Mekong River Commission

Basin Development Plan Programme, Phase 2

Technical Note

Economic, environmental and social impact assessment of basin-wide water resources development scenarios

Assessment methodology

(Work in Progress)

October, 2009

<u>Note to the reader</u>

This technical note is prepared to serve facilitation and discussion on the economic, environmental and social impact assessment of basin-wide development scenarios of Lower Mekong Basin for 2nd Regional Stakeholder Consultation and Dialogue of Basin Development Plan Programme, Phase 2. The assessment process is in progress and the results are expected in December, 2009.

Economic, environmental and social impact assessment of basin-wide water resources development scenarios

Assessment methodology

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Contents amendment record

This report has been issued and amended as follows:

Issue	Revision	Description	Date	Signed
1	0	Draft prepared for 2nd Regional Stakeholder Consultation and Dialogue of Basin Development Plan Programme, Phase 2	7 Oct 2009	

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Glossary

ADB	Asian Development Bank
AIFP	Agriculture, Irrigation and Forestry Programme
BDP	Basin development programme
BDP1	BDP Phase 1
BDP2	BDP Phase 2
DSF	Decision support framework
EP	Environment Programme
FMMP	Flood management and mitigation programme
FP	Fisheries Programme
HP	Hydropower Programme
IBFM	Integrated basin flow management
IQQM	Discharge modelling software
ISIS	Proprietary river modelling software
IKMP	Information and knowledge management programme
IWRM	Integrated water resources management
LMB	Lower Mekong Basin
MRC	Mekong River Commission
MRCS	Mekong River Commission Secretariat
NMC	National Mekong Committee
NP	Navigation Programme
PIN	Project Identification Note
PDS	Project Description Sheet
PNPCA	Procedures for Notification, Prior Consultation and Agreement
PWUM	Procedures for Water Use Monitoring
RTWG	Regional technical working group
SWAT	Open source hydrological modelling software
ToR	Terms of reference
WB	World Bank
WUP	Water utilisation programme
WUP-A	WUP component for DSF development

Preface

The purpose of this report is to explain the rationale and processes adopted in the economic, environmental and social impact assessment of basin-wide water resources development scenarios being conducted by MRC through Phase 2 of the Basin Development Programme.

This main report presents an overview of the overall process. It is supported by five annexes setting out the detailed approaches adopted for hydrological, environmental fisheries, social and economic assessments.

The report is intended to provide a basis for discussion with national and regional stakeholders as to the efficacy of the approach adopted and to elicit feedback and suggestions as to how improve the assessment process.

1 Introduction

1.1 Background

MRC's Basin Development Plan Phase 2 (BDP2) is designed to provide an integrated basin perspective through the participatory development of a rolling IWRM-based Basin Development Plan. The plan comprises:

- **Basin-wide Development Scenarios**, which will provide the information that Governments and other stakeholders need to develop a common understanding of the most acceptable balance between resource development and resource protection in the various parts of the LMB. Each considered scenario represents a specific balance between economic, social and environmental objectives. The results of the economic, environmental and social assessment of the considered scenarios will guide the formulation of the IWRM-based Basin Strategy.

- **IWRM-based Basin Strategy**, which provides a shared vision and strategy of how the water and related resources in the LMB could be developed in a sustainable manner for economic growth and poverty reduction, and a coherent and consistent IWRM planning framework that brings basin perspectives into the national planning process, and vice versa. The results will guide the formulation of the Project Portfolio.

- **A Project Portfolio** of significant water resources development projects and supporting non-structural projects that would require either promotion or strengthened transboundary water governance, as envisioned in the 1995 Mekong Agreement.

The preparation of the Plan will bring all existing and planned water and related resources development projects in a joint basin planning process, through a combination of participatory sub-basin and sector activities and a basin-wide integrated assessment approach.

1.2 Basin-wide Development Scenarios

The background to and the overall intent of the Assessment of Basin-wide Development Scenarios is set out in BDP's technical note *Scoping and planning of the assessment of basin-wide development scenarios*, March 2009, which was prepared in consultation with the MRC member countries.

Each scenario is intended to provide a different balance (or trade-off) between economic, environmental and social objectives of the MRC member countries. The assessment will appraise (quantify and qualify) how well each scenario would achieve these objectives. After basin-wide consultations on the assessment results, the countries will determine which scenario would provide the most acceptable balance between economic, environmental, and social outcomes in the LMB, and would bring mutual benefits to the LMB countries. The selected scenario will support the definition of the LMB development space as described in the IWRM-based Basin Strategy.

The scope of the development scenarios to be assessed is limited to those with transboundary impacts where trade-offs between sectors will have to be considered. The scope of the assessments of the development scenarios is to be triple bottom line, i.e. to embrace economic, social and environmental cumulative impacts, at a level of detail that enables decisions to be reached on the key issues within the defined time-frame. The scope of assessments is expressly not to endorse specific project-level interventions, which will require detailed studies of their own to confirm their individual viability and acceptability.

The extent of the assessment is limited to the following potential impact areas:

- Those areas directly affected by changed hydrological conditions in the mainstream. This is a corridor along the mainstream and up tributaries where backwater affects may occur of a width determined by the dependence of those living within that corridor whose livelihoods are directly affected by hydrological and water quality conditions in the mainstream.
- The Tonle Sap and adjacent areas and the flood plains in Cambodia and Vietnam.
- Those areas where there is direct dependence upon capture fisheries as defined by a corridor (overlaid on the above) delineated by the extent of fish migration (defined as the mainstream and significant tributaries up to the point where natural or existing, ie baseline, man-made obstructions prevent further migration).

Socio-economic benefits that arise, or could arise, outside the above areas will be evaluated only where they are directly linked to development and management of the mainstream (e.g. hydropower generated and irrigation made possible by increased dry season flows) and where they are relevant to the trade-offs under consideration. Since the precise locations where these benefits may arise will not be known, no attempt will be made to make environmental assessment of these unless it can be reasonably shown that their cumulative impacts might have an impact on mainstream water quality (e.g. from use of agricultural fertilisers and pesticides).

1.3 Scenario formulation

A development scenario in BDP2 context is defined as a hypothetical combination of possible changes in hydrological condition and/or multi-sector water demands and/or proposed interventions, describing a plausible future situation. Previous studies demonstrate that it is important for planning purposes to distinguish between the following future situations:

- **Baseline situation**, representing development conditions (physical and management characteristics) existing in 2000 and the hydro-meteorological conditions of 1985-2000, considered at the basin scale to represent the natural situation (or as close as can be reasonably quantified);

- **Definite future situation**, which includes water resources developments that will be fixed parts of the Mekong system in a few years from now, such as the planned dams in the Upper Mekong Basin, as well as water developments (eg hydropower and irrigation) that are being constructed in the LMB;

- **Foreseeable future situation**, representing development conditions that could become a reality during the next 20 years, based primarily on country plans and development opportunities;

- **Long-term future**, representing development conditions in the Mekong Basin that are plausible (or at least not implausible) in 50 years from now;

In addition to man-induced water resources development, the hydrological regime of the Mekong mainstream could also change during the coming decades as a result of climate change, sea level rise or continuing land use changes.

The development scenarios as currently formulated and for which assessments are required are set out in Table 1 overleaf.

1.4 Work components and plan

The assessment work plan is divided into seven components (see box) associated with, firstly hydrological assessment of all scenarios and secondly impact assessment of different scenarios. The basis for identifying these particular scenarios is founded on an understanding of key development issues as explained in BDP's technical note on scoping of the development scenarios.

Main work components of the scenario assessments

A. Assessment of hydrological changes

A1. The hydrological changes of the considered water resources development scenarios will be assessed to confirm and improve the results of the preliminary hydrological assessment conducted in 2008. The scenarios for the foreseeable future and the longer-term will be assessed for situations with and without climate change.

B. Assessment of the main economic, environmental and social impacts

B1. The available economic, environmental and social baseline information will be reviewed and improved as necessary and appropriate to support the assessment of the considered development scenarios.

B2. Assessment of the defined trade-off between the hydropower and irrigation sectors, on the one hand, and the fisheries sector, on the other in the LMB 20-Year Plan Scenario and alternative perspectives (the LMB 20-Year Plan Scenario without Mainstream Dams in the Middle and Lower LMB, and the LMB 20-Year Plan Scenario without Mainstream Dams).

B3. Assessment of the identified significant economic, environmental and social impacts caused by the Definite Future Scenario

B4. Assessment of the defined trade-off in various sub-scenarios of the Mekong Delta Flood Management Scenario between increased economic and social benefits of reduced levels of flood risk reduction, on the one hand, and the costs of flood protection measures and the forgone benefits in the agricultural and environmental sectors, on the other.

B5. The description of the economic, social and environmental impacts of the scenarios for the longer term, conducted in two stages: an initial report in July 2009 (B5a) and a detailed report (B5b) in February 2010.

B6. Delivery of a triple bottom line assessment of the considered scenarios, the comparison of the scenarios by country and sector, and a description of the options for discussion and decision-making

Table 1 List of scenarios to be assessed

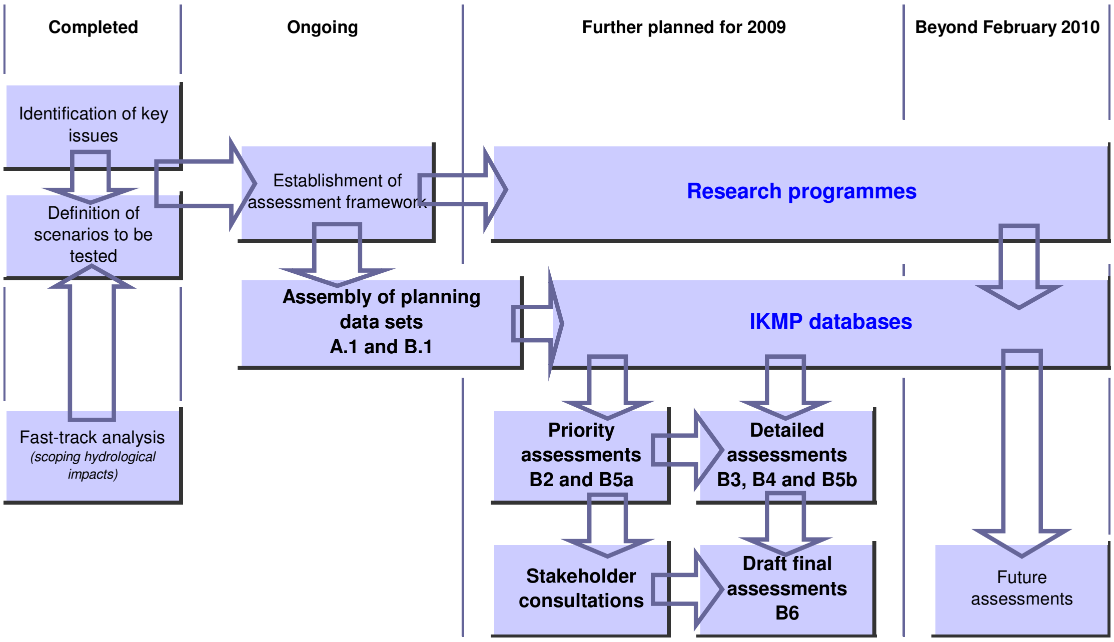
Ref	Title	Hydrology	Dams: China	Dams: Mainstream	Dams: Tributary	Irrigation and water supply demands	Flood control works	Remarks
1000	**Baseline scenario**	Standard 1985-00	No new	None	Existing in 2000 (11 no.)	As in 2000	No addition	
	Definite future situation							
2000	Upper Mekong Dam scenario	Standard 1985-00	First 6 no.	None	Existing in 2000 (11 no.)	As in 2000	No addition	
3000	Definite future scenario	Standard 1985-00	First 6 no.	None	Existing + 25 under construct.	As in 2008	No addition	
	Foreseeable future situation (2030)							
4000	LMB 20-year plan scenario	Standard 1985-00	First 6 no.	All 11 dams	Existing + 52 planned by 2030	Existing + planned by 2030*	No addition	
4001	- " -	**Climate change**	First 6 no.	All 11 dams	Existing + 52 planned by 2030	Existing + planned by 2030*	No addition	*Either A2 or B2 as agreed with BDP*
5000	LMB 20-year plan scenario without	Standard 1985-00	First 6 no.	None	Existing + 52 planned by 2030	Existing + planned by 2030*	No addition	
LMB 20-year plan scenario with different configurations of mainstream dams in LMB								
6000	With 6 dams in upper LMB	Standard 1985-00	First 6 no.	6 in upper LMB	Existing + 52 planned by 2030	Existing + planned by 2030*	No addition	
6100	With 9 dams excl. Ban Kum and Pakchom	Standard 1985-00	First 6 no.	9 of 11 dams	Existing + 52 planned by 2030	Existing + planned by 2030*	No addition	*Excl. Ban Kum and Latsua dams*
	Mekong delta flood management scenario							
7000	Mekong delta flood management scenario	Standard 1985-00	No new	None	Existing in 2000 (11 no.)	As in 2000	Existing + Option 1a	
7001		Standard 1985-00	No new	None	Existing in 2000 (11 no.)	As in 2000	Existing + Option 1b	*Configurations based on results*
7002		Standard 1985-00	No new	None	Existing in 2000 (11 no.)	As in 2000	Existing + Option 1c	*of FMMP-C2 assessment of flood*
7003		Standard 1985-00	No new	None	Existing in 2000 (11 no.)	As in 2000	Existing + Option 2a	*management options*
7004		Standard 1985-00	No new	None	Existing in 2000 (11 no.)	As in 2000	Existing + Option 2b	
7005		Standard 1985-00	No new	None	Existing in 2000 (11 no.)	As in 2000	Existing + Option 2c	
	Longer term future (2060)							
8000	LMB long-term development scenario	Standard 1985-00	First 6 no.	All 11 dams	Existing + 89 expected by 2060	Existing + expected by 2060*	Existing + Option 2a	
8001	- " -	**Climate change**	First 6 no.	All 11 dams	Existing + 89 expected by 2060	Existing + expected by 2060*	Existing + Option 2a	*Either A2 or B2 as agreed with BDP*
9000	LMB very high development scenario	Standard 1985-00	First 6 no.	All 11 dams	Existing + 108 further	Full potential **	Existing + Option 2c	
9001	- " -	**Climate change**	First 6 no.	All 11 dams	Existing + 108 further	Full potential **	Existing + Option 2c	*Either A2 or B2 as agreed with BDP*
	Additional scenarios							
10001 10002	Alternative scenarios - scenarios to be formulated by BDP based on results fro							
21	*scenario runs with DSF including 6 scenarios investigated by FMMP-C2*							

** Irrigation development includes progressive development of transfer schemes in Thailand*

*** Full potential irrigation development includes transfer out of basin in Thailand*

The work plan (see Figure 1 below) conforms to the overall timetabling requirements established by MRC. It also and recognises the importance of building up robust planning databases not only to facilitate the current assessments but also to lay a foundation for assessments to be made in the future.

Figure 1 Assessment work plan



The work plan also recognises that there are inevitably knowledge gaps and a subsidiary objective of the assessment approach is to identify critical areas where further research is needed to better understand those aspects of the resource system which have bearing on planning and decision-taking within the basin.

2 Assessment approach

2.1 Assessment framework

Working Group 2 of the WUP has conducted useful research on the characteristics of good assessment criteria. Subsequently, many different hydrological, environmental, social, and economic indicators have been defined and tested for specific purposes under WUP scenario modelling studies and related Integrated Basin Flow Management (IBFM) studies.

The review of this knowledge base of research and practical application experience, and subsequent discussions with the RTWG, suggests that good criteria for the assessment of the considered development scenarios comply with the following characteristics (see box).

The BDP2 has drawn on the vast amount of research and practical application experience that is available with the MRC and its member countries to select appropriate assessment criteria. The proposed criteria are based on a series of drafts prepared earlier in consultation with the RTWG and MRC Programmes[1]. It also incorporates the recommendations of the 28th meeting of the Joint Committee.

The final proposed criteria for the scenarios are illustrated overleaf in Table 2. This table also highlights which criteria are considered of particular relevance to the various scenarios under consideration.

Characteristics of good assessment criteria

- The assessment criteria must be policy relevant, which also implies that they should be clearly related to a specific development objective, as can be derived from the 1995 Mekong Agreement and national socio-economic and sector plans.
- The assessment criteria must be user driven, which implies that they are easy to understand by decision-makers and the public at large. Moreover, the number of criteria must be kept to a minimum to facilitate the presentation and comparison of considered development scenarios.
- The assessment criteria must be sensitive to changes caused by water and land resources developments.
- The assessment criteria must be measurable and attainable, i.e. the value of the indicator can be determined with confidence and within acceptable limits of uncertainty, using internationally proven methods, and within a short time frame using readily available data
- The assessment criteria must not duplicate each other.
- The assessment criteria must be acceptable to each of the four LMB countries.

[1] For the latest report on this see BDP report "Scoping and planning of the assessment of basin-wide development scenarios", Version: 3.1, dated 23 March 2009

Table 2 Assessment criteria

Goal	Primary Objectives	Specific development	Issue	Indicator: Description	Indicator: Unit	B2	B3	B4	B5	B6
		Assessment Criteria				**High relevance to Work Package**				
Sustainable development	Optimal development (triple bottom line) – 1 Economic development	**1.1 Increase irrigated agricultural production**	Irrigable area, production tonnage and value	Incremental area Incremental crop production Net incremental economic value	'000 ha '000 ton NPV US$m	✓		✓	✓	✓
		1.2 Increase hydropower production	Hydropower capacity, power generated and value	Incremental installed capacity Incremental power generated Net incremental economic value	MW GWh/year NPV US$m	✓			✓	✓
		1.3 Improve navigation	River transport	Incremental navigable days by class Net incremental economic value	'000 boat-days NPV US$m					✓
		1.4 Decrease damages by floods	Extent and duration of annual flooding by class	Average area flooded annually to max 0.5-0.9m depth Average area flooded annually > max 0.9m depth Incremental net economic value of flood damage	'000 ha '000 ha NPV US$m		✓	✓	✓	✓
		1.5 Maintain productivity of fishery sector	Capture fisheries and aquaculture production	Incremental annual average capture fish availability Incremental annual average aquaculture production Net incremental economic value	'000 ton '000 ton NPV US$m	✓		✓	✓	✓
			Impact of flow and sediment transport changes on deep pools	Sediment loads at specified locations on mainstream Water levels at specified locations on mainstream Net incremental economic values	Trend m Trend		✓		✓	✓
	2. Environmental protection	**2.1 Maintain water quality and acceptable flow conditions**	Water quality Flow characteristics	Water quality incl. sediment in transport in mainstream Key flow charcateristics (to be defined)	Trend Trend			✓	✓	✓
			Protection of forests around Tonle Sap	Forest flooded for specified depth duration at Tonle Sap Net incremental economic values	'000 ha NPV US$m			✓	✓	✓
		2.2 Maintain wetland productivity and ecosystem services	Productivity of wetland ecosystems	Incremental wetlands with required depth-duration Net incremental economic value	'000 ha NPV US$m			✓	✓	✓
		2.3 Manage salinity intrusion in the Mekong delta	Impact of salinity intrusion on land use potential	Area within delta within thresholds of salinity levels Net incremental economic value	'000 ha NPV US$m			✓	✓	✓
		2.4 Minimize channel effects on bank erosion	River bank erosion	Incremental area at risk to erosion Vulnerability to bank erosion Net incremental economic values	'000 ha Trend Trend		✓		✓	✓
		2.5 Conservation of biodiversity	Impacts of flow management changes on endangered species	Incremental area of suitable habitats Estimated number of species affected Incremental net economic value of habitat areas	'000 ha no. NPV US$m			✓	✓	✓
	3. Social development	**3.1 Maintain livelihoods of vulnerable resource-users**	Health, food and income security	No. of people affected Severity of impact on health, food and income security	'000 h/h Trend	✓		✓	✓	✓
		3.4 Increased employment generation in water related sectors	Incremental sustainable employment from water resource interventions	Incremental number of people engaged in: Agriculture Fisheries Water-related service industries Tourism	 '000 '000 '000 '000	✓		✓	✓	✓
	4 Equitable development	**4.1 Ensure that all four LMB countries benefit from the development of water and related resources**	Aggregate benefits by country	Summation of incremental net economic benefits Summary of non-quantifiable impacts	NPV US$m Trends	✓		✓	✓	✓

The assessment criteria illustrated above comprise:

- **The goal and primary objectives**: They are based on MRC's aspiration under the 1995 Mekong Agreement for economic and social development of the LMB through cooperation and protection of the natural environment. Together with shared benefits and a goal for optimal development, these represent the primary objectives of economic development, environmental protection, and social development.

- **Specific objectives**: The main objectives above are articulated through 13 specific objectives, which, in the context of river basin planning, are considered necessary to achieve in order to attain the main objectives. Each specific objective is further translated into a number of basin-level strategic issues to which measurable indicators can be applied. The specific objectives are derived from national policies, strategies and sector plans, the MRC Strategic Plan 2006-2010, and the Strategic Directions for IWRM in the LMB.

- **Measurable indictors**: The chosen indicators enable the measurement of how well a specific objective is met by a particular development scenario.

Table 2 shows that the assessment criteria cover the triple bottom line of economically beneficial, socially just, and environmentally sound development. They also cover two criteria that can measure how well each scenario achieves equitable development. The criteria were approved in principle by the JC in August 2008.

2.2 Overview of assessment processes

The overall assessment follows a logical process as illustrated in Figure 2 given overleaf. The key elements of this process are highlighted below.

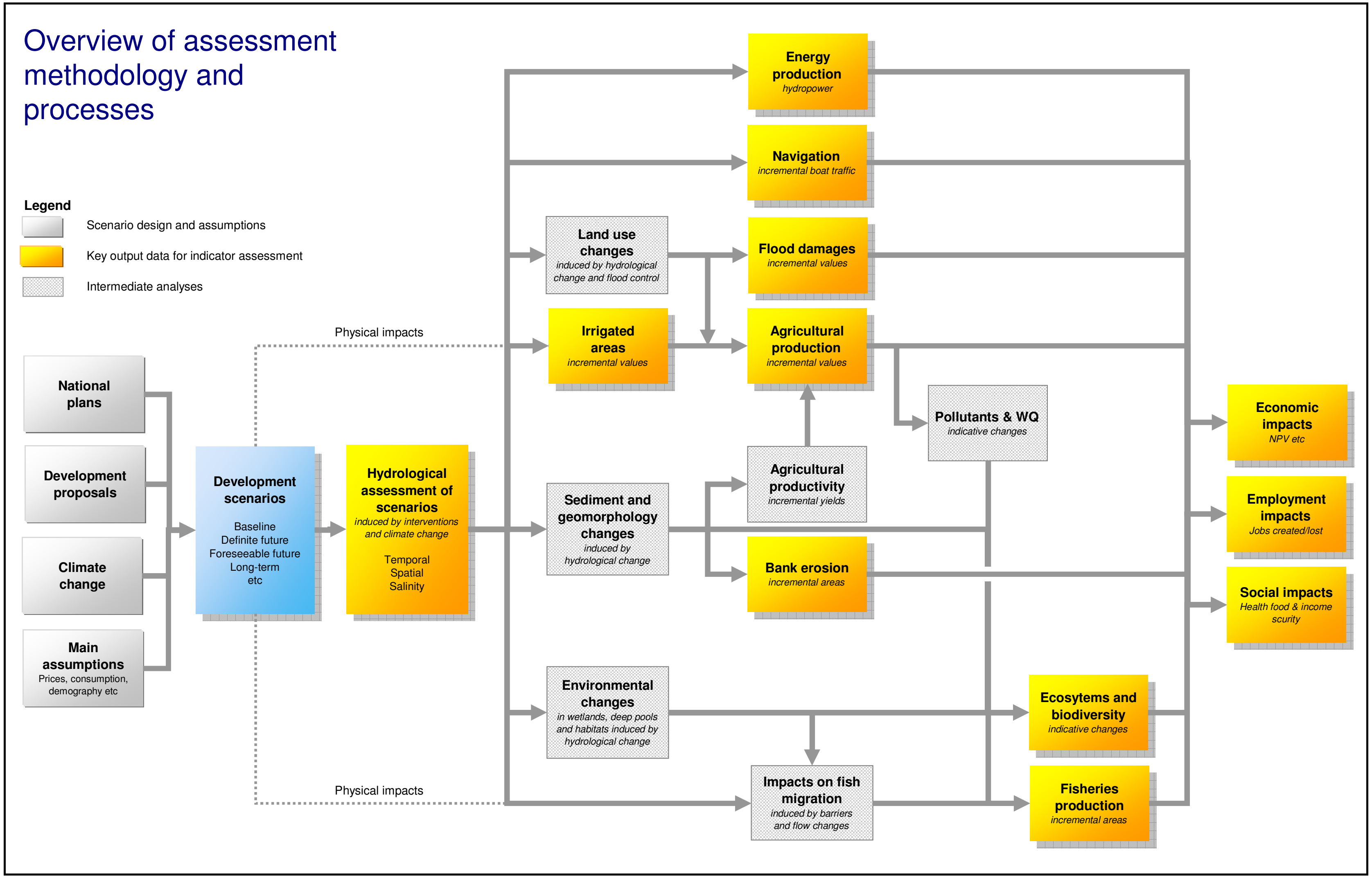
The overall process is designed to assess the economic, social and environmental impacts of the different development scenarios in accordance with the criteria established in consultation with national and regional stakeholders (see Section 2.1 above). The development scenarios are a product also of national and regional consultations and reflect current national plans and development proposals. They also are required to take into consideration the potential effects of climate change and assumed future trends in prices, consumption patterns, demography etc.

Initially the development scenarios are as described above in Section 1.3, but it is possible that on the basis of the understandings gained from the assessment of these that other scenarios may be constructed to examine specific issues in more detail and/or to test the effects of varied assumptions for which the associated levels of uncertainty are significant relative to the overall conclusions that may be drawn.

Each scenario contains a number of interventions (and/or assumed exogenous changes) for which the main impact will be to cause a change in mainstream flow conditions within the LMB. These changes will be simulated using the DSF with defined indicators at key points in the system quantified using the DSF's post-processing tools.

Most interventions will also have direct physical impacts (such as the barrier effect of mainstream dams on fish migration) and these will also have to be taken into account in the subsequent assessments along with the computed flow regime changes.

Figure 2 Flow chart of assessment process



The subsequent assessments follow a logical path as illustrated in Figure 2 which aligns with the concepts identified by Environment Programme through their integrated basin flow management (IBFM) techniques previously developed. These techniques in summary recognise that in order to understand the economic and social impacts of different interventions it is generally necessary to first establish an understanding of how the physical and flow regime impacts will affect environmental conditions within the LMB, and then in turn to assess how these impact on people, livelihoods and the economy.

2.3 Assessment linkages

The flow chart illustrated in Figure 2 highlights the key outputs for indicator assessment, which are those identified in the assessment criteria shown in Table 2. As can be seen, some of these can calculated directly from the assessment of induced flow regime changes using outputs from the DSF (eg irrigated areas), whereas others require understanding of intermediate indicators (eg fisheries production influenced by changes in environmental conditions at key locations, barriers to migration, changes in nutrients etc).

Given below is a summary of the principal linkages factored into the assessment approach. Further details are provided in Annexes 1 through 5 of this report.

- **Hydrological indicators**: Whilst hydrological change is in itself not included in the assessment criteria, it is clearly fundamental to assessing most other indicators. Furthermore, understanding the extent of change in the context of Articles 3, 6 and 9, which together define the acceptable limits of flow change, contributes directly to the concept of development space.

- **Irrigated areas**: Irrigated areas are determined in the DSF and are a product of the assumed installed irrigation facilities and the availability of water to meet the unit area water demands.

- **Energy production**: Energy production is similarly a product of the assumed installed hydropower facilities and the flows available to generate hydropower energy.

- **Navigation**: Impacts on navigation are principally a product of the extent to which boat traffic is affected by changes to the size and duration of low flows and to any unmitigated barriers introduced to boat traffic.

- **Flood damages**: Incremental flood damages are a product of the change in flood regime, the nature and extent of flood control measures, the value of the change in land use and extent to which irrigated agricultural production is impacted.

- **Agricultural production**: Changes in agricultural are brought about by changes in land use (including cropping patterns and yields), principally through irrigation development and flood management measures. In the latter case, this may be influenced by changes to sediments, nutrients and other geomorphological changes that might, for instance, affect land drainage potential.

- **Bank erosion**: The changes in extent and vulnerability of land to bank erosion are a product of changes in discharge and sediment transport characteristics of the river flows.

- **Eco-systems and biodiversity**: Changes to the functioning of eco-systems and biodiversity will be brought about by changes in flow conditions in sensitive areas, changes in sediments and nutrient flows, changes in water quality induced by the interventions particularly but not exclusively from agricultural residues, changes in salinity levels and land use changes.

- **Fisheries production**: Changes in fisheries productivity will be brought about by the same changes that eco-systems and biodiversity are susceptible to. In addition, barrier affects from dams and other control structures are expected to have significant impact on different species, as may also be the case in the way the sector is sustainably managed in the future.

- **Economic impacts**: The economic impact of scenarios is the sum of the incremental aggregate value of the economically productive water-related sectors, viz.: hydropower, navigation, flood damage reduction, agricultural and fisheries production.

- **Employment impacts**: The impacts on employment are a product of the changes in labour requirements within the economically productive sectors as above.

- **Social impacts**: Social impacts are a product of all of the above in terms of the impacts generated on household health, food and income security with particular attention paid to the consequent impacts upon poverty levels and especially to the consequences for vulnerable groups for whom the induced changes in livelihood conditions are beyond their ability to cope with.

3 Assessment methodologies

3.1 Integration of methodologies

3.1.1 Key challenges in designing the methodologies

In common with other assessments made in accordance with the principles of integrated water resource management (IWRM), the central challenge is to ensure that the methodologies adopted are both conceptually sound and conducted in a manner that allows the impacts in one sector to be readily absorbed as inputs to the assessments in another (as illustrated in Figure 2 and the preceding chapter).

In addition, it has to be recognised that knowledge of the many detailed environmental and socio-economic processes in play within the basin is finite and in some cases still rather limited. A second challenge is therefore to ensure that each assessment methodology is founded on sound scientific principles but structured in a manner that brings focus on the most relevant processes that are likely to influence strategic choices. In most instances, this requires assumptions to be made either in quantifying relationships describing important processes or in setting aside unquantifiable minor processes. It is important that these assumptions are made clear in the assessments so that, if necessary, they can be debated and, if needed, improved.

A third area of challenge is to ensure integration within both time and space. These are discussed below.

3.1.2 Temporal change

The methodologies adopted need to deal effectively within the assessments of future exogenous[2] changes about which opinions may be divided. Examples are the consequences of climate change, energy prices, fisheries practices, demographic change and investment capacity (there are many more), each of which may influence strategic choices now and in the future.

To address this, the approach adopted in each sector is generally to conduct the assessments first on the current social, economic and environmental situation within the basin (which within the limitations above can be undertaken with reasonable confidence) and thereafter to estimate how the conclusions may vary under postulated future conditions. Thus the first step in the assessment of, for instance, the 20-year scenario is to assess the impacts of the defined

[2] Exogenous ~ adj. of, relating to, or developing from external factors, Oxford English Dictionary

interventions as if they were suddenly all in place today and the second step is to then assess how those impacts may differ under assumed future conditions twenty years hence[3].

This approach is intended to make the overall assessments transparent and, in doing so, to identify which assumptions about the future are likely to impact upon strategic choices today.

3.1.3 Spatial integration

Most impacts have a spatial context which can be measured with varying degree of confidence. In general the impacts relate to changes brought about to the condition, use and/or value of the land or water body over which the impact occurs and thereby to the people who make use of that land or water body. These considerations lead to an assessment of economic productivity of these areas and the aggregate impact on national economies.

Areas impacted depend upon the situation being investigated. Flooding, for instance, is determined by hydrological and topographical conditions and the boundaries of flooding have no relationship with administrative boundaries. Fishing is conducted in water bodies, on flood plains and paddy fields. Different areas have a range of bio-diversity significance. On the other hand, people are measured within administrative units, from village/commune up to national level.

GIS offers the facility to integrate assessments across these different boundaries and a shared system will be used as a foundation to all spatial impact assessments. This will enable the assessment of, for instance, changes in fish abundance to be overlain on population mapping to assess how many would be affected by such changes.

Within any boundary in the GIS, it is necessary to assume uniform distribution of whatever parameter is being mapped. Thus, the greater the disaggregation of land units, in theory the more accurately these impacts can be assessed. However, this must be balanced against the resolution of the data actually available. The following principles have been adopted for all assessments.

- Land use, cover, water bodies, wetlands and topography – these will use the existing MRC mapping cover
- Extent of flooding and salinity intrusion – boundaries determined by the DSF
- Irrigation areas – based on BDP irrigation database (generally point data) and DSF results, aggregated to extent of area irrigated within each district
- Dams and hydropower – point data as available in MRC database

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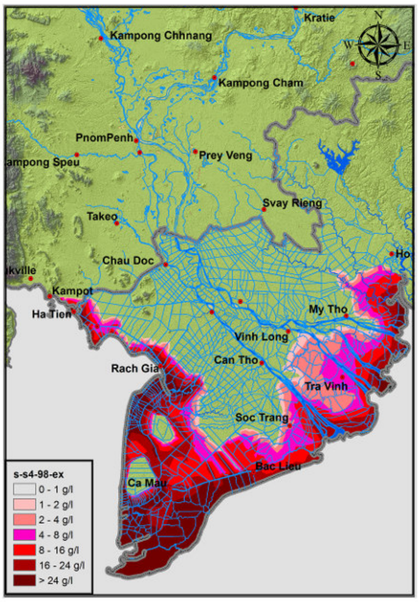
[3] As an example, as a consequence of poverty alleviation strategies now in place, the numbers of vulnerable people dependent upon capture fisheries for their livelihoods in 20 years' time is very likely to be less than today. Whilst the number today can be estimated based on existing data, the future number is conditioned upon assumptions upon the impacts of the poverty alleviation strategies. There are of course many other similar issues that need to be factored into the assessments.

- Agricultural data – aggregated or distributed to districts
- Fisheries productivity data - distributed to relevant land and water body types based on provincial and other data relevant to different guilds
- Population numbers and characteristics – aggregated or distributed to districts, with higher resolution only if needed in "hot spots" (eg around Tonle Sap)
- Economic data - aggregated or distributed to districts (except hydropower, on case by case basis)

3.2 Hydrological assessment

The hydrological assessment will be conducted using the MRC's DSF comprising a suite of three models, knowledge base and analysis and reporting tools. Each assessment is conducted on the basis of comparing hydrological conditions over a 16-year baseline (1985-2000)[4] between those observed in the scenario with those in the baseline condition.

Each scenario requires a different set-up of the models to represent the interventions included within the scenario. Interventions include dams/hydropower, irrigation facilities and flood management infrastructure. Operating rules also are defined where relevant. In addition climate change can be modelled by replacing the hydrometeorological data held in the knowledge base with a revised set representing assumed future conditions. The baseline hydrometeorological data have been quality assured by IKMP and BDP have verified the scenario setup data with each country.



The vast amount of data generated by the models and stored in the knowledge base for each scenario will be synthesised and reported upon. The principal reports will relate to:

- Areas irrigated
- Hydropower generated
- Extent and characteristics of flooding
- Extent and severity of saline intrusion
- Mainstream hydrological parameters relevant to flow maintenance and in-stream needs

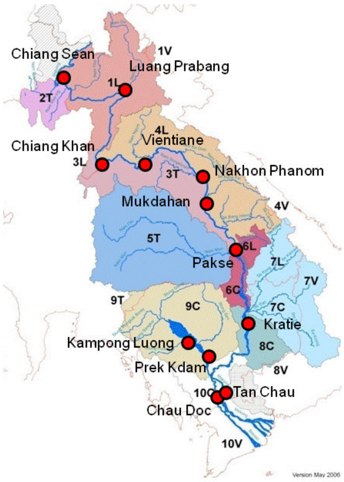
Tables of results will be generated along with flooding and salinity intrusion mapping. GIS layers will also be generated from the tabular results to illustrate changes

[4] Progress is being made to extending this baseline to 2005 or later, but this data set is unlikely to be available until early 2010.

in irrigation, power produced and storage provided.

Mainstream hydrological parameters will be reported in tabular and graphic form at 12 predetermined nodes. These data will be interpolated between nodes where needed to provide information of relevance to in-stream uses.

A report will be prepared for each scenario together with an overall hydrological assessment report that considers the hydrological significance of each scenario in the context of the natural variability of the basin's hydrology.



3.3 Environmental assessment

The purpose of the environmental assessment is to evaluate the environmental impacts of the different scenarios in the context of the five environmental development objectives previously agreed between the countries as being most relevant to strategic decision taking. The acceptability of these impacts to each member State is the principal means for determining the magnitude of the development space[5] that each scenario offers.

Environmental development objectives

- Maintain water quality and acceptable flow conditions
- Maintain wetland productivity and ecosystem services
- Manage salinity intrusion in the Mekong Delta
- Minimize channel effects on bank erosion
- Conservation of biodiversity

Environmental impacts that may result from changes in flow and related water levels in the river channels are changes in riverbed morphology and consequential impacts upon sand banks, rapids, and deep pools, in riverbank erosion, area available for riverbank gardening area available for riverine forest and saltwater intrusion in the Viet Nam Delta.

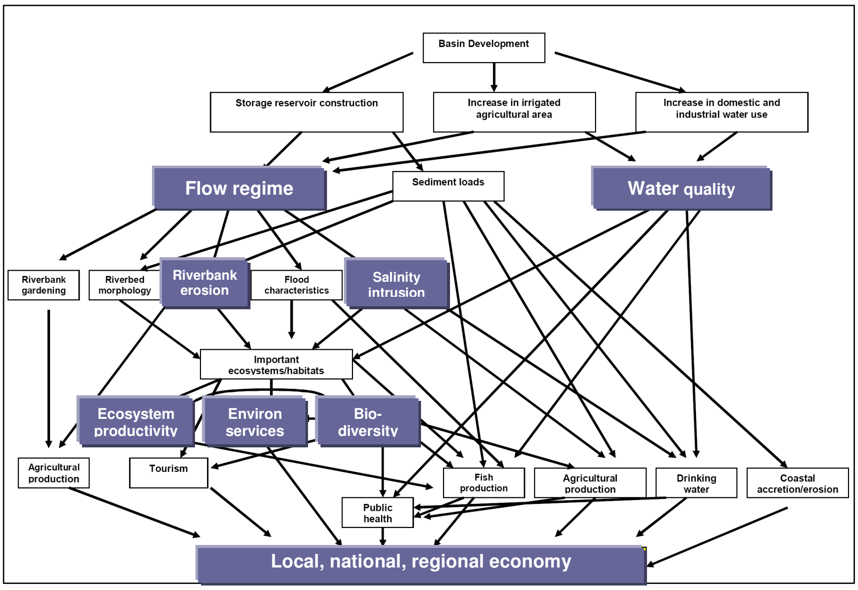
In addition changes in flood patterns will result in a change in area and distribution of valuable ecosystems/ habitats that, in their turn, have a number of secondary impacts including impacts on ecosystem productivity, environmental services provided and ecosystems/habitat existence and biodiversity, flora and fauna.

Similarly, changes in water quality, including changes in sediment concentrations and salinity, may have an impact on the availability of good quality drinking water, agricultural, wetland and inland, brackish water and coastal fisheries productivity, and biodiversity.

The cause-effect network (see diagram overleaf) is complex and the assessment will concentrate on those aspects of most relevance to the agreed key environmental indicators. These are

[5] The definition of *development space* is given in the BDP report "Scoping and planning of the assessment of basin-wide development scenarios", Version: 3.1, dated 23 March 2009. Conceptually it is the extent to which there is opportunity for further economic development of the basin's water resources within limits of sustainability considered acceptable by the member States. Conventionally, those limits are defined primarily in relation to environmental conditions, but may embrace social considerations as well, should the member States wish.

highlighted in the network diagram. For each box in the network information on the baseline situation has to be collected. Each arrow in the network represents a dependency or relationship for an understanding of the impact relationship is required.



Annex 2 describes how these relationships will be formulated and the data required for the assessments. Many of the impacts will be spatially distributed, and assessment will be made by overlaying GIS maps. Not only average annual conditions will be taken into account, but also the situation in a dry and a wet year.

Assessments will be made for each of the environmental indicators defined in Table 2. Special attention will be given to identified "hot spots" and, rather than attempting to list all species at risk, focus will be given to "flagship species such as the Mekong River Irrawaddy Dolphin, the Mekong Giant Catfish, the Sarus Crane and the Siamese Crocodile with their condition being considered as representative of threatened wetland habitats and their associated fauna in the Mekong basin.

3.4 Fisheries assessment

The purpose of the fisheries assessment is to quantify (within the limitations of existing knowledge) the likely 'new' yield of fish that might be expected under each development scenario. The spatial scope of the assessment is defined as being all aquatic fish habitats where changes to yield would be expected as a result of the diminished access to these habitats or arising from changes to hydrological conditions within them due to development activities. Impacts both positive and negative will be reported at the national level. Three major development sectors are included in the assessment, viz.: hydropower, irrigation and flood control (which overlaps irrigation).

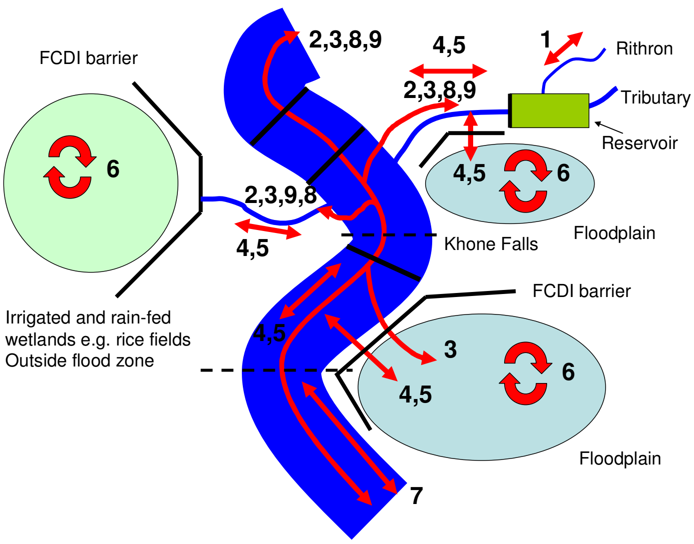
Future fish yield at the outset will be assumed to be unaffected by the growing basin population (potential fishing pressure) because: (i) management may effectively control growing fishing pressure; (ii) alternative livelihoods opportunities may grow and (iii) uncertainty surrounding existing levels of exploitation. At this stage, national level development plans for the aquaculture sector are not included within the defined development scenarios. However, the opportunities created for locally autonomous small-scale (informal) aquaculture development in reservoirs will be included.

