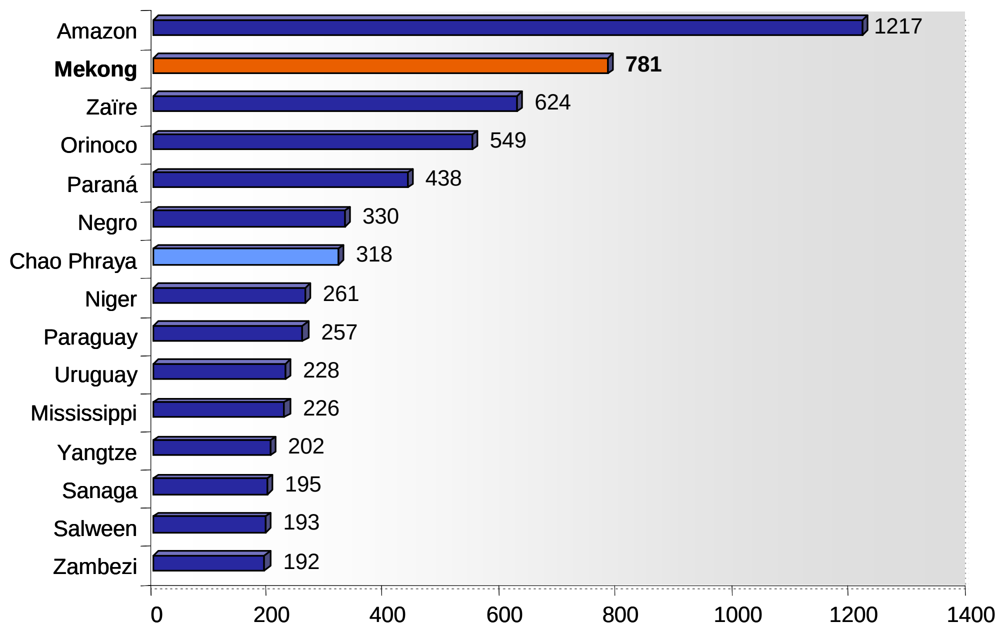


Figure 1: Fish species diversity in the Mekong and in the Tonle Sap, compared to other systems

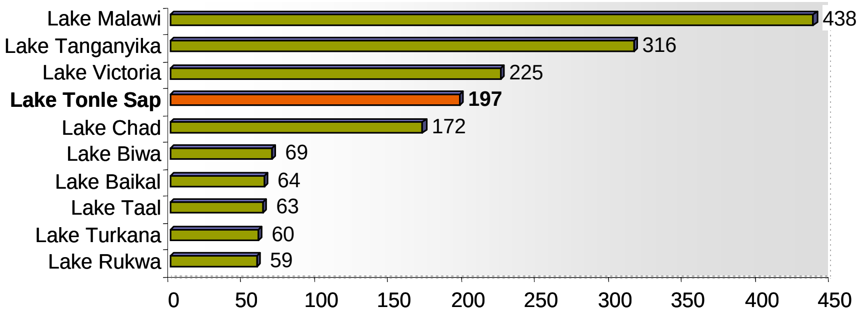


Figure 2: Fish species diversity in the Tonle Sap, compared to other systems

There is a strong gradient of species richness from the headwaters (low diversity, less than 50 species) down to the delta (very high diversity, more than 450 species). In the delta the high diversity is largely due to the conjunction of freshwater, estuarine and marine fish faunas.

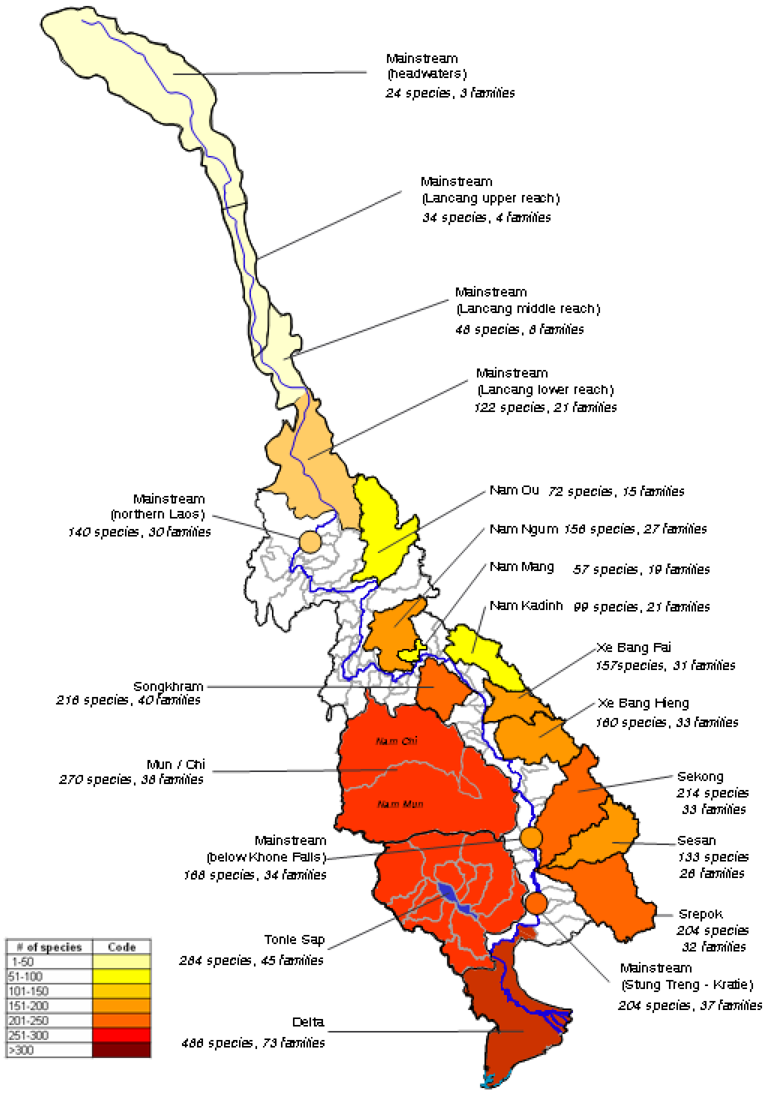


Figure 3: Fish species richness in 20 locations in the Mekong River Basin

In sub-basins, species richness is roughly proportional to the watershed surface area; the highest fish diversity is found in the Tonle Sap and in the Mun/Chi River Basins, followed by the Srepok, Sesan and Songkhram River Basins.

An analysis by ecological zone along the Mekong river confirms these results, but also shows that the proportion of endemic species is relatively higher upstream and decreases below Khone Falls. The ecological zone located between Pakse and Kratie is characterized by a relatively high fish biodiversity that can be related to the extent and diversity of specific habitats (waterfalls, islands and wetlands).

7.2 MEKONG FISH CATCH

According to national statistics, the inland fisheries sector in the four countries of the Lower Mekong Basin (LMB) produces around 755,000 tonnes per year and the Upper Mekong Basin in China produces around 25,000 tonnes per year. However, according to alternative scientific estimates based on field studies, the fish production of the Lower Mekong amounts to more than one million tonnes, and up to 2.6 million tonnes, with 2.1 million tonnes being the most reliable figure. Thus, depending on the source of information considered, Mekong fisheries produce between 7 and 22% of the world's freshwater capture fish, the most likely estimate being 18%. This Mekong capture fish production is higher than anywhere else in the world and higher than the production of the marine fishery sector of many countries. Cambodia's fishing intensity and freshwater fish catch per inhabitant are by far the highest in the world.