> **Quantitative assessment of fish yields**
>
> **Losses arising from:**
>
> - Barrier impacts of dams and flood control schemes
> - Flood modification impacts in the flood zone arising from water storage above dams and abstractions for irrigation
>
> **Gains arising from:**
>
> - Reservoir fisheries above tributary dams
> - Irrigation projects

Many potential impacts may arise to the fisheries sector as a result of development activities. Only some impacts can be readily **quantified** given existing knowledge, data and models. Other potential impacts will be highlighted and described, and where possible quantified in terms of likely scale and direction of change.

The **qualitative assessment** will examine additional impacts on fish yield that may arise from changes to hydrological conditions (flows, depths, inundated areas) and water quality (e.g. dissolved gas concentrations, temperature, salinity) upstream and downstream of the dams; and changes to sediment transport.

The methodology is founded on a **guild framework**. All species in the basin are expected to be affected by any flow (flood) modification arising from basin development. However, the barrier impacts of development will vary among fish species depending upon the (i) scale of their migrations; the types of migrations they undertake (longitudinal in the main channel, laterally between the main channel and the floodplain, or both) and (iii) physiological tolerance to environmental conditions and behavioural flexibility (adaptability). The multitude of existing fish species will be grouped into nine guilds according to these characteristics in order to provide a framework for the assessment.



The quantitative assessment of barrier impacts of dams and flood control schemes will be based upon changes to accessible spawning and feeding habitat area for each guild. Flood modification impacts in the flood zone arising from water storage above dams and abstractions for irrigation will be assessed in terms of changes to habitat availability measured in terms of flood extent and duration.

Potential gains in yield arising from (i) reservoir fisheries created above tributary dams and (ii) an expansion of rice field fisheries by irrigation projects will be estimated as the product of the 'new' areas of each type of fish habitat and typical mean areal yield estimates for the LMB.

3.5 Social assessment

The focus of the social assessment is on people's dependency on water and aquatic resources and their resilience to expected changes in these and expansion of irrigated agriculture. Dependency, resilience and vulnerability are closely linked concepts. Thus assessments of people's dependency, vulnerability and resilience (which is one element of vulnerability) will be the three main tools for the social assessment.

The District will be used as the basic spatial unit. Much statistical data are only available at lower resolutions such as provincial level, while data from fisheries and consumption surveys is available at higher resolutions such as communes and villages. These data sets will be up- or down-scaled, based on transparent criteria and any uncertainties such as error margins, significance levels etc will be presented.

The baseline or the 'vulnerability context', using the sustainable livelihoods nomenclature, will focus on data collection and analysis of the following dependency variables:

- Percentages of part-time (subsistence) and full-time fishers
- Consumption of fish and other aquatic animals
- Use of aquatic products (including NTFP)
- Food security
- Location in floodplains and related opportunities (eg flood recession rice growing)

Data will be tabulated and multivariate cluster analyses will yield clusters with ranks according to level of dependency. These will be saved as GIS layers. By overlaying population data, the analysis will yield the number of people who are dependent on river aquatic resources to various degrees.

Vulnerability to changes in the water and aquatic regime comprises three dimensions: exposure, sensitivity and resilience.

Exposure will be assessed based on the spatial analysis of impacts on fisheries, aquatic resources, floodplains, wetlands and irrigated rice generated by the other parts of the assessment for the baseline and for the scenarios. A population layer will be overlaid on these and the number of people exposed calculated.

Sensitivity will be assessed by overlaying a social capabilities layer on the impact layers for the different scenarios. The capabilities layer will include baseline data on poverty, health, education, and access to various services. In combination with the dependency layer, the areas and population groups most sensitive to changes in aquatic resources can be identified.

Resilience is a function of capabilities and support structures as they develop over time. Using only the baseline social situation to assess resilience in the long-term scenarios would be misleading. Therefore the assessment of social impacts twenty years hence and later will include assumptions regarding population and economic growth, poverty rates, structural economic change, urbanization, human development, dependency ratio and others[6].

Other areas of concern for social assessments such as equity, governance, participation, political economy are often used in assessments of long-term development plans that include major infrastructure projects with large-scale impacts on natural resources. For example, governance aspects are critical to assessing the resilience of people to adverse impacts since especially poor people will rely on different forms of government support. The social assessment team proposes to include these aspects in the assessment as relevant.

3.6 Economic assessment

The main purpose of the economic assessment is to estimate the benefits and costs of the various BDP development scenarios in order to determine compare the relative incremental net economic benefits of each scenario. Furthermore, the economic growth and employment creation resulting from the scenario interventions (e.g. hydropower, irrigation and flood mitigation) will also be assessed for each LMB country as well as the overall basin economy.

The general approach to the economic analyses is outline below and the specific methodologies which will be used for the assessment of various development scenarios are discussed in Annex 4. The economic valuation of benefits and costs will generally adopt an opportunity cost approach for commodities with a direct use value (e.g. energy, crops and fish) as well as resources which have alternative uses, e.g. land, labour and capital. However, for environmental benefits and losses related to changes in important ecosystems (such as wetlands), it is problematic to identify suitable opportunity cost values for a wide range of benefits. Alternative valuation methods will therefore have to be used, e.g. contingent valuation (CV) and benefit transfer.

Economic Analysis – For each development scenario, the economic analyses will be undertaken on an incremental (or marginal) basis by contrasting the annual net economic benefits in the "future with" and "future without" development situations projected over a given period. The "future with" development situation will also include the capital and annual recurrent costs of the interventions and measures.

The "future without" situation represents the likely trend in the development of resources without the specific interventions. For example, without irrigation development, rain fed crop productivity is likely to increase with the adoption of improved crop varieties and better management techniques and this trend will need to be taken into account in the analysis. Similarly, without mainstream hydropower dams, there could still be a decline in capture

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[6] These social scenarios could be divided into exploratory (starting with the baseline situation and explore the consequences of future hydrological scenarios) or normative (assuming a final state of affairs and seek possible preconditions). Furthermore, very long-term scenarios must be open for trend breaking and surprising, even improbable events.

fisheries production due to over fishing and this should also be included in the economic assessment.

By adopting this marginal analysis approach, it will also be possible to incorporate a number of trends in the analysis of both the "future with" and "future without" development situations with respect key determinants such as population growth, industrial/urban development, energy demand, crop productivity, crop diversification, capture/culture fisheries production and wetland biodiversity.

Based on the annual incremental benefit and cost streams, net present values (NPVs) will then be estimated for each sector (e.g. agriculture, fisheries, navigation, energy and environment) as well as the development scenario as a whole, using an appropriate discount rate.

Risks and Uncertainties – In order to take account of future risks and uncertainties, sensitivity analysis will also be undertaken with particular attention being given to the likely consequences of: (i) not achieving the expected production benefits with respect energy and agriculture, (ii) increases in capital and recurrent costs required for various interventions and mitigation measures, and (iii) higher social costs and environmental losses.

Distribution Analysis - Poverty reduction and the equitable distribution of benefits are the broad aims of water resource development within the LMB. For each development scenario, a distributional analysis will therefore be undertaken in order to determine the likely distribution of the incremental net economic benefits between the four LMB countries.

For each development scenario, the present annual net benefits of water resource use will also be evaluated by sector and this will then be compared incremental annual net economic benefits which will accrue to each country. This will clearly show the extent to which the different countries will benefit from the proposed interventions for each development scenario relative to their present level of water resource development.

In addition, the public and private capital investment required for the interventions in the foreseeable future 20 year plan scenario (with and without mainstream dams) will also be estimated for each development sector within the four LMB countries.

Employment Impact - The impact on employment, i.e. jobs/livelihoods created and lost, will be estimated. For each development scenario, the estimation of the additional net employment generated will be determined by contrasting the "future with" and "future without" labour requirements in the agriculture, fisheries, navigation and energy sectors. Information on labour requirements will be collected as part of the analysis of the key economic parameters, e.g. crop production costs. The employment created by the construction and operation/maintenance of hydropower dams, irrigation projects and flood mitigation measures will be derived the labour component of the capital and recurrent costs.

3.7 Overall assessment and use of results

3.7.1 Summarising the overall results

The results from each of the assessments above for each scenario will be summarised in an overall report. This will contain the results of the transboundary economic, social and environmental assessment presented in user-friendly diagrams, tables and figures. Comparisons of how each scenario performs against the agreed assessment criteria will be made, thus providing an indication of how well the specific development objectives of the MRC member countries are met.

Risks and uncertainties identified during the course of the assessment of each scenario also will be summarised, and their potential impact on decision-taking described. Possible trade-offs between water-related sectors and between member countries will be set out.

In the light of the results gained above and where considered appropriate to informed decision-taking, other water-related transboundary issues, which are not captured in the agreed water resources development scenarios, will be described and discussed.

3.7.2 Use of the assessment results

The assessment report will conclude with a section describing how the results of the comprehensive transboundary economic, social and environmental assessment may be used to:

(i) facilitate basin wide stakeholder discussions, government consultations and the detailed evaluations that each country must undertake to define the range of 'acceptable trade-offs', and ultimately

(ii) assist in the preparation of the Basin Development Strategy, in particular the definition of the 'development space' and the strategic guidance for the integrated development and management of the various water-related sectors.

4 Assessment timetable

The timetable for the assessment process of the scenarios is set out in Figure 1 overleaf. The key elements of this timetable and the underlying process are highlighted below.

4.1 Collegiate effort

The assessment of the development scenarios requires a collegiate effort, driven and managed by the BDP team but engaging with:

- **National and regional stakeholders –** in the choice of scenarios to be assessed, the methodologies applied in the assessment process and in drawing conclusions from the assessment results;

- **Parallel MRC Programme activities –** most notably building from understandings and results obtained in the Strategic Environmental Assessment (SEA) of the mainstream dams, geomorphological studies being undertaken by IKMP and the assessment of flood management options under FMMP;

- **Supporting MRC Programme activities –** contributions from IKMP in the running and reporting on hydrological assessments using the DSF and reporting tools, from FMMP-C2 in the initial assessments of flood management scenarios, from Fisheries Programme on the likely impacts of mainstream dams on fisheries production, and from Environment Programme in terms of provision of hydrometeorological data under climate change scenarios;

- **BDP consultants –** supporting BDP in development and application of the assessment methodologies and synthesising the results as a basis to the wider consultation process.

4.2 Phased approach

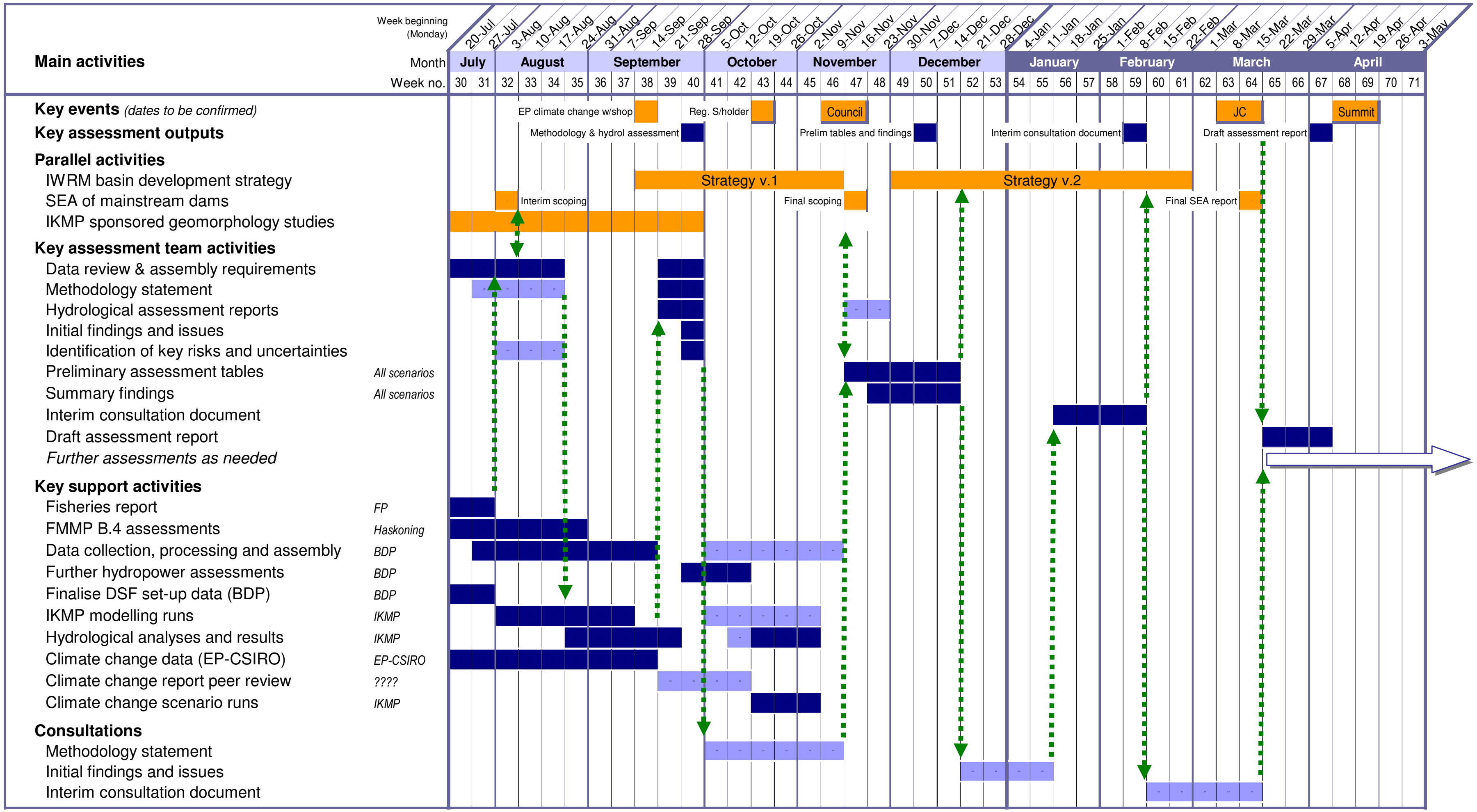
There are eight main phases in the assessment programme as summarised below.

- **Pre-July** – Agreement with the countries on the overall approach to scenario assessment, the basis to the assessment framework and the definition of the scenarios to be assessed;

- **July-September** – Assembly of the assessment team, detailing of the assessment methodologies, identifying data gaps and initiating filling of these, starting the hydrological assessments and summarising initial findings from these;

- **October-November** – Completing collection of identified additional data, national and regional consultations on assessment approach;

Figure 3 Assessment timetable



- **November-December –** Refinement of methodologies taking into account feedback from consultations, quantification of impacts (tables of results) and an initial summary of findings;
- **December-January –** National and regional consultations on initial findings as above;
- **January-February –** Based on feedback from consultations above, preparation of an interim consultation document drawing together and presenting the findings;
- **February-March** - discussions with in-country teams and other relevant stakeholders and presentation to Joint Committee for consideration and direction;
- **March-April –** Based on JC directions, preparation of a full assessment report

Thereafter further assessments may be required to either explore alternative development scenarios and/or to investigate in greater detail specific issues which have significant impact of future development choices.

Draft

Mekong River Commission

Basin Development Plan, Phase 2

Economic, environmental and social impact assessment of basin-wide water resources development scenarios

Assessment methodology

Annex 1
Hydrological assessment

October 2009

Economic, environmental and social impact assessment of basin-wide water resources development scenarios

Assessment methodology

Main report	Overview
Annex 1	**Hydrological assessment**
Annex 2	Environmental assessment
Annex 3	Social assessment
Annex 4	Economic assessment
Annex 5	Fisheries assessment

Contents amendment record

This report has been issued and amended as follows:

Issue	Revision	Description	Date	Signed
1	0	Draft to BDP team for comment	5 August 2009	MFW
1	1	Revised draft based on BDP team feedback	10 August 2009	MFW
1	2	Revised version incorporating additional sections on dealing with uncertainties	4 September 2009	MFW
2	3	Draft prepared for 2nd Regional Stakeholder Consultation and Dialogue of Basin Development Plan Programme, Phase 2	7 Oct 2009	

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Tables

Figures

Glossary

ADB	Asian Development Bank
AIFP	Agriculture, Irrigation and Forestry Programme
BDP	Basin development programme
BDP1	BDP Phase 1
BDP2	BDP Phase 2
C2	FMMP Component 2, Structural measures and flood proofing
DSF	Decision support framework
EP	Environment Programme
FMMP	Flood management and mitigation programme
FP	Fisheries Programme
HP	Hydropower Programme
IBFM	Integrated basin flow management
IQQM	Discharge modelling software
ISIS	Proprietary river modelling software
IKMP	Information and knowledge management programme
IWRM	Integrated water resources management
LMB	Lower Mekong Basin
MRC	Mekong River Commission
MRCS	Mekong River Commission Secretariat
NMC	National Mekong Committee
NP	Navigation Programme
PIN	Project Identification Note
PDS	Project Description Sheet
PNPCA	Procedures for Notification, Prior Consultation and Agreement
PWUM	Procedures for Water Use Monitoring
RTWG	Regional technical working group
SWAT	Open source hydrological modelling software
ToR	Terms of reference
UMB	Upper Mekong Basin
WB	World Bank
WUP	Water utilisation programme
WUP-A	WUP component for DSF development

1 Introduction

The purpose this report is to provide guidance to the hydrological assessment of the Basin-Wide Development Scenarios under Phase 2 of the BDP Programme. The report will also provide a record of the approach adopted for the hydrological assessment for future reference.

The background and the reasons for selecting these particular scenarios are set out in BDP2's earlier report[1], which has been subject to lengthy consultation with each country. The BDP report includes specification of the scenarios to be assessed, a preliminary overall assessment framework, identified key indicators and an overview of the expected information required for reporting the impacts of each scenario for comparison between scenarios and between countries.

The hydrological assessment represents an essential foundation to the subsequent assessment of economic, environmental and social assessments of the different scenarios. Hydrological changes are brought about changes in the manner that the water resource system is managed and made use of, together with exogenous factors relating to increasing consumptive demands over time and climate change. Climate change is expected to impact upon agricultural cropping systems, consumptive demands and sea level rise to greater or lesser degree depending upon the climate scenarios under consideration.

The primary tool for assessing hydrological change is the MRC's decision support framework (DSF) operated by the IKMP modelling team at MRCS and installed in each country. The DSF has the facilities to model different development scenarios and analyse the results in a manner that supports subsequent economic, environmental and social assessments. Further details of the DSF are given in the final report prepared on the DSF[2].

This report provides guidance on the following:

Chapter 2: The scenarios to be assessed with the DSF and the data to be used in setting up each scenario

Chapter 3: The assessment outputs, the methodologies to be used and how these will inform and support the subsequent economic, environmental and social assessments

Chapter 4: The reporting requirements required for each scenario and for the overall hydrological assessment of all scenarios

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[1] Scoping and Planning of the Assessment of Basin-Wide Development Scenarios, Technical note v3.1, BDP2, March 2009

[2] MRC WUP-A final report, Halcrow 2004

Chapter 5: A summary of the data requirements needed in addition to those already embedded in the DSF (where needed detailed listings of data are provided separately by BDP, such as irrigation and dam data).

Chapter 6: A summary of the work programme for the hydrological assessments to fit in with the wider overall scenario assessment work plan

2 Scenarios to be modelled

2.1 Overview of scenario runs

The scenarios to be modelled using the DSF are summarised in overleaf. In summary these comprise:

	Title	Time horizon	Runs 85-00	Runs CC	Interventions
1	**Baseline scenario**	Baseline (1985-'00)	1		Year 2000 infrastructure including existing HEP dams
2	**Upper Mekong Dam scenario** (UMDS)	Definite future over next 5-10 years	1		Baseline plus 6 existing, under construction and planned HEP dams in Upper Mekong Basin
3	**Definite future scenario** (DFS)		1		UMDS plus 25 additional HEP dams in LMB and updated flood measures in delta
	Foreseeable future situation (FSS)				
4	LMB 20-year plan scenario	Foreseeable future over next 20 years	1	1	DFS plus 11 LMB m/stream dams and planned tributary dams etc
5	LMB 20-year plan without mainstream dams		1		As above, excluding 11 LMB dams
6	LMB 20-year plan with 6 m/s dams in upper LMB		1		As above plus 6 LMB dams in upper LMB
	LMB 20-year plan with 9 m/s dams		1		As (5) excluding Ban Kum and Pakchom
7	**Mekong delta flood management scenario**	Baseline (1985-'00)	6		Baseline plus 6 different options for flood control in Cambodia and Viet Nam
	Long term future				
8	LMB long-term development scenarios	Long term future over next 50 years	1	1	LMB 20-year scenario plus all feasible infrastructure developments in LMB
9	LMB very high development scenarios		1	1	As above extended to full potential infrastructure developments
10	**Further scenarios**		2	1	To be determined by BDP assessment team
			17	**4**	

Other scenarios may emerge during the assessment process to refine or investigate specific assessments above. Depending on their relevance to the assessment of the current scenarios, these may be taken up to augment the findings above, or deferred to 2010 if considered more appropriate.

Table 1 Summary of scenarios to be investigated

Ref	Title	Hydrology	Dams			Irrigation and water supply demands	Flood control works	Remarks
			China	Mainstream	Tributary			
1000	**Baseline scenario**	Standard 1985-00	No new	None	Existing in 2000 (11 no.)	As in 2000	No addition	
	Definite future situation							
2000	Upper Mekong Dam scenario	Standard 1985-00	First 6 no.	None	Existing in 2000 (11 no.)	As in 2000	No addition	
3000	Definite future scenario	Standard 1985-00	First 6 no.	None	Existing + 25 under construct.	As in 2008	No addition	
	Foreseeable future situation (2030)							
4000	LMB 20-year plan scenario	Standard 1985-00	First 6 no.	All 11 dams	Existing + 52 planned by 2030	Existing + planned by 2030*	No addition	
4001	- " -	**Climate change**	First 6 no.	All 11 dams	Existing + 52 planned by 2030	Existing + planned by 2030*	No addition	*Either A2 or B2 as agreed with BDP*
5000	LMB 20-year plan scenario without	Standard 1985-00	First 6 no.	None	Existing + 52 planned by 2030	Existing + planned by 2030*	No addition	
LMB 20-year plan scenario with different configurations of mainstream dams in LMB								
6000	With 6 dams in upper LMB	Standard 1985-00	First 6 no.	6 in upper LMB	Existing + 52 planned by 2030	Existing + planned by 2030*	No addition	
6100	With 9 dams excl. Ban Kum and Pakchom	Standard 1985-00	First 6 no.	9 of 11 dams	Existing + 52 planned by 2030	Existing + planned by 2030*	No addition	*Excl. Ban Kum and Latsua dams*
	Mekong delta flood management scenario							
7000	Mekong delta flood management scenario	Standard 1985-00	No new	None	Existing in 2000 (11 no.)	As in 2000	Existing + Option 1a	
7001		Standard 1985-00	No new	None	Existing in 2000 (11 no.)	As in 2000	Existing + Option 1b	*Configurations based on results*
7002		Standard 1985-00	No new	None	Existing in 2000 (11 no.)	As in 2000	Existing + Option 1c	*of FMMP-C2 assessment of flood*
7003		Standard 1985-00	No new	None	Existing in 2000 (11 no.)	As in 2000	Existing + Option 2a	*management options*
7004		Standard 1985-00	No new	None	Existing in 2000 (11 no.)	As in 2000	Existing + Option 2b	
7005		Standard 1985-00	No new	None	Existing in 2000 (11 no.)	As in 2000	Existing + Option 2c	
	Longer term future (2060)							
8000	LMB long-term development scenario	Standard 1985-00	First 6 no.	All 11 dams	Existing + 89 expected by 2060	Existing + expected by 2060*	Existing + Option 2a	
8001	- " -	**Climate change**	First 6 no.	All 11 dams	Existing + 89 expected by 2060	Existing + expected by 2060*	Existing + Option 2a	*Either A2 or B2 as agreed with BDP*
9000	LMB very high development scenario	Standard 1985-00	First 6 no.	All 11 dams	Existing + 108 further	Full potential **	Existing + Option 2c	
9001	- " -	**Climate change**	First 6 no.	All 11 dams	Existing + 108 further	Full potential **	Existing + Option 2c	*Either A2 or B2 as agreed with BDP*
	Additional scenarios							
10001 10002	Alternative scenarios - scenarios to be formulated by BDP based on results fro							
21	*scenario runs with DSF including 6 scenarios investigated by FMMP-C2*							

** Irrigation development includes progressive development of transfer schemes in Thailand*

*** Full potential irrigation development includes transfer out of basin in Thailand*

2.2 Scenario set-up data

2.2.1 Introduction

Each scenario modelled in the DSF is defined by the hydrometeorological conditions that determine the run off generated in the system and, together with estimated cropping patterns, the irrigation unit area demands, the assumptions of boundaries flows from the Upper Mekong Basin as affected by major dams constructed in China, water supply demands determined on the basis of population, and the water resource management infrastructure known or assumed to be in place.

The following sections summarise the scenario set up data and should be read in conjunction with Table 1 above.

2.2.2 China dams

A cascade of dams is being developed in the Upper Basin in China (see map) where the Mekong river is known as the Lancang. Eight hydropower dams have been planned taking the advantage of an 800 m drop over 750 km of river in the middle and lower sections of the Yunnan stretch of the Mekong. Two are already constructed and with the first being present during part of the current hydrological baseline (1985-2000):

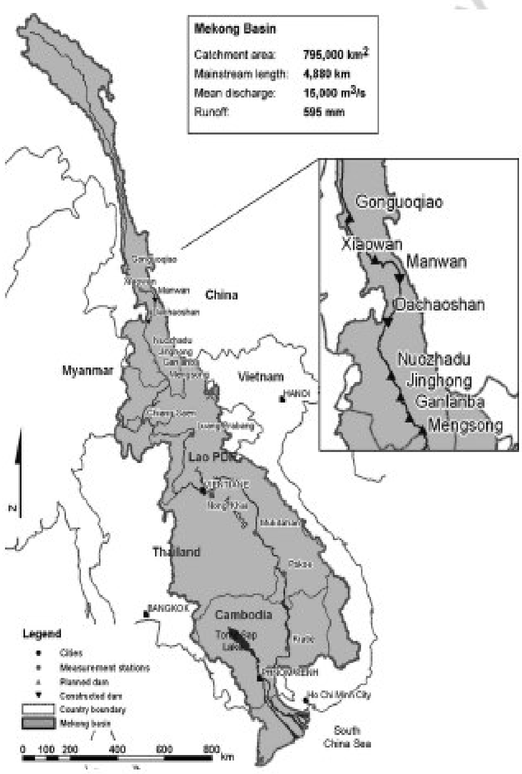
- Manwan (1993)
- Dachaoshan (2003)

Four further dams are understood to be under various stages of implementation:

- Xiaowan (completion by 2012)
- Jinghong (completion by 2013)
- Gonguoqiao (completion by 2011)
- Nuozhadu (completion by 2104)

The further two dams planned are Ganlanba and Mengson (both before 2025). Data for storages of the latter two are not available, but are expected to be small, and these are excluded from any of the scenarios under consideration.

All of the dams are assumed to be operated to meet energy production requirements and their inclusion in the scenarios and their key data are summarised below in Table 2.



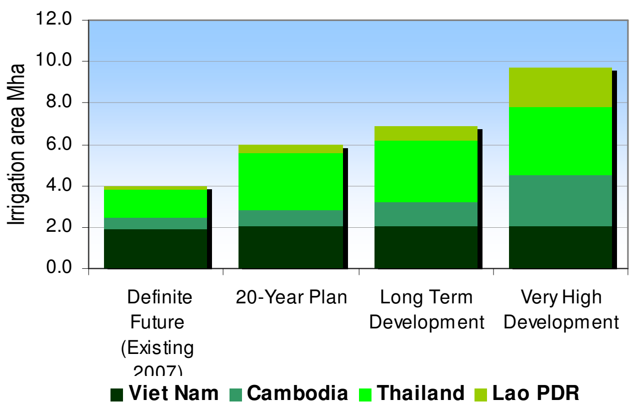
Source: M. Kummu, O. Varis / Geomorphology 85 (2007) 275–293

Table 2 Chinese dams in scenarios

Dam	Scenario	Active storage MCM	Installed capacity MW
Manwan	Implicit in part of baseline and present in all other scenarios	257	**1,500**
Dachaoshan	All except baseline & detailed flood management (#5000-5)	367	**1,350**
Xiaowan		9,900	**4,200**
Jinghong		249	**1,500**
Gonguoqiao		120	**750**
Nuozhadu		12,300	**5,500**
Ganlanba	*Not included in analyses*	n/a	*150*
Mengson		n/a	*600*
Totals		**> 23,193**	**14,800** + *850*

2.2.3 *Irrigation*

A database of existing and planned irrigation projects throughout the LMB has been prepared[3]. Based on this and consultations with each country, estimates have been prepared for irrigation areas to be included in each scenario. Detailed data are provided separately to the IKMP modelling team and are in summary as given in Table 3 overleaf.



Due to its position in the tributaries of NE Thailand, the incremental irrigable area in Thailand requires to an increasing degree that pumped transfer schemes are constructed to abstract water from the mainstream (or from tributaries near to the mainstream) in order that sufficient water is available at the upper and middle parts of the catchments to enable additional irrigation to happen. In the other three countries no such pumped transfers are planned. The transfer schemes in Thailand that are represented in different scenarios are as set out in Table 4.

[3] Regional Irrigation Sector Review for Joint Planning Process, BDP2, March 2009

Table 3 Total irrigation areas assumed in each scenario ('000 ha)

Country	Irrigable area	1st Season Area	2nd Season Area	3rd Season Area	Non-rice Area
Definite Future (Existing 2007)					
Lao PDR	**166**	166	97	0	7
Thailand	**1,412**	1,355	148	0	253
Cambodia	**504**	273	261	17	12
Viet Nam	**1,920**	1,670	740	1,479	330
Total LMB	**4,002**	**3,465**	**1,246**	**1,495**	**602**
20-Year Plan					
Lao PDR	**451**	450	330	0	40
Thailand with intra diversion	**2,718**	2,635	428	0	561
Cambodia	**778**	457	379	22	20
Viet Nam	**2,045**	1,795	740	1,479	391
Total LMB	**5,993**	**5,337**	**1,876**	**1,500**	**1,012**
Long Term Development					
Lao PDR	**718**	715	508	0	111
Thailand with intra diversion	**2,972**	2,760	454	0	682
Cambodia	**1,156**	678	747	388	21
Viet Nam	**2,063**	1,813	1,106	1,547	424
Total LMB	**6,908**	**5,966**	**2,815**	**1,935**	**1,238**
Very High Development					
Lao PDR	**1,899**	1,896	1,262	0	528
Thailand with intra and inter diversion	**3,241**	2,994	490	0	950
Cambodia	**2,433**	1,667	2,070	1,648	22
Viet Nam	**2,098**	1,848	1,106	1,576	531
Total LMB	**9,671**	**8,406**	**4,927**	**3,224**	**2,030**

* Note that the baseline scenario for Cambodia is predicated on an assumed amount of informal irrigation outside of Government schemes, as explained in the WUP-A final report of 2004; the scenario set-ups assume that this is replaced by the introduction of formal systems, be they public or private sector financed

Table 4 Transfer schemes included in the scenarios for Thailand irrigation

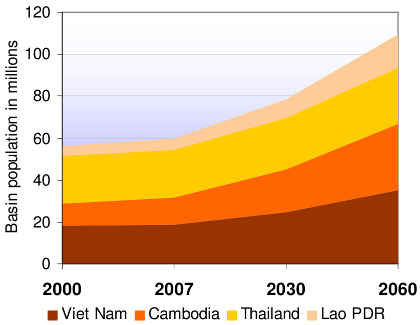
Transfer scheme	Scenario(s)	Remarks
Kong-Chi-Mun Phase 1	Foreseeable future (2030) and both long term scenarios	Q_{max} = 250 m^3/s
Kong-Chi-Mun Phase 2	Long term and very high development scenarios	Q_{max} = 380 m^3/s
Kong-Chi-Mun Phase 3	Very high development scenario only	Q_{max} = c.500 m^3/s
Kok Ing Nan	Very high development scenario only	Transfer of c.140m3/s capacity out of Mekong basin

2.2.4 *Water supply*

Water supply has two components related to domestic and industrial demands. Both are driven by population growth, which are based on estimates discussed and agreed with each country. These are summarised below in Table 5 below.

Table 5 Estimated populations in basin (million)

Country	2000	2007	2030	2060
Viet Nam	18.1	18.7	24.6	35.3
Cambodia	10.8	13.0	20.5	31.3
Thailand	22.3	23.1	24.7	27.1
Lao PDR	5.0	5.2	8.4	15.6
Total LMB	**56.2**	**59.9**	**78.2**	**109.3**

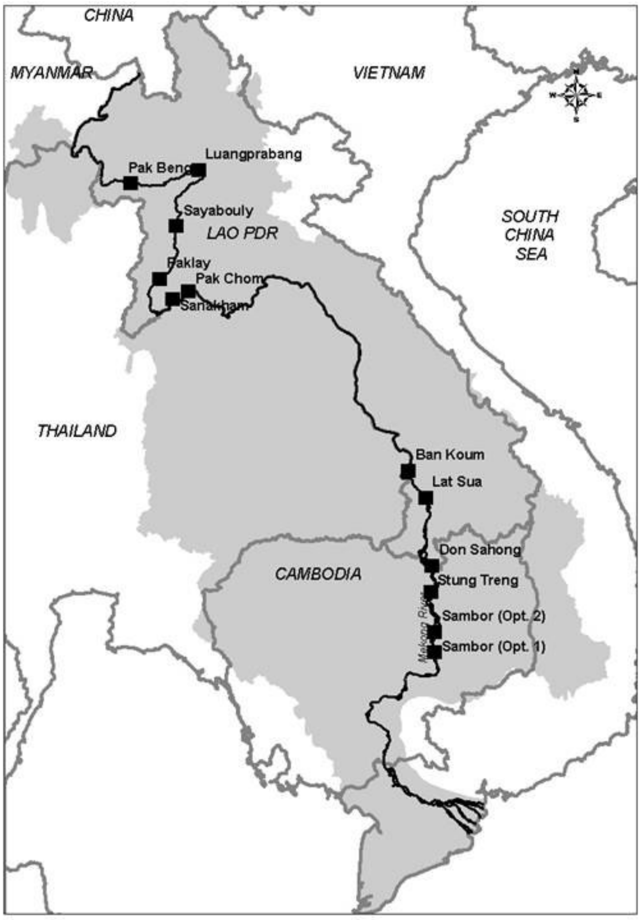


Following further consultations with each country, current and future per capita water demands have been estimated as shown in Table 6. Industrial demands are taken as 20% of gross domestic demand.

Table 6 Estimated domestic water demands

Country	Average per capita use (lit/day)			
	2000	2007	2030	2060
Lao PDR	64	Rural = 60 Town = 140 Urban = 180	Rural = 80 Town = 160 Urban = 200	Rural = 100 Town = 160 Urban = 200
Thailand	115	170	180	200
Cambodia	32	Rural = 90 Urban = 130	Rural = 100 Urban = 150	Rural = 100 Urban = 170
Viet Nam	67	Rural = 60 Urban = 100	Rural = 80 Urban = 150	Rural = 100 Urban = 175

2.2.5 *Mainstream dams*



Eleven mainstream dams are currently under consideration. These are:

In upper LMB:

- Pak Beng
- Luang Prabang
- Sayabouly
- Paklay
- Sanakham
- Pak Chom

And in the middle and lower LMB:

- Ban Khoum
- Lat Sua
- Don Sahong
- Stung Treng
- Sambor (Options 1 and 2)

Each dam is essentially run-of-the-river and is assumed to be operated to maximise hydropower. The scenarios variously involve both groups above (being all of the above, only the first six in the upper LMB, and none of the above. A summary of the key characteristics of each potential mainstream dam is given below in Table 7 overleaf.

2.2.6 *Tributary dams*

A database of dams in the LMB has been assembled by BDP in consultation with the countries, for which documentation has been provided in the Hydropower Sector Study conducted by BDP[4].

Following further consultation with each country, planned developments have been incorporated into each scenario. The results of these consultation are given in and summarised overleaf in Table 7.

[4] Hydropower Sector Review for the Joint Basin Planning Process, BDP2, February 2009

Table 7 Summary characteristics of main dams

Country	ID	Project name	Province	Installed capacity MW	Live storage MCM
Lao PDR	L034	Don sahong mainstream	Champasack/	360	**115**
Lao PDR	L052	Pakbeng mainstream	Oudomxay/Pak Beng	1,230	**442**
Lao PDR	L053	Luangprabang mainstream	Luangprabang/Luangprabang	1,410	**734**
Lao PDR	L054	Xayabuly mainstream	Xayabuly/Xayabuly	1,260	**225**
Lao PDR	L055	Paklay mainstream	Xayabuly/Paklay	1,320	**384**
Lao PDR	L056	Sanakham mainstream	Vientiane/Sangthong	1,200	**106**
Lao PDR/ Thailand	L057	Sangthong-Pakchom mainstream	Vientiane/Sangthong	1,079	**12**
Lao PDR/ Thailand	L058	Ban Kum mainstream	Champasack/	1,872	**0**
Lao PDR	L059	Latsua mainstream	Chmpasack/	800	**0**
Cambodia	C005	Sambor mainstream	Kratie / Kratie	3,300	**2,000**
Cambodia	C006	Stung Treng mainstream	StungTreng / Thala Bariwat	980	**70**
			Totals	**14,811**	**4,088**

Table 8 Summary of mainstream and tributary dams included in each scenario

Installed capacity (MW)

Country	Total potential: Installed capacity MW	Total potential: M/strm	Baseline 1000	China dams 2000	Definite future 3000	Foreseeable future 2030: All m/s dams 4000-01	Foreseeable future 2030: No m/s dams 4100-01	Foreseeable future 2030: M/s dams in upper LMB 4200-01	Foreseeable future 2030: No Thai m/s dams 8000	Foreseeable future 2030: All m/s + flood control 8001	Long term 2060: Long term 2060 6000-01	Long term 2060: Very high dev. 2060 7000-01
Cambodia	5,590	4,280			1	4,917	637	637	4,917	4,917	5,507	5,590
Lao PDR	20,907	10,531	570	570	3,495	18,664	8,133	15,632	15,713	18,664	20,373	20,894
Thailand	745		244	244	244	244	244	244	244	244	244	244
Viet Nam	2,583		720	720	2,284	2,583	2,583	2,583	2,583	2,583	2,583	2,583
Totals	**29,824**	**14,811**	**1,533**	**1,533**	**6,023**	**26,408**	**11,597**	**19,096**	**23,457**	**26,408**	**28,707**	**29,310**
No. of dams	136	11	11	11	36	84	73	79	82	84	111	130

Live storage (BCM)

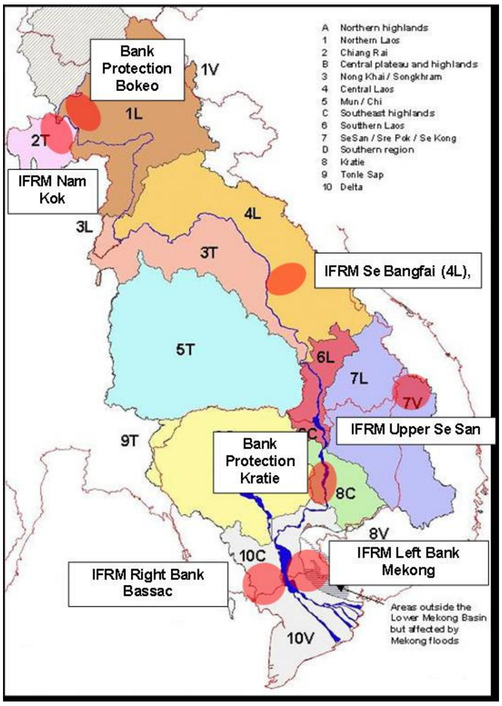
Country	Total potential: Live storage BCM	Total potential: M/strm	Baseline 1000	China dams 2000	Definite future 3000	Foreseeable future 2030: All m/s dams 4000-01	Foreseeable future 2030: No m/s dams 4100-01	Foreseeable future 2030: M/s dams in upper LMB 4200-01	Foreseeable future 2030: No Thai m/s dams 8000	Foreseeable future 2030: All m/s + flood control 8001	Long term 2060: Long term 2060 6000-01	Long term 2060: Very high dev. 2060 7000-01
Cambodia	18.9	2.1			0.0	4.6	2.5	2.5	4.6	4.6	15.7	18.9
Lao PDR	57.5	2.0	5.6	5.6	17.2	37.6	35.6	37.5	37.6	37.6	49.1	57.5
Thailand	3.6		3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
Viet Nam	3.2		0.8	0.8	2.6	3.2	3.2	3.2	3.2	3.2	3.2	3.2
Totals	**83.1**	**4.1**	**9.6**	**9.6**	**23.0**	**48.6**	**44.5**	**46.4**	**48.6**	**48.6**	**71.3**	**82.8**

Note: Data above exclude small dams, notably in Thailand and Lao

2.2.7 *Flood management*

The MRC Flood Management and Mitigation Programme under its Component 2 (FMMP-C2) have been studying flood management options in the Cambodian and Viet Nam flood plains as well as other locations within the LMB.

A total of 36 possible projects have been shortlisted under ProDIP (six each for Thailand and Lao and twelve each for Viet Nam and Cambodia). From these five are being developed (to more or less prefeasibility level) as demonstration projects with guidelines. These cover flood risk assessment in Nam Mae Kok (Thailand), integrated flood risk management plans for Xe Sang Rai (Lao) and West Bassac (Cambodia), development of flood protection criteria in Viet Nam and a joint Cambodia-Viet Nam project on transboundary impacts.



Whilst clearly all flood management schemes are important, it is evident that only those in the Cambodian and Viet Nam flood plains have particular significance at basin-level due to the potential transboundary impacts between Cambodia and Viet Nam.

The scenarios to be studied now draw on the wealth of information and knowledge assembled during FMMP-C2[5] and may be considered in two groups:

(i) Foreseeable Future scenario

Relevant measures up to the year 2030, in which the existing agreed plan for flood protection in the Mekong Delta in Vietnam is expected to be completed, and a mix of early and full flood protection in the Cambodia part of the delta:

- Option 1A: Increasing the number of canals in the Plain of Reeds and Long Xuyen Quadrangle and in the West Bassac area.
- Option 1B: Increasing the flow capacity of the West Vaico River through a regulator at the mouth of the Vaico River
- Option 1C: Combination of options 1A and 1B.

[5] Report reference to be added when available

(ii) Long Term Future scenario

Possible developments up to year 2060, providing an outlook towards full flood protection in the Vietnamese part of the delta and a mix of early and full flood protection in the Cambodia part:

- Option 2A: Increasing the number of canals in the Plain of Reeds and Long Xuyen Quadrangle and in the West Bassac area.
- Option 2B: Diversion and regulation of flow in the Tonle Sap – Great Lake system. This option has much wider objectives, especially to increase dry season flow
- Option 2C: Combination of options 2A and 2B.