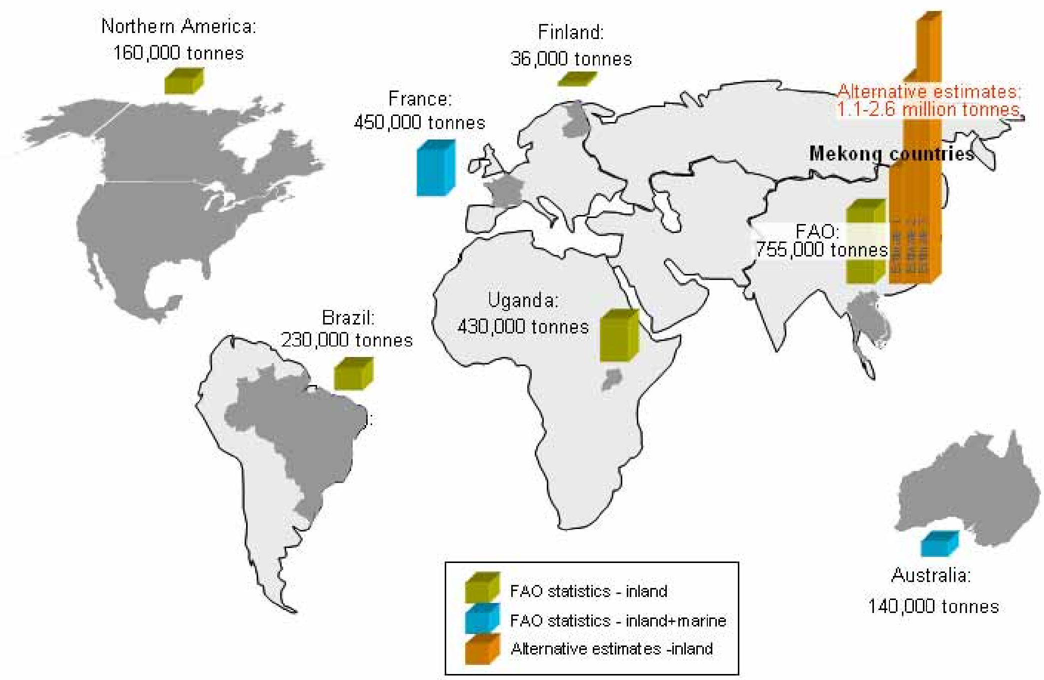


Figure 4: Comparison of fish production in the Mekong and in other countries worldwide.

7.2.1 MEKONG FISH CONSUMPTION AND FOOD SECURITY

The four countries of the Lower Mekong Basin feature the highest consumption of freshwater fish in the world. Cambodia in particular holds the world record for consumption of freshwater fish.

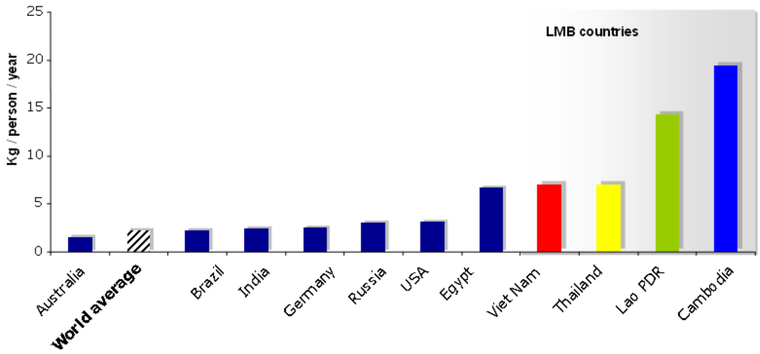


Figure 5: Freshwater fish consumption per person and per year worldwide and in the LMB countries

Again, there are discrepancies between national statistics reflected by the FAO (1.55 million tonnes of freshwater fish consumed per year in the LMB according to this source) and scientific surveys (2.1 million tonnes of freshwater fish consumed per year in the LMB according to a review of 20 consumption studies). This latter figure corresponds to around 80 grams of fresh fish per person, each day of the year.

In the Lower Mekong Basin, 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 Laos, 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.

In conclusion, Mekong fish resources are gigantic by global standards and crucial to food security in the region. However, the analysis of the importance of fisheries to local livelihoods and national/provincial economies is made difficult by the discrepancy between national statistics and field-based scientific studies.

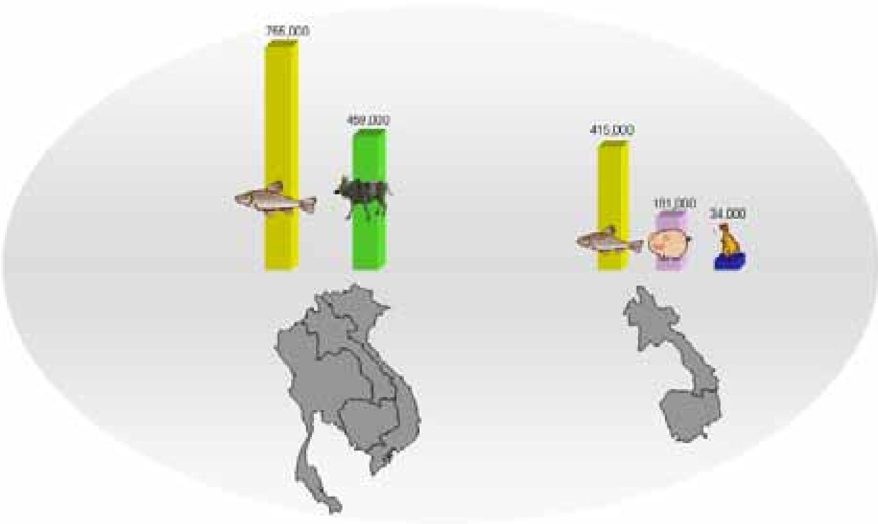


Figure 6: Importance of fish compared to other sources of protein in some selected cases.

7.2.2 CATCHES BY COUNTRY AND ALONG THE MEKONG

According to all studies and sources of data, Cambodia, Thailand and Vietnam each produce nearly one third of the overall Mekong fish catch, and Lao PDR produces around 5%. Along the Mekong mainstream, most of this catch (85%) is realized between Pakse, the Tonle Sap and the sea. However, in a system characterized by intensive migrations, a large harvest of adult fish downstream is largely conditioned by the connection with upstream zones and tributaries where fish have to migrate for breeding. In that regard, mainstream dams downstream of Pakse would have the most dramatic impact on fish production.

7.2.3 ECONOMIC VALUE OF THE MEKONG FISH CATCH

The importance of the catch is poorly reflected in economic statistics, and the valuation of fish resources remains a much neglected issue in the Mekong Basin. In particular, no transparent price per kilo or tonne of fish has ever been produced. The most recent estimate (2009) values Mekong capture fish resources at USD 2.1-3.8 billion on first sale and between USD 4.2-7.6 billion on retail markets. In the aquaculture sector, during the 2005-2007 period, farming activity generated each year around USD 60, 100, 400 and 1,800 million in Cambodia, Laos, Thailand and Vietnam respectively, i.e. around USD 2.4 billion all together.

7.3 MEKONG AQUACULTURE

The freshwater aquaculture sector produces more than Mekong capture fisheries in Thailand and Vietnam. In Laos, production is similar, and in Cambodia the production of the aquaculture sector is 12 to 22 times inferior to that of the capture fishery sector.

When all countries are lumped, the current production of the inland/brackish aquaculture sector is more than double of that of the inland fisheries sector. However, when the exceptional case of Vietnam is put aside, the aquaculture production in Cambodia, Laos and Thailand remains inferior to the production of the inland fisheries sector in these countries.

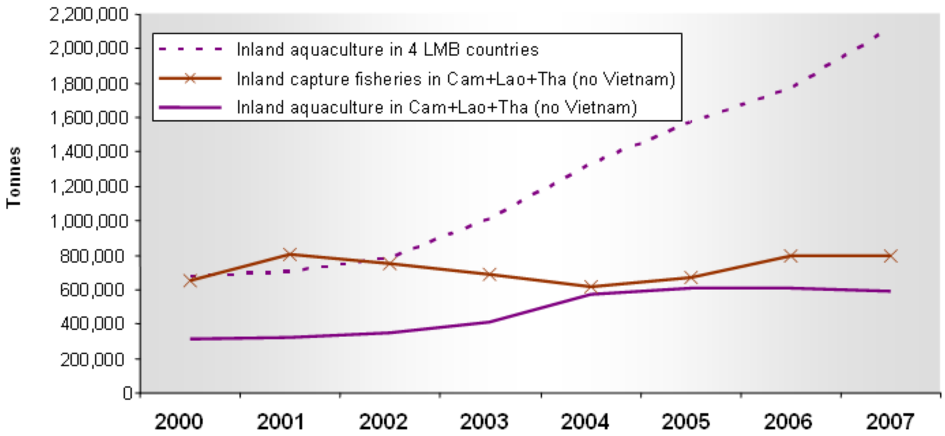


Figure 7: Inland/brackish water aquaculture versus capture fisheries

Pangasiid catfishes are the dominant fish group produced in aquaculture. The second dominant species is the introduced tilapia *Oreochromis niloticus*. It is followed by a number of other catfishes (Silurids), in particular the hybrid "*Clarias gariepinus x C. macrocephalus*". The first native cyprinid farmed in the region is the Java/silver barb *Barbonymus gonionotus*, present in particular in Cambodia.

7.4 CHANGES IN CAPTURE FISH CATCHES

There is no evidence from national statistics that the yield from capture fisheries is declining in any of the four LMB countries. However, there has been a decline in the catch per fisherman: the fish biomass harvested has increased substantially over time, but it has not increased as fast as the human population sharing it (this has been demonstrated in the Tonle Sap area, over the last 60 years). Overall, little or no growth is to be expected from the capture fisheries sector in the years to come.

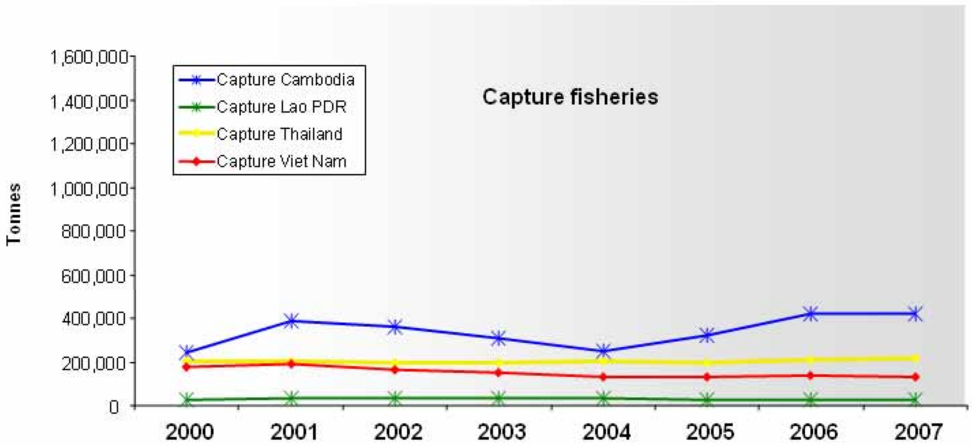


Figure 8: Production in inland capture fisheries in the four LMB countries since 2000.

7.5 CHANGES IN THE AQUACULTURE SECTOR

In the inland/brackish water aquaculture sector only one country, Vietnam, features high annual growth (+28% a year over the last 5 years) and high production levels (1.5 million tonnes in 2007). In Cambodia, annual growth is substantial but the production level is very low; in Laos figures are erratic but low; and Thailand is showing signs of stabilization if not decline.

7.6 DRIVERS AND CONSTRAINTS OF FISHERY PRODUCTION

High fish production is correlated with high floods, long floods, and with the presence and accessibility of refuges for fish in the dry season. It is also probably correlated with the vegetation diversity in floodplains. Fish production sustainability is also very dependent on the possibility for fish to move between their breeding and feeding zones. All these factors will be modified to a certain extent by mainstream dam construction and operation. Sediment retention by dams is also a factor to be considered. In the Mekong, the connection between river sediment outflow and coastal fisheries productivity has been suspected for more than 80 years but never scientifically addressed; this remain a significant knowledge gap to be filled.

7.7 MIGRATIONS

Fish migrations are a major feature of the Mekong Basin. Migrations are driven by breeding and feeding needs. Upstream migrations are mainly breeding migrations undertaken by large, often adult, fishes; downstream migrations are mainly feeding migrations undertaken by adults and juveniles. Fish movements also include lateral migrations between the mainstream or tributaries and floodplains.

Overall, in the Mekong, the migratory fish resource at risk from mainstream dam development is in the range 0.7 -1.6 million tonnes per year. An analysis of migration corridors shows that the area between Phnom Penh and Stung Treng features the highest number of migratory species for which migration maps exist. The 3S system (Sesan, Srepok, Sekong Rivers) seems to play an important role (as important as the Tonle Sap River) among migratory species.

7.8 MEKONG FISH GROUPS, MIGRATIONS AND IMPACT OF DAMS

Mekong fish can be classified into three main categories according to their sensitivity to the impact of dams: white fish (long distance migrants, very sensitive), black fish (local residents, resilient) and grey fish (short distance migrants, intermediate). More specifically, the four fish groups of migrant fishes most sensitive to the impact of dams are:
- main channel spawners that migrate between floodplains and upstream spawning grounds;

- main channel refuge seekers that spawn in floodplains and migrate to mainstream deep pools;
- semi-anadromous fish that come from the sea and enter fresh/brackish waters to breed or as juveniles;
- catadromous fish that spawn and start growing at sea but migrate to rivers as juveniles or sub-adults.

7.9 CONCLUSIONS

In 2025 and in absence of mainstream dams, the prospects of sustainability of Mekong fisheries would be approximately a third of what they are now, for a combination of reasons pertaining to fishing pressure, dams existing and in construction on tributaries, and changes in the floodplain environment. Two other trends can be predicted: further reduction in the abundance of large valuable species, with replacement by less valuable small ones, and increased fluctuation in catches, with years of high abundance followed by years of shortage.

In the aquaculture sector, if the average growth rate of the past 7 years is sustained, Vietnam is expected to reach a production plateau a few years from now, while Thailand will reach the same plateau around 2020. In the same period, aquaculture production in Cambodia and Lao PDR will reach around 200,000 and 300,000 tonnes respectively.

Aquaculture is often presented as a means of replacing the losses of capture fisheries. However, replacing capture fisheries production by aquaculture production is not realistic, for several reasons:

- under current conditions the aquaculture sector depends on capture fisheries for feed;
- in some countries the aquaculture sector still depends largely, under current conditions, on capture fisheries for fingerlings;
- intensive aquaculture largely targets the export market and generates income, but does not contribute much to local food security, in particular in rural areas;
- extensive aquaculture is not very productive; there are technical ways to improve productivity but strong socioeconomic and institutional constraints (e.g. land availability, tenure issues, access to quality fry) keep impeding the development of this sector in some of the LMB countries;
- producing one tonne of aquaculture fish is ultimately much more costly than catching it from the wild.

Thus, aquaculture can ameliorate fish supply from capture fisheries but cannot replace it.

8 SOCIAL SYSTEMS

Theme	*Key issues (relevant to hydropower)*
Social systems	1. Poverty, Ethnic Groups and Natural Resource Based Livelihoods 2. Health and Nutrition 3. Resettlement and Human Trafficking

8.1 PAST TRENDS AND CURRENT SITUATION

8.1.1 POVERTY AND NATURAL RESOURCE BASED LIVELIHOODS

- Impressive steps made by LMB countries to meet MDG goals in poverty reduction, but regression in key areas
- All countries except Vietnam showing regression on natural resource depletion or contamination. Very high livelihood dependence of all LMB countries (Thailand less so) on river and land resources, particularly among ethnic minorities
- National revenues from hydropower increasing, but association with poverty alleviation in all LMB countries still not clarified

The definition of what poverty is exactly and how it can be measured has been much debated for many years. Whatever the global figure, it is well recognised that no single factor is the cause of poverty, which is a condition far more diverse and complex than simply measuring income, spending power, or calorie intake. The definition of poverty has gradually become re-defined as a state of "capability deprivation", a range of limitations and barriers that prevent individuals from rising out of poverty. These include social, political, environmental and economic factors. Also included are ethical and social equity dimensions, which look at whether a suitable environment is created for people to live a decent life, where they are free to make their own decisions, and where external factors do not create an environment of uncertainty, fear or periodic shocks from which people progressively cannot recover or where their resilience is persistently and effectively undermined.

LMB countries have developed national poverty alleviation strategies in line with Millenium Development Goals (MDGs) as well as with individual national priorities. All countries share the view that the most successful poverty reduction policies are based on sound macroeconomic policies and promotion of efficient resource allocation. However, the definition of what these resources are, how they should be allocated, and who should exploit them, varies considerably not just between LMB countries, but between line agencies in each country.