The details of these options have been established through a process of dialogue between FMMP-C2 and working groups in both countries and the schematisations of each have been set-up accordingly by the FMMP-C2 team. The same schematisations are used by both FMMP-C2 and the IKMP modelling team (MT), in the former case to contact location specific assessments of the flood control measures and in the latter case to assess the basin-level impacts in the context of these and the other interventions under consideration within the basin.

2.2.8 Climate change and sea level rise

The hydrometeorological baseline used in the DSF covers 16 years (1985-2000)[6]. This period was selected during development of the DSF (1999-2004) as being that period for which there was the most contiguous set of hydrometeorological data across the LMB with a spatial resolution consistent with basin-scale modelling[7].

The baseline is being extended and data are being collected from each country in the expectation that the baseline can be extended up to 2008, adding a further 8 years. This exercise includes also review and quality assurance of the records received and replacement with actual data of gaps that had to be infilled in the current baseline data sets. The exercise is not expected to be complete until late 2009 and may necessitate recalibration of the DSF before the extended baseline can be used in the assessment of BDP scenarios.

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[6] See MRC WUP-A final report, Halcrow 2004

[7] Note whilst, whilst the DSF is set up to compare relative impacts between a scenario and the baseline over the agreed sixteen-year period (which is acknowledged now as representing a relatively dry sequence of years), FMMP-C2 adopts a different analytical technique more appropriate to project-level studies where flood impacts are considered for different return periods so that risks can be evaluated and project designs optimised. Accordingly, FMMP-C2 have used 97 years on mainstream records to identify periods of wet season records representative of different return periods. FMMP-C2 assessments focus only on assessment of impacts associated with improved management of wet season flows, whereas the DSF considers year-round impacts of all interventions.

MRC Environment Programme has taken up a Climate Change and Adaptation Initiative (2008-2012) under which estimates of climate change within the Mekong basin have been made[8].

Estimates have been prepared based on the daily climate data provided by the SEA-START group in Bangkok (Dr Anond Snidvong and Dr Supparkorn Chinvano) for two of the IPCC scenarios (A2 and B2) generated by one of the IPCC models (ECHAM4). The ECHAM4 projections have been downscaled to the Mekong region using the PRECIS program, available from the Hadley Centre in the UK. Downscaled data for A2 scenario have been used tested by application in the DSF model and adjustments to the data made.

IKMP plan to peer review the data provided by EP (possibly using comparable datasets generated by the University of Washington) and once complete climate change datasets relevant to the periods 2010-30 and 2030-60 will be assembled and made ready to load into the DSF's knowledge base as alternatives to the existing baseline hydrometeorological data.

Sea level rise is an important further component of climate change scenario modelling. Predictions vary and include estimation of up to 1m rise by 2100. Viet Nam has been conducting various studies and will be consulted in firming up estimates for 2030 and 2060 downstream boundary conditions for the DSF.

BDP will agree with Viet Nam an appropriate set of estimated coastal boundary conditions representative of alternative sea level rise scenarios and these will be stored in the DSF knowledge base for use in current and future modelling exercises.

2.3 Addressing uncertainties

As in any assessment there are questions of uncertainty that need to be addressed. These arise from three perspectives: data quality, model accuracy and development assumptions.

2.3.1 Uncertainties in data quality

There are inevitable uncertainties about the accuracy of the underlying data used in the analyses. It would be incorrect of course to suggest that these are 100% accurate.

All of the basic hydrological input data have been through a quality assurance process when the DSF was first constructed[9]. It should be recalled also that the basis to all assessments is founded on the *difference* between conditions predicted in one scenario versus those predicted in the baseline scenario. Discrepancies in *relative* values therefore will be substantially less than discrepancies observed in *absolute* values and are unlikely to significantly affect decisions made based on relative change.

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[8] Report reference to be added when available

[9] See MRC WUP-A final report, Halcrow 2004

However, it has become recognised that the hydrometeorological data series embedded in the DSF (1985-2000) covers a relatively dry period historically and that, as a consequence, indicative estimates drawn from this period would intuitively underestimate absolute values of recurrent flooding and the severity of low flow constraints. Steps are in hand to extend the time series input data to, hopefully, 2007 (a further seven years), which is understood to be a noticeably wetter period, thus making the overall time series representative of average conditions in the basin. Again though, it should be remembered that decisions are to be made based on change observed and, whilst the additional data would be unquestionably valuable, it is unlikely to radically change the course of strategic decisions.

A further significant area of uncertainty lies with the topographic data, notably in the flood plains. This is reflected in both the accuracy with which measurement stations have been levelled in as well as the absolute levels and barrier features (eg roads, bridges, embankments etc) present on the flood plain. The prediction of the extent, depth and duration of flooding is highly dependent upon these field measurements. Furthermore, changes in infrastructure (those obstructing flood flows) do continually happen and there is a need to regularly update the topographic data.

FMMP has recognised the limitations of the existing digital elevation model (DEM) and advocates that it is upgraded. This would be a relatively expensive and time-consuming task, which in any event is unlikely to happen and be completed within the current BDP phase 2. When the DSF was first set-up, comparisons were made between predicted and observed (satellite imagery) flooded areas, and these were found to reasonably correlate. FMMP have made some improvements to the representations of the flood plain and the IKMP team is looking at how these might be incorporated in the DSF.

Given the uncertainties over topographic data, again it is important to (a) focus attention on estimated total areas affected (as opposed to the exact delineation of flooded areas) and (b) base decisions on relative changes rather than absolute values.

2.3.2 Uncertainties in model accuracy

When the DSF was first established, the predicted baseline flow parameters were calibrated within acceptable tolerances agreed by each country and IKMP have taken steps to preserve the quality of this calibration[10]. The question is whether the models equally well predict changes that would occur as a result of new developments in the basin. In part the answer to this lies in the underlying algorithms within each of the three models that are founded on established understandings of physical processes, not only encountered in the Mekong basin but in many other similar locations around the world.

[10] The SWAT / IQQM combination of models, which are used to simulate the areas upstream from Kratie, were calibrated to the following criteria: 1) flows always within 2 - 3% in the mainstream and 10% in the tributaries and 2) total volumes always within 1% in the mainstream and 5% in the tributaries. The ISIS models downstream of Kratie were calibrated inter alia to tolerances of 20cm.

In reality there are three ways of dealing with uncertainties in model accuracy. The first is to ensure that the models are responding to change in an intuitively correct way (eg increased wet season storage leads to proportionately increased dry season flows). This has been addressed in the various previous uses of the DSF such as in the WUP-A demonstration scenarios and in the subsequent modelling work done for World Bank.

The second is to run scenarios with slightly varied assumptions (eg increased abstractions) and to check that downstream flows change in a proportionate and convincing manner (see section 2.3.4 below).

The third is to employ an altogether separate set of models and check whether similar results are observed. It is very improbable that exactly the same results would be obtained (for a variety of valid reasons), but it would be reasonable to expect most importantly that the directions of change in key parameters are the same and secondly, that similar orders of magnitude of relative change are observed. BDP, together with IKMP, are looking to arrange such a comparison (possibly with assistance from Washington State University who are understood to have their own models of the Mekong river system based on remotely sensed data).

2.3.3 Uncertainties in development assumptions

Whilst issues of the accuracy of input data and the models themselves as described above are clearly important in promoting confidence in the predictions made using the DSF, in terms of orders of magnitude, the accuracy of forecasting future developments within the basin is a very much more significant issue in terms of how the hydrological regime of the mainstream may change.

Conceptually, the issue of how well known future changes are falls into two categories:

(i) Changes which are within the member States' remit to plan and directly or indirectly control, such as the development of tributary and mainstream dams, irrigation, flood control etc; and

(ii) Changes which are wholely or substantially outside the member States' control, such as climate change, dams and any abstractions in the upper basin and, depending upon one's point of view, population increase and related production demands and impacts on the watershed landscape;

The first category relate to the choices that the member States can make as to how best to develop the basin, the second relates to the circumstances within which those choices need to be made. Thus, in theory at least, the accuracy of future predictions of how much productive use (agriculture, fisheries, hydropower, navigation, environmental protection etc) of the river system may be put in place is not in effect an outcome but an input to the overall assessments (to be judged on social, economic and environmental grounds).

The second category is far more important in terms of how well they can be predicted (in order to determine the best sustainable choice of future development). From the earlier studies made by MRC, factors which are expected to have considerable direct influence on the hydrological regime outside the direct control of each member State are, in rough order of significance[11]:

- Hydropower and other developments in the upper basin;
- Climate change in terms of both hydrometeorological change and sea level rise;
- Land use changes induced by social and economic policies (outside the water sector) as may affect watershed management and flood plain infrastructure and use;

To these may be added also the cumulative impacts of tributary storages on the flow regime as may be constrained by implementation capacity within certain time horizons.

The best approach to identifying which uncertainties are the most significant is to review the initial scenarios and to see which parameters are most significant in impacting on the choice of development opportunities. Those with high uncertainty but having little impact on the choices to be made are of much less interest than those which, by virtue of relatively small changes in assumptions, have significant impact on the development space.

2.3.4 Actions to address uncertainties

In summary of the above, the following actions are needed to address uncertainty:

(i) Continued vigilance and efforts to quality assure data used in the assessment processes;

(ii) When data are available, extension of the hydrometeorological baseline and re-evaluation of (by then) key scenarios;

(iii) Re-run of key scenarios with varied input data to assess the models responsiveness to changes;

(iv) Peer review of the models through comparison of results obtained with different models;

(v) Review of results of initial scenarios and identification of key parameters affecting, or likely to affect, the outcomes of the scenario assessments significantly, and

(vi) Construction of alternative scenarios in which the impacts of varied assumptions of the key parameters identified above are tested and analysis of the implications of the changed outcomes on how this would affect future development choices.

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[11] These are the factors affecting principally flow volumes. They overlap also issues to do with sediments and water quality. They do not however attempt to reflect issues of uncertainty associated with the wider demand predictions such as of population growth, increased food security demands, energy pricing and hydropower viability, fisheries management policies and capture fisheries sustainability etc, which are each pertinent to the member States in determining their own development needs and priorities.

In the context of the last point above, clearly the assumptions on developments in the upper basin are likely to have significant impact on development choices for the future. A provisional ToR for assessing the uncertainties of what might happen in the Upper and Lower Basins is set out in Appendix A . This should be reviewed following the assessment of the initial scenarios described in this report and may be added to in the light of this assessment.

3 Assessment outputs

3.1 Overview

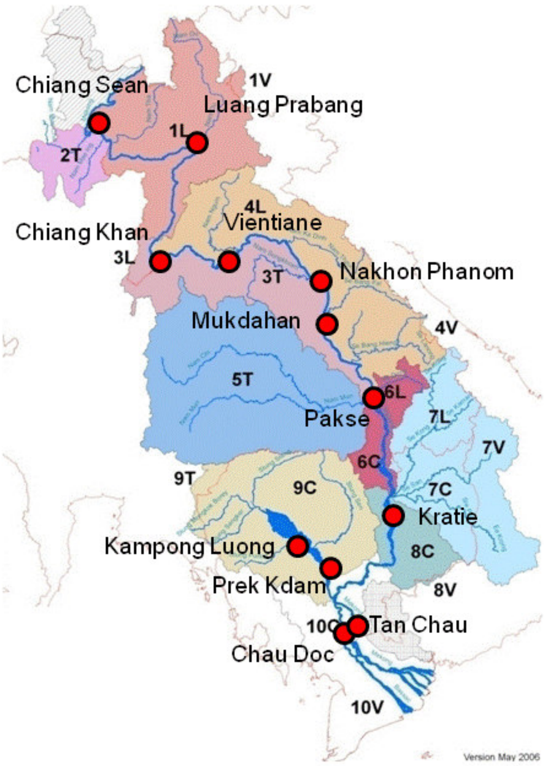
The aims of the hydrological assessments are three-fold:

(i) To make an assessment of the nature and magnitude of the hydrological changes in the Mekong LMB mainstream relative to baseline conditions brought about by the assumed set-up conditions in each scenario;

(ii) To create an information platform upon which other assessments (fisheries, irrigated agriculture, geomorphology, water quality environmental, social and economic) can be undertaken in a manner that relates these assessments to changing hydrological conditions; and

(iii) To prepare a report on each scenario run together with an overall assessment drawing together the findings from each scenario test conducted.

The DSF was designed with both these functions in mind and equipped with the necessary tools to accomplish this[12].



3.2 Key reporting nodes

Twelve reporting nodes in the DSF have been selected for all assessments of temporal hydrological changes. These are:

- Chiang Sean
- Luang Prabang
- Chiang Khan
- Vientiane
- Nakhon Phanom
- Mukdahan
- Pakse
- Kratie
- Kampong Luong
- Prek Dam
- Tan Chau
- Chau Doc

[12] See WUP-A final report, Halcrow 2004, for further details. Note, some additional reporting tools may be required, but these are relatively minor in nature and can be set up within the current work programme by IKMP with support from their consultants

In addition, spatial changes (flooding and salinity intrusion will be reported on with appropriate maps and related areal data.

3.3 Time-series reporting

For each scenario the following time-series reports are needed as given in Table 9.

Table 9 Time-series reporting at key nodes for each scenario

	Title	Specific requirement	Key relevance(s)
All nodes			
1	Average seasonal flow and water level in wet and dry seasons	Seasonal volume (MCM), average discharge (m3/s), average WL (m)	Overview of hydrological changes
2.0	Average seasonal flow and water level in dry season	Seasonal volume (MCM), average discharge (m3/s), average WL (m)	Overview of hydrological changes
2.1	Average seasonal flow and water level in dry season	Seasonal volume (MCM), average discharge (m3/s), average WL (m)	Environmental assessments
2.2	Average seasonal flow and water level in dry season	Seasonal volume (MCM), average discharge (m3/s), average WL (m)	Environmental assessments
3.0	Average monthly flow and water level	Monthly volume (MCM), average discharge (m3/s), average WL (m)	Overview of hydrological changes
3.1	Average monthly flow and water level for a dry year	Monthly volume (MCM), average discharge (m3/s), average WL (m)	Environmental assessments
3.2	Average monthly flow and water level for a wet year	Monthly volume (MCM), average discharge (m3/s), average WL (m)	Environmental assessments
4	Average daily flows and water level	Average daily flows (m3/s) and water level (m)	Article 6. Maintenance of Flows on the Mainstream
5	Annual average minimum and maximum daily flow and water levels;	Average, maximum and minimum daily discharges (m3/s)	Overview of hydrological changes
6	Wet and dry seasonal flow volumes during wet, dry and average years;	Seasonal volumes (MCM) in notional 1:5 wet year, 1:5 dry year and average	Overview of hydrological changes
7	Depth exceedence duration data	Average days depth exceeds range of depths (navigation critical drafts)	Impacts on navigation and other riverine activities and potential ecological changes
8	Timing and duration of flows within critical range	Average dates and durations of flow within fish-critical discharge ranges	Fish migration
9	Annual season change dates (dry, TR1, wet, TR2)	Annual , average, maximum and minimum dates	Fish migration, agriculture, ecological changes and overview of hydrological changes
10	Annual number of freshes in TR1	Annual , average, maximum and minimum number of freshes	Fish migration and other ecological changes
11	Annual recession rate in TR2	Annual , average, maximum and minimum recession rate	Fish migration, sedimentation, ecological change, recession agriculture

Table 9 continued

	Title	Specific requirement	Key relevance(s)
For Prek Kdam only			
12	Annual reverse flow to Tonle Sap	Annual , average, maximum and minimum flow volumes	Article 6. Maintenance of Flows on the Mainstream
13	Annual outflow from Tonle Sap	Annual , average, maximum and minimum flow volumes	Article 6. Maintenance of Flows on the Mainstream
14	Annual flow reversal dates	Annual , average, maximum and minimum dates	Article 6. Maintenance of Flows on the Mainstream and fish
For Kampong Luong only			
15	Average annual reverse flow water level to Tonle Sap	Annual , average, maximum and minimum water levels (m)	Article 6. Maintenance of Flows on the Mainstream
16	Average annual outflow water level from Tonle Sap	Annual , average, maximum and minimum water levels (m)	Article 6. Maintenance of Flows on the Mainstream
17	Annual flow reversal dates	Annual , average, maximum and minimum dates	Article 6. Maintenance of Flows on the Mainstream and fish

3.4 Creating an assessment platform

3.4.1 Approach to assessing BDP indicators

The BDP assessment criteria for the scenarios and related indicators have been developed by BDP in consultation with the Regional Technical Working Group (RTWG) and are reported on by BDP[13].

The nature of the assessment and of the general approach to the assessment is to relate changes in each of the indicators to changes in hydrological conditions prompted by the interventions and external conditions assumed for each scenario. The manner in which this will be done is illustrated in Table 10 overleaf and described further below.

3.4.2 Increase in irrigated agricultural production

The key indicator for the hydrological assessment is **incremental area** of irrigated area production measured in '000ha.

[13] BDP report Scoping and planning of the assessment of basin-wide development scenarios, v3.1, March 2009

Table 10 BDP assessment criteria and related DSF outputs

	Specific development objective	Issue	Indicator		DSF output			
			Description	*Unit*	*Basic results required*	*Unit*	*Report tables*	*Report maps*
Economic	1.1 Increase irrigated agricultural production	Irrigable area, production tonnage and value	Incremental area	'000 ha	Areas irrigated at each node in each scenario	'000 ha	Areas irrigated aggregated by district and by country	Percent of district irrigated (five suitable ranges)
	1.2 Increase hydropower production	Hydropower capacity, power generated and value	Incremental installed capacity	MW	Installed capacity at each hydropower damsite	MW	Installed capacity, active storage and energy generated in tributaries aggregated by country and individually for each mainstream dam	Size of average energy generated at each location (area of circles proportion to energy generated) Ditto for active storage
			Incremental power generated	GWh/year	Active storage at all dam sites Average power generated per year at each hydropower site	MCM GWh/year		
	1.3 Improve navigation	River transport	Incremental navigable days by class	'000 boat-days	Depth exceedence duration data (see table)		See table	Locations with increasing or decreasing navigability by class
	1.4 Decrease damages by floods *	Extent and duration of annual flooding by class	Average area flooded annually to max 0.5-0.9m depth	'000 ha	Area flooded annually to max 0.5-0.9m depth for average, wet and dry years	'000 ha	Areas flooded aggregated by district and by country	Average area flooded to max 0.5-0.9m depth vs baseline
			Average area flooded annually > max 0.9m depth	'000 ha	Area flooded annually > max 0.9m depth for average, wet and dry years	'000 ha		Average area flooded > 0.9m depth vs baseline
	1.5 Maintain productivity of fishery sector	Capture fisheries and aquaculture production	Incremental annual average capture	'000 ton	*Assessments based on expert opinion drawing on hydrological assessment*			
		Impact of flow and sediment transport changes on deep pools	fish availability Water levels at specified locations on mainstream	m	Areas of deep pools and indicative changes avergae minimum WL sustained for 30, 60 and 90 day durations	'000 ha, m and days	Areas of deep pools aggregated by reach and water level changes sustained for specified durations	Deep pools and changes in water levels sustained for specified durations
Environmental	2.1 Maintain water quality and acceptable flow conditions	Flow characteristics	Key flow charcateristics (to be defined)	Trend	See time-series analysis requirements			
		Protection of forests around Tonle Sap	Forest flooded for specified depth duration at Tonle Sap	'000 ha	Average forest area flooded annually to depth > 0.3m	'000 ha	Average, max and min areas of flooded forest	Total forest area and area meeting criteria
	2.2 Maintain wetland productivity and ecosystem services	Productivity of wetland ecosystems	Incremental wetlands with required depth-duration	'000 ha	Average area of wetlands defined as having flooding of any depth for more than or equal to 90 days	'000 ha	Areas of wetlands meeting criteria aggregated by district and by country	Scenario wetland area compared to baseline wetland area overlying official wetland mapping from EP
	2.3 Manage salinity intrusion in the Mekong delta	Impact of salinity intrusion on land use potential	Area within delta within thresholds of salinity levels	'000 ha	Average total area within which salinity exceeds 4g/l for a range of durations (see table)	'000 ha	Areas irrigated aggregated by district and by country	Change in area exceeding 4g/l vs baseline
					Average total area experiencing range of maximum salinity concentrations	'000 ha		Average salinity contours
	2.4 Minimize channel effects on bank erosion	River bank erosion	Incremental area at risk to erosion	'000 ha	*Assessments based on expert opinion drawing on hydrological assessment*			
	2.5 Conservation of biodiversity	Impacts of flow management changes on endangered species	Incremental area of suitable habitats	'000 ha	Areas of habitats and indicative changes avergae minimum WL sustained for 30, 60 and 90 day durations	'000 ha, m and days	Areas of habitats aggregated by reach and water level changes sustained for specified durations	Habitats and changes in water levels sustained for specified durations
Social	3.1 Maintain livelihoods of vulnerable resource-users	Health, food and income security	No. of people affected	'000 h/h	*Assessments based on direct impacts of flooding and irrigation and indirect (via fisheries and environmental assessments) impacts on people*			
			Severity of impact on health, food and income security	Trend	*Assessments based on understanding of local conditions related to people affected above*			
	3.2 Increased employment generation in water related sectors	Incremental sustainable employment from water resource interventions	Incremental number of people engaged in agriculture, fisheries, water-related service industries and tourism	'000	*Assessments based economic assessments of impacts on productive sectors as above*			

Based on this information, the irrigation and economics team are able to determine **incremental crop production** ('000 ton) and **net incremental economic value** (US$ 'million) by applying crop budgets, economic prices and development and recurrent costs. Application of the crop budgets to the incremental areas also enable estimates to be made of increased labour requirements in agriculture and related processing industries to contribute to the social indicator (3.2) of **incremental number of people in employment**. Similarly, estimates can be made of future agricultural inputs (including fertiliser and pesticides) that would contribute to the assessment of water quality (2.1).

The assessment of incremental irrigated areas is undertaken using the DSF models. The DSF computes for each scenario the area that can be irrigated at each model node with irrigation attached up to the maximum irrigable area present at that node. The area irrigated is thus constrained by the irrigation demands (which are dependent upon climate assumptions) and the water resources available (which are dependent upon both climate assumptions and water management infrastructure in place, principally dams and storage reservoirs)[14].

The data generated from the DSF is reported at each irrigation node as the maximum feasible area irrigated in each year during the run (baseline 1985-2000). These are abstracted and an average area computed at each node which is then aggregated for reporting purposes by district and country by comparing the area in the scenario less that in the baseline.

A map for each scenario is then produced plotting the percentage of the gross area of each district which is irrigated, providing a visualisation of where irrigated areas are in the basin in each scenario.

3.4.3 *Increase in hydropower production*

The key indicators for the hydrological assessment are the **incremental installed capacity** of hydropower measured in MW and the **incremental power generated** measured in GW/hr.

Based on this information, the hydropower specialist together with the economics team can compute the **net incremental economic value of hydropower generated** (in US$ 'million) for each scenario by applying economic prices to the power generated and the capital and recurrent costs of generating and distributing the hydropower energy.

The assessment of hydropower generated is undertaken by the DSF models based on the available water flows throughout the year, the installed capacity and the assumed operating rules at each site. In the case of mainstream dams, more detailed modelling has been undertaken of each of the eleven dams under consideration in the LMB and this information, where relevant, is used in preference in the economic assessments.

[14] The DSF is also capable of investigating the impact of land cover changes in terms of impacts upon run-off.

The data generated from the DSF is reported at each hydropower node as the energy generated in each year during the run (baseline 1985-2000). These are abstracted and an average energy generated computed at each node which is then aggregated for reporting purposes by site and country for comparison of the energy generated in the scenario and that in the baseline.

Two maps for each scenario are then produced plotting firstly the average power generated at each site and secondly the active storage at each site. The representation of both will be dots to denote the location sized to reflect the parameter in question. This will provide a visualisation of where hydropower is being generated in the LMB and where active storage is available for each scenario.

3.4.4 *Improved navigation*

The key indicator for the navigation improvement is the **incremental navigable days** by class of boat, measured between each reporting node in the mainstream.

Based on this information, the economics team can compute the **net incremental economic value of navigation** (in US$ 'million) for each scenario by applying net economic prices to the value of navigation in the mainstream for different classes of boat.

The assessment of incremental navigable days is based on depth-duration analyses conducted at each reporting node. Upstream of Kratie, where the DSF generates discharge information only (below Kratie depths are computed directly in the hydrodynamic model), rating curves are used at each node to convert discharge into depth. Data are then abstracted from the DSF and the number of days each year critical depths are exceeded in each year is computed and then averaged for the entire period in the form of depth exceedence – duration tables for each node. The depth exceedence – duration relationship for each reach, defined as the mainstream between each reporting node, is taken as the average of the two nodes.

The critical depths for navigation are as follows:

Critical minimum draught	Boat class	Remarks
To be confirmed	*To be confirmed*	*To be confirmed*

The data reported from the DSF will be in the form of tables of the average days of exceedence of the critical depths at each node and in each node and the changes relative to the baseline.

In addition a map will be produced for each scenario showing which reaches are experiencing increased (eg green) or decreased (eg red) navigability together with the percent change by boat class of navigable days in each reach relative to the baseline.

3.4.5 *Decrease in damages by floods*

The key indicators for the decrease in damage by floods are the **average area flooded annually to maximum of 0.5-0.9m depth** and the **average area flooded annually to greater than 0.9m**. These indicators have been selected having in mind that these flooding characteristics would have a significant impact on choices made in land use by those living in the flood affected areas[15].

Based on this information and data provided from the FMMP-C2 team from their more detailed assessment of flood damages and other impacts, the economics team can compute the **net incremental economic value of flood damage** (and other related impacts) in US$ 'million for each scenario by applying economic prices to the impacts and the capital and recurrent costs of additional flood management works (as determined by FMMP-C2).

The DSF has the facility to generate spatial data on the extent of flooding predicted in each scenario and for the relevant areas to be computed and compared with baseline. The output requirements are tables of average areas flooded in each category above by district and by country and changes relative to the baseline. In addition maps are produced for each scenario for each category of scenario showing the average extent of flooding compared to baseline conditions.

3.4.6 *Maintain productivity of fishery sector*

The key indicator for fishery productivity is the **incremental annual average capture fish availability** measured in '000 tons. The methodology for this assessment is set out in Annex 3.

The MRC Fisheries Programme has identified a number of key issues for the maintenance of ecological functioning of the LMB ecosystem with reference to migratory fish[16]. These include:

- Spawning habitats – principally in the accessible parts of middle and upper reaches of the river system where rapids alternate with deep pools;
- Dry season refuge habitats – principally deep pools;
- Flood season feeding and rearing habitats – principally flood plains in Cambodia and Viet Nam, but also elsewhere including along major tributaries;
- Migration routes – principally the mainstream, connections with Tonle Sap, Sesan sub-basin and other major tributaries and connectivity between floodplain habitats and river channels

[15] Further studies, including those of FMMP-C2 and by the irrigated agriculture specialist, may reveal that different flood depth ranges are more appropriate in the determination of land use, but at the outset the above appear a reasonable starting point based on experience with flood plain agriculture elsewhere.

[16] MRC Technical Paper No.8, October 2002

- Hydrology – the annual patterns, timing and duration of flooding, flow reversal in Tonle Sap river, and critical water levels and discharges that trigger fish migration[17]

The assessments made with the DSF can contribute to the understandings needed to assess the impacts of interventions on capture fisheries in the following ways:

(i) Extent of flooding on flood plains: The analyses given in Section 3.4.5 below will indicate changes in the extent of flooding and duration of flooding on flood plains caused by the interventions modelled. Flood plains are important to capture fisheries as areas of feeding and capture according to species, and changes in flood regime will affect both.

(ii) Extent of wetlands: The analyses given in Section 3.4.8 below will indicate changes in the extent of wetlands caused by the interventions modelled. Wetlands are important to capture fisheries as areas of spawning, feeding and capture according to species, and changes in wetland areas will affect all three.

(iii) Water level changes in deep pools: The analyses given in Section 3.4.8 below will indicate changes in the water levels in deep pools over a series of minimum durations caused by the interventions modelled. Deep pools are important to capture fisheries as areas of spawning, feeding and refuge, and changes in water levels at deep pools will affect all three. The depth of deep pools may also be affected by changes in sedimentation patterns.

(iv) Habitat analysis: The techniques discussed in Section 3.4.10 (which are methodologically the same as for deep pools) can be used to assess water level changes in any designated habitat area and can therefore be used to assess hydrological impacts in any areas related to mainstream conditions not covered in the assessments above.

(v) Migration triggers: Fish migration is significantly (but not exclusively) dependent upon a variety of hydrological conditions including the timing and quantum of water levels and discharge. Assessments of these are made as described in Section 3.3 above. In addition the size of catch has been shown by FP to be greatly influenced by prevalent discharges, for instance at Khone Falls between 2,000 and 4,000 cumec when 90% of the dominant species are caught. Test no. 8 in Section 3.3 above is set up to assess the change of timing and duration of these critical flow conditions.

3.4.7 *Maintain water quality and acceptable flow conditions*

The key indicators for maintaining water quality and acceptable flow conditions in the mainstream are the **key flow characteristics** as included in Section 3.3 above and the **forest area flooded for specific duration around Tonle Sap**. Further indicators are water quality and sediment conditions in the mainstream, for which the assessment methodology is set out in Annex 5.

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[17] MRC Technical Paper No.14, December 2006

Appreciation of the extent of flooded forest areas around Tonle Sap will inform the environmental and fisheries assessments as described in Annexes 3 and 6.

The DSF has the facility to generate spatial data on the extent of flooding around Tonle Sap as predicted in each scenario and for the relevant areas of forests (based on land use maps) to be computed and compared with baseline. The output requirements are tables of average areas of forest flooded each year to depth greater than 0.3m (which is assumed to be the minimum depth that would significantly affect ecological conditions) and compared to baseline conditions. In addition maps are generated comparing total forest area with that flooded in the scenario and in baseline conditions.

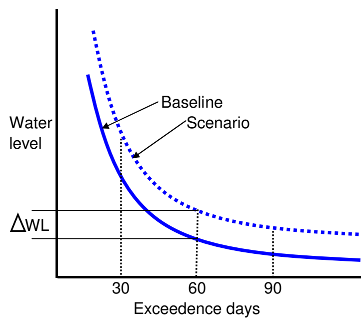
3.4.8 *Maintain wetland productivity and ecosystem services*

The key indicators for maintaining wetland productivity and ecosystem services are the **incremental area of wetlands** and **water levels at specified locations on the mainstream** as related to deep pools.

Appreciation of the extent of wetland areas and of the changes in water levels at deep pools will inform the environmental and fisheries assessments as described in Annexes 3 and 6.

The MRC has adopted the definition for wetlands in line with the Ramsar Convention[18]. This definition is broad and covers marine/coastal wetlands, inland wetlands and human-made wetlands. The MRC Environment Programme (EP) has prepared a map (GIS) of all wetlands in the basin conforming to this definition and which include all water bodies, permanently and seasonally flooded land and irrigated areas. For the purposes of assessing the impacts of different interventions on wetlands, a more workable definition for wetlands has been adopted in the scenario assessments, being all land flooded to any depth for at least 90 days.

In relation to **wetlands**, the DSF has the facility to generate spatial data on the extent of flooding predicted in each scenario and for the relevant areas to be computed and compared with baseline. The output requirements are tables of average areas flooded each year for at least 90 days aggregated by district and by country and changes relative to the baseline. In addition maps are required for each scenario of the average extent of flooding compared to baseline conditions and to the EP layer of wetlands as described above.

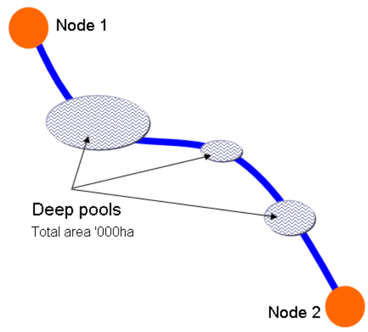


The analysis of the impact of interventions on water levels in **deep pools** is constrained by the lack of detailed data of deep pool profiles. Thus, whilst EP has mapped the location and size of deep pools throughout the LMB, it is not possible to compute the absolute depths of water at each pool. Instead, it is possible to estimate the changes in average minimum water levels sustained over periods of 30, 60 and 90 days, reflecting

[18] See http://www.ramsar.org/ris/key_ris_types.htm

the critical periods when deep pools are used as refuges, spawning and sometimes feeding areas for migratory fish.

The assessment of changing water levels for deep pools is based on depth-duration analyses conducted at each reporting node. Upstream of Kratie, where the DSF generates discharge information only (below Kratie depths are computed directly in the hydrodynamic model), rating curves are used at each node to convert discharge into depth. Data are then abstracted from the DSF and the water levels prevailing at each reporting node for at least 30, 60 and 90 days each year are computed and then averaged for the entire period in the form of depth exceedence – duration tables.



The area of deep pools, abstracted from the EP mapping, is then calculated and tabulated alongside the difference in water levels exceeding 30, 60 and 90 days between the scenario and the baseline for both the upstream and downstream nodes. In this manner, a statement is made possible to the effect that within the reach in question there are "a"000ha of deep pools for which the water level prevailing for 30 days will increase/decrease on average relative to the baseline by "x_1"m and "x_2"m, for 60 days between "y_1"m and "y_2"m and for 90 days between "z_1" and "z_2"m.

A map can then be prepared for each scenario showing those deep pools with improving and those with deteriorating water levels for the specified durations.

3.4.9 *Manage salinity intrusion in the Mekong delta*

The key indicator for managing salinity intrusion in the Mekong delta is the **area within the delta within thresholds of salinity level**.

The DSF has the facility to generate spatial data on the extent of salinity intrusion as predicted in each scenario. Two sets of results are computed for each scenario, both of which to be aggregated by district and country (saline intrusion is limited to Viet Nam):

(i) The average area within which salinity exceeds 4g/l for a range of durations (4g/l is considered a key parameter affecting choices of land use); and

(ii) The average total area experiencing a range of maximum salinity concentrations

In addition maps are prepared, firstly, recording the maximum area exceeding 4g/l for the scenario compared to the baseline and, secondly, average salinity contours for the scenario.

The output requirements are tables of average areas of forest flooded each year to depth greater than 0.3m (which is assumed to be the minimum depth that would significantly affect ecological conditions) and compared to baseline conditions. In addition maps are generated comparing total forest area with that flooded in the scenario and in baseline conditions.

3.4.10 *Conservation of biodiversity*

The key indicator for conservation of biodiversity is the **incremental area of suitable habitats** measured in '000ha.

The relationships between the sustainability of habitats and hydrological conditions are not as yet well understood. Consequently a similar approach is adopted as for deep pools as described in Section 3.4.8 above, but in this case related to habitat maps with each habitat related to a mainstream reach.

This approach leads to the following statement which is intended to inform the assessment of key habitat areas: associated with the reach in question there are "a"000ha of key habitats for which the water level prevailing for 30 days will increase/decrease on average relative to the baseline by "x_1"m and "x_2"m, for 60 days between "y_1"m and "y_2"m and for 90 days between "z_1" and "z_2"m.

A map can then be prepared for each scenario showing those habitats associated with increasing and those with decreasing water levels for the specified durations.

4 Assessment reports

4.1 Overview

The outputs for the hydrological assessments of scenario reports take two forms:

- **A report on each scenario –** this is a succinct report focussed on factual reporting of the set-up, key assumptions (if any) in setting up the models, and presentation of the outputs as called for in Chapter 3; and

- **An overall assessment report –** summarising the key findings from the individual scenario assessments and providing a commentary on these and the implications for basin development

The nature of the contents of each are summarised in the following sections.

4.2 Scenario reports

Individual scenario reports are to be factual and succinct. They will be accompanied by relevant excel and GIS files associated with the outputs as presented in the report. The key elements of each report are as follows.

4.2.1 Scenario description

A brief description of the scenario investigated including BDP scenario reference numbers.

4.2.2 Scenario set up

A summary description of the data used in each model in the DSF together with a listing of the interventions included in the model set-ups, making reference to the source of all data used.

4.2.3 Issues and assumptions

A description of any issues encountered in setting up and running the models and, where relevant, any actions and/or assumptions made in undertaking the model runs.

4.2.4 Report on time-series analyses

Provision of tables and graphs of the time-series analyses conducted in accordance with Section 3.3 above, viz.:

	Title	Specific requirement
All nodes		
1	Average seasonal flow and water level in wet and dry seasons	Seasonal volume (MCM), average discharge (m3/s), average WL (m)
2.0	Average seasonal flow and water level in dry season	Seasonal volume (MCM), average discharge (m3/s), average WL (m)
2.1	Average seasonal flow and water level in dry season	Seasonal volume (MCM), average discharge (m3/s), average WL (m)
2.2	Average seasonal flow and water level in dry season	Seasonal volume (MCM), average discharge (m3/s), average WL (m)
3.0	Average monthly flow and water level	Monthly volume (MCM), average discharge (m3/s), average WL (m)
3.1	Average monthly flow and water level for a dry year	Monthly volume (MCM), average discharge (m3/s), average WL (m)
3.2	Average monthly flow and water level for a wet year	Monthly volume (MCM), average discharge (m3/s), average WL (m)
4	Average daily flows and water level	Average daily flows (m3/s) and water level (m)
5	Annual average minimum and maximum daily flow and water levels;	Average, maximum and minimum daily discharges (m3/s)
6	Wet and dry seasonal flow volumes during wet, dry and average years;	Seasonal volumes (MCM) in notional 1:5 wet year, 1:5 dry year and average
7	Depth exceedence duration data	Average days depth exceeds range of depths (navigation critical drafts)
8	Timing and duration of flows within critical range	Average dates and durations of flow within fish-critical discharge ranges
9	Annual season change dates (dry, TR1, wet, TR2)	Annual , average, maximum and minimum dates
10	Annual number of freshes in TR1	Annual , average, maximum and minimum number of freshes
11	**Annual recession rate in TR2**	Annual , average, maximum and minimum recession rate
For Prek Kdam only		
12	Annual reverse flow to Tonle Sap	Annual , average, maximum and minimum flow volumes
13	Annual outflow from Tonle Sap	Annual , average, maximum and minimum flow volumes
14	Annual flow reversal dates	Annual , average, maximum and minimum dates
For Kampong Luong only		
15	Average annual reverse flow water level to Tonle Sap	Annual , average, maximum and minimum water levels (m)
16	Average annual outflow water level from Tonle Sap	Annual , average, maximum and minimum water levels (m)
17	Annual flow reversal dates	Annual , average, maximum and minimum dates
For Kampong Luong only		
15	Average annual reverse flow water level to Tonle Sap	Annual , average, maximum and minimum water levels (m)
16	Average annual outflow water level from Tonle Sap	Annual , average, maximum and minimum water levels (m)
17	Annual flow reversal dates	Annual , average, maximum and minimum dates

4.2.5 *Report on parameters supporting impact assessments*

Provision of tables, graphs and maps of analyses conducted in accordance with Section 3.4 above, viz.:

	Basic results required	Unit	Report tables	Report maps
1	Areas irrigated at each node in each scenario	'000 ha	Areas irrigated aggregated by district and by country	Percent of district irrigated (five suitable ranges)
2	Installed capacity at each hydropower damsite	MW	Installed capacity, active storage and energy generated in tributaries aggregated by country and individually for each mainstream dam	Size of average energy generated at each location (area of circles proportion to energy generated)
3	Active storage at all dam sites	MCM		
4	Average power generated per year at each hydropower site	GWh/year		Ditto for active storage
5	Depth exceedence duration data for critical depths for navigation		Depth exceedence duration data for critical depths for navigation in each reach	Locations with increasing or decreasing navigability by class
6	Average area flooded annually to max 0.5-0.9m depth	'000 ha	Areas flooded aggregated by district and by country	Average area flooded to max 0.5-0.9m depth vs baseline
7	Average area flooded annually > max 0.9m depth	'000 ha		Average area flooded > 0.9m depth vs baseline
8	See time-series analysis requirements			
9	Average forest area flooded annually to depth > 0.3m	'000 ha	Average, max and min areas of flooded forest	Total forest area and area meeting criteria
10	Average area of wetlands defined as having flooding of any depth for more than or equal to 90 days	'000 ha	Areas of wetlands meeting criteria aggregated by district and by country	Scenario wetland area compared to baseline wetland area overlying official wetland mapping from EP
11	Areas of deep pools and indicative changes avergae minimum WL sustained for 30, 60 and 90 day durations	'000 ha, m and days	Areas of deep pools aggregated by reach and water level changes sustained for specified durations	Deep pools and changes in water levels sustained for specified durations
12	Average total area within which salinity exceeds 4g/l for a range of durations (see table)	'000 ha	Areas irrigated aggregated by district and by country	Change in area exceeding 4g/l vs baseline
13	Average total area experiencing range of maximum salinity concentrations	'000 ha		Average salinity contours
14	Areas of habitats and indicative changes avergae minimum WL sustained for 30, 60 and 90 day durations	'000 ha, m and days	Areas of habitats aggregated by reach and water level changes sustained for specified durations	Habitats and changes in water levels sustained for specified durations

4.2.6 *Issues encountered in conducting analyses*

A description of any issues encountered in undertaking the analyses above and, where relevant, any actions and/or assumptions made in undertaking the analyses.

4.2.7 *QA and documentation*

A listing of the DSF file references related to the modelling and analyses

A listing of report output files prepared during the analyses and their location

Records of who conducted the modelling and analyses and dates of when work was undertaken

Actions taken and evidence of checking of the model runs

Actions taken and evidence of checking of the post-run analyses

4.3 Hydrological assessment report

The hydrological assessment report will provide an overview of the scenario assessment reports and a commentary on these and the implications for basin development. The report will include:

- **Introduction –** briefly describing the scenarios investigated and the assessment process

- **Natural hydrological variability** - to summarise the historically observed long-term year-to-year natural hydrological variability of the historically observed natural year-to-year variability since 1913 of the mainstream and Tonle Sap, supported by appended self-explanatory tables charts of the key hydrological characteristics (see box)

- **A review of each scenario –** highlighting significant changes in the hydrology in the LMB induced by the interventions modelled in the context of maintenance of mainstream flows

Important hydrological characteristics

- Historical time series of annual dry season and wet season flows at a few locations along the mainstream, *see for example Peter Adamson's upcoming paper "The Nature of the Mekong – Environmental Flow Indicators for a Large Tropical Monsoonal River System, Figure 5, to be updated through 2008.*
- Historical overview of average seasonal flow in wet and dry season at a few locations along the mainstream
- Historical time series of annual dry season and wet season water levels at a few locations along the mainstream
- Historical overview of average seasonal water level in the dry and wet season at a few locations along the mainstream
- Historical overview of annual minimum and maximum daily flow and water levels a few locations along the mainstream.
- Historical overview of maximum annual flood inundation area in the Delta (incl. Tonle Sap*), see for example BDP library Volume 4, Figure 9.4*
- Historical time series of annual outflow from and reverse flow volume to Tonle Sap at Prek Kdam station
- Historical time series of annual outflow water level from and reverse flow water to Tonle Sap at Kampong Luong station
- Historical onset and duration of the flood season, dry season and the two transition seasons at a few locations along the mainstream, *see for example Figure 6 and Table 2 in the aforementioned paper*
- Historically observed annual flow reversal dates for Prek Kdam and Kampong Luong.

and potential impacts on environmental conditions, taking into account natural variability

- **An overview of the scenarios** as a whole – highlighting the key hydrological issues noted from the scenario hydrological assessments both in terms of significant departures from current conditions in relation to the baseline and its natural variability as well as making note of those scenarios where changes are of no or little hydrological significance.

5 Data requirements

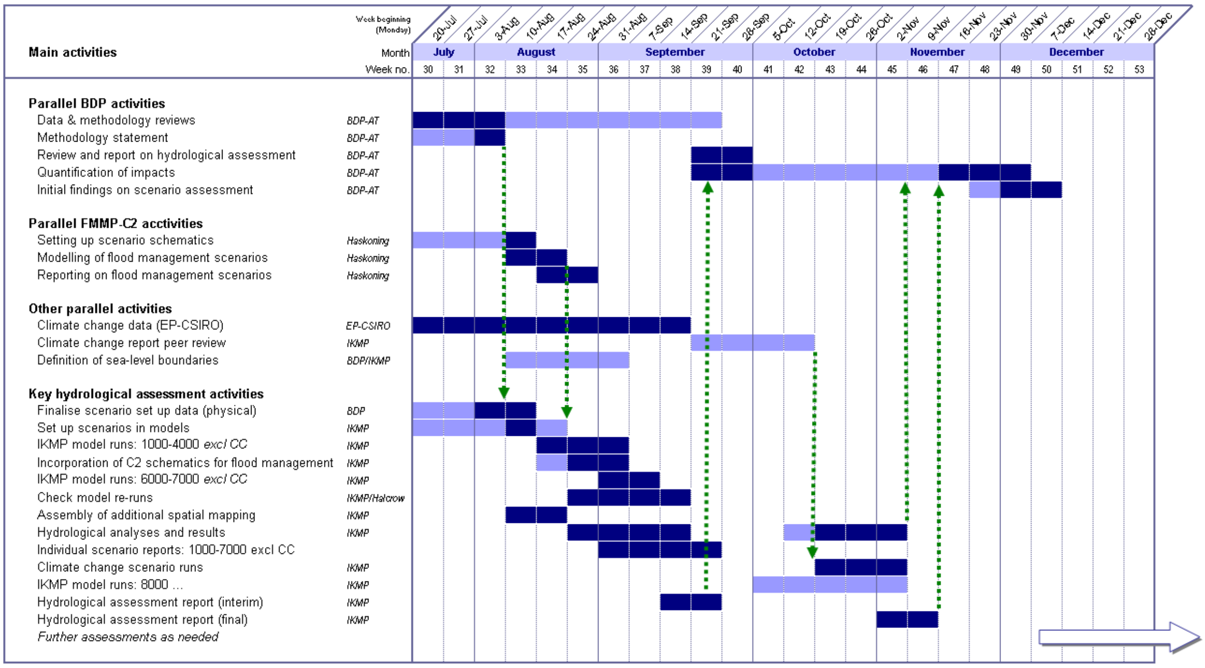
Much of the data required for the hydrological assessments described in this report are already embedded in the DSF and these are not reiterated here. The key further data required are:

- **Schematisations for the flood management options** – to be collected from FMMP-C2;
- **Detailed model set-up data** for different scenarios – including irrigation areas, cropping patterns, transfer scheme details, dam and hydropower data including operating rules, and water supply demands, all of which is provided by BDP with geo-referencing;
- **Hydrometeorological data for climate change scenarios A2 and B2** – these are to be provided by EP and may require peer review before loading into the Knowledge Base; depending upon the formats in which the data are provided, they may require post-processing into input files for changed run-off and irrigation demands;
- **Seal level rise** – revised boundary conditions associated with climate change scenarios for 2030 and 2060, to be provided by Viet Nam with assistance from BDP;
- **Spatial data** (GIS format) – including mapping of forest areas around Tonle Sap, wetlands, and deep pools, all of which is available in MRCS-IS; and
- **Spatial data** (GIS format) – habitats of special significance, to be confirmed by EP environmental assessment team.

6 Work programme

An outline work plan has been prepared to establish both an appropriate time-scale for the hydrological assessment and to highlight the key parallel activities that have bearing on the hydrological assessment work plan. This is summarised in Figure 1 below.

Figure 1 Overall hydrological assessment programme requirements



Appendix A Provisional ToR for assessment of uncertainties in the assumptions on major reservoir developments

A.1 Assessment of the degree of uncertainty of the predicted increases of dry season flows due to hydropower developments in the "Upper Mekong Basin"

1. *Background*

The ongoing hydrological assessment of basin-wide development scenarios by BDP/IKMP suggests that in the foreseeable future (next 20 years) the flows in the mainstream will considerably increase as a result of:

1) Re-regulated water from the hydropower cascade that is being developed on the Lancang in China. In particular the Xiaowan and the Nuozhadu hydropower projects, with 9,800 and 12,400 million m3 of active storage will cause a very significant seasonal redistribution of flow within a few years from now.

2) New tributary dams in the Lower Mekong Basin, in particular Lao PDR. Almost fifty new dams are planned in Lao PDR over the next 20 years, some of which have a reservoir that is designed to re-regulate water flows from the wet season to the dry season.

Moreover, the scenario assessment demonstrates that the predicted increases in dry season flows are more than sufficient to source the (ambitious) water development plans of the MRC member countries in the foreseeable future (next 20 years). The table below shows the predicted increases in water availability in the LMB during the dry season caused by the Chinese Dam Scenario. These predictions have not considered the impact of climate change.

Month	Simulated mainstream flow (mcm)		Increase in water availability (%)
	Baseline Scenario	Chinese Dam Scenario	
Measuring Station: Vientiane			
January	4506	6044	34.1
February	3346	4700	40.5
March	2946	4096	39.0
April	3297	4121	25.0
May	5399	5505	2.0
Measuring Station: Kratie			
January	10310	11680	13.3
February	7338	8629	17.6
March	5886	6979	18.6
April	5979	6810	13.9
May	11017	11228	1.9

Month	Simulated mainstream flow (mcm)		Increase in water availability (%)
	Baseline Scenario	Chinese Dam Scenario	
Measuring Station: Tan Chau			
January	17116	18560	8.4
February	11092	12574	13.4
March	6919	8331	20.4
April	5912	6662	12.7
May	8084	8538	5.6

Thus, from water availability point of view there would be no need during the coming 20 years to infringe or impact on the current Baseline Scenario, which represents the natural dry season flow regime. Therefore, the difficult issue of utilizing some of the natural dry season flow to meet development demands over this time period would not be a problem. The four countries could adopt the natural dry season flow regime (represented by the Baseline Scenario) as part of the PMFM guidelines on the basis that the "new" water in the system during the dry season could meet the expected development plans of the countries.

However, the question can be asked: "How certain is it that the predicted levels of "new" water during the dry season will actually become available". This note scopes the actions needed to assess the reliability of predicted increases in dry season flows caused by developments in the Upper Mekong Basin[19].

2. *Objective*

The objective of the assignment is to assess the degree of certainty of predicted changes in dry season flows during the coming 20 years due to developments in the Upper Mekong Basin. The results should allow decision making regarding the availability of water for development with knowledge of the degree of reliability of future increases in dry season flows.

3. *Scope of work*

The scope of work focuses on the assessment of the main factors affecting the degree of certainty of the predicted increases in dry season flows, as follows:

The design and construction of the hydropower cascade on the Lancang

Assess the degree of certainty that the cascade will be developed as currently planned. Of the eight components in the cascade, only two have major reservoir storage components. The Xiaowan and Nuozhadu dams would hold about 95% of the total active storage of the cascade.

[19] Another TOR addresses the actions needed to assess the reliability of the predicted increases in dry season flows due to new hydropower developments in the Lao PDR.

Both dams are critical parts of the cascade. The construction of the Xiaowan dam has started. Both storage dams would be operational in 2015. If the degree of certainty is less than 80%, provide the most likely changes in design of the cascade. The impact of the modified design on the downstream flows can then be studied with the DSF.

The operation of the hydropower cascade on the Lancang

Assess the degree of certainty (probability) that the cascade will be operated to maximize the production of power. The data and information available at the MRCS demonstrate that the cascade will be operated to maximize power production. The operating strategy of the cascade (rule curves) has been developed (using the recently developed "reservoir rule curve tool") to inform the basin-wide scenario assessments. In case the probability is less than 80%, develop an operating strategy that corresponds to the most probable alternative operating objective. The impact of the alternative operating strategy on the downstream flows can then be studied with the DSF.

Inflow to the dams on the Lancang

Currently, the inflows to various dams of the hydropower cascade on the Lancang are based on an assumed proportional distribution of measured flow data from the most downstream monitoring station in the Upper Mekong Basin, which is situated close to the China/Lao PDR border. Assess the impact of possible errors in this assumption on the operating strategy of the cascade with the recently developed "reservoir rule curve tool". The impact of significant changes in the operating strategy on the downstream flows can then be studied with the DSF.

Consumption of water resources in the Upper Mekong Basin

Make a cursory assessment of the area that feasibly could be brought under irrigation during the next 20 years in the Upper Mekong Basin and any other possible consumptive demands, such as urban/city and industrial use. Estimate the adverse impact this would have on the power generation of the hydropower cascade using the recently developed "reservoir rule curve tool". Assess the probability that China and Myanmar could utilize significant dry season flows for developing irrigation, or other uses, in the Upper Mekong Basin. If the probability is larger than 20%, the impact of the incremental irrigation on downstream flows will be studied with the DSF. It is noted that China has no plans to develop irrigation in the upper part of the basin, but there is very limited suitable land.

Inter-basin water transfer

Make a cursory assessment of the possibility and feasibility of a water diversion from the upper part of the Mekong Basin in China and Myanmar into an adjoining basin during the next 20 years, such as the Yangste. Assess the potential amount of water involved and estimate the adverse impact on the power generation of the hydropower cascade, depending on the location of such a diversion. Depending on the result, the impact of a diversion on downstream flows can then be studied with the DSF. It is noted that China and Myanmar have no plans for an inter-basin transfer of water from the Upper Mekong Basin.

Synthesizing of the above assessments

The results of the above assessments will be debated and the outcome used to formulate an alternative Chinese Dam Scenario(s) for hydrological assessment with the DSF. The results of the assessment would among other things provide upper and lower limits for the predicted monthly flow changes during the dry season in the LMB. For example:

Month	Simulated mainstream flow (mcm)		Increase in water availability (%)
	Baseline Scenario	Chinese Dam Scenario	
Measuring Station: Vientiane			
January	4506	4800 - 6044	10-34
February	Etc	Etc	Etc

Similarly, the BDP2/IKMP modeling team will establish upper and lower limits for the predicted monthly flow changes during the dry season caused by the new hydropower developments in the LMB during the next 20 years.

Subsequently, the combined impact of the uncertainties regarding the water-related developments in the Upper Mekong Basin and the hydropower developments in the LMB on the flow changes in the LMB will be predicted with the DSF.

4. *Implementation*

The immediate next step is to discuss the draft TOR, including the expertise needed and the level of effort, with relevant technical staff of MRCS.

Subsequently the updated TOR would be discussed with the MRCS management to explore the option to hire a consultant from China to support the BDP scenario assessment team in the implementation of this TOR.

A.2 Assessment of the degree of uncertainty of the predicted increases of dry season flows due to hydropower developments in the "Lower Mekong Basin"

1. *Background*

The ongoing hydrological assessment of basin-wide development scenarios by BDP/IKMP suggests that in the foreseeable future (next 20 years) the dry season flows in the mainstream will considerably increase as a result of:

1) Re-regulated water from the hydropower cascade that is being developed on the Lancang in China. In particular the Xiaowan and the Nuozhadu hydropower projects, with 9,800 and 12,400 million m3 of active storage will cause a very significant seasonal redistribution of flow within a few years from now.

2) New tributary dams in the Lower Mekong Basin, in particular Lao PDR. Approximately large hydropower projects are under construction and about 50 large hydropower projects are planned for construction over the next 20 years. Several projects have a reservoir that is designed to re-regulate water resources from the wet season to the dry season.

Moreover, the scenario assessment demonstrates that the predicted increases in dry season flows are more than sufficient to source the (ambitious) water development plans of the MRC member countries in the foreseeable future (next 20 years). The table below shows the predicted increases in water availability in the LMB during the dry season caused by the LMB 20-Year Plan Scenario (which includes the countries' ambitious irrigation plans and increases in other consumptive uses). These predictions have not considered the impact of climate change.

Month	Simulated mainstream flow (mcm) in the dry season		Increase in water availability (%)
	Baseline Scenario	LMB 20-Year Plan Scenario	
Measuring Station: Vientiane			
January	4506	6419	43
February	3346	5015	50
March	2946	4485	52
April	3297	4410	34
May	5399	5517	2
Measuring Station: Kratie			
January	10310	11898	15
February	7338	9036	23
March	5886	7686	31

Month	Simulated mainstream flow (mcm) in the dry season		Increase in water availability (%)
	Baseline Scenario	LMB 20-Year Plan Scenario	
April	5979	7820	31
May	11017	11294	3
Measuring Station: Tan Chau			
January	17116	18149	6
February	11092	12497	13
March	6919	8523	23
April	5912	7260	23
May	8084	8803	9

This increase of dry season water availability comes at the expense of wet season flows but they being relatively very large this is not a significant issue under the scenarios for the foreseeable future (next 20 years).

Thus, from water availability point of view there would be no need during the coming 20 years to infringe or impact on the current Baseline Scenario, which represents the natural dry season flow regime. Therefore, the difficult issue of utilizing some of the natural dry season flow to meet development demands over this time period would not be a problem. The four countries could adopt the natural dry season flow regime (represented by the Baseline Scenario) as part of the PMFM guidelines on the basis that the "new" water in the system during the dry season could meet the expected development plans of the countries.

However, the question can be asked: "How certain is it that the predicted levels of "new" water during the dry season will actually become available". This note scopes the actions needed to assess the reliability of predicted increases in dry season flows caused by developments in the LMB[20].

2. *Objective*

The objective of the assignment is to assess the degree of certainty of the predicted changes in dry season flows during the coming 20 years due to the hydropower developments in the LMB. The results should allow decision making regarding the availability of water for development with knowledge of the degree of reliability of future increases in dry season flows.

[20] Another TOR addresses the actions needed to assess the reliability of the predicted increases in dry season flows due to new developments in the Upper Mekong Basin.

3. *Scope of work*

The scope of work comprises the following activities:

- Based on the Hydropower Database[21], list the relevant characteristics of the hydropower projects with an installed capacity of more than 10 MW that are under construction. It may be assumed that all these projects will be part of the Mekong system in a few years from now. The total active storage of the projects is estimated at about 10,000 mcm.

- Define relevant criteria for priority ranking of planned and potential hydropower projects with an installed capacity of more than 10 MW, such as:

  - ✓ Project licensing: project not under construction but licensed for development

  - ✓ Project preparation: 1) project at the level of hydroelectric master plan or inventory ((cursory study only), 2) project is at the level of prefeasibility studies (preliminary investigations, rough drawings)

  - ✓ Project ownership: 1) owner is government, public utility or state company, 2) owner is independent power producer, and 3) owner is partnership of government and IPP.

  - ✓ Project energy cost: projects with has energy cost over USD 80/MWh might be not attractive for investment

  - ✓ Benefit cost ratio

  - ✓ Other: implementation capacity, investment capacity???

The required data for the priority ranking can be obtained from the Regional Hydropower Database.

- Discuss the criteria in the RTWG and with staff of the ISH and come to an agreement of which criteria to use and how they should be used. For example, the following criteria could be agreed to establish an upper and lower limit of the hydropower projects that would come on stream in the foreseeable future (next 20 years):

  - ✓ <u>Upper boundary</u>: all LMB hydropower projects that are under construction and the planned hydropower projects that: 1) have energy cost less than USD 80/MWh, 2) have been studied at pre-feasibility level, and 3) are licensed for development. These projects are currently included in the LMB 20-Year Plan Scenario. Their total active storage capacity is about 30,000 MCM

[21] Developed by BDP2 in collaboration with the MRC member countries

- ✓ Lower boundary: all LMB hydropower projects that are under construction and the planned hydropower projects that: 1)have a loan agreement in place (financial close) and 2) non-mainstream projects at feasibility level with energy costs under USD 50/MWH (in practice one should really look at the results and decide if the spread between lower and upper boundary is reasonably large; if it is not then maybe pre-feasibility level should be allowed)

- The results of the above assessments will be used to formulate two alternative LMB Tributary Dam Scenarios (representing the upper and lower boundary projects) for hydrological assessment with the DSF. The results of the assessment would among other things provide upper and lower limits for the predicted monthly flow changes during the dry season in the LMB due to new hydropower developments in the LMB. For example:

Month	Simulated mainstream flow (mcm)		Increase in water availability (%)
	Baseline Scenario	LMB Tributary Dam Scenario	
Measuring Station: Vientiane			
January	4506	5000 - 6419	11 - 43
February	3346	4000 - 5015	20 - 50
Etc	Etc	Etc	Etc

Similarly, the BDP2/IKMP modeling team will establish upper and lower limits for the predicted monthly flow changes during the dry season caused by the new developments in the Upper Mekong Basin during the next 20 years.

Subsequently, the combined impact of the uncertainties regarding the water-related developments in the Upper Mekong Basin and the hydropower developments in the LMB on the flow changes in the LMB will be predicted with the DSF.

4. *Implementation*

The scope of works can be implemented by the BDP team with support of the IKMP modeling team.

Appendix B Dams included in each scenario

Country	ID	Project name	River	Province	Installed capacity MW	Live storage mcm	M/strm	Baseline 1000	China dams 2000	Definite future 3000	Foreseeable future 2030: All m/s dams 4000-01	Foreseeable future 2030: No m/s dams 4100-01	Foreseeable future 2030: M/s dams in upper LMB 4200-01	Foreseeable future 2030: No Thai m/s dams 8000	Foreseeable future 2030: All m/s + flood control 8001	Long term 2060: Long term 2060 6000-01	Long term 2060: Very high dev. 2060 7000-01
Lao PDR	L001	**Nam Ngum 1**	Nam Ngum	Vientiane / Keo oudom	149	4,700		□	□	□	□	□	□	□	□	□	□
Lao PDR	L002	**Nam Dong**	Nam Dong	Louangpabang / Louangpabang	1	0		□	□	□	□	□	□	□	□	□	□
Lao PDR	L003	**Xelabam**	Xedon	Champasack /Sanasomboune	5	1											
Lao PDR	L004	**Xeset 1**	Xeset	Saravan /	45	0				□	□	□	□	□	□	□	□
Lao PDR	L005	**Theun-Hinboun**	Nam Theun, hinboun	Bolikhamxay	210	15		□	□	□	□	□	□	□	□	□	□
Lao PDR	L006	**Houayho**	Houayho, Xekong	Attapeu/Samakhixay	150	649		□	□	□	□	□	□	□	□	□	□
Lao PDR	L007	**Nam Leuk**	Nam Leuk, Nam Ngum	Vientiane /	60	228		□	□	□	□	□	□	□	□	□	□
Lao PDR	L008	**Nam Mang 3**	Nam Mang, Nam Ngum	Vientiane / Tou La Khom	40	45				□	□	□	□	□	□	□	□
Lao PDR	L009	**Nam Ko**	Nam Ko	Oudomxay/Xay	2	0											
Lao PDR	L010	**Nam Ngay**	Nam Ngay	Phongsaly/Phongsaly	1	1											
Lao PDR	L011	**Nam Theun 2**	Nam Theun, Xe Bangfai	Khammuane	1,075	3,378				□	□	□	□	□	□	□	□
Lao PDR	L012	**Xekaman 3**	Houayho, Xekong	Xekong	250	109				□	□	□	□	□	□	□	□
Lao PDR	L013	**Xeset 2**	Xe Set	Saravan /	76	9				□	□	□	□	□	□	□	□
Lao PDR	L014	**Nam Ngum 2**	Nam Ngum	Vientiane	615	2,994				□	□	□	□	□	□	□	□
Lao PDR	L015	**Nam Lik 2**	Nam Lik	Vientiane	100	826				□	□	□	□	□	□	□	□
Lao PDR	L016	**Nam Ngum 5**	Nam Ngum	Louangpabang /	120	251				□	□	□	□	□	□	□	□
Lao PDR	L017	**Xekaman 1**	Xe Kaman	Attapeu	290	1,683				□	□	□	□	□	□	□	□
Lao PDR	L018	**Xekaman-Sanxay**	Xe Kaman	Attapeu	32					□	□	□	□	□	□	□	□
Lao PDR	L019	**Theun-Hinboun expansion**	Nam Theun	Bolikhamxay	222	15				□	□	□	□	□	□	□	□
Lao PDR	L020	**Theun-Hinboun exp. (NG8)**	Nam Theun	Bolikhamxay	60	2,262				□	□	□	□	□	□	□	□
Lao PDR	L021	**Nam Ngum 3**	Nam Ngum	Vientiane	440	979					□	□	□	□	□	□	□
Lao PDR	L022	**Nam Theun1**	Nam Theun	Bolikhamxay	523	2,549					□	□	□	□	□	□	□
Lao PDR	L023	**NamNgiep 1**	Nam Ngiep	Bolikhamxay	260	1,192					□	□	□	□	□	□	□
Lao PDR	L024	**Nam Ngiep-regulating dam**	Nam Ngiep	Bolikhamxay	17	5					□	□	□	□	□	□	□
Lao PDR	L025	**Nam Tha 1**	Nam Tha	Bokeo/Pha Oudom	168	676					□	□	□	□	□	□	□
Lao PDR	L026	**Nam Long**	Nam Ma	Luangnamtha/Mouang Long	5	0											
Lao PDR	L027	**Xepian-Xenamnoy**	Xepian/Xenamnoy	Attapeu/Samakhixay	390	885					□	□	□	□	□	□	□
Lao PDR	L028	**Xe Katam**	Xenamnoy	Champasack/Paksong	61	115					□	□	□	□	□	□	□
Lao PDR	L029	**Xekong 4**	Xekong	Xekong/	300	3,100					□	□	□	□	□	□	□
Lao PDR	L030	**Nam Kong 1**	Nam kong	Attapeu/	75	505					□	□	□	□	□	□	□
Lao PDR	L031	**Xe Kong 3up**	Xekong	Xe Kong/	145	95					□	□	□	□	□	□	□
Lao PDR	L032	**Xe Kong 3d**	Xekong	Xe Kong/	91	168					□	□	□	□	□	□	□
Lao PDR	L033	**Xe Kong 5**	Xekong	Xe Kong/	248	1,356					□	□	□	□	□	□	□
Lao PDR	L034	**Don sahong mainstream**	Mekong	Champasack/	360	115	□				□			□	□	□	□
Lao PDR	L035	**Nam Ou 1**	Nam Ou	Luangprabang/Pak Ou	180	10					□	□	□	□	□	□	□
Lao PDR	L036	**Nam Ou 2**	Nam Ou	Luangprabang/Nam Bak	90	8					□	□	□	□	□	□	□
Lao PDR	L037	**Nam Ou 3**	Nam Ou	Luangprabang/Ngoy	300	14					□	□	□	□	□	□	□
Lao PDR	L038	**Nam Ou 4**	Nam Ou	Phongsaly/ Muang Khua	75	9					□	□	□	□	□	□	□
Lao PDR	L039	**Nam Ou 5**	Nam Ou	Phongsaly/Muang Xampan	108	11					□	□	□	□	□	□	□
Lao PDR	L040	**Nam Ou 6**	Nam Ou	Phongsaly/Phongsaly	210	363					□	□	□	□	□	□	□

Country	ID	Project name	River	Province	Installed capacity	Live storage	M/strm	Baseline	China dams	Definite future	Foreseeable future 2030: All m/s dams	No m/s dams	M/s dams in upper LMB	No Thai m/s dams	All m/s + flood control	Long term 2060: Long term 2060	Very high dev. 2060
					MW	mcm		1000	2000	3000	4000-01	4100-01	4200-01	8000	8001	6000-01	7000-01
Lao PDR	L041	**Nam Ou 7**	Nam Ou	Phongsaly/Nhod Ou	180	1,134					□	□	□	□	□	□	□
Lao PDR	L042	**Nam Lik 1**	Nam Lik	Vientiane/Hin Heup	54	7					□	□	□	□	□	□	□
Lao PDR	L043	**Nam San 3**	Nam San	Xiengkhuang/	48	122					□	□	□	□	□	□	□
Lao PDR	L044	**Nam Pha**	Nam Pha	Luangnamtha/	147	2,738					□	□	□	□	□	□	□
Lao PDR	L045	**Nam suang 1**	Nam Suang	Luangprabang/	40	88					□	□	□	□	□	□	□
Lao PDR	L046	**Nam Suang 2**	Nam Suang	Luangprabang/	134	2,015					□	□	□	□	□	□	□
Lao PDR	L047	**Nam Nga**	Nam Ou	Luangprabang/	98	1,565										□	□
Lao PDR	L048	**Nam Beng**	Nam Beng	Oudomxay/Pak Beng	30	98					□	□	□	□	□	□	□
Lao PDR	L049	**Nam Feuang 1**	Nam Feuang	Vientiane/	28	30											□
Lao PDR	L050	**Nam Feuang 2**	Nam Feuang	Vientiane/	25	5											□
Lao PDR	L051	**Nam Feuang 3**	Nam Feuang	Vientiane/	20	5											□
Lao PDR	L052	**Pakbeng mainstream**	Mekong	Oudomxay/Pak Beng	1,230	442	□				□		□	□	□	□	□
Lao PDR	L053	**Luangprabang mainstream**	Mekong	Luangprabang/Luangprabang	1,410	734	□				□		□	□	□	□	□
Lao PDR	L054	**Xayabuly mainstream**	Mekong	Xayabuly/Xayabuly	1,260	225	□				□		□	□	□	□	□
Lao PDR	L055	**Paklay mainstream**	Mekong	Xayabuly/Paklay	1,320	384	□				□		□	□	□	□	□
Lao PDR	L056	**Sanakham mainstream**	Mekong	Vientiane/Sangthong	1,200	106	□				□		□	□	□	□	□
Lao PDR	L057	**Sangthong-Pakchom mainstream**	Mekong	Vientiane/Sangthong	1,079	12	□				□		□		□	□	□
Lao PDR	L058	**Ban Kum mainstream**	Mekong	Champasack/	1,872		□				□				□	□	□
Lao PDR	L059	**Latsua mainstream**	Mekong	Chmpasack/	800		□				□			□	□	□	□
Lao PDR	L060	**Xe Pon 3**	Xe Banghieng	Saravan /	75	368										□	□
Lao PDR	L061	**Xe Kaman 2A**	Xe Kaman	Attapeu/	64	4										□	□
Lao PDR	L062	**Xe Kaman 2B**	Xe Kaman	Attapeu/	100	217										□	□
Lao PDR	L063	**Xe Kaman 4A**	Xe Kaman	Attapeu/	96	17					□	□	□	□	□	□	□
Lao PDR	L064	**Xe Kaman 4B**	Xe Kaman	Attapeu/	74	21					□	□	□	□	□	□	□
Lao PDR	L065	**Dak E Mule**	Xe Kong	Xe Kong/	105	154										□	□
Lao PDR	L066	**Nam Khan 1**	Nam Khan	Luangprabang/Xieng Ngeun	102	805										□	□
Lao PDR	L067	**Nam Khan 2**	Nam Khan	Luangprabang/Xieng Ngeun	140	528										□	□
Lao PDR	L068	**Nam Khan 3**	Nam Khan	Luangprabang/Xieng Ngeun	47	861										□	□
Lao PDR	L069	**Nam Ngum 4A**	Nam Ngum	Xiengkhuang/	54	332										□	□
Lao PDR	L070	**Nam Ngum 4B**	Nam ngum	Xiengkhuang/	54	2										□	□
Lao PDR	L071	**Nam Ngum, Lower dam**	Nam ngum	Vientiane Capital/Pak Ngum	90	243										□	□
Lao PDR	L072	**Nam Pay**	Nam ngum	Vientiane/Poun district	62	52										□	□
Lao PDR	L073	**Nam Mang 1**	Nam Mang	Borikhamxay	51	551											□
Lao PDR	L074	**Nam Pouy**	Nam Pouy	Xayabuly	44	499										□	□
Lao PDR	L075	**Nam Poun**	Nam Poun	Xayabuly	85	339										□	□
Lao PDR	L076	**Nam Ngao**	Nam Ou	Oudomxay	20	434										□	□
Lao PDR	L077	**Nam Chian**	Nam Ngiep	Xiengkhuang/	148	8										□	□
Lao PDR	L078	**Nam Ngieu**	Nam Ngiep	Xiengkhuang/	30	19										□	□
Lao PDR	L079	**Nam Pot**	Nam Ngiep	Xiengkhuang/	22	45										□	□
Lao PDR	L080	**Nam San 3B**	Nam San	Xiengkhuang/	38	12											□

Country	ID	Project name	River	Province	Installed capacity	Live storage	M/strm	Baseline	China dams	Definite future	Foreseeable future 2030: All m/s dams	Foreseeable future 2030: No m/s dams	Foreseeable future 2030: M/s dams in upper LMB	Foreseeable future 2030: No Thai m/s dams	Foreseeable future 2030: All m/s + flood control	Long term 2060: Long term 2060	Long term 2060: Very high dev. 2060
					MW	mcm		1000	2000	3000	4000-01	4100-01	4200-01	8000	8001	6000-01	7000-01
Lao PDR	L081	**Nam San 2**	Nam San	Borikhamxay	60	1,946										□	□
Lao PDR	L082	**Nam Pok**	Nam Ou	Phonsaly/	3	5											□
Lao PDR	L083	**Nam Phak**	Nam Ou	Oudomxay/Mouang La	5	2											□
Lao PDR	L084	**Nam Hinboun 1**	Nam Hinboun	Kham Mouan	45	1,224										□	□
Lao PDR	L085	**Nam Hinboun 2**	Nam Hinboun	Kham Mouan	13	26											□
Lao PDR	L086	**Xe Bang Fai**	Xe Bang Fai	Kham Mouan	107											□	□
Lao PDR	L087	**Xe Neua**	Xe Bang Fai	Kham Mouan	60	624											□
Lao PDR	L088	**Nam Theun 4**	Nam Theun	Borikhamxay	30	807											□
Lao PDR	L089	**Nam Mouan**	Nam Theun	Borikhamxay	110	1,960											□
Lao PDR	L090	**Xe Bang Hieng 2**	Xe Bang Hieng	Savannakhet/	16	643											□
Lao PDR	L091	**Xedon 2**	Xe Don	Saravan /	54	1,743											□
Lao PDR	L092	**Xe Set 3**	Xe Don	Saravan /	20	4					□	□	□	□	□	□	□
Lao PDR	L093	**Xe Bang Nouan**	Xe Bang Nouan	Savannakhet/	18	1,477											□
Lao PDR	L094	**Xe Lanong 1**	Xe Bang Hieng	Savannakhet/	30	374											□
Lao PDR	L095	**Xe Lanong 2**	Xe Bang Hieng	Saravan /	20	79											□
Lao PDR	L096	**Nam Phak**	Nam Phak	Champasack/	75	35					□	□	□	□	□	□	□
Lao PDR	L097	**Xe Nam Noy 5**	Xe Kong	Xekong/	20	9										□	□
Lao PDR	L098	**Houay Lamphan**	Xe Kong	Champasack/Xekong	60	128					□	□	□	□	□	□	□
Lao PDR	L099	**Nam Kong 2**	Xe Kong	Attapeu	74	140										□	□
Lao PDR	L100	**Xe Xou**	Xe Kong	Attapeu	63	1,714										□	□
Cambodia	C001	**O Chum 2**	O Chum	Ratanak Kiri / O Chum	1	0				□	□	□	□	□	□	□	□
Cambodia	C002	**Lower Se San2 + Lower Sre Pok 2**	Se San	Stung Treng / Se San	480	379					□	□	□	□	□	□	□
Cambodia	C003	**Battambang 1**	Sangker	Banttambang / Ratanak Mondul	24	1,040					□	□	□	□	□	□	□
Cambodia	C004	**Battambang 2**	Sangker	Battambang/ Samlot	22	110					□	□	□	□	□	□	□
Cambodia	C005	**Sambor mainstream**	Mekong	Kratie / Kratie	3,300	2,000	□				□			□	□	□	□
Cambodia	C006	**Stung Treng mainstream**	Mekong	StungTreng / Thala Bariwat	980	70	□				□			□	□	□	□
Cambodia	C007	**Pursat 1**	Pursat	Pursat / Veal veng	100	690					□	□	□	□	□	□	□
Cambodia	C008	**Pursat 2**	Pursat	Pursat / Kravanh	10	295					□	□	□	□	□	□	□
Cambodia	C009	**Lower Se San 3**	Se San	Ratanak Kiri / Voeun Sai	243	3,120										□	□
Cambodia	C010	**Prek Liang 1**	Prek Liang	Ratanak Kiri / Ta Veng	35	110											□
Cambodia	C011	**Prek Liang 2**	Prek Liang	Ratanak Kiri / Ta Veng	25	180											□
Cambodia	C012	**Lower Sre Pok 3**	Sre Pok	Ratanak Kiri / Lum Phat	204	5,310										□	□
Cambodia	C013	**Lower Sre Pok 4**	Sre Pok	Mondul Kiri / Koh Nhek	143	2,700										□	□
Cambodia	C014	**Stung Sen**	Stung Sen	Preah Vihear / Rovieng	23	2,890											□
Viet Nam	V001	**Upper Kontum**	Se San/ Dak Bla/Dak Nghe	Kon Tum/Quang Ngai	250	123					□	□	□	□	□	□	□
Viet Nam	V002	**Plei Krong**	Se San/ Kroong Po Ko	Kon Tum	100	948				□	□	□	□	□	□	□	□
Viet Nam	V003	**Yali**	Se San	Gia Lai / Kon Tum	720	779		□	□	□	□	□	□	□	□	□	□
Viet Nam	V004	**Se San 3**	Se San	Gia Lai / Kon Tum	260	4				□	□	□	□	□	□	□	□
Viet Nam	V005	**Se San 3A**	Se San	Gia Lai / Kon Tum	96	4				□	□	□	□	□	□	□	□
Viet Nam	V006	**Se San 4**	Se San	Gia Lai / Kon Tum	360	264				□	□	□	□	□	□	□	□

Country	ID	Project name	River	Province	Installed capacity	Live storage	M/strm	Baseline	China dams	Definite future	Foreseeable future 2030					Long term 2060	
											All m/s dams	No m/s dams	M/s dams in upper LMB	No Thai m/s dams	All m/s + flood control	Long term 2060	Very high dev. 2060
					MW	mcm		1000	2000	3000	4000-01	4100-01	4200-01	8000	8001	6000-01	7000-01
Viet Nam	V007	**Se San 4A**	Se San	Gia Lai / Kon Tum		8				□	□	□	□	□	□	□	□
Viet Nam	V008	**Duc Xuyen**	Sre Pok/Krong Kno	Daklak/DakNong	49	413					□	□	□	□	□	□	□
Viet Nam	V009	**Buon Tua Srah**	Sre Pok/Krong Kno	Daklak/DakNong	86	523				□	□	□	□	□	□	□	□
Viet Nam	V010	**Buon Kuop**	Sre Pok	Dak Lak/DakNong	280	15				□	□	□	□	□	□	□	□
Viet Nam	V011	**Dray Hlinh 2**	Sre Pok	Dak Lak/DakNong	16	2				□	□	□	□	□	□	□	□
Viet Nam	V012	**Sre Pok 3**	Sre Pok	Daklak/DakNong	220	63				□	□	□	□	□	□	□	□
Viet Nam	V013	**Sre Pok 4**	Sre Pok	Daklak/DakNong	70	10				□	□	□	□	□	□	□	□
Viet Nam	V014	**Dray Hlinh 1**	Sre Pok	Daklak/DakNong	12	2				□	□	□	□	□	□	□	□
Viet Nam	V015	**Sre Pok 4A**	Sre Pok	Daklak/DakNong	64					□	□	□	□	□	□	□	□
Thailand	T001	**Chulabhorn**	Nam Phrom	Chaiyaphum / Khon San	40	145		□	□	□	□	□	□	□	□	□	□
Thailand	T002	**Huai Kum**	Nam Phrom	Chaiyaphum / Kasetsomboon	1	20											
Thailand	T003	**Nam Pung**	Nam Pung	Sakon Nakhon / Kut Bak	6	157		□	□	□	□	□	□	□	□	□	□
Thailand	T004	**Pak Mun**	Mun	Ubon Ratchathani / Khong Chiam	136	125		□	□	□	□	□	□	□	□	□	□
Thailand	T005	**Sirindhorn**	Lam Dom Noi	Ubon Ratchathani / Pibulmangsaha	36	1,135		□	□	□	□	□	□	□	□	□	□
Thailand	T006	**Ubol Ratana**	Nam Pong	Khon Kaen / Ubol Ratana	25	1,695		□	□	□	□	□	□	□	□	□	□
Thailand	T007	**Lam Ta Khong P.S.**	Lam Ta Khong	Nakorn Ratchasima / Sikhiu	500	290											
						Number	**11**	**11**	**11**	**36**	**84**	**73**	**79**	**82**	**84**	**111**	**130**
						Mainstream	**11**				**11**		**6**	**9**	**11**	**11**	**11**
						Tributary		**11**	**11**	**36**	**73**	**73**	**73**	**73**	**73**	**100**	**119**

Draft

Mekong River Commission

Basin Development Plan, Phase 2

Economic, environmental and social impact assessment of basin-wide water resources development scenarios

Assessment methodology

Annex 2
Environmental assessment

October 2009

Economic, environmental and social impact assessment of basin-wide water resources development scenarios

Assessment methodology

Main report	Overview
Annex 1	Hydrological assessment
Annex 2	**Environmental assessment**
Annex 3	Social assessment
Annex 4	Economic assessment
Annex 5	Fisheries assessment

Contents amendment record

This report has been issued and amended as follows:

Issue	Revision	Description	Date	Signed
1	0	Draft to BDP team for comment	02-10-2009	
2	1	Draft prepared for 2nd Regional Stakeholder Consultation and Dialogue of Basin Development Plan Programme, Phase 2	7 Oct 2009	

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Contents

Tables

Figures

Glossary

ADB	Asian Development Bank
BDP	Basin Development Programme
BDP1	BDP Phase 1
BDP2	BDP Phase 2
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
dS/m	deci Siemens per meter
DSF	Decision Support Framework
EC	Electric Conductivity
EP	Environment Programme
FMMP	Flood Management and Mitigation Programme
FP	Fisheries Programme
GEF	Global Environmental Facility
GIS	Geographical Information System
HEP	Hydroelectric Power
IUCN	International Union for the Conservation of Nature
IBFM	Integrated Basin Flow Management
IKMP	Information and Knowledge Management Programme
IWRM	Integrated Water Resources Management
LMB	Lower Mekong Basin
MRC	Mekong River Commission
MRCS	Mekong River Commission Secretariat
mS/m	micro Siemens per meter
NMC	National Mekong Committee
RTWG	Regional Technical Working Group
SEA	Strategic Environmental Assessment
ToR	Terms of Reference
UMB	Upper Mekong Basin
UNDP	United Nations Development Programme
WB	World Bank
WUP	Water Utilisation Programme
WQIag	Water Quality Index for agricultural use
WQIal	Water Quality Index for aquatic life
WQIhi	Water Quality Index for human impact
WWF	World Wide Fund for Nature

1 Introduction

1.1 Main purpose of report

This report is in draft for review and comments. Following receipt of comments, the report will be revised and then form part of the Methodology Statement for the BDP assessment of basin-wide development scenarios.

The report describes the approach and methodology that will be followed in the environmental assessment of the 9 basin-wide development scenarios developed under Phase 2 of the BDP Programme (BDP2). The background of and the reasons for selecting these particular scenarios are discussed in detail in the report 'Scoping and Planning of the Assessment of Basin-Wide Development Scenarios, Technical note v3.1', BDP2, March 2009, which has been subject to lengthy consultation with each country.

The report includes a specification of the scenarios to be assessed, an overall assessment framework, identified key indicators and an overview of the expected information required for reporting the impacts of each scenario for comparison between scenarios, sectors and countries.

In the preparation of the environmental assessment methodology, the main tasks comprised:

- Establishment of a clear approach and analytical framework for the assessment;
- Description of the analytical tools which will be used in the environmental analyses of the various BDP development scenarios;
- Review the available reports and databases within MRCS that can be used in the environmental assessment;
- Identification of data and information gaps;
- Detailing of further data requirements including data sources and the technical experts responsible for providing the information; and
- Specification of the tasks required for the environmental assessment and preparation of a work programme.

1.2 Report contents

Chapter 2 summarizes the rationale for the environmental assessment of the various development scenarios as given in the Scoping and Planning of the Assessment of Basin-Wide Development Scenarios report. The specific development objectives and their key environmental indicators, as agreed upon after consultation with the countries, are also given.

The proposed methodology for the environmental assessment is described in Chapter 3.

Chapter 4 details the data requirements for the environmental assessment. A distinction is made between data related to ecosystems (mainly wetlands), data related to sediments and river morphology and data related to water quality including salinity. The data sources are specified together with the technical expert responsible for providing the information.

A work programme for the environmental assessment is given Chapter 5. The main tasks to be undertaken and the proposed schedule of work up to December 2009 are given.

2 Development scenarios and key environmental indicators

2.1 Rationale for assessment of basin-wide development scenarios

A basin development strategy needs to be based on an acceptable balance between the primary objectives of water resources development (namely sustainable economic growth and poverty reduction) and the conservation of the riverine and floodplain ecology on which a high proportion of the population depends on for their livelihoods.

An approach to achieving this acceptable balance is to define an agreed “development space for water and related resources” within which the LMB countries can plan and implement water resources projects, taking into account the impact of foreseeable developments in the upper part of the basin. This approach also supports the 1995 Mekong Agreement which highlights the importance of: (i) maintaining agreed flows in the mainstream; (ii) equitable utilisation of water resources; and (iii) recognising sovereign and territorial integrity in the utilisation and conservation of the water resources.

In order to define the LMB “development space” in a way that is beneficial to all the LMB countries, as well as sustainable and practical to implement, the MRC embarked on a basin-wide dialogue based on the results of a comprehensive assessment of various scenarios that represent different levels of water resource development in the LMB. Each scenario has been formulated to represent different combinations of development interventions that recognise the synergies and trade-offs between the different sectors.

The LMB development scenarios comprise: (i) baseline scenario, (ii) Chinese dam scenario, (iii) definite future scenario, (iv) foreseeable future 20 year plan scenario (with alternative perspectives for mainstream hydropower dams), (v) Mekong Delta flood management scenario; and (vi) long term future 50 year development scenarios.

The LMB development scenarios are described in detail in the BDP Technical note: Scoping and Planning of the Assessment of Basin-Wide Development Scenarios, BDP2, March 2009. The time horizon and primary interventions for each development scenario are summarised in Table 2-1.