Substantial poverty alleviation progress has been made over the past 20 years. Between 1990 and 2009 Thailand and Vietnam reduced their undernourished populations by more than 50%, while Cambodia and Laos 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 Vietnam on HIV/AIDS prevalence (Goal 6). All LMB countries except Vietnam show regression on Goal 7, Environmental Sustainability, with a very substantial reverse trend in forest cover.

Those living in Mekong river riparian provinces and districts depend for their livelihoods on some of the most productive land in the region. The higher the level of dependence on natural resources, the greater the opportunity for impoverishment of communities affected by any change in such resources. Because riparian areas provide the best agricultural land, and because the Mekong river itself provides unsurpassed opportunities for communities to diversify their livelihoods through fishing, gathering of aquatic products, and transportation, to name just a few options, they are also the most heavily populated, particularly in Vietnam. Mekong riparian provinces support a population of just over 32 million people. At 66%, Lao PDR has the highest percentage of its population living in Mekong river riparian provinces, while the largest riparian provincial population is in Vietnam (55%).

For the majority of the population living beside the Mekong mainstream river, and dependent on its water and land resources, nutritional intake (as well as household income) is reliant on a wide variety of forest, river, wetland and agricultural resources, consisting of fish, aquatic animals (frogs, snails etc.), aquatic plants (particularly the protein-rich weed called *kai*), insects, wild animals, livestock (cattle, buffalo, pigs and poultry), paddy rice, vegetables grown on riverbank gardens, and in some locations on non-timber forest products such as bamboo shoots, mushrooms, etc.

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. Indeed, some nutritional specialists refute the idea that rice insufficiency is the cause of food insecurity in the LMB, rather that it is due to loss of wildlife habitat and resources (not just fisheries) which is eroding the nutrition base and contributing to greater food insecurity.

This factor is confirmed by a recent MRC study which notes that proximity to the Mekong mainstream is also essential to dependency levels on the river's ecosystem. This was particularly noted in areas such as northern Laos, where the topography shows steep land elevation from the river bank, and upland communities living less than 15kms from the Mekong river showed little or no use of its aquatic resources. By contrast, the study notes that where the topography makes the Mekong river more accessible, as in the Tonle Sap in Cambodia, people travel considerable distances each year to profit from the seasonal fisheries opportunities. Thus a combination of easy access with proximity are determining factors of the extent of use of the Mekong river's aquatic resources.

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. Laos and Vietnam have the greatest representation of ethnic groups in their populations, with 48 groups and 47.5% of the population in Laos, and 54 groups accounting for some 14% of the population in Vietnam.

A history of wars in the region, recent population growth, improved living standards, and national compulsory relocation policies, have all contributed to the re-distribution of many ethnic groups away from their ancestral lands, and still tend to influence national policies. Ethnic minority groups still tend to live in remote and marginal areas and are often less able to access health and education services than national majorities.

Despite improvements in national trends and decline in poverty of ethnic minorities, some observers of LMB countries suggest that conditions for ethnic minorities in upland areas are worsening, with associated impacts on health, mortality rates and life expectancy. Reasons cited include policies to reduce swidden cultivation, assignment of land to foreign concessions which limits rotational areas, and population relocation. This puts added pressure on Mekong river riparian land, which is among the most agriculturally productive in all countries. Riparian landowners not only have to deal with loss of cultivable land due to urban growth, but also due to sequestration of land for foreign concessions and to accommodate population growth resulting from compulsory relocation and natural migration.

By the mid 2000's, countries began to express their concerns that their efforts towards poverty reduction came at the expense of dependence on external financing, in turn creating more reliance on the wishes and perspectives of external funders. The desire to follow a more independent road has contributed to development of national revenue generation strategies to give national governments more control over their own resources, and more say as to how revenues from such resources are distributed.

Hydropower has been promoted for some 10 years as in the national interest for poverty reduction and self-reliance based on two perceived opportunities: increasing national revenues, and maximising the economic potential of a national resource base. The presumption is that social equity is built-in through benefits sharing, ie. increased national revenues mean greater financial resources to fund activities which will help a country meet MDG targets, such as construction of schools and health centres, provision of clean water supply and sanitation, etc., while simultaneously reducing the need for external financing for this purpose.

The assumption that social equity through benefits sharing has not yet been confirmed through current experience, and considerable gaps remain between revenue generation and revenue management for poverty alleviation. There remains disagreement between LMB countries and between national line agencies, whether mainstream hydropower is in the national interest for poverty reduction and self-reliance, because of transboundary effects and the potential for exacerbating tensions between countries.

While at national levels, hydropower fits into national strategic plans for poverty alleviation, at local, implementing levels, the way in which hydropower developers function still present substantial challenges in whether their activities and operations contribute to poverty alleviation or to poverty augmentation. Experience to date of hydropower projects in the region indicates the distribution of benefits often appears arbitrary and often leaves out those directly affected by the project. Observers of China's mainstream dams have questioned the validity of the claim that these contribute to local poverty alleviation. Local people affected by the Manwan dam have no access to the electricity it generate, claim not to have received promised compensation, and additional relocation has been necessary following riverbank landslips. Local employment benefits from Manwan and Dachaoshan dams were available for a few years during construction, but these were short-term in nature and have not made substantial contributions to sustainable economic growth in the area.

The key as to whether hydropower development is an effective response to poverty alleviation is not just whether the national resource base of the Mekong river provide opportunities for economic development, but:

(i) whether the offset of resources lost in the hydropower development process are comparable to resources gained as a result of hydropower operations;
(ii) whether positive revenue generation is equally matched by effective expenditure management for poverty alleviation;
(iii) whether those responsible for constructing and managing hydropower projects are as competent in social, livelihood and environmental design and risk mitigation management as they are in engineering design and management;
(iv) whether local administrative capacities are sufficient to link relevant national poverty alleviation policies to on-the-ground hydropower-related activities; and
(v) whether the number of affected people are correctly estimated beforehand or not.

8.1.2 HEALTH AND NUTRITION

- Status of health issues related to poverty, population movement and water resource management, variable in different LMB countries
- Disease transmission closely associated with poor nutrition, poor water resource management & drainage (Lao PDR & Cambodia)

MDG health and nutrition indicators have shown gradual improvements in the LMB over the past 20 years or so. Thailand has removed the MDG relating to clean water supply and sanitation from its targets, having achieved almost universal clean water supply and sanitation by 2007. However, the remaining countries retain this MDG and have some way to go to achieve these objectives.

Life expectancy and children's health are important measures of quality of life and significantly affect a country's ability to be economically productive. Progress in improving health conditions is an important indication of their importance in national strategies. Problems remain, due either to under-funding, ignorance, access, or customary practices which may increase vulnerability to food insecurity and to health threats. Improvements reflect advancements in primary health care programmes, surveillance programmes, and socio-economic improvements, leading to better nutrition, sanitation and health services. However, there remain some gaps which continue to give rise to concern. In general, Cambodia and Lao PDR have demonstrated the slowest progress towards achieving all MDG goals.

Ethnic minorities experience significantly poorer health status than members of the majority population in all LMB countries. This is partly due to the often remote areas in which they live and relative inaccessibility of health facilities, to overall lower educational levels particularly among women, to lower standards of sanitation and hygiene, to different languages which make public communication on health messages a greater challenge, and to significant loss of the variety of natural resources from which ethnic groups obtain diverse food sources. Intestinal parasitic infections are endemic, contributing to high levels of stunting and wasting among children.

Malnutrition is associated with more than half of child deaths worldwide. Undernourished children are more prone to disease and less able to develop healthy immune systems, they are more prone to faltering growth, and may be more learning impaired than healthy, well-nourished children. It is also linked to poor educational standards of parents, as well as either limited income or limited access to the natural resources needed to provide a well-balanced diet. In Lao PDR, there is also a significantly higher percentage of the effects of malnutrition in highly sloping areas, especially among ethnic minorities. Sino-Tibetan groups, such as Akha, demonstrate the highest percentage of stunting among children (61.9%) as well as underweight children (39.8%), while Mon-Khmer and Hmong-Mien also demonstrate very high stunting rates (55%). Cambodia also acknowledges chronic malnutrition, particularly in rural areas, as does Vietnam, with an estimated 40% of children under the age of 5 being underweight and 38% suffering from stunting. A recent World Food Programme study alarmingly concluded that every second rural child in Laos under the age of 5, is stunted.