The main aim of the development scenario assessments is to provide the MRC member states with an analysis of alternative development strategies, particularly with respect to their economic, social and environmental impacts, in order to reach a consensus on the key decisions that will shape the future development and management of the water resources within the LMB.

Table 2-1 Basin-wide development scenarios

	Title	Time horizon	Runs		Interventions
			85-00	CC	
1	**Baseline scenario**	Baseline (1985-'00)	1		Year 2000 infrastructure including existing HEP dams
2	**Upper Mekong Dam scenario** (UMDS)	Definite future over next 5-10 years	1		Baseline plus 6 existing, under construction and planned HEP dams in Upper Mekong Basin
3	**Definite future scenario** (DFS)		1		UMDS plus 25 additional HEP dams in LMB and updated flood measures in delta
	Foreseeable future situation (FSS)				
4	LMB 20-year plan scenario	Foreseeable future over next 20 years	1	1	DFS plus 11 LMB m/stream dams and planned tributary dams etc
5	LMB 20-year plan without mainstream dams		1		As above, excluding 11 LMB dams
6	LMB 20-year plan with 6 m/s dams in upper LMB		1		As above plus 6 LMB dams in upper LMB
	LMB 20-year plan with 9 m/s dams		1		As (5) excluding Ban Kum and Pakchom
7	**Mekong delta flood management scenario**	Baseline (1985-'00)	6		Baseline plus 6 different options for flood control in Cambodia and Viet Nam
	Long term future				
8	LMB long-term development scenarios	Long term future over next 50 years	1	1	LMB 20-year scenario plus all feasible infrastructure developments in LMB
9	LMB very high development scenarios		1	1	As above extended to full potential infrastructure developments
10	**Further scenarios**		2	1	To be determined by BDP assessment team
			17	**4**	

2.2 Development objectives and key environmental indicators

With respect to the environment, the specific development objectives, which are directly linked to the national development objectives of the four riparian countries, are given in Table 2-2.

The key environmental indicators and their measurable units, which will be used in the environmental assessment of the various development scenarios, have been identified for each development objective and are given in Table 2-2 as well. The approach and methodologies used to evaluate the key environmental indicators are discussed in Chapter 3, while the data sets and information required for this environmental assessment are detailed in Chapter 4.

Table 2-2 Development objectives and key environmental indicators

Specific development objectives	Key environmental indicators	Unit
Maintain water quality and acceptable flow conditions	Water quality incl. sediment transport in the mainstream	Trend
	Key flow characteristics	Trend
	Forest flooded for specified depth and duration at Tonle Sap	‘000 ha
	Net incremental economic values	US$ million
Maintain wetland productivity and ecosystem services	Incremental wetlands with required depth duration	‘000 ha
	Net incremental economic value	US$ million
Manage salinity intrusion in the Mekong Delta	Area in the delta within thresholds of salinity	'000 ha
	Net incremental economic value	US$ million
Minimize channel effects on bank erosion	Incremental area at risk to erosion	'000 ha
	Vulnerability to bank erosion	'000 ha
	Net incremental economic value	US$ million
Conservation of biodiversity	Incremental area of suitable habitats	'000 ton
	Estimated number of species affected	No.
	Incremental net economic value to tourism	US$ million

Source: BDP Technical note v3.1: Scoping and Planning of the Assessment of Basin-Wide Development Scenarios, March 2009

3 Environmental assessment of development scenarios

3.1 General approach and analysis framework

3.1.1 *Starting points*

The general approach for the environmental assessment of the basin-wide development scenarios is based in the following starting points:

- The assessment will be based on readily available data;
- The assessment is limited to the following impact areas:
  - Areas directly affected by changed hydrological and water quality conditions in the mainstream, including areas affected by combined flooding (backwater flooding) near the confluences of tributary rivers;
  - The Tonle Sap and adjacent areas and the floodplains in Cambodia and Vietnam delta; and
  - Areas where there is a direct dependence on capture fisheries, delineated by the extent of fish migration.
- The assessment will make use as much as possible of studies/ methods/ techniques already applied in foregoing studies and assessments, e.g. in the Integrated Basin Flow Management (IBFM) studies.

Socio-economic benefits that arise outside the above areas will be evaluated only where they are directly linked to development and management of the mainstream (e.g. hydropower generated and irrigation made possible by increased dry season flows) and where they are relevant to the trade-offs under consideration. Since the precise locations of where these benefits may arise will not be known, no attempt will be made to make environmental assessment of these unless it can be reasonably shown that their cumulative impacts might have an impact on mainstream water quality (e.g. from use of agricultural fertilisers and pesticides).

3.1.2 *Main drivers of environmental changes (causes of impact)*

The basin-wide development scenarios under consideration consist of a (combination of a) number of elements: further hydropower development by construction of storage reservoirs (a cascade of hydropower dams in the Upper Basin in China as well as in the tributaries of Lao, Cambodia and Viet Nam within the LMB), construction of run-of the river dams on the main stream in the LMB, implementation of flood protection measures in the Cambodian and Viet Nam floodplains, development of irrigated agriculture, and increase in domestic and industrial water use driven by population growth.

These developments (causes of impact) will induce a number of changes in the physical and bio-chemical environment and will ultimately have an impact on the human use of the natural resources.

The hydropower development will result in changes in river flow regimes. These changes on their turn result in changes in water levels in the downstream channels and ultimately in changes in river flooding patterns along the main channel, along the lower reaches of the (backwater effected) larger tributaries, and in the floodplains of Tonle Sap and the Cambodian and Vietnamese Mekong Delta. Besides, construction of storage reservoirs may result in a sharp decrease in both the rivers' suspended sediment load and bed load. since a large proportion of the inflowing sediment may become trapped in the reservoirs.

Further development of the irrigated agriculture and the increased domestic and industrial water use will have an effect on river flows (part of the extracted water will not return to rivers) and on the water quality. Return flows from agriculture may be polluted by pesticides and nutrients, whereas domestic and industrial waste water discharges may result in increased levels of BOD, COD, nutrients and contaminants.

The main causes of impacts are thus changes in flow (water levels) in the main channel, changes in flooding pattern in the flood plains and changes in water quality.

3.1.3 Environmental impacts

Environmental impacts that may result from changes in flow and related water levels in the river channels are:

- Changes in riverbed morphology, size and distribution of sand banks, rapids, and deep pools;
- Changes in riverbank erosion;
- Changes in area available for riverbank gardening;
- Changes in area available for riverine forest; and
- Changes in saltwater intrusion in the Viet Nam Delta.

The first two impacts are not only caused by changes in flow but also by changes in sediment load of the river as well.

Changes in flood patterns will result in a change in area and distribution of valuable ecosystems/ habitats that, in their turn has a number of secondary impacts:

- Changes in ecosystem productivity
  - Fish and other aquatic animals

  - Other products (e.g. Mekong Riverweed)
- Changes in environmental services provided
- Water supply in the dry season
- Flow regulation
  - Water purification capacity
  - Cultural/religious values
  - Aesthetic/tourism/recreational values
- Changes in ecosystems/habitat existence and biodiversity, flora and fauna

Changes in water quality, including changes in sediment concentrations and salinity in the delta area, may have an impact on:

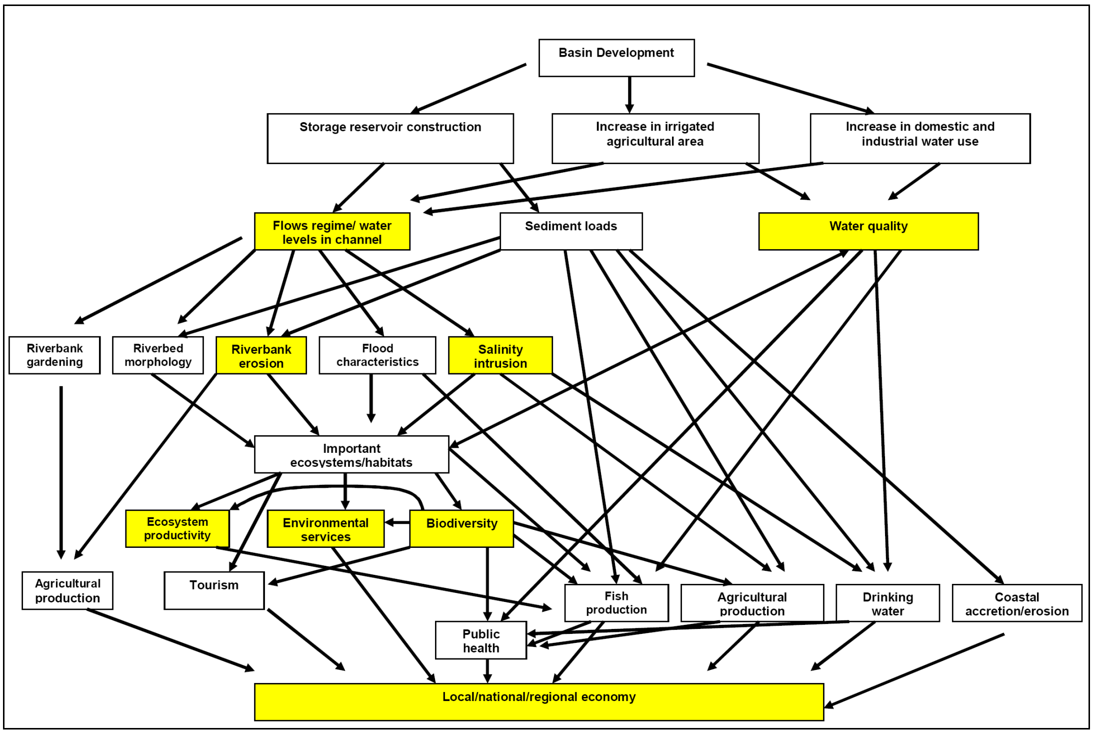
- The availability of good quality drinking water;
- Agricultural production in flooded areas (fertilizing effect of sediment);
- Wetland productivity (fertilizing effect of sediment);
- Fish production (nutrient status of flood water);
- Biodiversity;
- Agricultural production in the Vietnamese Delta (salinity related);
- Impacts on the ecosystem productivity in the Vietnamese Delta (salinity related);
- Biodiversity in the Vietnamese Delta (salinity related);
- Coastal fisheries potential and brackish water aquaculture in the Delta (salinity related)
- Changes in coastal accretion/erosion patterns.

The following cause effect network illustrates the relationships between the expected developments, and the resulting first and higher order impacts.

The environmental assessment will concentrate on the agreed upon environmental development objectives and the key environmental indicators as given in Table 2-2. In the cause effect network these impacts are highlighted.

The cause-effect network provides a good framework for the assessment. It shows the different steps that have to be made in the assessment to arrive at the final level of economic valuation of the impacts. For each of the boxes in the network information on the baseline situation has to be collected. Each arrow in the network represents a dependency or relationship: if the state of the lower order impact changes, the higher order impact will change as well. To be able to assess the highest order impacts, the impacts at the end of the impact chain, the dependencies have to be known. To describe dependencies some kind of impact functions have to be used. This can be mathematical models, empirical formula or simple rules of thumb.

Figure 3-1 Cause effect network for basin development scenarios



3.1.4 *Valuable (wetland) ecosystems/habitats*

The joint UNDP, IUCN, MRC, GEF funded programme on Mekong Wetlands Biodiversity Conservation and Sustainable Use, distinguished a number of wetland ecosystems/habitats, that are particularly valuable, either because they support the very valuable inland fisheries or other livelihoods of the people in the basin, or because they are very important for the sustenance of the rich biodiversity of the area. In the environmental assessment of the basin-wide development scenarios this wetland ecosystem/habitat subdivision will be used as much as possible. In Table 3.1 these valuable ecosystems/habitats are listed and briefly described. A detailed description can be found on the Programmes website (*www.mekongwetlands.org*).

Table 3-1 Valuable wetland ecosystems/habitats in the Mekong river basin

Valuable ecosystems	Description of their importance
1- River channels of the Mekong and its largest low gradient Tributaries	
- Main river channels	Channels are vitally important for the seasonal longitudinal migration of white fish species and for a distinctive guild of riverine bird species.
- Deep pools	Deep pools are a vital dry season refuge for both resident and migratory fish species and probably contain a diverse assemblage of undescribed invertebrates.

Valuable ecosystems	Description of their importance
- Rapids	Rapids support a diverse assemblage of fish (and invertebrate) species, fish biodiversity experts recommend that every species permanently associated with rapids be classified as critically endangered.
- Small islands and riverine sandbars	The smaller sand bars and islands provide safe breeding sites for many species of water birds, some of which are globally rare and endangered.
- Seasonally inundated riverine forest	The biodiversity values of this habitat are not well known, but the forest is probably important for fish breeding and shelter during peak flow. Some fish species are known to feed on the fruit of the trees. The forest may also be important for monkeys and gibbons.
2- Permanent and seasonally-inundated floodplain wetlands (along the mainstream and major tributaries and in the Cambodian floodplain)	
- Seasonally-inundated riparian forest	One of the most important wetland habitats of the Lower Mekong Basin. Over 200 species of plants have been found in these inundated forests. Woody species of this forest are often laden with fruits and seeds at the time of inundation, providing food for the 34 species of fruit-eating fish of the Lower Mekong Basin. Over 200 species of fish use this habitat as a feeding, breeding, and nursery ground and it is vitally important for breeding colonies of large water birds. The forest of Lake Tonle Sap is the best known and most productive example of this habitat.
- Marshes, small pools and seasonal wetlands in the lowland plain	In the dry season, these wetlands are vital in maintaining breeding stocks of floodplain fish, including air-breathing species, while in the wet season they function as breeding and nursery grounds for many fish species These wetlands are important for almost all water birds in the Lower Mekong Basin.
- Inundated grasslands	These areas support a number of globally rare and endangered species (Sarus Crane, White-shouldered Ibis, Bengal Florican and Greater and Lesser Adjutants). Although, in the Lower Mekong Basin, these areas are greatly disturbed, they do hold more substantial grasslands that other parts of S.E. Asia and thus are a priority for conservation.
3- Deltaic Formations and the Plain of Reeds (Vietnamese floodplain)	
- Lowland forests	Melaleuca forests are encountered in areas of acid sulphate soils. A high proportion of them are of relatively recent origin, and many are within wood production reserves. Although today's melaleuca forest is low in plant biodiversity, they act as one of the few sources of fish, amphibian, reptilian and bird biodiversity in the Delta. These melaleuca forests are of prime important for their breeding colonies of large water birds and are one of the few refuges in the Delta for freshwater species such as turtles.
Inundated grasslands	Like in the Cambodian floodplains, the remaining grasslands are important for water birds including the Sarus Crane, White-shouldered Ibis, Greater and Lesser Adjutants and the Bengal Florican.
Mangroves	This is an ecologically important area as a breeding ground for many species of fish, crabs and shrimps. Over 300 species of fish have been recorded in the Delta. the wildlife is diverse with mammals such as fishing cats, otters and crab-eating macaques. Many fish and shrimp species depend upon the estuaries of the Delta for their breeding and nursery areas. Some marine species of fish ascend the rivers to spawn in the gradient or freshwater zone of the estuaries, while the larvae of many economically important shrimp species, spawned in the shallow coastal areas, are moved by tides into the brackish water zone where they stay as juveniles for 2-4 months amongst abundant food and safe from predators.

3.1.5 *Ecosystem services to be taken into account*

Ecosystems, and particularly wetlands, provide a wide range of goods and services for human production and consumption. Examples are fish, timber, fuel, food, medicines, crops and fodder. Natural ecosystems such as forests and wetlands generate important economic services which maintain the quantity and quality of water supplies. Furthermore, they help to mitigate or avert water-related disasters such as flooding and drought. Often ecosystems provide a more effective, cost-efficient, equitable and affordable means of supplying these goods and services than engineered alternatives. The ecosystem services that will be considered in the environmental assessment are given in table 3.2.

Table 3-2 Ecosystem services to be taken into account in the assessment

Ecosystem service	Description
Regulation of flows	By storing large amounts of water, that are gradually released, wetlands delay and even out peak flows and so attenuate downstream flooding.
Regulation of water quality	For example wastewater purification and control of sedimentation and siltation. Wetlands absorb, filter, process and dilute nutrients, pollutants and wastes. They usually have a high nutrient retention capacity and are effective in removing bacteria and microbes and in some cases, removing toxic chemicals. Nutrient retention in wetlands makes them among the most productive recorded, rivalling even intensive agricultural systems.
Conservation of biodiversity	Wetlands are usually very diverse and productive ecosystems. Freshwater wetlands hold more than 40 percent of the world's species and 12 percent of all animal species. The Mekong wetlands support over 1,200 recorded fish species and a diverse fauna of other aquatic animals such as shrimps, crabs, molluscs, reptiles and insects (Sverdrup-Jensen 2002) as well as waterfowl and other birds and animals. The diversity of the flora is also extremely high.
Source of fish and other food	Wetlands are a main source of food - rice, fish and other aquatic animals. They are the basis for people's strategies to cope with rice deficit and the major source of protein for much of the population. Non-fish aquatic animals harvested from wetlands include several species of frogs, water birds, molluscs, turtles, crabs etc. A variety of aquatic plants is also consumed. Roughly 2 million tonnes fish are caught each year in the Lower Basin. Another 0.5 M ton are produced by aquaculture and reservoir fisheries. The direct economic value of this fish production is about 2 B US$ (Johnston et al, 2003), 2/3 of the population of the basin is involved in fisheries one way or another.
Provision of goods	Collection of craft materials, fuels, construction material, medicines and raw materials
Cultural value	Wetlands are frequently of religious, historical, archaeological or other cultural significance at the local or national level.
Recreation and (eco)tourism	Many wetlands are prime locations for tourism; some of the finest are protected as National Parks, World Heritage Sites, Ramsar sites, or Biosphere Reserves. Many wetland sites generate considerable income from tourism locally and nationally.
Water supply	Most types of wetlands store, regulate and recharge both surface and sub-surface water supplies, as well as groundwater. Water from wetlands is extracted for domestic, agricultural and industrial use. Some wetlands are used as a water supply for villages.
Riverbank stabilization and shoreline protection	Coastal wetlands play a critical role in protecting the land from storm surges and other weather events; they reduce wind, wave and current action, and coastal vegetation helps to hold sediment in place.

3.1.6 Hotspots and flagship species

Within the Mekong basin a number of environmental 'hotspots' can be identified, that are considered to be of utmost importance for the functioning of the Mekong environmental system and having transboundary significance in ecological, socio-cultural, and economic aspects.

Three Ramsar Sites (Wetlands of International Importance) are located in the LMB. They are Nong Bong Khai in Chiangrai, Thailand; Bung Kong Long in Nongkhai, Thailand, and Stung Treng of Cambodia. Siphandon in Lao PDR is nominated as a potential future Ramsar Site. The site is also important as a major tourist attraction.

There are two Biosphere Reserves in the basin, Prek Toal of Cambodia and the Can Gio Mangroves of Vietnam. Tonle Sap Lake in Cambodia is both a Biosphere Reserve and a World Heritage Site.

The Tonle Sap Lake system plays a vital role in the functioning of the whole lower part of the Mekong River system, in terms of the production of fish and other river products, and as a moderator of flows and salinity intrusion in the Mekong Delta.

Important areas for maintaining biodiversity include the Chiang Saen / Chiang Kong areas (for Giant Catfish); Bung Kong Long (for birds and fish habitat); Siphandon (4,000 low-lying rocky islands, unique ecosystem for Irrawaddy Dolphins); Stung Treng (unique ecosystem for inundated vegetation, river reeds, and Irrawaddy Dolphins); Stung Treng to Kratie (for Irrawaddy dolphins); Tram Chim National Park in the Vietnamese Delta (grassland for Eastern Sarus Crane, rare bird habitat); and rapids and deep pools (dry-season refuges for many resident and migratory fish species, and habitats of endangered species). Deep pools in the mainstream Mekong occur in discrete clusters. From fisheries perspective, the most important clusters are found in northern Lao PDR especially in Luang Prabang, in the area around Khone Falls, between Khone Falls on the border between Cambodia and Lao PDR downstream to Kratie, and in the section of the Mekong from Kratie to Stung Treng.

Four globally threatened so-called flagship species have been selected by the Mekong Wetlands Biodiversity programme. These species are regional in distribution and trans-boundary and inhabit a broad diversity of important wetlands. They are therefore thought to be representative of threatened wetland habitats and their associated fauna in the Mekong basin. The selected species are: The Mekong River Irrawaddy Dolphin, the Mekong Giant Catfish, the Sarus Crane, and the Siamese Crocodile.

'Hotspots' and flagship species will receive special attention in the assessment.

3.1.7 *Impact zones and impact seasons*

In the analysis a number of distinct impact zones will used. At the highest level a distinction will be made to impacts on and along the main channels and the channels of the low gradient main tributaries (including impacts on wetlands) upstream of Kratie, the Tonle Sap lake and surrounding floodplains, the floodplains in the Cambodian Delta and the floodplains in the Vietnamese Delta. The channel upstream of Kratie will be sub-divided in the four zones that will also be applied in the SEA for the main stream dams:

1. China to Chiang Saen
2. Chiang Saen to Vientiane;
3. Vientiane to Mun River confluence (Pakse); and
4. Pakse to Kratie.

Furthermore, results of the impact assessment will be summarized at the country level.

At a lower level impact will be assessed for each of the important ecosystems/habitats described in Chapter 3.1.4 and for the hotspots discussed in Chapter 3.1.6.

Not only the spatial distribution of the impacts in important, but also the distribution over the seasons. IBFM distinguished 4 impact seasons. The dry season flow (December to April) is of ecological significance since it provides habitat for fish and other food organisms in the dry season and for the control of the salinity intrusion in the Delta. The first transition period (May) is of importance because small flood peaks (freshets) trigger fish migration and facilitate movement along the mainstream. Also water quality improves by dilution of pollutants. In the flood season (June to October) floodplains inundate, thus providing fish spawning areas and storage of water for release in the dry season. The second transition period (November) is important for the timing of the downstream fish migrations and the drying out of the floodplains.

3.2 Quantification of impacts

3.2.1 *General remarks*

The environmental impacts of the basin development scenarios as given in Chapter 3.1.3 will be assessed as much as possible quantitatively to arrive at the key environmental indicators given in Table 2-2. Many of the impacts will be spatially distributed, and assessment will be made by overlaying GIS maps. Not only average annual conditions will be taken into account, but also the situation in a dry and a wet year.

In the following assessment methods for each key environmental indicator as related to each of the environmental development objectives will be discussed.

3.2.2 *Development objective 1: Maintain water quality and acceptable flow conditions*

(a) Water quality, including sediment transport in the mainstream

Water quality is a key factor affecting the health of the Mekong River system and associated wetlands. Presently, at the local level, along the mainstream, pollution levels can rise above the standards during the dry season, particularly downstream of inflowing tributaries that drain sub-basins with larger or expanded irrigated areas e.g. the northeastern Thailand and the Mekong Delta. Many wetlands contribute significantly to wastewater disposal and treatment before entering the Mekong mainstream.

In 2005 there were 87 water quality sampling stations in the Mekong basin, 55 primary stations with a basin wide or transboundary significance and 32 secondary stations. Twenty-three of the primary stations are located along the main stream, 23 on tributaries and 9 in the Delta. Data are available for a period of about 20 years.

Three water quality indices (WQI) are used: (i) for the protection of aquatic life (WQIal), (ii) for human impact (WQIhi) and (iii) for agricultural use (WQIag). Each WQI is composed of a number of water quality parameters. For WQIal these are DO, pH, NH_3, Conductivity, NO_{3-2} and total-P. The human impact WQI is considers DO, COD_{mn} and NH_4. The agricultural water quality index is based on salinity.

In the mainstream and tributaries the water quality for aquatic life is generally high; in the Delta conditions are less favorable. Signs of human impact on water quality are observed in most of the tributaries, and in the mainstream, downstream of Phnom Penh. Water quality does not restrict agricultural use, except in the Delta.

Pollution with pesticides or industrial contaminants has not been detected.

Under the development scenarios pollutant loads to the rivers will increase due to increased return flows from irrigated agriculture (containing pesticides and nutrients) and increased discharges of (untreated) domestic and industrial waste water (having high levels of BOD, COD, nutrients and pollutants). At the same time flows in the receiving river change.

The main areas of irrigation development and population growth/industrial development will be mapped in the GIS and the points were the return flows/waste water discharges of these main areas enter in the main stream will be identified. Pollutant loads will be estimated using person equivalent loads of BOD, Total-P and Total-N and averages losses of N and P per ha irrigated area per year as given in the MRC Technical Paper No 19, An assessment of water quality in the Lower Mekong Basin (Nov 2008). However, these figures need refinement using international literature. An estimate of future pesticide and fertilizer use in the irrigated agriculture in the basin as well as an estimate of pesticide and nutrient concentrations in irrigation return flows will be made by the agriculture expert. The final effect of these pollutant loads on the water quality of the main river depends on the discharge of the river, being highest during low flows. The assessment will therefore concentrate on dry season conditions.

In the wet season discharges in the main river are so high that increased loads will be diluted very much.

Special attention will be given to suspended sediments. Storage reservoirs disrupt the natural flow of sediments. With decreasing stream velocity in the reservoir the sediment transport capacity of the flow decreases and suspended sediments drop out. Bed load of a river entering a reservoir is usually deposited at the reservoir inflow, where a delta may develop. Sediment trapping efficiencies of reservoirs are commonly between 60 and 95%, depending on the ratio between reservoir storage volume and average annual inflow and the grain size distribution of the sediment.

Sediment depleted water released from a reservoir has a high sediment transport capacity (erosive power) and will start to erode the receiving channel, thereby scouring the downstream streambed and banks until the equilibrium sediment load is re-established. Bars and islands may erode and disappear, as may riffles and pools. Bank erosion may increase and a number of important habitats may disappear.

Sediment trapping of existing mainstream reservoirs is considerable. Manwan Dam, the first dam in the Lancang Cascade was opened in 1993. It had a very significant impact on the sediment flux downstream along the Lower Mekong. It has a sediment trapping efficiency of 68% and as a result of the dam construction the sediment flux at Chiang Saen, 660 km downstream has more than halved from 70 million ton per year to 31 million ton per year. Impacts are noticeable as far downstream as Pakse, where post Manwan Dam sediment average annual sediment loads are 20% lower than pre-Manwan loads.

Sediment trapping efficiency of the whole cascade is estimated at 94%, so a further reduction in sediment flux has to be expected.

Impacts of reservoir construction on suspended sediment concentrations in the downstream river and flood waters, as well as on river channel morphology, with emphasis on rapids, deep pools and small islands and sandbars, will be assessed by he morphologist. It has to be taken into account that these changes are not only the result of changes in sediment loads, but rather the combined effect of changes in flows and changes in sediment concentrations.

(b) Key flow characteristics

The 1995 Mekong Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin requires the member states to cooperate in the maintenance of:

- Acceptable minimum monthly flows for each month in the dry season;
- Acceptable natural reverse flow of the Tonle Sap during the wet season; and
- Prevention of daily peak flows greater than occur naturally.

Above parameters have not been specified by the member countries. Therefore the present situation (Baseline scenario) will be used as the reference situation. The various scenarios will be assessed against the baseline.

(c) Forest flooded for specified depth and duration at Tonle Sap

Flooded forests at Tonle Sap are but one of the ecosystems habitats that are of vital importance for maintaining the very valuable white fish fisheries in the basin. Changes in flooded forest area, their productivity and the associated impacts on biodiversity will be discussed below as part of the assessment methodology for Development objectives 2 and 5.

3.2.3 *Development objective 2: Maintain wetland productivity and ecosystem services and 5: Conservation of biodiversity*

Changes in flow and flooding affect area and distribution of valuable wetland ecosystems and also ecosystem productivity and biodiversity. Therefore Development objectives 2 and 5 have to be considered in conjunction.

(a) Area of valuable wetland ecosystems/habitats

A distinction has to be made between the ecosystems/habitats in and directly along the channels of the Mekong and its major tributaries, and ecosystems in the annually flooded floodplains of along the main channel and major tributaries and in Cambodia and Viet Nam.

Channel ecosystems/habitats
The ecosystems/habitats in this group, the channel itself, deep pools, rapids , small islands and riverine sandbars and seasonally inundated riverine forest, will be affected when water levels and sediment loads of the river change. Rapids may 'drown', deep pools may fill in with sediment and the area available for riverbank forests on the riverbanks may change.

Maps displaying areas of deep pools, rapids, small islands and riverine sandbars and seasonally inundated riverine forest will be overlain with maps displaying changes in average dry season water levels for each of the scenarios. Dry season water levels are used since these are thought to change more and to be more critical than average annual or wet season water levels.

By combining this information with an estimate of the average bank slope, areas lost or (potentially) gained riverine forests can be calculated applying the following formula:

$$\text{Area lost} = (\text{length of riverine forest along river bank}) \times (\text{change in water level}/\sin\alpha)$$

in which α is the slope of the riverbank.

The same approach will be used to assess the area available for riverbank gardening along the main channel.

Impacts on deep pools, rapids and small islands and riverine sandbars will be estimated by the river morphologist. For the deep pools an estimate of changes in area and depth (and so in volume) will be made, for the rapids changes in total area and flow velocities will be estimated, whereas for the small islands and riverine sandbar only changes in area will be assessed. Assessments have to be made for the average dry season situation. It is noted that, in relationship to the IBFM programme, the hydraulics and sedimentation of deep pools in the lower Mekong River has been the topic of a PhD study. The study may be important in providing basic relationships that could be used in predicting pool depth changes.

Floodplain ecosystems/habitats

The following ecosystems/habitats in the Cambodian floodplain/Tonle Sap system and in the flooded areas near the confluences of the major tributaries with the main river will be considered:

- Flooded forests;
- Marshes, small pools, seasonal wetlands;
- Inundated grasslands; and
- Inundated rice fields.

In the Vietnamese floodplain the following ecosystems/habitats are taken into account:

- Flooded lowland forest;
- Inundated grasslands;
- Mangroves;
- Inundated rice fields, and
- Aquacultural areas.

Impacts on areal distribution, flood depth and flood duration will be assessed by overlaying ecosystem/habitat maps with flooding maps for each of the nine scenarios. This results in maps displaying both the change in total area of each of the ecosystems/habitats as well as an indication of areas in which flood conditions (depth, duration) change. The results will be tabulated per impact zone. This will result in approximately 50 tables, which will form the basis for the assessment of the impact on ecosystem productivity and biodiversity.

Flood maps are required for all areas that were flooded during the year 2000 flood, assuming this to be the maximum flooded area, for each of the scenarios, for an average year, a dry year and a wet year. The following parameters have to be mapped:

- Flood inundation area;
- Flood duration; and

- Flood depth.

A similar procedure will be followed for the hotspots.

(b) Ecosystem productivity, ecosystem services and biodiversity

Changes in wetland area, as well as in depth and duration of flooding will influence the ecosystem productivity and the biodiversity. GIS map overlays as described above will give an indication of the magnitude of change. The consequences of these changes for ecosystem productivity and biodiversity will be very hard to assess, since relationships between flood conditions (depth, duration) and ecological functioning are not available.

Probably only the direction of change (improvement or deterioration) and a very rough indication of the possible magnitude of change can be given by applying simple expert judgement based relationships (impact functions). Such impact functions describe the relationship between an external condition (e.g. flood duration) and an internal ecosystem condition (e.g. production). Two point of the curve are known: the present situation and the origin, the form of the curve in between has to be determined by expert judgement. Figure 3-2 gives an example of possible impact functions.

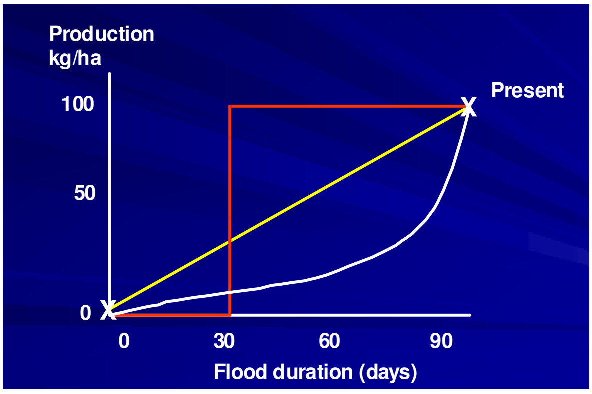


Figure 3-2 Example of impact functions to be developed

For the assessment of impacts on biodiversity special attention will be given to the flagship species and rare and endangered species, known to be associated to each of the identified important ecosystems/habitats.

The environmental services provided by each of the distinguished ecosystems will be assessed for the baseline situation, using information from the Wetland Valuation study being conducted by the Environment Programme (EP). This present study includes a wide range of wetland types and covers the valuation of a number of wetland functions such as flood control, shoreline protection, groundwater recharge, water quality control and biodiversity conservation. Losses of certain ecosystems can directly be translated to losses in services. Changes in ecosystem condition (as a result of changes in flood depth and duration) will be tentatively translated into partial loss of services, again using impact functions.

Assessment of the impact on biodiversity will concentrate on the flagship species discussed earlier and on a limited number of rare and endangered species, that are known to be dependent on a certain ecosystem/habitat. Losses of these specific ecosystems can directly be translated to losses in these specific species. Changes in ecosystem condition (as a result of changes in flood depth and duration) will be very hard to translate to changes in biodiversity. Probably only the likely direction of change can be indicated and possibly a rough estimate of the magnitude of change. This will only be possible for groups of species (e.g. birds nesting on islands and sandbanks, birds nesting in steep riverbanks) not for individual species.

3.2.4 *Development objective 3: Manage salinity intrusion in the Mekong Delta*

(a) Area in the Delta within thresholds of salinity

Changes in areas with salt water intrusion in the Delta will be assessed applying the DSF. Areas with salinities that make the water unsuitable for agriculture and aquaculture will be mapped. Recent research indicates that rice is not effected if mean salinities (EC) during the growing season remain below 190 mS/m (= 1140 mg/l). Older studies report a decrease in yields already starting at EC values above 0.7 mS/m or about 400 mg/l. Not only the mean salinity is of importance, but also the time of exposure, early stages of development, and more so the 20 day period between three leaf and panicle initiation stage, being most sensitive.

For the Water Quality Index for agricultural use in the Mekong Delta the following yield depression figures are applied for irrigated paddy rice (MRC Technical Paper No. 19, Nov. 2008):

- Conductivity < 200 mS/m (= 1200 mg/l): no yield reduction;
- Conductivity between 300 and 480 mS/m (= 1200 to 2880 mg/l) yield reduction of 10 to 50%; and
- Conductivity > 480 mS/m (> 2880 mg/l): yield reduced by more than 50%.

In literature a number of salinity-yield depression functions are given, which indicate a more gradual reduction in yield with increasing salinity and take into account the various stage of plant development.

The agricultural specialist will select a salinity-yield depression function which is applicable in the Vietnamese Delta and, using the function, select a threshold salinity (e.g. the salinity above which yield reduction is more than 25%) to be applied. He will also indicate for which critical period this threshold should not be surpassed, e.g. on average during the growing season, or for more than e.g. 10 days in the first month after establishment etc. By combining mapped information on salinity distributions during the critical period with the selected salinity-yield reduction curve, reductions in total yield can be calculated with the GIS.

Impacts of changes in salinity on the wild fisheries and aquaculture potential will be assessed by the fisheries expert.

3.2.5 *Development objective 4: Minimize channel effects on bank erosion*

(a) Incremental area at risk to erosion

The Mekong presently erodes its banks in many points, especially in IBFM Zone 2. Riverbank erosion will become more serious in the foreseeable future due to flow changes and changes in sediment load of the river related to the basin-wide development scenarios. Increase in the mean flow velocity and a lower sediment concentrations can cause bank erosion to intensify.

Areas presently subject to bank erosion will be mapped. An assessment of the likely changes in bank erosion patterns will be made by the river morphologist.

(b) Vulnerability to bank erosion

Vulnerability of riverbanks to erosion is mainly related to the inherent characteristics of the banks (geologic/soil material, vegetation). On the basis of these characteristics the river morphologist will make an estimate of the vulnerability to bank erosion along the riverbank. Actually an assessment of the vulnerability is needed to be able to assess changes in risk. Vulnerable banks have a higher risk under the same conditions than less vulnerable banks.

It is noted that as part of the IBFM programme a physically-based bank-erosion model has been developed. The model runs within a GIS framework that utilizes knowledge of riverbank geotechnical parameters and river flow parameters to predict bank erosion rates during specified hydrographs. However, the model seems not to be operational.

4 Data requirements for environmental assessment

4.1 Overview

The environmental assessment of BDP development scenarios will require comprehensive and reliable data sets. The environmental impacts will mainly result from changes in river flows and the related changes in flooding patterns in the floodplain. Therefore data to be provided by the modelling team are of prime importance. Of importance are furthermore the expected changes in water quality with emphasis on suspended sediments and salinity in the Delta.

Data collection comprises the gathering of all documents, maps and databases available from the various MRC programmes as well as other relevant information obtainable from the four riparian countries and a number of NGOs like IUCN, WWF, Birdlife International and Wetlands International. The data will as much as possible be in a geo-referenced format to be able to make map overlays and to generate information at specific locations (e.g. hotspots, river reaches, other identified impact areas).

Once established and quality assured, the data sets would be placed on BDP database and would be freely accessible. It is important that, as part of the quality assurance, the level of accuracy of the data is also clearly shown in order to provide planners with a guide to the validity of conclusions that can be drawn from the results. Finally, it is essential that the data sets are: (i) transparently assembled, (ii) consistently used by the scenario assessment team, and (iii) archived by IKMP for future used by BDP and other MRC programmes.

The main data requirements for the environmental assessments are related to:

- River flows and water levels;
- Flooding patterns;
- Wetland Ecosystems and Habitats;
- Irrigated Agriculture;
- Population growth in relation to domestic and industrial water use;
- Water quality (including suspended sediments);
- Saline intrusion in Mekong Delta;
- Riverbank erosion and sedimentation/erosion in the channel; and
- Flood management in Mekong Delta and other areas of LMB.

Details are given in the tables on the following pages.

4.2 River flows and water levels

Data on river flows and water levels are needed for each of the considered scenarios, at each of the 12 key monitoring stations and at hotspot sites (located in or directly along the channel) in between.

Table 4-1 Data required on river flows and water levels

Data Type	Unit	Data Source	Comment/Responsibility
Average seasonal flows and water levels for an average, a dry and a wet year	million m^3 m above datum	DSF	Data available with modelling team for the key monitoring stations, not for hotspots in between. A map with hotspot locations is being made by the environment team
Average monthly flows and water levels for an average, a dry and a wet year	million m^3 m above datum	DSF	Data available with modelling team for the key monitoring stations, not for hotspots in between. A map with hotspot locations is being made by the environment team
Average daily flows and water levels for an average, a dry and a wet year	million m^3 m above datum	DSF	Data available with modelling team for the key monitoring stations, not for hotspots in between. A map with hotspot locations is being made by the environment team
Annual average minimum and maximum daily flows and water levels	million m^3 m above datum	DSF	Data available with modelling team for the key monitoring stations, not for hotspots in between. A map with hotspot locations is being made by the environment team
Reverse flow to Tonle Sap at Prek Kdam	million m^3 m above datum	DSF	Data available with modelling team

4.3 Flooding patterns

Flood maps are required for all areas that were flooded during the year 2000 flood, assuming this to be the maximum flooded area, for each of the scenario's, for an average year, a dry year and a wet year. This includes areas along the main tributaries where backwater effects induced flooding often occurs at the confluence with the main stream.

Table 4-2 Data required on flooding patterns

Data Type	Unit	Data Source	Comment/Responsibility
Total flooded area during an average, a dry and a wet year	ha	DSF	Model available for the Cambodian and Vietnamese Delta and Tonle Sap area. Work in progress by modelling team. No model available for the more upstream areas along the main channel and tributaries. Possibilities to extend the model are presently investigated by modelling team
Flood duration during an average, a dry and a wet year	days	DSF	
Flood depth during an average, a dry and a wet year	m	DSF	To be provided by modelling team. GIS mapping required by GIS Specialist.
Connectivity of flooded areas, i.e. the flooded area directly connected to the river, leaving out not connected areas flooded by local rainfall/rivers, for an average, dry and wet year	ha	DSF	Data as such not available, to be derived from 'total' flood maps by the GIS specialist.

4.4 Wetland ecosystem/habitat data

Wetland ecosystem/habitat data will be collected for each of the identified 'important' ecosystems/habitats: deep pools, rapids, small islands and riverine sand bars, and seasonally inundated riverine forest in and directly along the channels and, seasonally inundated riparian forest, mashes, small pools and seasonal wetlands, inundated grasslands, lowland forests and mangroves in the floodplains and delta. To this list flooded rice fields have to be added: these are considered wetlands as well.

Three types of information are needed: maps displaying the present areal distribution of these wetlands, information on the ecological functioning of these ecosystems and their likely response to changes in flood conditions, and overlay maps showing changes in flooded area, average flood depth and average flood duration for an average year, a dry year and a wet year for each of the BDP scenarios.

Table 4-3 Mapped data required on important wetland ecosystems

Data Type	Unit	Data Source	Comment/Responsibility
Wetland map of the LMB, distribution and spatial extent of each of the distinguished important wetland.		IKMP MRC Wetland Database/map	Map is available, but not quality checked. The legend of the detailed maps (level 5 maps) is too complicated. Number of different wetlands has to be reduced to the 10 important wetlands distinguished (plus area under irrigated agriculture and area under aquaculture). A key for this translation has been provided to the GIS specialist. Simplified map to be made by the GIS specialist

Data Type	Unit	Data Source	Comment/Responsibility
Land cover map			Available as LMB Land cover 97 & LMB-forest 97 map. Legend : river, forest dense, forest open, forest mosaic, deciduous, deciduous mosaic, regrowth, plantation, bamboo, mangrove, wood & shrubland, grassland, mosaic of cropping, agriculture, bare land, rocks, urban area, wetland, water.
Location map of rapids in the Mekong mainstream and major tributaries			Only available for the upper & middle part of the basin. Maps are presently completed by the GIS expert using Google earth. To be checked by the river morphologist.
Location map of deep pools in the Mekong mainstream and major tributaries			Available: 20 sites including 3 major sites, 15 minor sites included. Maps are presently completed by the GIS expert using Google earth. To be checked by the river morphologist.
Location map of sandbars / islands in the Lower Mekong mainstream and major tributaries			Basic data available, GIS expert is working on completing the map. River morphologist to provide input. Maps are presently completed by the GIS expert using Google earth. To be checked by the river morphologist.
Environmental hotspot map		Various	Map to be compiled by the GIS specialist. A list of which areas have to be included is presently being prepared by the Environmental Team
Map of riverbank gardens			GIS expert is presently compiling a map using Google earth. The SEA team will probably start a separate exercise to map the riverbank gardens

Table 4-4 Data required on wetland functioning and response to changes

Data Type	Unit	Data Source	Comment/Responsibility
Physical characteristics under the present conditions, soils, elevation, flooding depth and duration etc.		Various, literature, DSF	Collection of available information is ongoing, will be completed by the riparian environmentalist. Part of the information to be provided by the DSF/modelling team
Biological characteristics: flora and fauna, with emphasis on rare and endangered species.		Various, literature	Collection of available information is ongoing, will be completed by the riparian environmentalist.
Resource use/environmental services provided • Fish and other aquatic animals • Agriculture (rice and riverbank gardening) • Forest products and Non forest products • Conservation of water quality • Cultural recreational and tourism value • Water supply		Various, literature	Collection of available information is ongoing, will be completed by the riparian environmentalist. Fish information to be provided by the fisheries expert, information on agricultural production (including riverbank gardening) to be provided by the agricultural specialist.