The importance of free sources of nutritional intake from natural resources, such as fish, non-timber forest products, and wild game, cannot be underestimated, particularly in poorer and more remote areas of the Lower Mekong Basin. Different regions have different nutrition characteristics. For example, while severe stunting, wasting and underweight of children due to poor diet is a feature throughout Lao PDR, some of its southern provinces (Salavane, Sekong, Attapeu, Champassack) have the highest incidence among children of underweight (50%), of stunting, characteristic of chronic, long-term malnutrition (46.2%), and of severe stunting (19.3%). Both Stung Treng and Kratie provinces also indicate a high prevalence of provincial stunting, wasting and low weight for age of children. Lack of district data from Cambodia prevents further analysis of whether Mekong river proximity has any influence on this prevalence.

Seasonal shifts in groundwater flows and levels result in waterlogging and related health and livelihood risks associated with elevated groundwater, increased drainage problems, affected sanitation, and greater potential to damaged land and property through saline intrusion. The northeast of Thailand already suffers from this latter problem, mainly attributed to natural attributes exacerbated by deforestation and irrigation development. This risk is elevated in proportion to type of riparian terrain – the flatter the riverbank and more prone to seasonal flooding, the greater the risk. Risk of waterlogging is therefore higher in Mekong downstream areas than in the upper LMB. Very low proportions of households in Laos and Cambodia have access to safe drinking water and sanitation. In provinces located further downstream, such as Champassack (Lao PDR) as well as Stung Treng and Kratie (Cambodia), some 28% or less of provincial households have access to sanitation, and more than half the population have access to clean drinking water sources, representing high risk areas for seasonal disease transmission due to flooding or elevated groundwater levels.

The incidence of vector borne disease is also higher in downstream Mekong river areas. A situation analysis of Stung Treng province emphasises that poor access to clean water supply is believed to be responsible for the high incidence of intestinal diseases, while the area has the highest incidence of malaria in Cambodia, though it notes that this is more common in higher land away from the Mekong.

Schistosomiasis and filariasis also occur in provinces along the Mekong river, such as in Ubon Ratchathani (Thailand), Champassack (Laos), and Stung Treng (Cambodia).

Arsenic in groundwater is also a little-known phenomenon in Cambodia and Vietnam, as well as in southern provinces of Lao PDR. A risk assessment was carried out by the World Health Organisation (WHO), which identified arsenic contamination of groundwater in the Vietnam Mekong river delta, as well as in approximately 1600 villages in 6 provinces in Mekong river floodplains. The report indicated uncertainties in the number of people potentially currently affected in Cambodia, as well as the degree of exposure. Laos was also affected but in a very small way compared to Cambodia and Vietnam, and exposure in other Mekong river riparian areas has not been identified.

The growth in regional transport networks has opened up markets, brought economic growth, and offers access to remote communities to health care and new livelihood opportunities. But it has also displaced communities, destroyed homes, disrupted livelihoods and facilitated trans-boundary migration with its associated risks of easier transmission of diseases such as HIV/AIDS. Construction brings truck drivers and construction workers, mainly male migrants, living away from home for long periods and often nationals of neighbouring countries.

In Lao PDR for example, roads and support infrastructure construction using foreign labour, particularly of Chinese and Vietnamese migrants, have facilitated human movement, especially in areas previously remote with a high ethnic minority population, such as border areas between China and Laos, Burma, and Vietnam. Many Chinese and Vietnamese construction companies prefer to bring in their own labour, introducing opportunities for sex workers in beershops and entertainment places which can be found more in main transit and transport routes and on construction sites. Sex workers are very mobile, typically staying 1-3 months in an area and then moving on as camp followers of construction workers. Many construction worker partners are also sex workers who also do not access local health services because of their very mobility, or who are not authorised to use the contractor's health services. Construction workers travelling to their home country for holiday may then have unprotected sex, either infecting their home partner or infecting the sex worker on their return.

Other changes are happening which mean that while national progress has made forward steps, there are other pressures which result in backward steps also. For example, Vietnam had the lowest rate of HIV/AIDS infection amongst 15-49 year olds in the world, but the infection rate has increased from 0.1% to 0.5% in eight years (1999-2007). The rate in Lao PDR, while still small, has doubled in the same period. Rates may be higher than acknowledged as people either do not know they are infected, or are afraid to acknowledge it, fearing the social stigmatisation that often follows. Thailand has the highest HIV prevalence rate, a risk internally, as well as for migrants from other countries. For those LMB countries experiencing an influx of migrant workers or which are able to take advantage of the closer commercial links between neighbouring countries through infrastructure improvements, the risk of disease transmission is elevated. Greater access to markets, skills, technologies and products, also carries associated risk of increase in sexually transmitted diseases, trafficking of women and children, and greater pressure on often already limited health facilities.

Public expenditure on health in countries in the LMB is variable, Thailand has both one of the highest percentage of government expenditure as well as per capita expenditure. Cambodia has the highest percentage of general government expenditure, but one of the lowest per capita figures. Health issues related to construction workers on hydropower projects and on associated facilities such as roads, transmission lines, etc., are considered the responsibility of individual contractors, who may or may not prepare and implement appropriate health plans. Two useful ways to address the issue so far have been (i) local village-level knowledge, information and awareness programmes - these have been quite successful in several parts of the LMB; (ii) well prepared health programmes integrated into infrastructure projects targeting nutritional causes of stunting and malnutrition, project migrant labour, and health of sex workers – for example, on the Nam Theun 2 hydropower project.

8.1.3 RESETTLEMENT

- Numerous policy and procedural gaps in land acquisition and compensation compared to international best practice. Social equity at risk with lack of consistent LMB compensation and mitigation framework
- 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

The seriousness of the social and political economy of resettlement was recognised by both civil society and national government during SEA national scoping workshops. It is the only topic where all LMB countries are in agreement as being one of the most important transboundary strategic issues facing Mekong river mainstream dam development. International standards of resettlement policy and practice, as well as of mitigation measures, now treat resettlement as much more than loss of home and land resolvable through cash compensation. The term "resettlement" has been used for more than 10 years to define the total spectrum of socio-economic impacts of project-induced activities throughout the whole project cycle, including displacement, expropriation of resources which prevent or inhibit people from their livelihoods, loss of cultural, historical and social resources, health risks arising from project activities, to name but a few. In short, "resettlement" has come to mean all stages of risk management planning and implementation before, during and after a project.

A variety of policies and legislation are used as reference basis for both expropriation and compensation as a result of projects such as dam constructions. In the LMB, all 4 countries have revised their own national policies and practices to better reflect best international practice. Key improvements in Lao and Vietnamese legislation over the past 5 years include: provision for wider eligibility for compensation, including for those without tenure documentation, increased amounts (and coverage) for transition and moving expenses in relocation i.e. it provides for livelihood stabilization, assistance for affected people (APs) deriving an income from agricultural production who have to change occupation, and 'other' assistance as required for special cases; and requires establishment of resettlement zones with at least pre-project conditions for relocating APs.

However, even where legislation may meet international standards, application of these standards regularly falls well short in practice. There is a tendency to approve projects without willingness or competence to anticipate or require adequate procedures and finances to address problems. The process to obtain required feedback, comments, document approvals, and safeguard frameworks is often long and time consuming, and easily skipped by line agencies who may have limited understanding of the relevant legal and institutional framework, and even if understood, know that formal approval of inadequate plans carry no repercussions or sanctions if they are either poorly applied or not even enforced.

The experience to date over social and environmental planning for hydropower development in all LMB countries has not been satisfactory. The lack of national experience in hydropower construction and development, together with the lack of human and budgetary capacity among government institutions in hydropower planning, social and environmental mitigation planning and implementation, and in monitoring, render the institutional framework in LMB countries relatively ineffective. Social impact assessments (SIAs) are not de-linked from environmental impact assessments (EIAs) during preliminary feasibility stages, although they require very different types of skill and expertise, are not conducted in sufficient time before impacts start being felt, and in some cases, SIA/EIAs do not even consider upstream and downstream impacts, whether they occur in the same country or in another country, nor do they often take into account facilities associated with hydropower construction, such as rights-of-way, access roads, transmission lines and substations. Even so, SIA procedures tend to be more advanced that the baseline data on which the SIA process depends. Poor data lead to unreliable assessments of likely social and environmental impacts.