Data Type	Unit	Data Source	Comment/Responsibility
Economic value of environmental services provided		Various, literature	Collection of available information is ongoing, will be completed by the riparian environmentalist in collaboration with the economy team.
Response of ecosystems to change in conditions		Various, literature	Simple response curves to be compiled by the environment team for estimation of change. Important to have a better insight in the magnitude of the expected changes, to be provided by the DSF/modelling team

Table 4-5 Map overlays required

Data Type	Unit	Data Source	Comment/Responsibility
Map overlays of the important floodplain ecosystems (flooded forests; marshes, pools, seasonal wetlands; inundated grasslands; mangroves; rice fields and aquacultural areas) with maps of flooded area, average flood depth and average flood duration for an average year, a dry year and a wet year have to be made. Results for each ecosystem type have to be summarised in summary tables for the different impact areas and separately at country level.		DSF, wetland map	Flood extent, depth and duration maps are presently being prepared by the modelling team. The wetland map is being compiled by the GIS specialist. Overlays to be prepared by the GIS expert.

4.5 Irrigated agriculture

Data on irrigated agriculture are needed to be able to assess impacts of increased and intensified irrigated agriculture on the water quality in downstream areas.

Table 4-6 Data required on irrigated agriculture

Data Type	Unit	Data Source	Comment/Responsibility
Area of present and planned irrigated agriculture (of each of the scenarios) in each of the main tributaries, the Cambodian floodplain (West of the Bassac and East of the Mekong), and the Vietnamese Delta (Long Xuyen Quadrangle and Plain of Reeds). Location of the main drain discharge point.	ha	DSF	To be provided by the GIS specialist
Estimation of present and future use of agro-chemicals (fertilisers and pesticides) in irrigated agriculture.	kg/ha		To be provided by the agricultural specialist.

Data Type	Unit	Data Source	Comment/Responsibility
Estimation of % of used agro-chemicals that leaves the irrigated area with the return flow.	%		EP has estimated N and P losses from irrigated areas in Thailand and the Delta. These figures need to be refined by the agricultural specialist.

4.6 Population growth, domestic and industrial water use

Data are needed to estimate the impact on water quality of increased discharges of domestic and industrial wastewater.

Table 4-7 Data required on domestic and industrial water use

Data Type	Unit	Data Source	Comment/Responsibility
Location and size of major population concentrations, at present and for each of the scenarios. Location of major outfalls.		DSF	To be provided by the GIS expert.
Location and size of major industrial outfalls, at present and for each of the scenarios. Location of major outfalls.		DSF	To be provided by the GIS expert.
Person equivalent loads of BOD, and nutrients (Total-P and Total-N), present and future figures. For the future situation a % treatment has to be assumed.	g/person/ day	MRC water quality database	Figures for present situation are available; figures for future situation may need refinement by environment team in collaboration with EP. Estimates of future % treatment to be made by environment team/EP.
Estimates of type and magnitude of industrial discharges (after treatment).	ton/year		Presently no information is available within MRC EP on industrial discharges. Estimated to be made by the environment team, in collaboration with the economy team and the EP.
Estimates of the self purifying capacity of the river.		Literature	EP does presently not apply a factor for the self purifying capacity of the river and associated floodplains. This could lead to overestimations of the loads. The environmental team will make an estimate based on documented cases elsewhere.

4.7 Water quality, including suspended sediments

Data requirements for water quality assessment pertain to general water quality information. Data requirements on salinity and related to sediments and riverbank and bed erosion/ sedimentation will be discussed separately

Table 4-8 Data required on water quality, including suspended sediments

Data Type	Unit	Data Source	Comment/Responsibility
Locations of WQ monitoring stations in the basin, information on available records.		MRC water quality database, EP, reports and publications	Available.
Past and present information on water quality parameter included in the WQIal and WQIhi index, values and trends.		MRC water quality database, EP, reports and publications	Information is available for nearly a hundred monitoring stations in the basin.
Past and present information on measured parameters not included in the WQIal and WQIhi index, values and trends.		WQIal and WQIhi index, values and trends.	Information is available for nearly a hundred monitoring stations in the basin.
Data on heavy metals, pesticides, PAH's, PCB's, dioxins, and furans, as collected during special water and sediment sampling campaigns in 203 and 2004.		WQIal and WQIhi index, values and trends.	Information is available for 2 sampling campaigns held in 2003 and 2004.
Past and present information and predictions for the various scenarios on suspended solids: values and trends for the main stations along the river.	mg/l; average annual, during dry season and during wet season	Water quality database, literature	To be provided by the river morphology specialist.
Past and present information and predictions for the various scenarios on suspended solids loads being discharged into the sea.	ton/year	Water quality database, literature	To be provided by the river morphology specialist.
Past and present information and predictions for the various scenarios on suspended solids loads being retained in the Tonle Sap area, the Cambodian Delta and the Vietnamese Delta.	kg/ha	Water quality database, literature	To be provided by the river morphology specialist.

4.8 Saline intrusion data

The data required to assess the impact on changes in salt water intrusion will be required for the assessment of changes in yield reduction due to changes in salinity.

Table 4-9 Data required on salinity intrusion

Data Type	Unit	Data Source	Comment/Responsibility
Areas affected by saline intrusion: location and extent of areas affected by saline intrusion at present and in the future.	ha	DSF	Areas affected have to be mapped by the GIS and overlays with land use types have to be made.
Threshold values for damage to agriculture and a salinity-yield depression function for irrigated paddy rice.	mg/l during a certain period	MRC water quality database, literature.	EP uses 1200 mg/l (average annual value) as a threshold above which irrigated rice yields start to decline. Above 2880 mg/l yields are supposed to be less than 50 % of the normal level. These values are probably not very appropriate. The agricultural specialist will provide a salinity yield depression curve to be used to set thresholds.
Threshold values for damage to aquaculture and a salinity-yield depression function.	mg/l during a certain period or crop stage	Literature.	To be provided by the fisheries expert.
Threshold values for changes in mangrove forest composition.	mg/l during certain periods	Literature.	Environmental team.

4.9 Riverbank erosion and sedimentation/erosion in the channel

Table 4-10 Data required for economic assessment of impact on riverbank erosion

Data Type	Unit	Data Source	Comment/Responsibility
Areas affected by riverbank erosion: location and extent within vulnerable areas in present and in future for the various scenarios.	ha	IKMP	To be estimated by river morphologist using GIS.
Location and extent of river islands and sandbanks in the channel, at present and in future for the various scenarios. Dry season conditions.	ha	IKMP	To be estimated by river morphologist using GIS.
Location and extent of rapids in the main channel, at present and in future for the various scenarios. Dry season conditions.	ha	IKMP	To be estimated by river morphologist using GIS.
Estimate of flow velocities over the rapids at present and in future for the various scenarios, dry season conditions.	m/sec	IKMP	To be estimated by river morphologist using GIS.
Location, extent and depth of deep pools, at present and in future for the various scenarios. Dry season conditions.	ha, m	IKMP	To be estimated by river morphologist using GIS.
Location and rate of coastal accretion or erosion, at present and in future for the various scenarios.	ha/year	IKMP	To be estimated by river morphologist using GIS.

5 Work programme

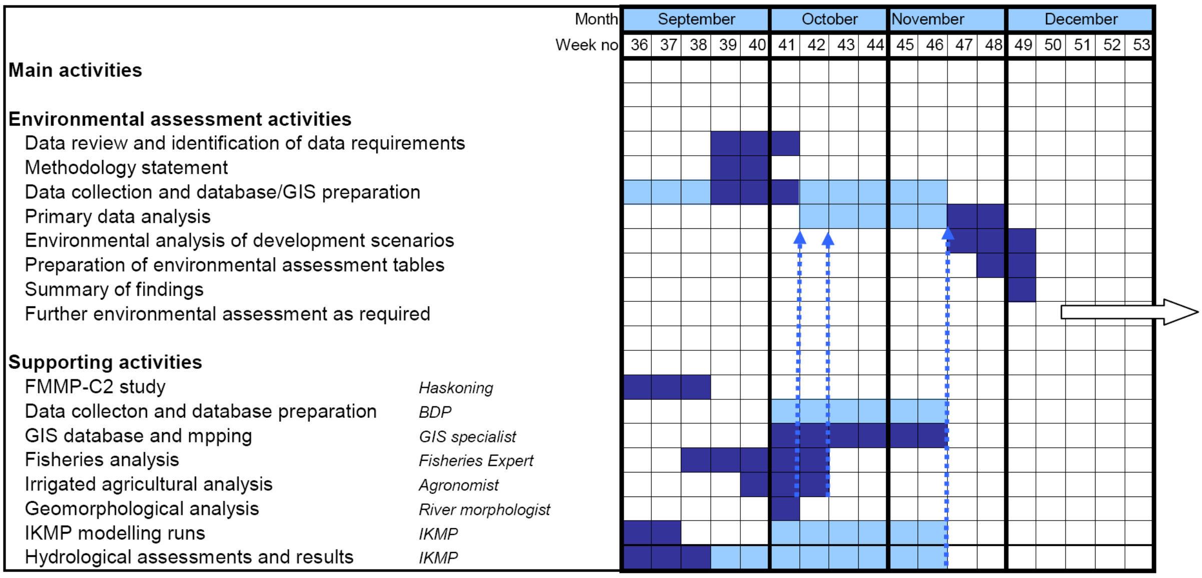
A work programme has been prepared to:

- Specify the main tasks of the economic assessment up to December 2009;
- Outline the schedule for the economic assessment within the given time frame; and
- Identify the timing of key supporting activities and establish linkages to the environmental assessment.

Following a review of the findings of the economic assessment and the preparation and submission of an interim consultation document in February 2010, it is envisaged that a draft assessment report will be prepared in March 2010.

The work programme for the environmental assessment activities, as well as linkages to the supporting activities, is summarised in Figure 5-1 below.

Figure 5-1 Work programme for environmental assessment of BDP development scenarios



Draft

Mekong River Commission
Basin Development Plan, Phase 2

Economic, environmental and social impact assessment of basin-wide water resources development scenarios

Annex 3
Social Assessment

DRAFT

Version 1

October 11, 2009

Contents

Summary

The overall framework for the social assessment is defined by the specific objectives for "social development" namely: 1) Maintain livelihoods of vulnerable resource users; 2) (Create) Increased employment generation in water related sectors. The ToR requires baseline assessment of the 'extent of people's dependence of river resources in different locations' and 'resource users resilience to changes in three categories: (i) baseline vulnerability, (ii) extent of social services, and (iii) available livelihood opportunities (coping strategies)'.

The key question to answered by the social assessment can be phrased as:
Who, and how many people, who live where, will be negatively/positively affected how much through the impacts on fish and aquatic resources, environment, irrigation, and economic opportunities by changes in the river flows and volumes as predicted in the hydrological scenarios. How are these people likely to react – what strengths and weaknesses do they have?

Dependency, resilience and vulnerability are closely linked concepts. Thus assessments of people's dependency, vulnerability and resilience (which is often considered an element of vulnerability) will be the three main dimensions for the social assessment.

The baseline or the 'vulnerability context' will focus on data collection and analysis of the following dependency variables: percentages of part-time (subsistence) and full-time fishers, consumption of fish and other aquatic animals, use of aquatic products (including NTFP), food security, location in floodplains (flood recession rice growing) and proximity to Mekong river and main tributaries. Various approaches such as creation of indices, statistical analyses such as geospatial analysis and multivariate cluster analysis will yield clusters and data values according to level of dependency and vulnerability. These will be saved as GIS layers. By overlaying population data and other data such as access to services and ethnicity, the analysis will yield the number of people who are dependent on river aquatic resources to various degrees.

Thus vulnerability to changes in the water and aquatic regime comprises three dimensions:
1) exposure, 2) sensitivity and 3) resilience.

1. Exposure will be assessed based on the spatial analysis (location) of impacts on fisheries, aquatic resources, floodplains, wetlands and irrigated rice generated by the other parts of the assessment for the baseline and for the scenarios. To produce these layers will be a complicated task and it is key that the full team works together on this. In its most simple, the social analysis will overlay a population layer on these impact layers and the number of people who are likely to be exposed to changes in the water regime at various levels will be calculated.

2. Sensitivity is more complex from a social assessment perspective. Sensitivity will be assessed by overlaying various GIS layers generated by the analysis of sensitivity variables on the impact layers for the different scenarios. The areas and population groups most sensitive to changes in aquatic resources can then be identified.

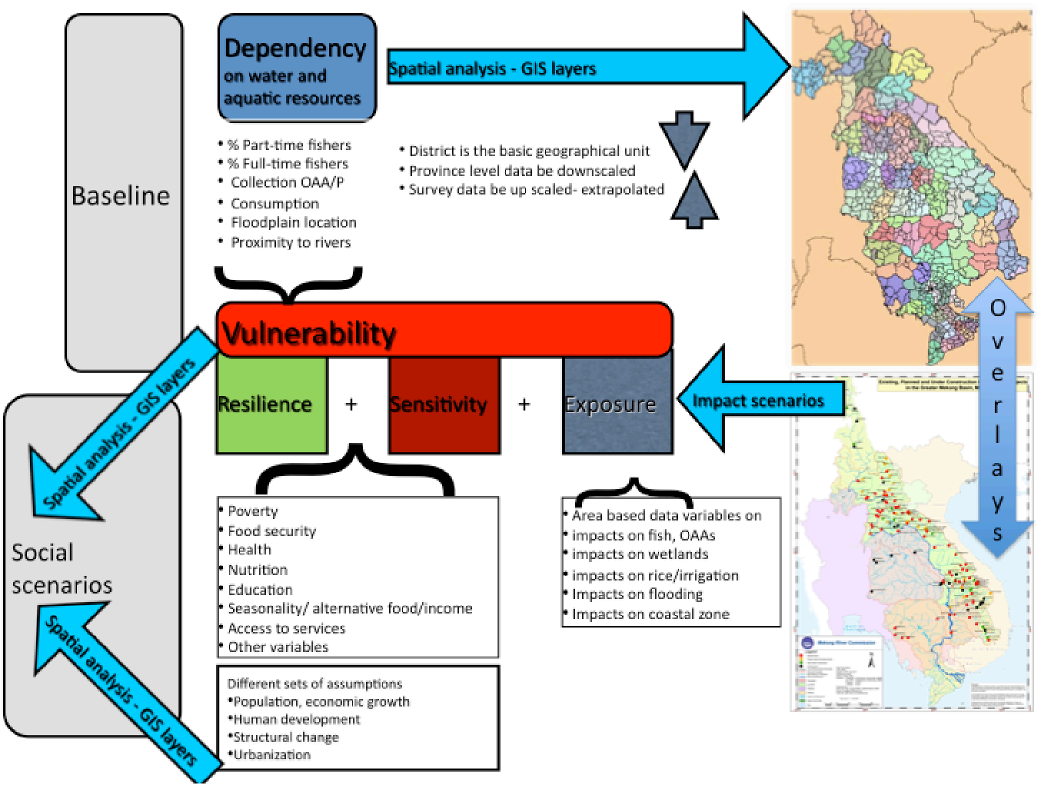
3. Resilience is the concept most difficult to assess. It comprises responses to impacts, coping strategies and adjustment/adaptation. Resilience is function of capabilities, such as measured with the five capitals used in the SL approach, and not least societal support structures provided by governments.

Changing the data values according to assumptions about future social development will create scenarios. Including different assumptions regarding population and economic growth, poverty rates, structural economic change, urbanization, human development, dependency ratio and others can create a number of sub-scenarios for each main scenario. Long-term scenarios however, cannot just extrapolate current trends in a surprise-free linear fashion, but must be open for trend breaking and surprising, even improbable events.

The District is the basic spatial unit for the assessment. Much statistical data is only available at lower resolutions (higher scale) such as provincial level, while data from fisheries and consumption surveys is available at higher resolutions (lower scale) such as communes and villages. The methodology will downscale and up scale (extrapolate) these data, based on transparent criteria, which in many cases will be qualitative, such as: proximity - data from adjacent or nearby provinces; geographic similarity; averaging of data from several spatial units; use of conservative assumptions for drier or mountainous provinces. The uncertainty in these statistical operations such as error margins, significance levels etc will be presented.

Areas of concern for social assessments such as equity, governance, participation, political economy, that are often used in assessments of long-term development plans that include major infrastructure projects with large-scale impacts on natural resources, are not included in the ToR. For example, governance aspects are critical to assessing the resilience of people to adverse impacts since especially poor people will rely on different forms of government support. The existence of a government service does of course not guarantee that it is applied in an equitable fashion. The social assessment team proposes to include these aspects in the assessment as relevant. The approach to this will be developed in the next stage in November.

Figur 1 Overview of social assessment approach



1 Introduction

1.1 Main purpose of report

The purpose of this report is to provide guidance to the approach and methodology for the social assessment of the basin-wide development scenarios under Phase 2 of the BDP Program. The report also provides a record of the approach and analytical techniques to be used for future reference.

The report is the first deliverable of the Social Assessment Consultant. The work took place in Vientiane from September 22 to October 12, 2009.

The work during the first input has included:

- Discussions with the full assessment team and with BDP professionals
- Establishing an approach for the social assessment
- Description of the analytical tools
- Obtain understanding within the social assessment team of the approach and methods
- Review of existing available data sets
- Meeting and exchange of data with the SEA social consultant
- Detailing of further data requirements
- Developing a work plan for the social assessment

The social assessment methodology presented is for discussion by MRC programs, stakeholders and the BDP assessment teams. Comments are expected to be received before November 5th to be able to make changes and obtain additional data during the next input of the Social Assessment Consultant and the full team, scheduled for November 5 to December 10.

Once all comments, data sets and GIS layers have been obtained, cleaned and made ready for the actual analysis the detailed methodology will be further developed.

1.2 Report contents

The report outlines the approach, the analytical methods, the data requirements and comments on data availability for the social assessment.

Chapter 2 presents the development objectives and key social indicators.

Chapter 3 presents the general approach and the dimensions of the assessment with the key indicators, definitions of the key concepts and the approach to developing scenarios.

Chapter 4 presents the data requirements for the social assessment overall, discussing some of the data variables in detail.

Chapter 5 presents a work plan for the social assessment work up to end 2009.

2 Development scenarios and key social indicators

2.1 Development objectives and key social indicators

According to the Scoping Report for the development objectives for the social assessment are

- Maintain livelihoods of vulnerable resource users; and
- Increased employment generation in water related sectors.

Livelihoods are to be assessed in terms of health, food and income security. The number of people affected, and the severity of impacts on health, food and income security is to be assessed.

Employment is to be assessed in terms of incremental sustainable employment from water resource interventions, measured in terms of incremental number of people engaged in agriculture, fisheries, water-related service industries and tourism.

The required baseline information is to be divided into two overall dimensions:

- The extent of people's dependence of river resources in different locations:
- Resource users resilience to changes in three categories: (i) baseline vulnerability, (ii) extent of social services, and (iii) available livelihood opportunities (coping strategies).

Dependence on river resources relates to vulnerability in opposite ways: as a part of people's natural capital which is part of their resilience, and as part of people's sensitivity to the changes in their environment caused by impacts on river water and aquatic resources.

Resilience is often taken as a sub-set of vulnerability, and not, as implied in the ToR, vulnerability being a sub-set of resilience. Vulnerability is often calculated as: Vulnerability = function of (Impact - resilience). The theoretical issues pertaining to vulnerability assessments are discussed in subsequent sections.

Figure 1 shows the key variables of the four dimensions of the Vulnerability context to be used in the social assessment, with the dependency variables being included as both sensitivity and resilience factors.

A more extensive list of indicators and variables for the social assessment is presented in Section 4.

3 Social assessment of baseline and development scenarios

3.1 General approach to social assessment

The social assessment team will work closely with the other assessment teams, and have collaborate with especially the environment program and the fisheries program, as well as with other MRC units.

The social assessment team has met with the social expert of the SEA team. There is a substantial overlap of the social assessment and the SEA, and the synergy effects this can achieve will be fully explored. Duplication of effort will be avoided, while data and approaches will continue to be shared.

3.1.1 The vulnerability context and the sustainable livelihoods approach

The sustainable livelihoods (SL) approach will be a frame of reference for the social assessment. What is called the 'vulnerability context' in the SL approach frames the external environment in which people exist. People's livelihoods and the wider availability of assets are fundamentally affected by critical trends as well as by shocks and seasonality over which they have limited or no control. The application of the SL approach will be tailored to the scope of the social assessment, which means that detailed analysis of household level assets across the LMB, using the social, human, financial, physical and natural capital distinction, will not be within the scope. The focus will be on social variables that can be identified to have direct relationship to water and aquatic resources. The variables for resilience (or adaptive capacity) have been grouped according to the five capitals to establish a link to the SL approach (Figure 1).

The elements and definitions of the assessment of the vulnerability context are:

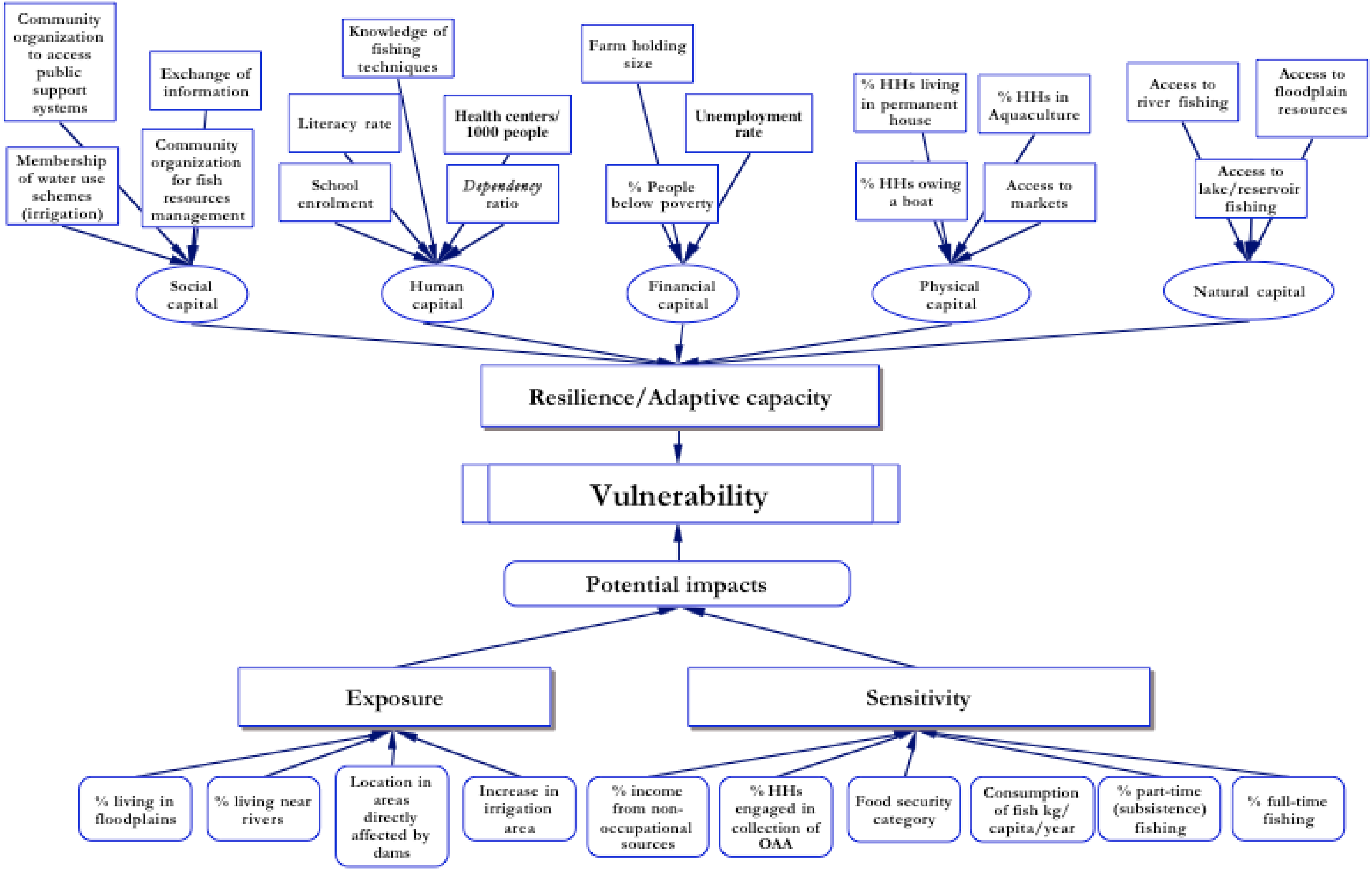
Vulnerability = *f* (Exposure (Location), Sensitivity, Resilience)

- Vulnerability: The degree to which a social group (in the context of the social assessment) is likely to experience negative effects due to exposure to changes in its environment
- Exposure: 1) Location: The presence of people or structures and their location relative to the change in environment, 2) Frequency and magnitude a change in the environment within an area over time
- Sensitivity: Susceptibility of an exposed social group to negative impacts of a change in the environment
- Resilience: Ability of a social group to maintain livelihoods and well being despite disturbance and their ability to bounce back to a reference state

Figure 1 shows an outline of relevant variables identified at this stage of the work and how they will feed into the analysis.

Again it should be made clear that the variables identified at this stage are not exhaustive, and will be amended and added to in the process of data exploration in November.

Figure 1 Overview of indicators and variables



3.1.2 Geographical scope and scales

After discussions in the whole assessment team, it is clear that the social assessment in principle will have to include the whole basin and cannot be limited to a smaller area as assumed in the Scoping Report. Thus the social assessment data must also cover the whole basin. The reasons are:

1) The requirement for analysis of social impacts of increased irrigation, i.e., the planned irrigation projects in the GIS database, are spread throughout the basin, and
2) The analysis of impacts on fisheries through impacts on fish migration will probably imply effects up into upper tributaries.

Thus the social assessment must assume that there will be social impacts through increased irrigation and changes in the fisheries and use of aquatic resources in all parts of the basin. However, the impacts will obviously to be at very different magnitudes in different areas. In general it can be assumed that impacts will decrease with increasing distance from the main river, floodplains and main tributaries.

The social assessment team, together with the fisheries and environmental assessment teams and the GIS specialist, will delineate the most sensitive and vulnerable geographical areas and subject these to more in-depth social assessment.

Different types of data are available in different spatial resolutions and this fact will require the social assessment to apply both downscaling and up scaling (extrapolation) of data. Data on consumption of fish and aquatic products have already been extrapolated to province level. This extrapolation is the basis for current estimates of total production of fisheries in the LMB.

Downscaling and up scaling of data will be based on transparent geospatial criteria, and expert judgment such as: proximity - data from adjacent or nearby provinces; geographic similarity; and averaging of data from several spatial units. The intention is to include advanced geospatial analysis such as Moran analysis in these procedures. The uncertainty in these statistical operations such as error margins, significance levels etc will be presented.

Scales

The social assessment will recognize the importance of different scales such as individual, household, community, local government – District – Province, and state level.

An example of different scales with regard to risks and vulnerability is given in the Table 2. This is only a preliminary outline of the type of risks that could be identified at different levels.

Table 1 Examples of risks at different social levels

<table>
<tr><th>Level</th><th>Risks</th><th>Vulnerability proxy</th></tr>
<tr><td rowspan="2">State</td><td rowspan="2">Socio-political unrest
Downstream trans-boundary water use conflicts</td><td>Absence/presence of protective policies for the poor and for their access to natural resource
Adherence/non-adherence to basin-wide decision bodies</td></tr>
<tr><td rowspan="2">% Income from fisheries taxes and customs
High poverty ratio</td></tr>
<tr><td rowspan="2">Local governments (Province, District, Communes)</td><td rowspan="2">Decrease in income
Socio-political unrest
Food crisis</td></tr>
<tr><td rowspan="2">% Population with high dependency on river and aquatic resources
High poverty ratio</td></tr>
<tr><td rowspan="2">Village/Community</td><td rowspan="2">Food crisis
Decrease in income
Conflicts over user rights to water and aquatic resources</td></tr>
<tr><td>Food security status</td></tr>
<tr><td>Household</td><td>Sudden significant decrease in fish catches
Reduced access to natural aquatic resources, land disputes</td><td>High dependency on fish and OAA
Full-time fisher
Poverty
Weak capabilities
Landlessness</td></tr>
</table>

3.2 Vulnerability

Expanding on the short definition of vulnerability given above in section 3.1, a commonly used definition of vulnerability is

"Vulnerability defines the characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a hazard." (Wisner et al, 2004). It involves a combination of factors that determine the degree to which someone's life, livelihood, property and other assets are put at risk by a discrete and identifiable event (or series or cascade of such events) in nature and society" [1].

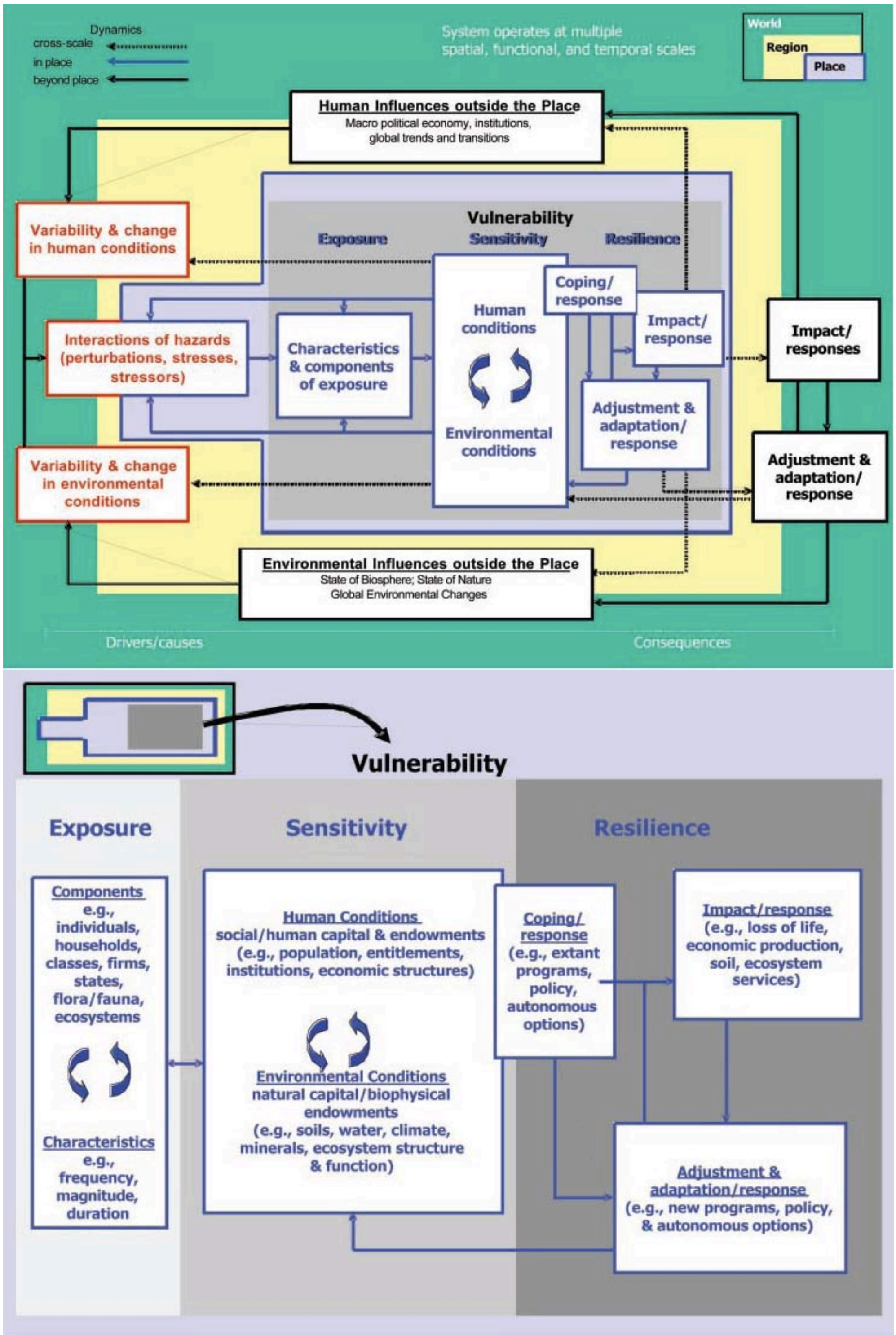
Vulnerability is a complex concept as highlighted by numerous theoretical articles. For example the following: "We identify the following elements for inclusion in any vulnerability analysis, particularly those aimed at advancing sustainability:

(i) Multiple interacting perturbations and stressors/stresses and the sequencing of them;
(ii) Exposure beyond the presence of a perturbation and stressor/stress, including the manner in which the coupled system experiences hazards;
(iii) Sensitivity of the coupled system to the exposure;
(iv) The system's capacities to cope or respond (resilience), including the consequences and attendant risks of slow (or poor) recovery;
(v) The system's restructuring after the responses taken (i.e., adjustments or adaptations); and
(vi) Nested scales and scalar dynamics of hazards, coupled systems, and their responses" [2] .

[1] Wisner et al, 2004).Cited from Participatory Vulnerability Assessment, ActionAid

[2] A framework for vulnerability analysis in sustainability science. B. L. Turner IIa,b,c, Roger E. Kaspersonb,d, Pamela A. Matsone, James J. McCarthyf, Robert W. Corellg, Lindsey Christensene, Noelle Eckleyg,h, Jeanne X.

These elements are interactive and scale dependent, such that analysis is affected by the way in which the coupled system is conceptualized and bounded for study. The two graphs below from the same article show the full and the more pragmatic 'reduced complexity' approach to vulnerability assessment; the latter is the approach taken in the social assessment.



Kaspersonb,d, Amy Luerse, Marybeth L. Martellog, Colin Polskya,b,g, Alexander Pulsiphera,b, and Andrew Schillerb. PNAS ,July 8, 2003, vol. 100, no. 14

However, it should be highlighted that the social assessment cannot go into depth with analysis of the complexity of couplings and feedback mechanisms. Similarly, consideration of stochastic and non-linear processes is beyond the scope of the assessment.

For the social assessment the challenge is to find a set of indicators that is as small and simple as possible to ensure transparency and easy communication, yet still captures as much of the complexity as possible, and furthermore which are already available in the existing data sets.

Thus vulnerability to changes in the water and aquatic regime comprises three dimensions:
1) exposure, 2) sensitivity and 3) resilience.

4. Exposure will be assessed based on the spatial analysis (location) of impacts on fisheries, aquatic resources, floodplains, wetlands and irrigated rice generated by the other parts of the assessment for the baseline and for the scenarios. To produce these layers will be a complicated task and it is key that the full team works together on this. In its most simple, the social analysis will overlay a population layer on these impact layers and the number of people who are likely to be exposed to changes in the water regime at various levels will be calculated.

5. Sensitivity is more complex from a social assessment perspective. Sensitivity will be assessed by overlaying various GIS layers generated by the analysis of sensitivity variables on the impact layers for the different scenarios. The areas and population groups most sensitive to changes in aquatic resources can then be identified.

6. Resilience is the concept most difficult to assess. It comprises responses to impacts, coping strategies and adjustment/adaptation. Resilience is function of capabilities, such as measured with the five capitals used in the SL approach, and not least societal support structures provided by governments.

3.2.1 Exposure

Location will be the basic variable to determine exposure. The general location parameters will be proximity to main river and tributaries, and location within and proximity to floodplains and wetlands. The second parameters will be location of Districts in relation to areas of impacts from dam construction, floodplain protection, irrigation development, impacts on fish and aquatic life as delineated by the fisheries assessment and the environmental assessment.

In addition to location, an important dimension of exposure is risk. Risk is the probability of occurrence of a shock to a system – an individual, a household, a community etc. As a probability, risk is basically a statistical concept. Risks arising from the probability of shocks to consumption and incomes related to changes in water flows, volumes, and aquatic resources would include:

- Fisheries shocks: e.g., sudden significant decrease in fish catches, changes in timing of fisheries
- Riverbank changes: erosion, sudden changes in water levels
- Agricultural shocks: e.g., change in planting/harvesting cycles
- Covariate economic shocks: e.g., related to mass-closures of medium-large fishing operations

- Natural shocks: e.g., floods
- Idiosyncratic shocks: e.g., accidents relating to sudden changes in river flows
- Adverse unsustainable coping strategies: e.g., overfishing of certain species, distress sale of capital assets negatively affecting future earnings
- Social shocks: e.g., disputes about access to natural aquatic resources, land disputes due to appropriation of open access floodplains to rice fields
- Health and Diseases: e.g., decrease in protein intake, increase in water-borne diseases

Furthermore, macro level shocks (recession, inflation) could intensify vulnerability 'across the board' (e.g., as the current recession and in the past such as in 1998).

Calculating the probabilities of shocks is beyond the scope of the social assessment, though it may be attempted in the course of the analysis. Instead the scenarios will be made on the basis of assumptions regarding the occurrence of shocks.

The other side of exposure is people's access to positive impacts from dam construction etc. Location is also an important variable for assessing this. Nearness to dam construction sites could create employment opportunities for local people – but to what degree that would be the case needs inputs from the hydropower and economic assessment. Access to irrigation can create employment opportunities, and changes in livelihoods that would decrease dependency on natural resources (while creating new dependencies). Also tourism development is linked to location, however tourism development is more likely to be dependent on the strategies for and level of investment in tourism development.

3.2.2 Sensitivity

The key variables for the sensitivity assessment are proposed to be

- Consumption of fish kg/capita/year (data from Consumption study)
- Percent part-time (subsistence) fishing households (data from Fisheries Surveys)
- Percent full-time fishing households (data from Fisheries Surveys)
- Percent income from non-occupational sources (used in Thailand statistics, can be a proxy for dependency on aquatic resources in some areas)
- Percent households engaged in collection of other aquatic animals (OAA) (data will be from Fisheries Surveys)
- Food security (the categories used in existing food security surveys will be made comparable and used. No analysis of primary raw data from food security surveys will be done)

<u>Dependency on wild fish and collection of OAA (percentages of part-time (subsistence) and full-time fishers)</u>
In-depth studies of Mekong fisheries report that its importance is under-estimated in government statistics. Catches are under-reported and the actual level of participation in the fisheries is obscured by the use of statistical occupational classes such as farmer or fisher, that do not capture subsistence, or part-time, fishing. Therefore it is essential to use fisheries surveys and case studies, and not government statistics, to assess the dependency on fisheries. In subsistence fisheries is included the very important collection of OAA such as mollusks, frogs etc.

MRC's fisheries program has between 1998-2002 carried out fisheries surveys in four provinces that were deemed representative of the highlands in upper LMB (Luangprabang), floodplains in Thailand (Songkhram), floodplains of lower Mekong (An Giang) and the coastal zone (Tra Vinh). In 1997 an extensive socio-economic fisheries survey was carried out in Cambodia around the Tonle Sap. Since then a large number of studies has confirmed and updated its findings. These studies contain extensive information on subsistence fisheries and collection of of OAA, including the percentage of households that are involved in part-time fishing, and the perceived importance of these activities. Though the fisheries surveys are now almost 10 years old, they are still the most extensive and comparable source of information. A number of other studies provide additional information that can be used for extrapolation of the fisheries survey data.

The level of subsistence fisheries and collection of OAA, based on the fisheries surveys, will be extrapolated to Districts, and triangulated with other studies and government statistics.

Food security

Food security assessments are based on multiple variables and apply a number of analytical tools. Some common food security indicators are shown in table 3.

Table 2 Common Food Security Indicators

Social Level	Availability	Accessibility	Utilisation	Stability
Macro (national)	Fertility rate Food Production Population Flows	Food price Wages Per capita food consumption	Stunting rate Wasting rate Low Birth Weight rate	Food price fluctuation Regional gaps
Meso (province, district, commune, village)	Harvest-time staple food production	Market and retail food prices	Latrine coverage Diarrhoeal Disease rate	Pre-/post harvest food Women's Body Mass Index
Micro (household/family, individual)	Food storage Consumption of wild foods	Meal frequency Food frequency Employment	Weight-for-age Goiter Anaemia	Pre-harvest food practices Migration

Source: Food Security and Nutrition Cambodia website.

An example of food security indicators used in the LMB, from Thailand National Food Insecurity and Vulnerability Information and Mapping System (FIVIMS) is shown in Annex 1.

To illustrate the importance of including food security assessment in the social assessment, some findings from the Lao PDR: Comprehensive Food Security & Vulnerability Analysis[3] are presented:

- Over the seven-day recall period, big wildlife was eaten by 6 percent of the households, small wildlife by 26 percent, wild fish by 81 percent, OAA by 55 percent, fish from ponds by 20 percent, poultry and pork each by 41 percent, and buffalo/cow meat by 42 percent of the households.
- Out of all reported animal protein consumption days, wild fish alone made up 35 percent. These findings are supported by other studies highlighting the importance of freshwater biodiversity resources for the Lao diets.
- However, there is increasing pressure on these wild food resources, due to trade demands, unmanaged harvest, foreign investment schemes (in particular hydropower and

[3] Lao PDR: Comprehensive Food Security & Vulnerability Analysis, (CFSVA), Data collected in October-November 2006. WFP, EC

mining, large scale plantations) and large-scale infrastructure development.

- Overall, it is estimated that around 157,000 (±20,000) households, or 24 percent of the people in rural Lao PDR, would become food insecure if fishing, hunting and gathering were less productive or reduced (Taking into account how much the household diet depends on natural resources and their capacity to cope with the loss of these resources).
- Meat and fish from hunting and fishing are the most important sources of fat and protein in the Lao diet. These wild sources are under threat partly due to competing demands on the forests, and population movements away from these sources.

The social assessment will use the outputs of food security assessments done in the LMB at various levels as variables. No re-analysis of primary data of food security is considered.

Culture and ethnicity

Culture and ethnicity are important variables for sensitivity assessment. It can be noted that the Lao food security analysis mentioned in previous section observes that wild fish consumption was highest in the Mekong Corridor and among the Lao-Tai groups (4-5 days per week), followed by the Austro-Asiatic groups (2-3 days per week). Yet, a considerable amount of fish and OAA was also eaten in the uplands. For the Sino-Tibetan and Hmong-Mien groups living in the uplands, wild fish consumption was found to be higher than the consumption of domesticated animals.

The link between livelihoods based on natural resources, with aquatic resources taking a prominent place, and ethnicity is evident. This link can in some cases be established through the spatial analysis. For Lao PDR a GIS layer showing the dominant ethnic groups is available. Furthermore, the statistical data from the national census and surveys should include information on dominant ethnic group in each District. Case studies will be used to obtain more information on ethnicity and location.

It is well-known that the Mekong and rivers, wetlands and lakes have very significant cultural meanings. Spirit houses, water rituals, Naga's and so forth plays a significant role in the cultural identities of people in the LMB. The impact of water resources development on these cultural meanings and the values assigned to them will be included in the social assessment on the basis of case studies and anthropological knowledge. These important aspects will be described in a qualitative manner.

3.2.3 Resilience

Table 4 presents the variables identified for assessing resilience grouped according to the five capitals used in the Sustainable Livelihood approach. Data for many, but not all, of these variables can be found in official statistics.

For the poor, coping mechanisms are likely to come from public services, safety nets or social networks/institutions available at the community level. However, the existence of a government service does of course not guarantee that it will be applied in an equitable fashion. Governance aspects are critical to assessing the resilience of people to adverse impacts since especially poor people will rely on different forms of government support.

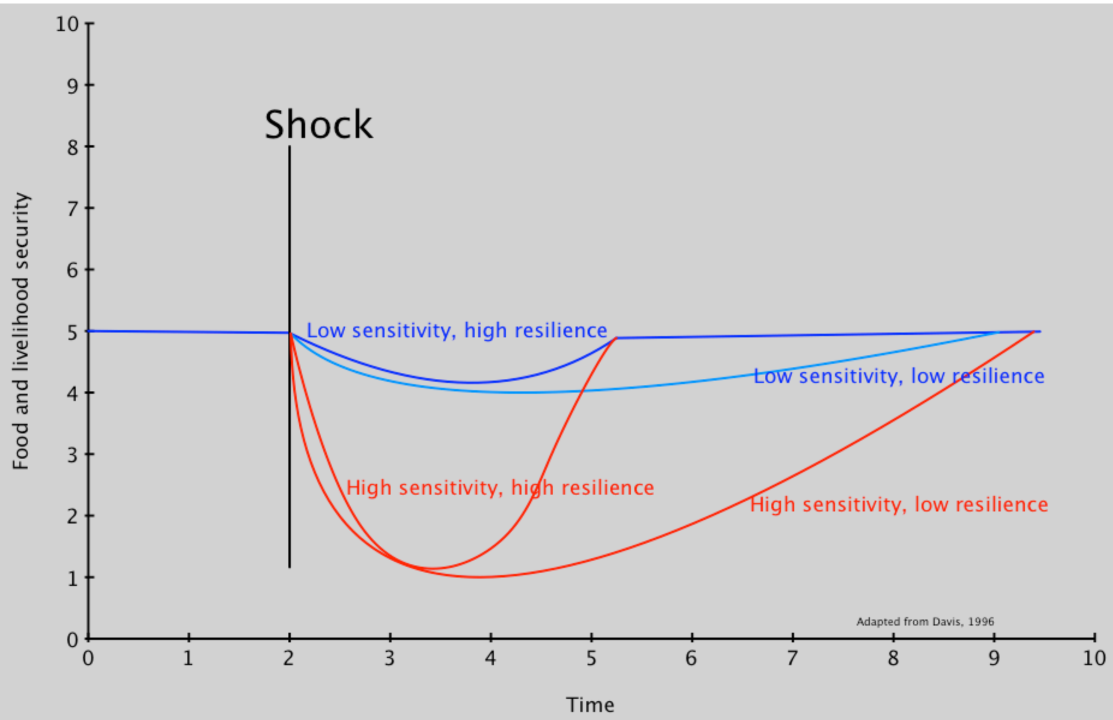
However, areas of concern for social assessments such as equity, governance, participation, political economy, that are often used in assessments of long-term development plans that include major infrastructure projects with large-scale impacts on natural resources, are not included in the ToR. The social assessment team proposes to include these aspects in the assessment as relevant. The approach to this will be developed in the next stage in November.

Table 3 Variables ordered in the five capitals of the Sustainable Livelihoods approach

The Five Capitals	Variables
Social	Community organization for fish resources management Membership of water use schemes (irrigation) Community organization to access public support systems Exchange of information
Human	Literacy rate School enrolment Knowledge of fishing techniques Dependency ratio - working age to elderly and children Health centers/doctors/1000 people
Financial	Farm holding size % People below poverty Unemployment rate
Physical	% living in permanent house % HHs in Aquaculture % owing a boat Access to markets
Natural	Access to floodplain resources Access to river fishing Access to lake fishing

It is also important to acknowledge that resilience and sensitivity are closely related concepts and must be understood in time as illustrated in figure 2. In the scenarios, different assumptions will be made regarding the time dimension of people's ability to 'bounce back' to a their previous state of well being.

Figure 2 Time dimensions of sensitivity and resilience



3.3 Analytical methods

A multitude of research is being done with regard to vulnerability to climate change assessment. It is obvious to consult this research for the purpose of the social assessment[4].

A very recent paper[5] has a good discussion on methods for assessing vulnerability, and some key points pertaining to analytical methods are summarized below (see full article for references to source documents):

Several quantitative and semi-quantitative metrics have been proposed and applied to quantifying vulnerability. These may be classified into two main approaches: the vulnerability variable assessments and the indicator approach.

The vulnerability variable approach measure and assess the vulnerability of selected variables of concern to specific sets of stressors. Vulnerability is defined in terms of the changes that have occurred or will occur in these selected variables (e.g., household assets or income) or stressors. This method can assess relationships across a wide range of stressors. To the extent that the selected stressors characterize a given place [please note the reference to spatial analysis, ed.], they provide an important indication of its vulnerability.

Generic vulnerability metrics include

- Variability of selected variables of concern as a metric of vulnerability, especially in economic and agricultural studies.
- Probability that a variable of concern will cross a threshold.

While these metrics are useful, no single measure can fully capture the multiple dimensions of vulnerability.

The indicator approach uses a specific set or combination of indicators (proxy indicators) and measures vulnerability by computing indices, averages or weighted averages for those selected variables or indicators. An advantage is that this approach can be applied at any scale (e.g., household, county/district, national, system).

The major limitation of the indicator approach is its inability to capture the complex temporal and social dynamics of the various systems being measured.

However, using indicators to identify zones of vulnerability, in combination with geospatial analysis, provides a systematic rationale for targeting proactive measures aimed at protecting populations [6].

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[4] For example, vulnerability assessments in the context of climate change has been made by MRC, UNDP, IUCN for a number of provinces and areas, including lower Songkhram in Thailand, Stung Treng in Cambodia, and Attapeu in Lao PDR.

[5] Mapping South African Farming Sector Vulnerability to Climate Change and Variability. A Sub-national Assessment, by Glwadys Aymone Gbetibouo and Claudia Ringler. IFPRI Discussion Paper 00885, August 2009

Use of indices

Given the requirement of the social assessment to produce clear and easy to understand information, the development and use of indicators for dependency and vulnerability can be defended. For the social assessment, it will surely be necessary to develop indices of some of the variables. However, there are various considerations regarding the use of indices, as discussed in the following.

As mentioned, an index presents a single-value measure of meaningful criteria based on multiple variables of different types. Such multiple variables, if considered individually, do not capture the complexity of dependency, vulnerability and resilience. But if they are presented side by side multiple variables can be difficult to understand and obtain an overview from. A single index value provides easy overview, but at the cost of reduced information content.

The averaging and weighting procedure is particularly important to this measurement tool. Composite indices are averages of different sub-indices. The single value they produce, may conceal divergences between the individual components or sub-indices, possibly hiding useful information. A composite index implies some form of trade-off between the sub-indices. Averaging would conceal, for example, situations where the effect of one variable cancels out the effect of another. In addition there is the problem of whether to take a simple average or a weighted average and, in the latter case, which weights are to be assigned to the different variables. Though weights can be generated through regression analysis, using the simple average has advantages in terms of simplicity and transparency[7].

<u>Example – Lao PDR District Vulnerability Analysis</u>

A district level vulnerability analysis was done in 2005 [8]. The eight indicators used in the analysis were selected because they all were assumed to have a relationship to vulnerability to food insecurity, and reliable and timely data at the district level was available for all (or most) districts in the country. The indicators used are presented in Annex 2. However, the weaknesses in using an index for vulnerability were identified as:

- "The creation of an index does not provide an objective benchmark to delineate the vulnerable from those who are not vulnerable; the cut-offs used to group the districts into the four vulnerability categories are subjective.
- The use of an index does not provide analytic leverage for understanding the underlying causes of vulnerability.
- Without any outcome variable for vulnerability, the relationship of the composite indicator to vulnerability can only be assumed. In addition, due to the low levels of correlation between the original indicators, creating a single index using PCA is problematic. Only 30% of the variation in the original data is captured in the index when using just the first principal component.
- A district level analysis can hide smaller pockets of higher or lower vulnerability to food insecurity".

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[6] Several composite indicators are known from the field of sustainable development: Human Development Index of the United Nations Development Programme, USAID) Food Emergency Warning Systems program, Food Security Index by Downing, Genuine Progress Indicator, State of the Future Index.

7 This section based on: Briguglio, Lino, *Head of the Economics Department at the University of Malta.* *http://www.ourplanet.com/imgversn/103/17_mea.htm*

[8] United Nations World Food Programme, Laos July 2005 Update

Cluster analysis using all eight principal components created in the principal component analysis as input was also applied in this study as an alternative analytical method. Districts were grouped based on the similarities of these components, creating categories of districts that were similar in their levels of the eight original indicators. The clusters' levels of the original eight indicators were compared to the national mean. The analysis found that

- "Strengths of this analysis:
  - The information in the original eight indicators is preserved.
  - Assumptions are not made in the analysis about the relationship of the indicators to vulnerability.
  - Information about each of the individual indicators for the clusters can aid in project design and geographic targeting.

- Weaknesses of this analysis:
  - Multiple clusters and lack of a simple two-dimensional indicator make interpretation more difficult.
  - Without any outcome variable indicating vulnerability to food insecurity, the relationship of the clusters to vulnerability must be assumed.
  - A district level analysis can hide smaller pockets of higher or lower vulnerability to food insecurity".

<u>Two methods of using principal component analysis</u>

Principal component analysis (PCA) is often used for creating weights for each variable. PCA is a technique for extracting from a set of variables those few orthogonal linear combinations of variables that most successfully capture the common information. The first principal component of a set of variables is defined as the linear index of all the variables that captures the largest amount of information common to all the variables.

Principal component regression (PCR) is a regression analysis that uses principal component analysis when estimating regression coefficients. It is a procedure used to overcome problems, which arise when the exploratory variables are close to being collinear. In PCR instead of regressing the independent variables (the regressors) on the dependent variable directly, the principal components of the independent variables are used. One typically only uses a subset of the principal components in the regression, making a kind of regularized estimation. Often the principal components with the highest variance are selected. However, the low-variance principal components may also be important, — in some cases even more important[9].

Ding and He [10] have found that the results of PCA and cluster analysis are very closely related: "A detailed analysis shows the close relationship between K-means clustering and principal component analysis (PCA) which is extensively utilized in unsupervised dimension reduction. We prove that the continuous solutions of the discrete K-means clustering membership indicators are the data projections on the principal directions (principal eigenvectors of the covariance matrix)".

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[9] Wikipedia

[10] Principal Component Analysis and Effective K-means Clustering by Chris Ding and Xiaofeng He Lawrence Berkeley National Laboratory University of California, Berkeley, CA 94720.

The above discussion of pros and cons of different methods to create indices will feed into the work during the next stage of the social assessment. It is clear that there will some trade-offs between information content and the clarity of the presentation of the findings.

The important considerations are that the methods are transparent, scientifically sound and acceptable to the countries.

3.3.1 GIS and geospatial analysis

The analysis of vulnerability must take explicit account of the spatial dimension of risks faced, both natural and man-made.

Neither the Lao District Vulnerability Analysis, nor the example from South Africa discussed in previous section, appear to include spatiality in their analysis, but basically just use the map to present the results of their statistical analysis.

Various GIS based techniques are being used to give a spatial representation of poverty and vulnerability, for example to climate change and to food security. Some recent very relevant examples and sources for geospatial analysis are:

- The Geography of Poverty and Inequality in the Lao PDR[11]
- Geospatial Flood Vulnerability in the Lower Mekong Basin[12]
- Lao PDR: WFP Vulnerability Analysis (142 Districts) (2003) and Lao PDR: WFP District Vulnerability Analysis, July 2005 Update.
- In Thailand a National Food Insecurity and Vulnerability Information and Mapping System (FIVIMS) was developed in 2004.
- In Cambodia a Poverty and Vulnerability Analysis Mapping was done in 2003[13].

The Geography of Poverty and Inequality in the Lao PDR atlas and report is probably the most methodologically advanced of the various spatial analyses of vulnerability and poverty that has been done in LMB. The report includes a substantial chapter on methodology, which is relevant for the social assessment.

Another relevant project is the Geospatial Flood Vulnerability in the LMB. However, the only information available at this time is a presentation in Powerpoint. The exact methods used for calculating the indices and transforming them to a GIS surface by rasterizing the values are not known. Regardless, this is an example of the GIS application that shows the advantages of using a similar approach (though not necessarily using rasterizing) for the social assessment. An excerpt is presented below.

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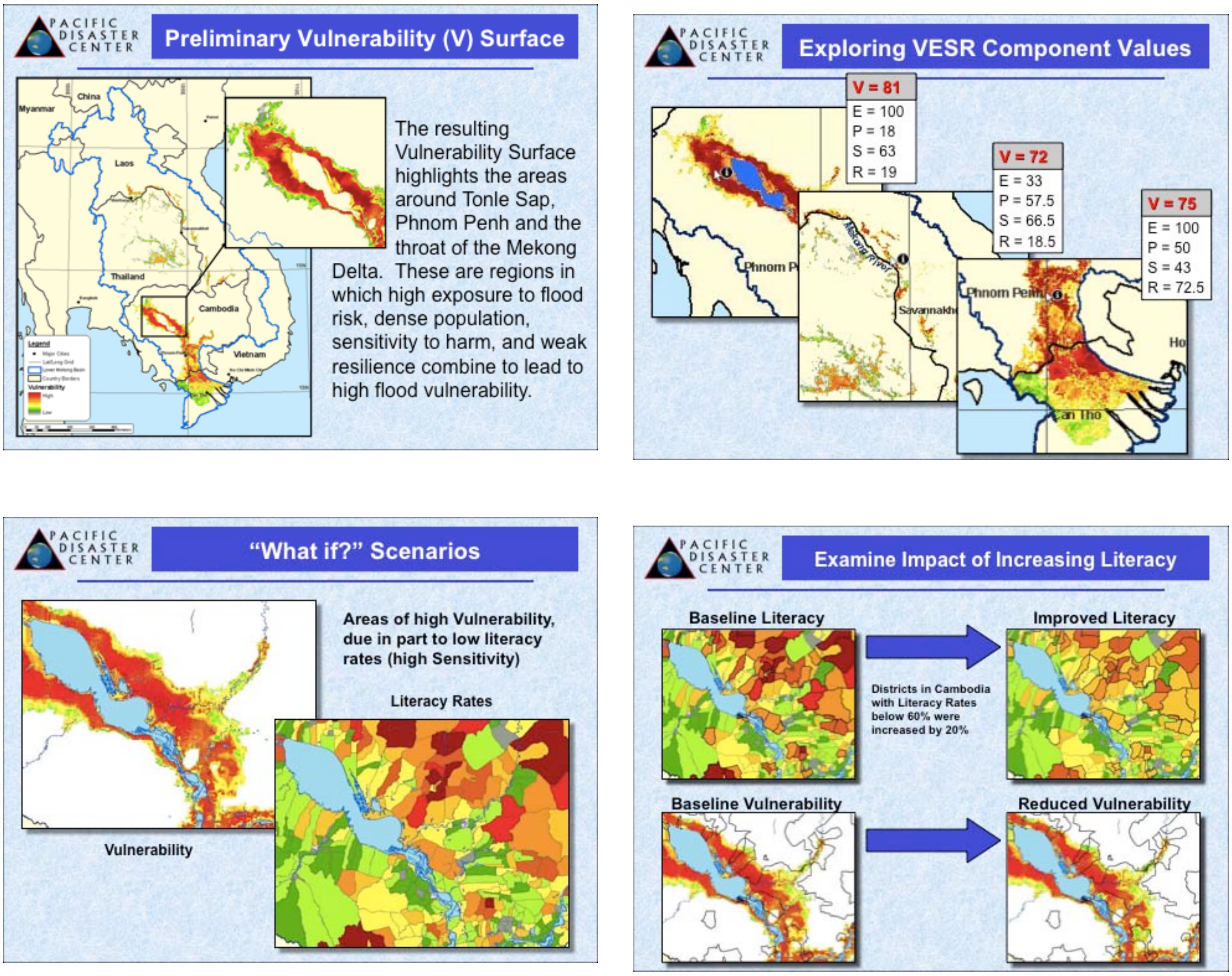
11 The Geography of Poverty and Inequality in the Lao PDR. Michael Epprecht, Nicholas Minot, Reno Dewina, Peter Messerli, Andreas Heinimann. Swiss National Centre of Competence in Research. (NCCR) North-South, Geographica Bernensia,, Berne, Switzerland. International Food Policy Research Institute (IFPRI), Washington DC, USA. 2008

12 Geospatial Flood Vulnerability in the Lower Mekong Basin, Chris Chiesa, Chief Information Officer and Pam Cowher, Sr. Geospatial Information Analyst. Pacific Disaster Center , Maui, Hawaii 96753. http://www.pdc.org

13 Poverty and Vulnerability Analysis Mapping in Cambodia. Mapping Poverty, Malnutrition, Educational Need, and Vulnerability to Natural Disasters in Cambodia. SUMMARY REPORT. Ministry of Planning, Royal Government of Cambodia. United Nations World Food Programme. March 2003

Figure 3 Example of GIS analysis of vulnerability

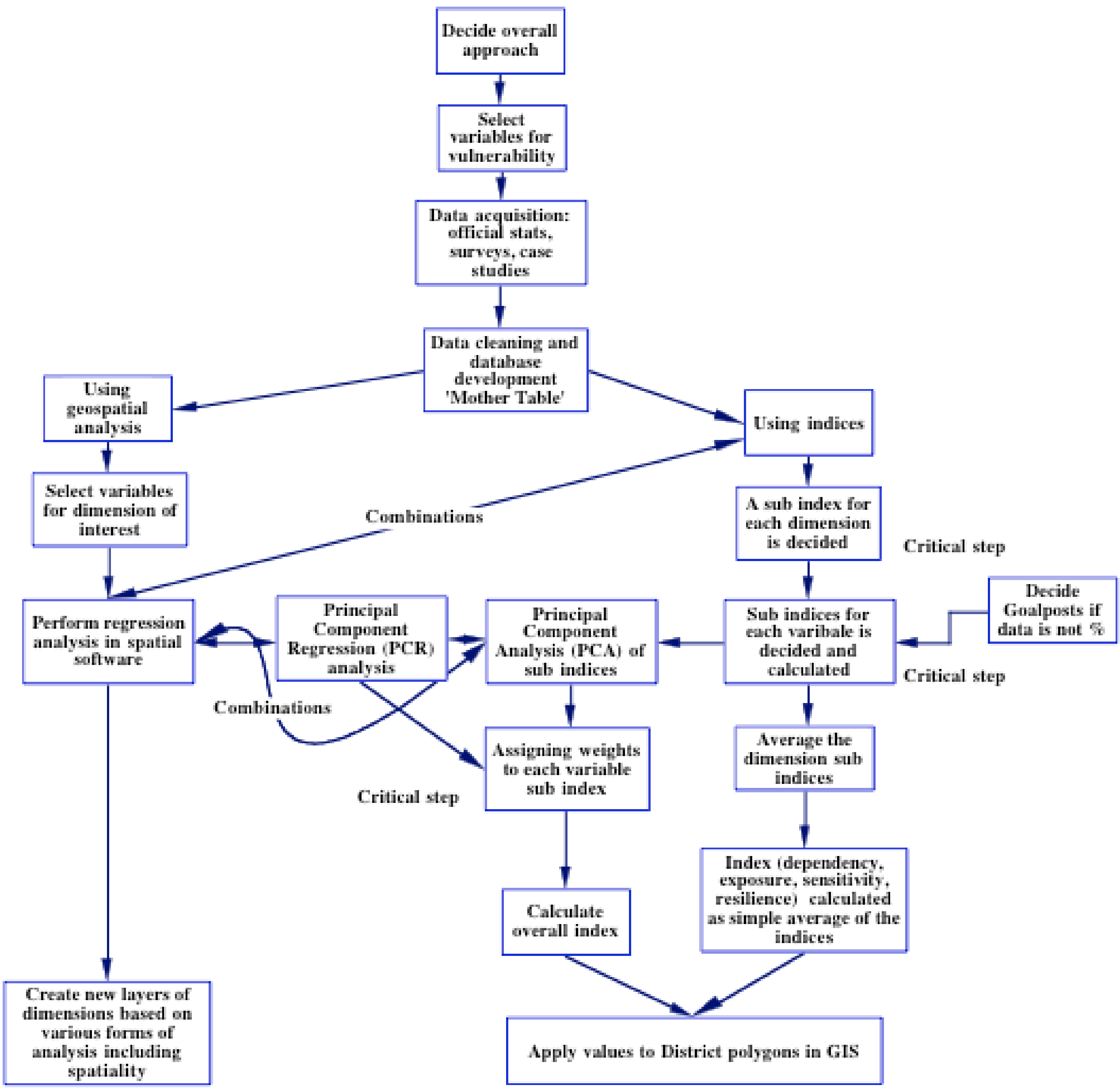


The four slides show different stages of the analysis: initial spatial vulnerability distribution, exploring the values of the different components making adjustments easy to do in a transparent manner, creating what-if scenarios by changing the values of the variables used for assessing vulnerability – exposure, sensitivity, and resilience.

The advantage of using the GIS is that simultaneous changes in several variables will show as one map. Using the GIS software's statistical capabilities, the number of people impacted in the various locations, and the severity of the impacts under different assumptions about their resilience can be calculated.

Figure 2 shows a flowchart of the process of analysis for the social assessment as discussed in this section.

Figure 4 Flowchart of the process of analysis (non-exhaustive)



3.4 Issues for social assessment of basin-wide development scenarios

The following important elements of scenario creation are relevant for the assessment:

Scenarios:

- Should never be confused with forecasts.
- Are plausible projections of the future given certain assumptions about the present, the potential course of events, and their interrelationships in the intervening period.
- Need to address all the major elements under consideration and the key uncertainties.

- Generally imply the requirement for a range of assumptions and outputs.
- Assumptions, component relationships and input values must be transparent to give confidence to the output.
- Output from scenarios must be effectively explained and communicated.
- Long-term scenario building should not just rely on extrapolation of current trends in a surprise-free linear fashion, but should be open for trend breaking and surprising, even improbable events.[14]

The social scenarios must include a number of assumptions regarding population and economic growth, poverty rates, structural economic change, urbanization, human development, dependency ratio and others. The assumptions will to the degree possible refer to linear projections of observed trends over the past years. However, the availability of data will determine how much can be done in this respect. Otherwise, clearly stated assumptions based on judgment will be made.

Time-scale and scenarios

The time dimension is equally important since social development processes moves on independently from changes in the river resources. Social development processes can in the longer-term very likely override the direct shorter-term impacts on people's livelihoods from dam construction, flood protection, and irrigation development.

Social processes in some areas of the region, e.g., in Vietnam, have moved at a fast pace in the last decade, with reduction in the poverty rate to well below 20 percent, and drastic increases in aquaculture in the Mekong Delta, to mention two relevant variables. In other parts of the basin social development has taken place at a slower rate. There are pockets of poverty and extensive areas where people's livelihoods to a very high degree depend on the quality and their access to natural aquatic resources.

Different approaches to creating sub-scenarios can be considered:

'Freezing' social development at baseline and super-impose the changes entailed in the hydrological scenarios and the assessed effects on fisheries, environment etc.

Apply various assumptions on social development attainment at specific times. This could yield the 22 possible scenarios shown in table 4.

The tabled possible scenarios assume linear growth on social development indicators, i.e. the variables for resilience, as the simplest method. But other assumptions could and should be presented in the scenarios.

For example, one assumption would be that the social impacts – negative and positive – of the various dams and interventions would not be linear. The negative impacts could perhaps be strongest in the first 5 years of e.g. the proposed mainstream dams in the lower parts of the basin, while positive impacts would gradually show over 10 years.

Once the data, the variables, and the GIS are put in place, changing a number of variables according to assumptions should not be difficult. Thus, in principle, many scenarios can be

14 Scenario-Building for Climate Change Policy Analysis, November-December 1996, IPIECA

created. However, analyzing and describing the effects of each change will be time consuming, and it is not found to be realistic to produce 22 scenarios. Therefore, the basic assumptions of the types of scenarios to include must be decided upon soon, and before mid-November.

Table 4 Possible types of social scenarios

No	**Development scenario**	**Time horizon**	**Primary interventions**	**Possible Social sub-scenarios**
1	Baseline scenario	Baseline (1985-'00)	Year 2000 infrastructure including existing HEP dams	1.1 Baseline
2	Chinese Dam scenario	Definite future over next 5-10 years	Baseline plus 6 existing, under construction and planned HEP dams in Upper Mekong Basin	2.1 Baseline
				2.2 Baseline + 5 years linear growth
3	Definite future scenario		CDS plus 25 additional HEP dams in LMB and updated flood measures in delta	3.1 Baseline
				3.2 Baseline + 10 years linear growth
4	Foreseeable future situation	Foreseeable future over next 20 years		
4.1	LMB 20-year plan scenario		DFS plus 11 LMB m/stream dams and planned tributary dams etc	4.1.1 Baseline
				4.1.2 Baseline + 10 years linear growth
				4.1.3 Baseline + 20 years linear growth
4.2	LMB 20-year plan scenario without mainstream dams		As above, excluding 11 LMB dams	4.2.1 Baseline
				4.2.2 Baseline + 10 years linear growth
				4.2.3 Baseline + 20 years linear growth
4.3	LMB 20-year plan scenario without mainstream dams in Middle and Lower LMB		As above plus 6 LMB dams in upper LMB	4.3.1 Baseline
				4.3.2 Baseline + 10 years linear growth
				4.3.3 Baseline + 20 years linear growth
5	Mekong delta flood management scenario	Baseline (1985-'00)	Baseline plus 6 different options for flood control in Cambodia and Viet Nam	5.1 Baseline
				5.2 Baseline + 5 years linear growth
6	LMB long-term development scenarios	Long term future over next 50 years	LMB 20-year scenario plus all feasible infrastructure developments in LMB	6.1 Baseline
				6.2 Baseline + 20 years linear growth
				6.3 Baseline + 50 years linear growth
7	LMB very high development scenarios		As above extended to full potential infrastructure developments	7.1 Baseline
				7.2 Baseline + 20 years linear growth
				7.3 Baseline + 50 years linear growth

4 Data requirements for Social assessment

The social effects are at the 'end' of the causal chain of causes and effects: the impacts of the dams and water resources development on aquatic resources, wetlands, fish, etc must be known before the impacts on livelihoods can be assessed. The social assessment of scenarios therefore depends on inputs especially from the fisheries and environment assessment teams: how much will the wild fish production decrease; how many wetlands will dry up; how much fish production can be expected from reservoirs etc.

Not only the impacts in terms of volumes of degradation of natural resources, but also the spatial extent of these impacts must be known to a reasonable degree to be able to calculate how many people will be affected.

Data from the Social Impact Monitoring and Vulnerability Assessment (SIMVA) carried out by the Environment program will be included. The data set has been acquired, however a closer look on the data and how to integrate them into the social assessment has not yet been possible. This will be done in November.

A number of issues related to social data must be highlighted: data for some relevant variables or for certain geographical areas will not be available; different methods of statistical compilation are applied across the countries; and errors in measurements of the variables must be taken into account. It is therefore important that descriptions all data sources are included.

A large number of reports on livelihoods, dependency and vulnerability is available. Many of these reports are case studies in a limited geographical area and with mostly qualitative data such as those being generated from participatory rural appraisal methods. Thus an important work for the social assessment team is to synthesize these reports, and to the degree possible extract quantitative data from them.

The data used will mainly be the ones in the original published reports. Analysis of available raw data will only be done to a limited extent if necessary, in order to elicit how the published results were arrived at.

All social data will be entered into a 'mother' table with Districts names as row identifiers. In some cases relevant data is available at commune and village level, and additional tables at these levels will be attached, aggregated for the mother table, and used for additional area specific analysis. This would be in areas where dam construction is planned, in ecological 'hot spot' areas, or along riverbanks where direct impacts on river gardens etc would be felt.

The indicators and variables will give a value for each District. A number of new data columns will be generated by various statistical analyses – primarily geospatial, cluster, and principal component analysis as discussed in section 3.3.

Table 5 presents a preliminary list of indicators and variables for the social assessment with comments on method of calculation and data sources.

Table 5 List of key indicators and variables

Indicator	**Variable**	**Method of calculation**	**Data generation needs**	**Available data sources**
Dependency on water and aquatic resources				
Part-time (subsistence) fishing households	% of the total population engaged in fisheries – Part-time (mainly subsistence)	% of households in Fisheries Surveys engaged in fishing and collection of OAAs extrapolated to non-survey Provinces based on similarity of characteristics: river systems and floodplains, main occupations, cultural/ethnic.	GIS - Combined cluster analysis rank	Fisheries Sector Reviews, Lao PDR, Vietnam, Thailand, MRC 2008; Luangprabang Fisheries Survey, AMFC/MRC and LARReC/NAFRI; Vientiane, 2000; Socio-economics of the fisheries of the lower Songkhram River Basin, northeast Thailand, MRC Technical Paper, No. 17, January 2008; The magnitude of capture fisheries and aquaculture in the Mekong Delta in Viet Nam. MRC Technical Paper No. XX, Mekong River Commission, Vientiane. XX pp. 2008; An Giang Fisheries Survey, AMFC/MRC and RIA 2;Vientiane, 2001
Full-time commercial fishing households	% of the total population engaged in fisheries – Full-time			
Collection of OAA	% of households engaged in collection of OAA			
Perceived importance of fisheries and collection of OAAs	% of households for which fisheries and collection of OAA is important/very important for subsistence	% of households in Fisheries Surveys for which fisheries and collection of OAAs are important/very important extrapolated to non-survey Provinces based on similarity of characteristic with regard to river systems and floodplains, main occupations, cultural/ethnic. Triangulation: Statistics on population in Agriculture/Farming	Yes – from fisheries surveys statistics	
Seasonality	To be determined. Possibly nos of months where fishing is main activity	of fishing – absence of alternative sources of income/activities during fishing season	Yes – from fisheries surveys statistics	

Wetlands	% of households dependent on wetlands	To be determined - if data is available	Yes – from environment assessment	Tra Vinh Fisheries Survey, AMFC/MRC/RIA2
Consumption of fish and OAA	% of total protein consumed/cap/year coming from fish and aquatic animals	Kg of fish and aquatic animals consumed/cap/year is available. Kg of other animal products is partly available, but with gaps. Need to convert Kg of fish/OAA to protein - divide by other protein sources	Consumption of animal products; Data on other protein sources	Consumption and the yield of fish and other aquatic animals from the Lower Mekong Basin. MRC Technical Paper No. 16, 2007
Aquatic products - NTFP	% of households using NFTP	Depends on the availability of data	Yes	Possibly official statistics from Thailand. Other countries not known at present.
Optional	% of household income coming from fisheries	% household income from fisheries		Statistical data from Mekong Delta available
Exposure				
Nos people directly impacted by changes in river flows and volumes	% District population within buffer zones of 5 and 10 km from rivers	Assumption: Location near to rivers and within floodplain and wetland areas implies direct exposure to changes in flows and volumes of water GIS delineation of areas overlaid on District polygons, with population data at lowest possible resolution gives % of population. Triangulation: Case Studies and reports	Yes - GIS based analysis – areas could be classified to belonging to a zone or socio-ecological area defined by hydro impacts/fish impacts/irrigation impacts. Location in areas with significant impacts (zone A, B. C etc)	GIS layers: wetlands, floodplains, irrigated areas, flood protection zones
Nos people directly impacted by construction activities	% Population in areas directly affected by dams			
Nos people directly impacted by changes in river flows and volumes	% Population in floodplain classified areas			
Nos people directly impacted by expansion of irrigation	% Population in areas with increased irrigation			
Nos people directly impacted by flood protection measures	% Population in areas with flood recession agriculture			
Nos people directly impacted by flood protection measures	% Population in flooding risks areas			

Nos people directly impacted by changes (sub-set of above)	% Fishing population in areas with assessed change in composition of migratory fish versus black fish and OAA resources	Areas will be difficult to calculate		
Sensitivity and resilience				
Level of dependency on aquatic resources	Value for District Dependency on river water and aquatic resources	A composite index value may be calculated for dependency	Yes, by GIS analysis	
Poverty rate	% of households below poverty line	% households below poverty line	Yes - to make data comparable	Statistical data from Census, social development assessment – data to be collected
Sensitivity to reduced fish stocks	% of household catches from migratory/non-migratory fish	1) Downscaling of estimate by the fisheries assessment team to fishery surveys catch data; 2) extrapolation from fishery surveys to provinces.	Yes – to be discussed with fisheries assessment	Input from fishery assessment
Food security	Depends on the way food security is measured in the various countries	E.g., for Laos food security analysis three categories are used for geographical areas: food security poor, borderline, acceptable	Yes - to make data comparable	Lao PDR: Comprehensive Food Security & Vulnerability Analysis, (CFSVA), Data collected in October-November 2006. WFP, EC Data from other countries to be identified Living Standards Surveys,
Public financial dependency	% income from fisheries	District, provincial budgets	Yes - to make data comparable	Data to be identified and collected
Access to health care	Number hospitals/schools/1000 people (or similar)	From official statistics	No	From official statistics

Access to markets and services	Average distance from or travel time to nearest District town	Should be obtained from existing data. If not available, this indicator may be omitted, though it can be calculated in GIS	No	From official statistics
Access to information	Literacy rate	From official statistics	No	From official statistics
Dependency ratio	Working-age adults to children and elderly	From official statistics	NO	From official statistics
Access to alternative livelihoods	% households with aquaculture (to be discussed)		Possibly extrapolation from surveys	Statistics from the Mekong Delta include this information. For other areas data needs to be obtained if available.
Other social and socio-economic variables – refer below list	Use % as much as possible		No	Census data, Living standard surveys, Agricultural census

4.1.1 Data acquisition

Acquisition of official statistical data will be done by the BDP office through contracts with the national statistical offices. The BDP Economist will supervise the work and ensure that data are delivered timely and in the format agreed upon. An outline of ToR for the contracts is found in Annex 3.

The general social data to be used for sensitivity and resilience assessment in baseline and various scenarios are listed in table 6. These data must be provided by District, with District and Province name in English.

Table 6 General social variables from official statistics

General demographics	Rural Population
	Urban population
	Child Population
	Youth Population
	Adult Population
	Elderly Population
	Population Growth rate (specify time)
	Population density
	Dependency Ratio
	Youth Dependency Ratio
	Household Size
	Female Household Heads %
	Sex Ratio - M/F
Migration	Internal migration - born in different District
	District net migration (immigrants minus emigrants) (specify time scale)
	Total migration (in-migration+ out-migration)
Ethnicity	Dominant Ethnicity
	Minority Population (%)
Occupations/economic activities	Labour Force Participation Rate
	Female Labour Force Participation
	Agricultural Employment (males/females)
	Fisheries employment (males/females)
	Industrial Employment (males/females)
	Services Employment (males/females)
	Unemployment (males/females)
	Unemployment Rate (males/females)
Employment status	Paid employee
	Employer
	Own account worker/Self-employed

	Labourer
	Unpaid family worker
Poverty	Poverty Rate
	Poverty Gap/Gini
	Average per capita expenditure
Access to services	Access to Safe Water (% of population)
	Access to Sanitation (% of population)
	Access to Electricity (% of population)
	Nos of doctors/1000 people
	Nos health facilities/1000 people
	Nos of markets
Health	Infant Mortality Rate
	Child Malnutrition
	Male Life Expectancy
	Female Life Expectancy
	Total Fertility Rate
	Malaria Incidence
	HIV Prevalence
Food security	Food security status
	(food security is a composite of a large number of variables)
Education	Primary Net Enrolment
	Primary Enrolment Gender Gap
	Primary Attainment
	Secondary Net Enrolment
	Lower Secondary Attainment
	Adult Literacy
	Male Literacy
	Female Literacy
	Male Activity Rate
Housing	% of population living in temporary house
	% of population living in semi-permanent house
	% of population living in permanent house
Agricultural census data	Average size of land-holdings (ha)
	Rice-fields (person/ha)
	Nos Fishponds
	Fishponds (person/nos)
	Production of fish from fishponds (Tons)
	Nos Fish cages
	Production of fish from cages (Tons)

Most of the above variables were included in the Social Atlas, 2004. However, the source data for this is more than 10 years old and need to be updated. The same data is available in Census reports, Household Living Standard and Socio-economic Surveys, Agricultural Census.

Though Living Standard Surveys most often are sampled by other geographical units than Districts, extrapolation to Districts will be done if possible, stating the uncertainties this operation will involve. This will be done as part of the contracts with the national stastitical offices.

Agricultural Census reports often include data on farmers' activities including fishing, and furthermore relevant data on land sizes etc., and will be used.

All statistical data should be acquired in softcopy (CD), with relevant database descriptions.

Trend analysis
Time scale data will be needed for trend analysis. It will probably require additional effort (and cost) to acquire time scale data on the official statistical data. To minimize this, the following data are considered the most important for trend analysis:

- Rural Population
- Urban population
- Population Growth rate (specify time)
- Population density
- Total migration (in-migration+ out-migration)
- Minority Population (%)
- Agricultural Employment (males/females)
- Fisheries employment (males/females)
- Industrial Employment (males/females)
- Services Employment (males/females)
- Unemployment (males/females)
- Poverty Rate
- Access to Safe Water (% of population)
- Access to Electricity (% of population)
- Infant Mortality Rate
- Life Expectancy
- Adult Literacy
- % of population living in permanent house
- Average size of land-holdings (ha)
- Rice-fields (person/ha)
- Nos Fishponds
- Fishponds (person/nos)
- Production of fish from fishponds (Tons)
- Nos Fish cages
- Production of fish from cages (Tons)

Data processing
It will be a big job to access, clean and organize the data into a consistent 'mother table' that can be directly used in GIS applications. How much time it will require depends on the quality of the data tables from the national statistical offices.

For data that needs to be extracted and extrapolated from surveys, case studies and other reports, it will take considerable time, and it requires a good understanding of data quality assessment and ability to screen a large number of reports for relevance and usability of the data for the methods of the social assessment.

It must be ensured that the professional input to do this is available in October and November, i.e., that the riparian consultants in the social team receive the necessary support from BDP to carry out this.

4.2 GIS layers and spatial information

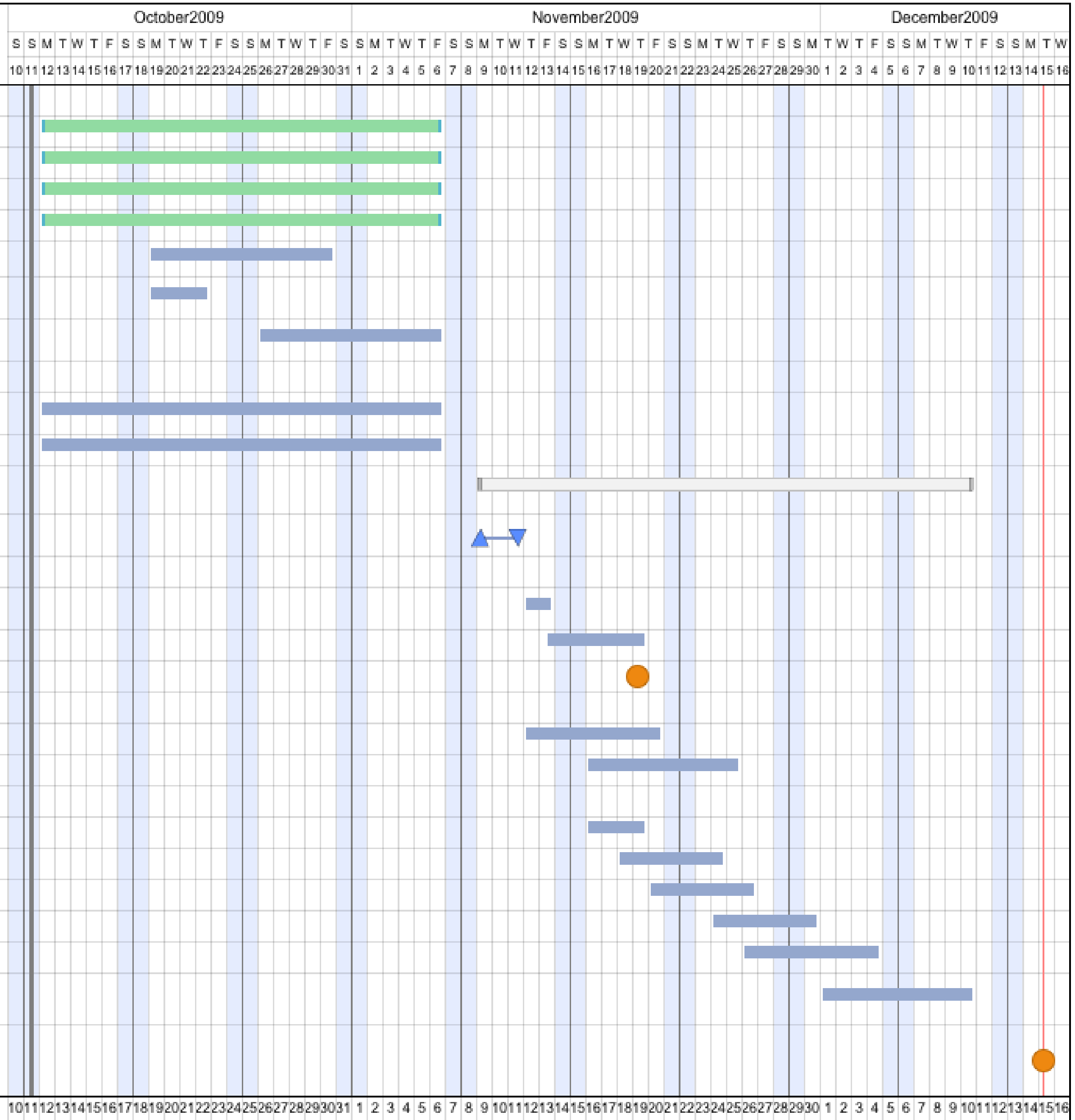
Since a substantial part of the social assessment of dependency and vulnerability will be based on GIS analysis, it is essential to have good and consistent GIS layers.

The following basic GIS layers are needed for the social assessment:

- Updated administrative boundaries, Commune, District and Province polygons (especially for Cambodia).
- A common set of District and Province names, with same spelling (in English) that all data tables must use.
- All towns, including information on town classification (according to size, number of services or whatever is used by the various countries) and population (with date). It would be very relevant to have information on growth rate, or population data from earlier years (1990, 1995, 2000, 2005).
- Mining activities – with information on type, size etc – what is available.
- Industries – type.
- Roads – all roads by class.
- Wetlands layer should be agreed upon.
- Floodplain classification.
- Flood recession rice classification.