Unfortunately many hydropower developers have not so far demonstrated a commitment to social and environmental responsibility, and are not willing to engage with local communities when unforeseen circumstances arise.

But land expropriation in the LMB occurs in several forms, not just in relation to development projects, and has regional variations. Compulsory relocation of people should not be confused with voluntary or economic migration. Types of land acquisition and forced displacement in LMB countries include:

1. land acquisition as a consequence of development for national benefit (e.g. road construction, public amenities, hydropower development);
2. land acquisition for major private investment and FDI projects (concessions awards);
3. change of land classification (e.g. from use forest to degraded) to provide land to concessions;
4. relocation of communities to pursue national objectives of reducing shifting cultivation, eradicating opium cultivation, and providing social service;
5. land grabbing by the rich and powerful at the expense of the poor and vulnerable.

The consequences of these land expropriation practices in all the LMB countries have subsidiary significance for other forms of construction development, creating a state of "double jeopardy". This means that land acquisition, forced displacement and short- and long-term livelihood consequences due to other activities already occurring in LMB countries serve to create a situation of double jeopardy for affected people when they find themselves in the path of an infrastructure project. Adding to the mix are consequences on natural resources of existing unsustainable practices by riparian communities themselves, including use of unsustainable or illegal fishing methods, water contamination through human, agricultural and industrial waste, illegal logging, and forest habitat and wetland destruction from land clearance for agricultural and commercial expansion. The absence of policy frameworks affect regional cooperation and coordination. Even where they exist, their implementation is limited, reflecting weak country capacities as well as incomplete data and inadequate monitoring.

8.2 FUTURE TRENDS WITHOUT THE LMB MAINSTREAM HYDROPOWER DEVELOPMENT

Zone	Status and Trends
Zone 1: China border to Chiang Saen	• high proportion of ethnic minorities living in hilly terrain, mainly swidden upland cultivators, heavily dependent on natural resources • high proportion of poor districts, limited access to facilities such as health clinics and schools, or amenities such as electricity. Often inaccessible during monsoon season • high levels of stunting, wasting and child mortality, particularly in ethnic minority groups • highest levels of vulnerability to food insecurity • strong push in Laos to relocate remote upland villages to valleys and riverbanks as a poverty alleviation strategy • considerable population movement across borders, particularly from China, Myanmar and Laos into Thailand, for trafficking as well as work migration • transboundary communications improving and increasing with road and bridge construction
Zone 2: Chiang Sen to Vientiane	• high proportion of ethnic minorities living in hilly terrain, changing to preponderance of majority nationalities as land flattens out along the Mekong river. Majority of population from Lao-Thai communities • gradual shift from upland swidden cultivation to more fixed subsistence and market agriculture as the land flattens out. Increasing importance of seasonal riverbank gardens for both subsistence and commercial purposes • higher concentration and density of populations, particularly for Laos where the largest population is located in and around Vientiane • improved access to health and educational facilities, and higher levels of literacy in the general population • still high levels of rural stunting and wasting, but lower overall in proportion to total population. Vulnerability to food insecurity still high in northern riparian districts, but reducing on approach to Vientiane • Vientiane providing the main magnet for in-country migration • lowest national poverty rate for Vientiane, and lowest national poverty rates overall after Vientiane
Zone 3: Vientiane to Pakse	• very high levels of transboundary movement between Laos and Thailand, facilitated by bridges at Vientiane/Nong Khai and Savannakhet/Mukdahan • improved GMS road networks resulting in rise of transboundary migration from Vietnam to Laos, and thence through to Thailand • high levels of foreign traders establishing bases in riparian towns and villages, controlling both wholesale and retail networks of agricultural and consumer products • main population from Lao-Thai communities

	• larger proportions of poor households in northeastern Thailand and considerable degredation of land-based resources. Higher dependency on alternative livelihoods • higher proportion of better-off households but still medium levels of vulnerability in Bolikhamxay and Khammouane provinces, still high poverty rates in parts of Champassack, but less in riparian districts. Higher poverty density in urban areas • highest proportion of flat riparian land, heavily cultivated by settled subsistence and market agriculturalists • better infrastructure provision and amenity base • medium levels of vulnerability to food insecurity
Zone 4: Pakse to Kratie	• lowest poverty rates for Laos after Vientiane • higher national poverty rates for Ubon Ratchathani • highest national rates of transboundary migration and trafficking for Laos and Vietnam to Thailand • lowest levels of vulnerability to food insecurity in Laos, but higher in Cambodia • among the highest concentrations of land concessions in Cambodia allocated in Stung Treng • high rates of households in Stung Treng and Kratie without access to safe drinking water supply or sanitation • increase in likelihood of vector borne diseases (e.g. malaria, filariasis, dengue), both in Laos, Thailand and Cambodia
Zone 5: Kratie to Tonle Sap	• beginning of natural arsenic occurring in Mekong river riparian groundwater in Kratie • agriculture shifting from mixture of paddy and cash crops more to intensive paddy farming and higher fisheries dependence in Tonle Sap • higher density of population and greater urbanisation • greater population movement for internal economic seasonal migration • households more reliant on self-employment and wage labour and less reliant on agriculture and common property resources, including forests. Better off households are earning more from agriculture and self-employment, while poorer households are more reliant on wage labour than in the past. • about 1 million people estimated directly dependent on fisheries
Zone 6: Mekong delta	• most densely population zone in the LMB • heavy dependence on paddy cultivation and fisheries • natural resource base under pressure from increasing saline intrusion • high proportion of rural children underweight, stunted and wasted, compared to national average and to urban children • increasing risk of vulnerability to impoverishment due to land fertility loss from saline intrusion and land erosion

9 CLIMATE CHANGE

Theme	*Key issue (relevant to hydropower)*
Climate Change	1. What changes are foreseen in climate and hydrological variability and extremes? 2. What implications will those changes have for natural and social systems in the basin? 3. What implications will those changes and their effects have for development sectors in the basin including hydropower? (for example, in terms of energy generation, operations, GHG emissions and carbon financing)

9.1 PAST TRENDS AND CURRENT SITUATION

Already, climate changes in the Mekong region are influencing ecosystems, livelihoods and development through changes in regular weather – ie daily, seasonal and annual patterns – and through changes in the frequency of extreme events. The main influences (and indicators of change) are temperature, rainfall and runoff, sea level, tidal fluctuations and natural disasters such as storms, floods and drought.

Over the past 3 to 5 decades, trends of increasing mean annual temperature have been recorded in each LMB country. In Cambodia, for example, from 1960 to 2005, the average temperature increased by 0.8°C. The rate of increase is most rapid in the drier seasons at a rate of 0.2-0.23°C per decade and slower in the wet seasons at a rate 0.13-0.16°C per decade. 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 Laos and Cambodia, a decrease in Thailand, and decreases in most localities in the north of Vietnam with increases in most areas of the South during all seasons. In winter in Vietnam rainfall fell by 23%.

Seasonal changes are important, with most increases in rainfall occurring during the wet season. All countries have experienced decreasing rainfall during the dry season with aggravated drought and water stress situations in many catchments.

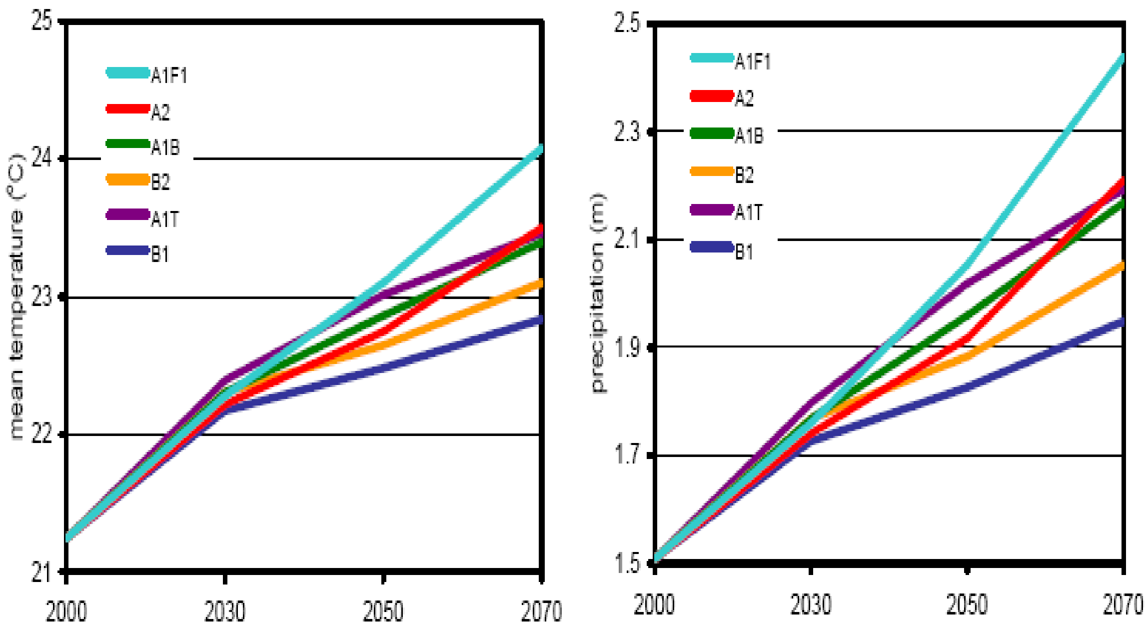
Green house gas emissions: GHG emissions are a consideration in defining energy options. The total emissions from the four LMB countries is about 1.5 per cent of total world GHG emissions and about 35 per cent of emissions from the ASEAN countries (WRI 2009). Cambodia has the lowest per capita emissions while Thailand has the highest and is close to the world average. From 2000 to 2005, the emissions intensity decreased for all four LMB countries reflected a reduction in emissions relative to economic growth. Those figures do not include emissions from planned irrigation and hydropower reservoirs under the BDP Definite Future Scenario. An estimate of GHG emissions from hydropower reservoirs in the region is provided in the SEA baseline power theme chapter.

9.2 FUTURE TRENDS WITHOUT THE LMB MAINSTREAM HYDROPOWER DEVELOPMENT

9.2.1 FUTURE TRENDS IN CLIMATE AND HYDROLOGY

During the past decade, future climate change has been assessed using a range of models, IPCC scenarios and methods. The projections vary according to the IPCC development scenario modeled, which is to be expected, given the range of GHG emissions across scenarios. Projected changes in the basin vary from catchment to catchment, North to South, season to season and year to year – findings also to be expected given the differences in latitude, altitude, topography and other climatic influences such as marine and coastal forces. Projections also vary with the models used, which is a concern and reflects the embryonic nature of climate change science. Despite this variability and continuing uncertainty, distinctive and consistent trends are discernable across all studies and models – just varying in extent. For all IPCC scenarios, increases in temperature and rainfall are projected, with sharper increases and divergence between scenarios from 2030 (Figure 1).

Figure 1: Projected mean annual temperature and mean annual rainfall for the Mekong Basin for different IPCC scenarios at 2030, 2050 and 2070



Source: Eastham et al. 2008

Results for A1B – selected by CSIRO as it represents a mid-range scenario in terms of development impacts on GHG emissions – provide a good indication for the overall trends in the region, and for the hydro-ecological zones. They are used here as the main basis for summarising trends to 2030 as reflected in Table 1 and Figure 2.

Temperature: 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.

Rainfall: Annual rainfall to increase by 13.5% (0.2m) mainly due to increases during the wet season (May to Oct). Dry season rainfall will increase in northern hydro-ecological zones (1 and 2) and decrease in southern zones (3 to 6 – ie from Vientiane to the Delta). The overall disparity between wet and dry seasons will increase especially in zones 3 to 6.

Runoff: Total annual runoff from the basin is projected to increase by 21% mainly during the wet season with the annual discharge at Kratie increasing by 22% with increases in all months but mainly the wet season. This projection takes into account estimates for water use by future populations in the basin and irrigation.

Table 1: Climate change in the Mekong basin – annual averages (2030 for A1B)

Indicator	Historical record 1951-2000	2030	Increase
Temperature	▪ 21.2°C	▪ 22.0°C	▪ **3.7%** or 0.8°C
Rainfall	▪ 1.509 m	▪ 1.712 m	▪ **13.5%** or 0.2m
Runoff	▪ ~512,000 mcm	▪ ~619,000 mcm	▪ **21%** or ~107,000 mcm
Flow (the mean annual discharge at Kratie)	▪ 13600 m3s-1, (from 1924-2006)	▪ 16592 m3/s	▪ **22%**
Flooding (incidence of extreme wet events at Kratie – zone 5)	▪ Annual probability 5% ▪ Duration 5.1 months	▪ Annual probability 76% ▪ Duration 5.7 months	▪ **71%** increased probability ▪ **12%** increase in duration ▪ Increase of 3,800km^2 area of flooding in delta

Flooding: Flooding is projected to increase throughout the basin – with downstream zones affected most. For example at Kratie (zone 5) the annual probability of extreme wet flood events will increase from 5% (ie historic conditions) to 76%. It will increase to 96% in the wet season. The duration of flooding will increase in this zone with an earlier onset. The maximum and minimum area and water levels in Tonle Sap would increase annually. The annual average flooding in Delta would also increase by 3,800km^2 The impacts of this increase in flow and flooding could be expected to be greatest on the mainstream Mekong due to cumulative contribution from tributaries.

Drought and dry seasons flow: Despite rainfall increases, zones 3 to 6 are projected to experience reduced rainfall and runoff during the dry season. Southern Laos, Northeast Thailand, Central and Southeastern Cambodia, including the Tonle Sap catchment and the Delta region are still susceptible to high water stress during the dry season. More dry spells and a greater severity in drought periods are expected. The past trend of increasing variability with greater extremes between wet and dry seasons, especially in southern and eastern areas, is projected to continue.

Figure 2: Summary of predicted regional climate change impacts by hydro-ecological zone (A1B)

LMB Catchment	Agricultural Productivity	Food Availability	Temperature	Annual Precipitation	Dry Season Precipitation	Annual Runoff	Dry Season Runoff	Annual Water Stress	Dry Season Water Stress	Flooding Potential	Max Flows/water level	Flood Duration	Flooded Area	Dry Season Minimum Flows	Saline Intrusion
Zone 1 – China to Chiang Saen – headwaters and mountain river	-	-	+	+	=	+	=			+	+	+		+	
Zone 2 – Chiang Saen to Vientiane – upland river in steep narrow valley	-	-	+	+	+	+	+			+		+	+		
▪ **Moung Nouy: Northern Lao PDR**	-	-	+	+	+	+	+			+					
▪ **Luang Prabang: Northern Thailand and Northern Lao PDR**	-	-	+	+	+	+	+			+					
▪ **Vientiane: Northern Lao PDR and of North-east Thailand**	+	- [1]	+	+	+	+	+			+					
Zone 3 – Vientiane to Pakse – the Thai/Lao midstream section and tributaries	+	- [1,2]	+	+	-	+	+/-	+ [3]	+ [5]	+					
▪ **Tha Ngon: Central Lao PDR**	-	-	+	+	-	+	+			+					
▪ **Nakhon Phanom: Central Lao PDR and North-east Thailand**	+	- [2]	+	+	-	+	-			+					
▪ **Mukdahan: Southern Lao PDR and North-east Thailand**	=	- [2]	+	+	-	+	+			+					
▪ **Ban Keng Done: Central Lao PDR**	+	- [1]	+	+	-	+	-			+					
▪ **Yasothon: Northeast Thailand**	+	- [1]	+	+	-	+	+	+ [3]	+ [5]	+					
▪ **Ubon Ratchathani: Northeast Thailand**	+	+	+	+	-	+	+	+ [4]	+ [5]	+					
Zone 4 – Pakse to Kratie, including wetlands of Siphandone, Khone Falls, Stung Treng and Kratie, including a	+	- [1]	+	+	-	+	-	+	+	+	+	+			

LMB Catchment	Agricultural Productivity	Food Availability	Temperature	Annual Precipitation	Dry Season Precipitation	Annual Runoff	Dry Season Runoff	Annual Water Stress	Dry Season Water Stress	Flooding Potential	Max Flows/water level	Flood Duration	Flooded Area	Dry Season Minimum Flows	Saline Intrusion
number of significant tributaries															
▪ **Pakse: Southern Lao PDR and Northeast Thailand**	+	- [1]	+	+	-	+	-	+	+	+					
▪ **Se San: Southern Lao PDR, NE Cambodia & Central Highlands of Vietnam**	+	- [1]	+	+	-	+	-			+	+	+			
Zone 5 – Kratie to Phnom Penh and the Tonle Sap - Floodplains and the Great Lake	+	- [1]	+	+	-	+	-		+	+	+	+	+	+	
▪ **Kratie: Far southern Lao PDR and Central Cambodia**	+	- [1]	+	+	-	+	-			+	+	+	+	+	
▪ **Tonle Sap: Central Cambodia**	+	- [1]	+	+	-	+	-		+	+	+	+	+	+	
Zone 6 – Phnom Penh to the sea – Mekong delta, tidal zone	-	-	+	+	-	+	-	+ [2]	+	+	+	+	+	+	+
▪ **Phnom Penh: South-eastern Cambodia**	-	- [1]	+	+	-	+	+	+ [2]	+	+			+		
1. Border: Southern Cambodia and South Vietnam	-	- [2]	+	+	-	+	-	+ [2]	+	+	+	+	+	+	+
2. Delta: South Vietnam	-	- [2]	+	+	-	+	-	+ [2]	+	+	+	+	+	+	+

1= due to decrease in surplus; 2 = due to population growth; 3 = moderate level; 4 = medium level; 5 = high level

+	Predicted increase	-	Predicted decrease	=	Status quo		Unstated

Source: ICEM drawing from Eastham et al. 2008, TKK 2009, MRC 2010 and other sources

9.2.2 GOVERNMENT POLICIES AND TARGETS FOR THE THEME

Mekong countries are launching climate change plans and programs which set out the issues and needed responses. For example, China's National Climate Change Program (CNCCP), June 2007[8] sets out a wide range of adaptation and mitigation principles and targets for 2010. Adaption targets involve extensive ecological restoration, the expansion of protected area systems and the wise use of water resources. The CNCCP requires government ministries and departments to strengthen co-ordination andco-operation, so as to achieve integration in addressing climate change. Vietnam's National Target Program for Climate Change 2008[9] is similar in its coverage but gives greater emphasis to "Mainstreaming the NTP in Strategies, Plans, Socio-economic Development Planning and other Sectoral/Local Development Plans".[10] In Cambodia and Lao PDR, the national policy framework takes the form of a National Adaptation Program of Action to Climate Change (NAPA). Thailand has prepared the 'Action Plan on National Climate Change as the Five Year Strategy on Climate Change 2008 to 2012'. In general, climate change issues are not integrated into the broader policy frameworks of national Governments or in specific sector and local government development plans.

9.2.3 MODIFYING EFFECTS OF HYDROPOWER AND IRRIGATION

Some of the projected trends in climate change would be moderated by economic developments in the basin. The planned hydropower dams and irrigation projects, in particular, would interact in various ways to modify the hydrological effects of climate change. Hydropower storage reservoirs can control the release of water and affect daily, seasonal and annual flows. Irrigation extracts water from rivers or reservoirs affecting flow volume. Other water users such as industry and domestic sectors are expected to double over the next 20 years but will remain relatively small consumers.

The SEA baseline assessment works with a projected baseline to 2030 – taking in the BDP Definite Future Scenario and the LMB 20 year scenario without LMB mainstream dams. The DFS includes 40 tributary dams constructed since 2000, under construction or committed and 6 China mainstream dams. In the DFS, the total live or active storage of the tributary dams and of the Chinese reservoirs[11] is 21,222 MCM or 4.6% and 22,189 MCM or 4.7% respectively of the annual water volume leaving the Delta – making a total of 9.3%. Under the LMB 20 year "without" scenario, there are 70 tributary dams (30 additional to the DFS with a live storage of 20,185 MCM or 4.2%) and the 6 Chinese dams – with a total active storage making up 13.5% of Mekong water.

During full operation of all the existing and planned hydropower dams, one might expect a significant effect in seasonal regulation of the 21% increase in total annual flow projected with climate change. During the annual flood, the dams might hold back water, and during the dry they might increase normal flows. In practice over the next 20 years to 2030, the regulatory influence of the planned dams will be determined by their construction schedules – most take 5 to 10 years to construct once approved and inevitably, development of projects will be staggered, potentially expanding the influence of the construction phase over several decades. The total storage

[8] Downloadable at http://en.ndrc.gov.cn/newsrelease/P020070604561191006823.pdf

[9] MONRE, 2008, National Target Program to respond to Climate Change *(Implementing the Government's Resolution No. 60/2007/NQ-CP dated 3rd December 2007).* As of August 2008, the second draft of the NTP prepared by MONRE was before Government for approval.

[10] Draft 1 of the NTP, May 2008, section 4.8.

[11] The Manwan reservoir in Yunnan has been in operation since 1993, but its live storage is minor (250 MCM) therefore it is included with the other Chinese reservoirs

(ie active and dead) of these reservoirs could be three times the live storage. While dams are being filled, water is being withheld from the Mekong effecting both wet and dry season flows.

The expansion of the irrigated areas in the basin will increase 10.9% annually mainly for dry season irrigation when water runoff and flow is lowest. Until 2030, that development and increasing consumption (35% on 2000 levels) will occur while the hydropower dams are under construction. The combined "withdrawal" of storage water for the reservoirs and for irrigation would have significant effects on wet and dry season flow.

In summary - For the "construction" period from now until 2030, tributary and Chinese hydropower dams could:

(i) Reduce dry season flows and make them more unpredictable – offsetting the benefits of increased flows due to climate change in zones 1 and 2 and compounding reduced dry season flows in the others.
(ii) Reduce wet season flows potentially reducing the increased threat of flooding due to climate change up to a defined capacity – after which more serious flooding might occur because of the need for substantial releases from many dams
(iii) Compound the trend of increasing saline intrusion in the Delta by further reducing dry season flows.

Increased extraction for irrigation could:

(i) Reduce dry season flows and make them more unpredictable – offsetting the benefits of increased flows due to climate change in zones 1 and 2 and compounding reduced dry season flows in the others.
(ii) Compound the trend of increasing saline intrusion in the Delta by further reducing dry season flows.

9.2.4 CLIMATE CHANGE EFFECTS ON DEVELOPMENT SECTORS

The projected 2030 increases in temperature, rainfall and runoff with more extreme climate events will influence the productivity of economic sectors and livelihoods.

Agriculture: Overall agricultural productivity will increase in the basin (around 3.6% by 2030) but food security will decrease, despite the increasing areas under irrigation. Those decreases are due to:

(i) Reduced dry season rainfall and runoff in central and southern zones
(ii) Increasing saline intrusion in the Delta due to storm surge and tidal influences and decreases in dry season rainfall and runoff.
(iii) Increasing populations and reduced production in excess of demand

Fisheries: Overall 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:

(i) Decreased agricultural productivity and food security increasing demand and pressure on fish populations
(ii) Increased riparian populations and fishing pressure
(iii) Dramatically reduced fish migration and aquatic biodiversity in zone 1 and in Mekong tributaries due to dam and infrastructure construction
(iv) Reduction of flooded forest habitat in Central Cambodia due to increased area and depth of Tonle Sap
(v) Reduced fresh water habitat in the Delta due to increased saline intrusion (not adequately offset by increases in dry season releases from upstream reservoirs during hydropower dam operational period – ie following 2030 for most projects)

(vi) Increased disturbance and destruction of fish habitat due to flooding of riverine wetlands, construction of infrastructure and pollution from expanding settlements and industry.
(vii) 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 Vietnam.

Hydropower: Overall the hydropower sector will benefit from climate changes from increased capacity in basin catchments, but there are risks.

(i) Increased rainfall, runoff and flow throughout basin would increase potential capacity of tributaries for hydropower
(ii) 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
(iii) 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 – eg a 1 in 1000 flood?)
(iv) Dam design and retrofitting would need to take into account changing and more variable conditions of rainfall and runoff and of extreme events

Livelihoods: Aquatic and terrestrial natural systems are under increasing stress in the Mekong basin. While there are benefits, overall climate change will increase that stress by

(i) Increasing the need to make agriculture more productive and extensive and by increasing pressure to exploit aquatic resources.
(ii) Reducing fish habitat, feeding and nursery areas
(iii) Increasing water stress in some catchments and the frequency and intensity of drought periods

The negative natural systems impacts of climate change 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.

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