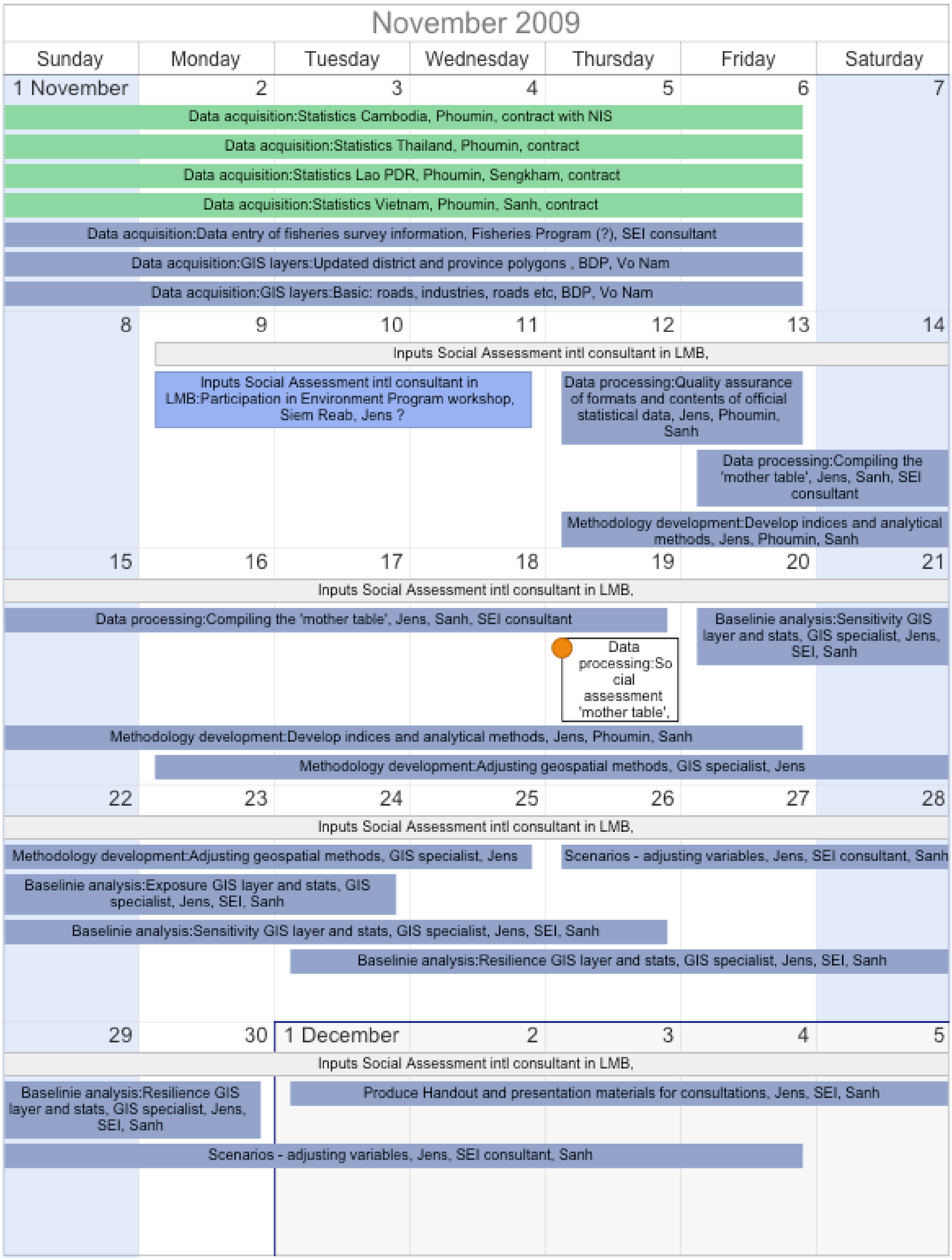
5 Work Plan for Social Assessment up to end 2009

Activity Name	Resources Assigned
Data acquisition	
Statistics Cambodia	Phoumin, contract with NIS
Statistics Thailand	Phoumin, contract
Statistics Lao PDR	Phoumin, Sengkham, contract
Statistics Vietnam	Phoumin, Sanh, contract
Fisheries and other statistics, Vietnam	Sanh
Data processing and entry of SIMVA data (by district)	to be decided
Data entry of fisheries survey information	Fisheries Program (?), SEI consultant
GIS layers	
Updated district and province polygons	BDP, Vo Nam
Basic: roads, industries, roads etc	BDP, Vo Nam
Inputs Social Assessment intl consultant in LMB	
Participation in Environment Program workshop, Siem Reab	Jens ?
Data processing	
Quality assurance of formats and contents of official statistical data	Jens, Phoumin, Sanh
Compiling the 'mother table'	Jens, Sanh, SEI consultant
Social assessment 'mother table'	
Methodology development	GIS specialist, Jens
Develop indices and analytical methods	Jens, Phoumin, Sanh
Adjusting geospatial methods	GIS specialist, Jens
Baselinie analysis	
Dependency GIS layer and stats	GIS specialist, Jens, Sanh, SEI
Exposure GIS layer and stats	GIS specialist, Jens, SEI, Sanh
Sensitivity GIS layer and stats	GIS specialist, Jens, SEI, Sanh
Resilience GIS layer and stats	GIS specialist, Jens, SEI, Sanh
Scenarios - adjusting variables	Jens, SEI consultant, Sanh
Produce Handout and presentation materials for consultations	Jens, SEI, Sanh
Interim results of social impact assessment including both quantitative and qualitative analysis	



October 2009

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
27	28	29	30	1 October	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
	Data acquisition:Statistics Cambodia, Phoumin, contract with NIS					
	Data acquisition:Statistics Thailand, Phoumin, contract					
	Data acquisition:Statistics Lao PDR, Phoumin, Sengkham, contract					
	Data acquisition:Statistics Vietnam, Phoumin, Sanh, contract					
	Data acquisition:GIS layers:Updated district and province polygons , BDP, Vo Nam					
	Data acquisition:GIS layers:Basic: roads, industries, roads etc, BDP, Vo Nam					
18	19	20	21	22	23	24
Data acquisition:Statistics Cambodia, Phoumin, contract with NIS						
Data acquisition:Statistics Thailand, Phoumin, contract						
Data acquisition:Statistics Lao PDR, Phoumin, Sengkham, contract						
Data acquisition:Statistics Vietnam, Phoumin, Sanh, contract						
	Data acquisition:Fisheries and other statistics, Vietnam,					
	Data acquisition:Data processing and entry of SIMVA data (by district), to be decided					
Data acquisition:GIS layers:Updated district and province polygons , BDP, Vo Nam						
25	26	27	28	29	30	31
Data acquisition:Statistics Cambodia, Phoumin, contract with NIS						
Data acquisition:Statistics Thailand, Phoumin, contract						
Data acquisition:Statistics Lao PDR, Phoumin, Sengkham, contract						
Data acquisition:Statistics Vietnam, Phoumin, Sanh, contract						
Data acquisition:Fisheries and other statistics, Vietnam,						
	Data acquisition:Data entry of fisheries survey information, Fisheries Program (?), SEI consultant					
Data acquisition:GIS layers:Updated district and province polygons , BDP, Vo Nam						


November 2009
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Data acquisition:Statistics Cambodia, Phoumin, contract with NIS
Data acquisition:Statistics Thailand, Phoumin, contract
Data acquisition:Statistics Lao PDR, Phoumin, Sengkham, contract
Data acquisition:Statistics Vietnam, Phoumin, Sanh, contract
Data acquisition:Data entry of fisheries survey information, Fisheries Program (?), SEI consultant
Data acquisition:GIS layers:Updated district and province polygons , BDP, Vo Nam
Data acquisition:GIS layers:Basic: roads, industries, roads etc, BDP, Vo Nam
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Inputs Social Assessment intl consultant in LMB,
Inputs Social Assessment intl consultant in LMB:Participation in Environment Program workshop, Siem Reab, Jens ?
Data processing:Quality assurance of formats and contents of official statistical data, Jens, Phoumin, Sanh
Data processing:Compiling the 'mother table', Jens, Sanh, SEI consultant
Methodology development:Develop indices and analytical methods, Jens, Phoumin, Sanh
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Inputs Social Assessment intl consultant in LMB,
Data processing:Compiling the 'mother table', Jens, Sanh, SEI consultant
Baselinie analysis:Sensitivity GIS layer and stats, GIS specialist, Jens, SEI, Sanh
Data processing:Social assessment 'mother table',
Methodology development:Develop indices and analytical methods, Jens, Phoumin, Sanh
Methodology development:Adjusting geospatial methods, GIS specialist, Jens
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Inputs Social Assessment intl consultant in LMB,
Methodology development:Adjusting geospatial methods, GIS specialist, Jens
Scenarios - adjusting variables, Jens, SEI consultant, Sanh
Baselinie analysis:Exposure GIS layer and stats, GIS specialist, Jens, SEI, Sanh
Baselinie analysis:Sensitivity GIS layer and stats, GIS specialist, Jens, SEI, Sanh
Baselinie analysis:Resilience GIS layer and stats, GIS specialist, Jens, SEI, Sanh
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1 December
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5
Inputs Social Assessment intl consultant in LMB,
Baselinie analysis:Resilience GIS layer and stats, GIS specialist, Jens, SEI, Sanh
Produce Handout and presentation materials for consultations, Jens, SEI, Sanh
Scenarios - adjusting variables, Jens, SEI consultant, Sanh

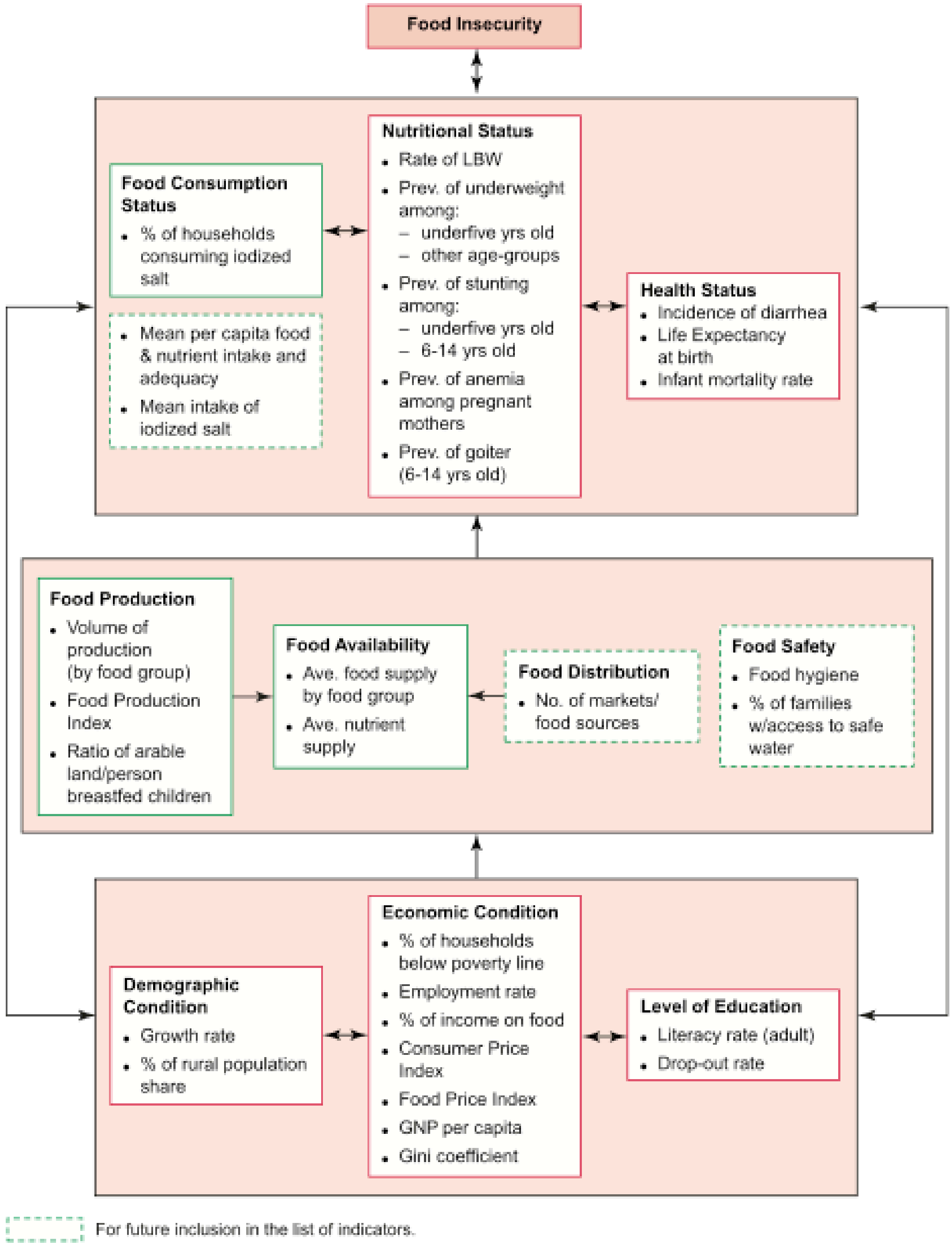
December 2009

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
29	30	1 December	2	3	4	5
Inputs Social Assessment intl consultant in LMB,						
Baselinie analysis:Resilience GIS layer and stats, GIS specialist, Jens, SEI, Sanh		Produce Handout and presentation materials for consultations, Jens, SEI, Sanh				
Scenarios - adjusting variables, Jens, SEI consultant, Sanh						
6	7	8	9	10	11	12
Inputs Social Assessment intl consultant in LMB,						
Produce Handout and presentation materials for consultations, Jens, SEI, Sanh						
13	14	15	16	17	18	19
		Interim results of social impact assessment including both quantitative and qualitative analysis,				
20	21	22	23	24	25	26
27	28	29	30	31	1 January	2

Annexes

Annex 1 Food security indicators used in Thailand

Figure 5 Food security indicators used in Thailand



Annex 2 Lao PDR District Vulnerability Analysis indicators

Indicator	Data source	Definition/Formula
Rice Production (wet season & dry season) per Capita	Agricultural Census 98/99, Provincial Rice Production Statistics 2000-2001	This indicator was calculated as: (Dry season planted area in ha * yield in t/ha + wet season planted area in ha * yield in t/ha) * 60% milling recovery rate from paddy to rice / population in 2003
Cropping Diversity (major crop classes)	Agricultural Census 98/99, Provincial Rice Production Statistics 2000-2001	Crop Diversity was derived from the main agricultural cropping classes in Laos, where the planted area in hectares of the individual crop classes were added to form the variable (in the absence of information on individual crop yields)
Livestock Ownership (cattle, buffaloes, pigs, chicken and ducks) per Household	Agricultural Census 98/99	This indicator was weighted and calculated as: Buffalo + Cattle + 0.75 * Pigs + 0.10 * Chicken & Ducks
Access to Forested Areas (and Non-Timber-Forest-Products) per Household (NTFP)	Mekong River Commission 97/98	In this analysis, forest cover classes 11 (Evergreen, high cover density) & 61 (Wood – shrub land, evergreen) were combined and an average value per village was extracted to represent village level access to forest
Access to Roads and Rivers (markets and services)	Department of Construction, Post, Transport and Communications, 2002	These indicators were first derived independently and then combined to form one indicator. Access = Roads + 0.5 * Rivers Roads: the distances to national and secondary roads were calculated for all villages and the final indicator was calculated as follows: Roads = Main Roads + 0.5 * Secondary Roads Rivers: the distances to all major rivers were calculated for all villages in Laos
Malaria Incidence	Center for Malariology, Parasitology and Entomology, 2002	This indicator was determined as the number of reported cases of malaria in 2002 divided by population.
Unexploded Ordnance (UXO) Impact	UXO Laos 2002	This indicator was calculated as level of impact (High = 8, Moderate = 4, Low = 2 and all other = 0) and then the indicator was converted into a continuous variable
Incidence of no or low Education	Population Census 1995	This indicator was calculated as the percent of household heads that have never been to school or finished Grade 1

Annex 3 Draft ToR data acquisition

Terms of Reference

For Statistical Data Acquisition for the Social Assessment of BDP2

Draft

Background

A social assessment of the baseline situation and development scenarios in the LMB will be carried out on District level based on official statistics on social and economic variables. The variables are grouped in four dimensions: dependency on river water and aquatic resources, exposure to impacts of water resources development, sensitivity to impacts from water resources development, and resilience to the negative impacts from these. The social assessment will also project social development processes and trends to future scenarios.

For this purpose statistical data on a number of variables is needed. A minimum set of data has been outlined, while other relevant variables will be identified and selected in a pragmatic way based on availability.

Tasks

The assignment will include, but not necessarily be limited to, the following task:

- Collect database descriptions of the most recent
  - Census
  - Living Standard and Expenditure Surveys/Household Economic Surveys
  - Agricultural Census
  - Other Social Census reports

- Collect the questionnaires, in English, for all the above, except the Census.
- If not available in the database descriptions, make a clear description of the variables.
- Collect information on sampling District locations of all surveys, except Census.
- After submission of the above, have discussions with and receive instructions from MRC on which variables will be extracted and provided.
- Extract and produce a dataset of the minimum statistical variables specified in the attached table 1.
- Extract and produce further datasets on selected variables according to instructions from MRC.
- Include details of the statistical uncertainty of the data as represented for each District

Outputs

The outputs will include

- A set of database descriptions and questionnaires for the most recent
  - Living Standard and Expenditure Surveys/Household Economic Surveys
  - Agricultural Census
  - Other Social Census reports

- Data tables in Excel format with the data listed in table 1, with the identifier fields as specified in the attached table 2.
- Description of the methods used for calculating the variables.
- Description of the year of the data.
- Description of locations of all surveys, sampling frame and size.
- Description of statistical uncertainty involved in variables for each District.

Timeframe

The assignment will be carried out between October 20 and November 10, 2009.

Final outputs must be submitted by November 10, 2009

Draft

Mekong River Commission

Basin Development Plan, Phase 2

Economic, environmental and social impact assessment of basin-wide water resources development scenarios

Assessment methodology

Annex 4
Economic assessment

October 2009

Economic, environmental and social impact assessment of basin-wide water resources development scenarios

Assessment methodology

Main report	Overview
Annex 1	Hydrological assessment
Annex 2	Environmental assessment
Annex 3	Social assessment
Annex 4	**Economic assessment**
Annex 5	Fisheries assessment

Contents amendment record

This report has been issued and amended as follows:

Issue	Revision	Description	Date	Signed
1	0	Draft to BDP team for comment	7 August 2009	JDR
1	1	Revised draft to BDP team	12 August 2009	JDR
2	2	Draft prepared for 2nd Regional Stakeholder Consultation and Dialogue of Basin Development Plan Programme, Phase 2	7 Oct 2009	

Contents

Tables

Figures

Glossary

ADB	Asian Development Bank
BDP	Basin Development Programme
BDP1	BDP Phase 1
BDP2	BDP Phase 2
CV	Contingent Valuation
DSF	Decision Support Framework
EP	Environment Programme
EPC	Engineering, Procurement and Construction
FMMP	Flood Management and Mitigation Programme
FP	Fisheries Programme
GIS	Geographical Information System
GW	Gigawatt = 1,000 MW
GWh	Gigawatt-hour = 1,000 MWh
HEP	Hydroelectric Power
HP	Hydropower Programme
IBFM	Integrated Basin Flow Management
IDC	Interest During Construction
IKMP	Information and Knowledge Management Programme
IWRM	Integrated Water Resources Management
IWT	Inland Water Transport
KW	Kilowatt
KWh	Kilowatt-hour
LMB	Lower Mekong Basin
MRC	Mekong River Commission
MRCS	Mekong River Commission Secretariat
MW	Megawatt = 1,000 KW
MWh	Megawatt-hour = 1,000 KWh
NMC	National Mekong Committee
NP	Navigation Programme
NP	Navigation Programme
NPV	Net Present Value
PIN	Project Identification Note
PDS	Project Description Sheet
PV	Present Value
RTWG	Regional Technical Working Group
SCF	Standard Conversion Factor
SEA	Strategic Environmental Assessment
TEV	Total Economic Value
ToR	Terms of Reference
UMB	Upper Mekong Basin
WB	World Bank
WUP	Water Utilisation Programme

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1 Introduction

1.1 Main purpose of report

This report is in draft for review and comments. Following receipt of comments, the report will be revised and then form part of the Methodology Statement for the BDP assessment of basin-wide development scenarios.

The main purpose this report is to provide guidance to the approach and methodology being adopted for the economic assessment of the basin-wide development scenarios under Phase 2 of the BDP Programme. The report will also provide a record of the analytical techniques used for future reference.

The background and the reasons for selecting these particular scenarios are set out in BDP2's earlier report[1], which has been subject to lengthy consultation with each country. The BDP report includes specification of the scenarios to be assessed, a preliminary overall assessment framework, identified key indicators and an overview of the expected information required for reporting the impacts of each scenario for comparison between scenarios and between countries.

In the preparation of the economic assessment methodology, the main tasks comprised:

- establishment a clear approach and analytical framework for the economic assessment;
- description of the analytical tools which will be used in the economic analyses of the various BDP development scenarios;
- review the existing reports and databases within MRCS to support the economic assessment;
- identification of data and information gaps;
- detailing of further data requirements including data sources and the technical experts responsible for providing the information; and
- specification of the tasks required for the economic assessment and prepare a work programme.

[1] Scoping and Planning of the Assessment of Basin-Wide Development Scenarios, Technical note v3.1, BDP2, March 2009

1.2 Report contents

Chapter 2 outlines the rationale for the economic assessment of the various development scenarios. The specific development objectives and their key economic indicators are then specified.

The proposed methodology for the economic assessment is described in Chapter 3. Firstly, the overall approach with respect to: (i) economic valuation, (ii) analytical methods, (iii) risks and uncertainties, (iv) distributional analysis and poverty impact, and (v) employment impact, is discussed. The detailed economic assessment methods are then described with respect to hydropower, irrigated agriculture, flood mitigation, navigation, fisheries, wetlands/biodiversity and riverbank erosion in the definite future, foreseeable future and long term future scenarios.

Chapter 4 details the data requirements for the economic assessment and this is divided into hydropower, irrigated agriculture, fisheries, navigation, wetlands, flood mitigation, saline intrusion and riverbank erosion. The data sources are specified together with the technical expert responsible for providing the information.

A work programme for the economic assessment is given Chapter 5 and this specifies the main tasks to be undertaken and the proposed schedule of work up to December 2009.

2 Development scenarios and key economic indicators

2.1 Rationale for assessment of basin-wide development scenarios

A basin development strategy needs to be based on an acceptable balance between the primary objectives of water resources development (namely sustainable economic growth and poverty reduction) and the conservation of the riverine ecology on which a high proportion of the population still depend on for their livelihoods.

An approach to this achieving this acceptable balance is to define an agreed “development space for water and related resources” within which the LMB countries can plan and implement water resources projects, taking into account the impact of foreseeable developments in the upper part of the basin. This approach also supports the 1995 Mekong Agreement which highlights the importance of: (i) maintaining agreed flows in the mainstream; (ii) equitable utilisation of water resources; and (iii) recognising sovereign and territorial integrity in the utilisation and conservation of the water resources.

In order to define the LMB “development space” in a way that is beneficial to all the LMB countries, as well as sustainable and practical to implement, the MRC will embarked on a basin-wide dialogue based on the results of a comprehensive assessment of various scenarios that represent different levels of water resource development in the LMB. Each scenario has been formulated to represent different combinations of development interventions that recognise the synergies and trade-offs between the different sectors.

The LMB development scenarios comprise: (i) baseline scenario, (ii) Chinese dam scenario, (iii) definite future scenario, (iv) foreseeable future 20 year plan scenario (with alternative perspectives for mainstream hydropower dams), (v) Mekong delta flood management scenario; and (vi) long term future 50 year development scenarios.

The LMB development scenarios are described in detail in the BDP Technical note v3.1: Scoping and Planning of the Assessment of Basin-Wide Development Scenarios, BDP2, March 2009. The time horizon and primary interventions for each development scenario are summarised in Table 2-1.

The main aim of the development scenario assessments is to provide the MRC member states with an analysis of alternative development strategies, particularly with respect to their economic, social and environmental impacts, in order to reach a consensus on the key decisions that will shape the future development and management of the water resources within the LMB.

Table 2-1 Basin-wide development scenarios

	Title	Time horizon	Runs 85-00	Runs CC	Interventions
1	**Baseline scenario**	Baseline (1985-'00)	1		Year 2000 infrastructure including existing HEP dams
2	**Upper Mekong Dam scenario** (UMDS)	Definite future over next 5-10 years	1		Baseline plus 6 existing, under construction and planned HEP dams in Upper Mekong Basin
3	**Definite future scenario** (DFS)		1		UMDS plus 25 additional HEP dams in LMB and updated flood measures in delta
	Foreseeable future situation (FSS)				
4	LMB 20-year plan scenario	Foreseeable future over next 20 years	1	1	DFS plus 11 LMB m/stream dams and planned tributary dams etc
5	LMB 20-year plan without mainstream dams		1		As above, excluding 11 LMB dams
6	LMB 20-year plan with 6 m/s dams in upper LMB		1		As above plus 6 LMB dams in upper LMB
	LMB 20-year plan with 9 m/s dams		1		As (5) excluding Ban Kum and Pakchom
7	**Mekong delta flood management scenario**	Baseline (1985-'00)	6		Baseline plus 6 different options for flood control in Cambodia and Viet Nam
	Long term future				
8	LMB long-term development scenarios	Long term future over next 50 years	1	1	LMB 20-year scenario plus all feasible infrastructure developments in LMB
9	LMB very high development scenarios		1	1	As above extended to full potential infrastructure developments
10	**Further scenarios**		2	1	To be determined by BDP assessment team
			17	**4**	

2.2 Development objectives and key economic indicators

With respect to the economic impact assessment, the specific development objectives which are directly linked to the national development objectives of the four riparian countries are given in Table 2-2.

The key economic indicators and their measurable units, which will be used in the assessment of the various development scenarios, were then identified for each development objective. The approach and methodologies used to evaluate the key economic indicators are discussed in Chapter 3, while the data sets and information required for this economic assessment are detailed in Chapter 4.

Table 2-2 Development objectives and key economic indicators

Development objectives	Key economic indicator	Unit
Increase irrigated agricultural production	Incremental area	'000 ha
	Incremental crop production	'000 ton
	Incremental net economic value of irrigated agriculture	US$ million
Increase hydropower production	Incremental installed capacity	MW
	Incremental power generated	GWh/year
	Incremental net economic value of hydropower	US$ million
Improved river transport	Incremental navigable days by class	'000 boat-days
	Incremental net economic value of river transport	US$ million
Decrease damages and losses due to floods	Average area flooded annually to max 0.5-0.9 m depth	'000 ha
	Average area flooded annually > max 0.9 m depth	'000 ha
	Incremental net economic value of flood mitigation	US$ million
Increase fisheries production and maintain productivity of capture fisheries	Incremental annual capture fish catch	'000 ton
	Incremental annual aquaculture production	'000 ton
	Incremental net economic value of fisheries	US$ million

In addition to evaluating the above key indicators, the economic assessment will also determine the incremental net economic values for a number of environmental indicators which are related to the following development objectives:

- Maintenance of wetland productivity and ecosystem services;
- Management of saline intrusion in the Mekong Delta;
- Minimise channel effects on riverbank erosion; and
- Conservation of biodiversity.

With respect to social development objectives, the economic assessment will also estimated the incremental employment opportunities created in the agriculture, fisheries, energy and navigation sectors which would be generated by the implementation of water resource development interventions, e.g. hydropower, irrigation and flood mitigation.

Finally, the distribution of the incremental net economic benefits between the riparian countries will also be assessed in order to determine whether the benefits and costs of the proposed development of water resources in the LMB will be equitably distributed.

3 Economic assessment of development scenarios

3.1 General approach to economic assessment

3.1.1 *Introduction*

The main purpose of the economic analyses is to determine the benefits and costs of the various BDP development scenarios from a broad, public perspective in order to assess whether the proposed investments will be able to generate adequate incremental net economic benefits per annum in the future. Furthermore, the contribution to economic growth and employment creation (jobs/livelihoods) within the four riparian countries, as well as the overall basin economy, which will be generated by the scenario interventions (e.g. hydropower, irrigation and flood mitigation) will also be assessed.

Conventional analytical methods, which have been well established by the major donor agencies (e.g. World Bank and ADB) over many years, will be used in the economic assessment. The quantitative analysis will be undertaken using a spreadsheet format (MS Excel) and will use the data sets assembled during the data collection exercise (see Chapter 4). The general approach to the economic analyses is outline below and the specific methodologies that will be used for the assessment of various development scenarios are discussed in Section 3.2.

3.1.2 *Economic Valuation*

The economic valuation of benefits and costs will generally adopt a conventional, opportunity cost approach for commodities with a direct use value (e.g. energy, crops and fish) as well as resources which have alternative uses, e.g. land, labour and capital. Market prices will therefore be adjusted to economic prices to reflect their opportunity cost within the overall basin economy. For example, economic prices for internationally traded goods (e.g. rice and fertilisers) will be derived from World Bank commodity price projections and adjusted for shipping, processing and transport/handling to determine the economic farm gate prices. Financial prices for goods and services not traded on the international market will be converted to economic prices by applying standard economic conversion factor derived for the LMB. These standard conversion factor (SCF) will be based on the SCFs used by national planning institutions and international funding agencies (e.g. ADB and World Bank).

Similarly, to reflect high levels of underemployment in the LMB, the economic value of rural labour (both family and hired labour) will be derived by applying a shadow wage rate factor to the prevailing financial price of labour.

In the derivation of economic capital and O&M costs of the proposed interventions, import duties and taxes will be omitted from the financial costs and standard conversion factors will then be applied to local costs. However, the financial cost of goods and services imported from outside the LMB region will remain unchanged.

For environmental benefits and losses related to changes in important ecosystems (such as wetlands), it is problematic to identify suitable opportunity cost values for a wide range of benefits, particularly indirect use, option and non-use benefits[2]. Consequently, alternative valuation methods will have to be used, e.g. contingent valuation (CV) and benefit transfer, using the Total Economic Value (TEV) framework[3] which incorporates direct, indirect, option and non-use values of ecosystem functions that do not have a market price.

3.1.3 Economic Analysis

For each development scenario, the economic analyses will be undertaken on an incremental (or marginal) basis by contrasting the annual net economic benefits in the "future with" and "future without" development situations projected over a 50 year period. The "future with" development situation will also include the capital and annual recurrent costs of the interventions/measures, e.g. hydropower, irrigation and flood mitigation. Incremental net economic benefit streams will then be derived for each development scenario over 50 years.

The "future without" situation represents the likely trend in the development of resources without the specific intervention. For example, without irrigation development, rainfed crop productivity is likely to increase with the adoption of improved crop varieties and better management techniques and this trend will need to be taken into account in the analysis. Similarly, without hydropower dams, there could still be a decline in capture fisheries production due to overfishing and this should also be included in the economic assessment.

By adopting this marginal analysis approach over a given time period, it will be possible to incorporate a number of trends in the analysis of both the "future with" and "future without" development situations with respect key determinants such as population growth, industrial/urban development, energy demand, crop productivity, crop diversification, capture/culture fisheries production and wetland biodiversity.

This analysis will also permit further assessment of environmental conservation and sustainability issues by exploring changes in relative economic values over time. For example, if capture fish stocks or wetland areas become increasingly scarce over time (and of greater importance to future generations), higher economic values can be assigned to capture fisheries and wetlands in the future relative to the value of energy or irrigated crops.

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[2] Wetland benefits: (i) direct use benefits include fishing, reed collection and recreation; (ii) indirect use benefits include flood mitigation, water storage and toxin reduction; (iii) option benefits relate the additional premium given wetlands for future use; and (iv) non-use benefits are intrinsic values derived from the existence of wetlands and often relate to cultural and/or spiritual values.

[3] The valuation of environmental benefits and losses using the TEV framework, with particular reference to wetland productivity, is given in "Methodologies and Sources for Valuation of Water Resources Demands in the Lower Mekong Basin", BDP Technical Paper, June 2005.

The estimation of annual benefits and costs over a 50 year time period also permits the scheduling of capital investment during the construction period as well as the phasing of annual net benefit streams in the "future with" development situations with respect to agriculture, fisheries, energy and navigation sectors.

Based on the annual incremental benefit and cost streams, net present values (NPVs) will then be estimated for each sector (e.g. agriculture, fisheries, navigation, energy and environment) as well as the development scenario as a whole, using an appropriate discount rate which reflects the overall opportunity cost of capital in the LMB. By using incremental net benefits streams and discounting techniques (which take account of the time value of money) to determine NPVs, the contribution of the proposed interventions to economic development within each sector will be evaluated for the various development scenarios.

This approach will significantly enhance the value of the economic assessment and will provide a greater insight into the relative economic benefits of the proposed development interventions in the context of medium and long term trends in key economic, social and environmental indicators within the LMB. Furthermore, the analysis will permit the distribution of the incremental net economic benefits between development sectors and between the four riparian countries.

It should, however, be noted that only direct economic benefits, such as increased energy and crop production, will be quantified. The wider, indirect benefits of the interventions to the economy through linkages with other sectors (e.g. industry and services) which could be induced by the proposed investment will not be included in the analysis.

3.1.4 Risks and Uncertainties

In order to take account of future risks and uncertainties, sensitivity analysis will also be undertaken with particular attention being given to an assessment of the likely consequences of: (i) not achieving the expected production benefits with respect energy and agriculture, (ii) increases in capital and recurrent costs required for various interventions and mitigation measures, and (iii) higher social costs and environmental losses.

3.1.5 Distribution Analysis

Poverty reduction and the equitable distribution of benefits are the broad aims of water resource development within the LMB. For each development scenario, a distributional analysis will therefore be undertaken in order to determine the likely distribution of incremental net economic benefits between the four riparian countries of Thailand, Viet Nam, Cambodia and Lao PDR. This distribution analysis will also show the overall division of the NPV of the incremental net economic benefits (discounted over 50 years) for each sector, e.g. energy, agriculture, fisheries, navigation and environment.

It can be expected that the incremental net benefits of the development scenarios will not be equally distributed among LMB countries. However, to aid discussion on the results of the scenario assessments, supporting information will be provided on: (i) present annual benefits of water resource use, and (ii) capital investment required by each country.

For the various development scenarios, the present annual net benefits of water resource use will also be evaluated by sector for each riparian country and this will then be compared incremental annual net economic benefits which will accrue to each country. This will clearly show the extent to which the different countries will benefit from the proposed interventions for each development scenario relative to their present level of water resource development.

In addition, the public and private capital investment required for the interventions in the foreseeable future 20 year plan scenario (with and without mainstream dams) will also be estimated for each development sector (i.e. energy, agriculture and fisheries) within the four riparian countries.

3.1.6 *Employment Impact*

Furthermore, the impact on employment (i.e. jobs/livelihoods created and lost) will also be estimated with respect to different sectors. For each development scenario, the estimation of the additional net employment generated will be determined by contrasting the "future with" and "future without" labour requirements in the agriculture, fisheries, navigation and energy sectors.

Information on labour requirements will be collected as part of the analysis of the key economic parameters, e.g. crop production costs, discussed in Section 3.2. The employment created by the construction and operation/maintenance of hydropower dams, irrigation projects and flood mitigation measures will also be estimated based on the labour component of the capital and recurrent costs.

3.2 Economic analysis of development scenarios

3.2.1 *Upper Basin Dams and Definite Future Scenarios*

The first scenarios comprise: (i) Chinese dams scenario: construction of hydropower dams in the Upper Mekong Basin (UMB), and (ii) Definite future scenario: UMB dams plus LMB hydropower dams (both existing and under construction since 2000) on the tributaries and irrigation development. The characteristics of the proposed hydropower dams in both UMB and LMB, together with the estimated expansion of the irrigated area within LMB, are outlined in Annex 1: Hydrological Assessment.

The economic assessment of the Chinese dam and definite future scenarios will focus on estimating the potential annual benefits from:

- hydropower development on the tributaries in the LMB;

- reduced flood losses and damage;
- reduced saline intrusion in the Mekong Delta;
- enhanced navigation and river transport (if significant); and
- fisheries development in LMB reservoirs.

To offset these benefits, the construction of hydropower dams and irrigation development will also have a number of adverse impacts such as:

- reduction in capture fisheries production as a consequence of the dams creating barriers to fish migration;
- increased riverbank erosion due to reduced river sedimentation during the wet season; and
- decline in the wetland areas resulting from a reduction in flooding.

The economic losses likely to arise from a decline in capture fisheries and reduction in wetland area, as well as riverbank erosion in the LMB, will therefore be evaluated.

(i) Hydropower production and alternative dam operation strategies

The economic assessment of the hydropower stations in LMB, which are either completed or under construction, will be primarily based on the benefit:cost analyses prepared for a wide range of the projects by the Hydropower Specialist[4]. In the economic analysis of the hydropower projects, dependable HEP capacity and annual power production have been estimated for each hydropower station. Capital requirements for development (i.e. EPC and IDC) of the hydropower stations and the transmissions lines have been calculated, as well as their respective operation and maintenance costs.

The annual economic benefits of the hydropower stations have also been estimated based on the costs of providing power from alternative thermal sources (i.e. diesel, natural gas and coal). The annual benefits comprise both direct energy benefits and capacity benefits (which contribute to the reliability of the electrical power system) and then adjusted by the trade impact (i.e. positive if exported and negative if imported).

Benefit:cost ratios were then calculated at a discount rate of 10% in order to assess the economic viability of the hydropower stations in terms of energy production. However, this analysis excluded economic losses related to capture fisheries (and loss of rural livelihoods), reduction in wetland areas and increased riverbank erosion, as well as potential benefits of an expansion of the irrigated area, improved flood control, enhanced navigation and reservoir fisheries. These

[4] "Hydropower Sector Review for the Joint Sector Planning Process" (draft), BDP, February 2009

other impacts of hydropower development will now be evaluated in the present economic assessment. Furthermore, the costs of resettling/compensating households displaced by reservoirs, as well as the costs of environmental mitigation measures, will also be estimated. The costs of resettlement will be based on the number of households to be displaced by each dam which is currently available in the hydropower database. These statistics will, however, be reviewed to ensure their reliability.

In addition, the economic benefits resulting from flood mitigation will also be assessed in relation to alternative dam operation strategies. This analysis will primarily focus on assessing the economic impact of different dam operation strategies with respect to flood risk reduction in the wet season. The alternative dam operation rules to be analysed will be determined by the Hydropower Specialist.

(ii) Reduced flood losses and damage

The annual economic benefits of mitigating floods during the wet season due to the improved regulation of river flows in the wet season, as a consequence of the UMB and LMB dams, will be evaluated. These benefits will primarily include lower crop losses as well as reduced damage to private property (i.e. households, businesses) and public infrastructure (i.e. roads, schools, health centres etc) within the LMB. In addition, the indirect benefits of mitigating flooding (e.g. lower income losses and reduced rescue/relocation costs) as well as the decline in the annual benefits of flooding (e.g. soil fertility and capture fisheries) will also be taken into account.

The area of land benefiting from flood risk reduction will be estimated from the assessment of hydrological changes resulting from the construction of the UMB and LMB dams. The location of specific areas directly benefiting from flood mitigation in terms of reduced flood damages will be mapped using the GIS database. Within areas where flooding risk has been reduced, information on the numbers of households and types of land use (i.e. crop production, forestry, lakes/ponds, settlements, infrastructure and wetlands) will be obtained from the GIS database.

The annual economic value of direct and indirect benefits of flood mitigation, as well as the reduction in the annual flood benefits, which have been estimated by FMMP-C2 as part of their study on flood damage and flood risk in focal areas of LMB (see FMMP-C2, Stage 1 Evaluation Report, 2008), will then be applied to population and land use data within each location in LMB benefiting from a reduction in flooding.

Alternatively, the economic value of the annual flood risk reduction could simply be based on existing data collected on damage and losses from historic flood events and then annualised over a number of years.

By contrasting the "future with" and "future without" annual net benefit streams within the areas benefiting from flood reduction, the incremental annual flood reduction benefits from the construction of UMB and LMB dams will then be derived over a 50 year period. The flood reduction benefit streams will then be used to estimate the NPV of incremental flood reduction benefits for each specific area and the LMB as a whole.

(iii) Reduced saline intrusion in Mekong Delta

The annual economic benefits of reducing saline intrusion, due to the increased river flows during the dry season, will also be evaluated. These benefits will include higher crop productivity and improved capture fisheries within areas in the Mekong Delta which currently experience saline intrusion.

The area of land that is likely to benefit from reduced saline intrusion will be based on the assessment of hydrological changes which will result from the construction of the UMB and LMB dams. The location of specific areas directly benefiting from reduced salinity should be mapped using the GIS database. Within areas where salinity is likely to been reduced, information on the types of land use (i.e. crop production, forest, lakes/ponds, settlements, infrastructure and wetlands) will also be obtained from the GIS database.

The annual economic value of crop benefits (based on information collected by FMMP-C2) will then be applied to crop patterns benefiting from a reduction in saline intrusion. The annual economic value of capture fisheries will be estimated by the Fisheries Specialist and Riparian Economist. By contrasting the “future with” and “future without” annual benefit streams within the areas benefiting from a reduction in salinity, the incremental annual benefits will then be derived over a 50 year period and this will then be used to estimate the NPV of salinity reduction benefits.

(iv) Enhanced navigation and river transport

If significant, the potential economic benefits for navigation and river transport due to an increase in the depth and duration of flooding (as a result improved regulation of river flows by the UMB and LMB dams) will also be assessed. These benefits mainly derive from an increase in the number of days per annum in which the river system is navigable due to an increase in the depth and duration of river flows during critical periods in the year.

However, a clear relationship between changes in river flows and the value of additional river transport is likely to be difficult to determine. It is generally the case that higher flows will facilitate the passing of larger boats, but it is not clear how total volumes (cargo and passengers) and unit costs might be altered as a result of changes in flow. There is also a lack of intra-country data on passenger numbers, cargo volumes and cargo values.

Nevertheless, it may be possible to focus on specific river reaches that have high potential for future growth and where some navigation studies have been undertaken. Based on the minimum safe draft requirements for different types of vessel and data from the hydrological assessment, experts from the navigation programme should be able to estimate number of days per annum when the river systems are navigable by river reach/zone for both the present situation and in the future when the UMB and LMB dams are operational.

The increase in the number of days of navigation will then be converted into an economic benefit by estimating the annual volume of inland water transport (IWT) cargo trade in both the “future with” and “future without” dams situations over a 50 year period for each river reach/zone. The economic value of the incremental IWT cargo trade will then be estimated by applying the net value (i.e. gross value less haulage costs) per tonne to the tonnage of incremental cargo over 50 years.

This analysis will therefore be undertaken to determine the overall "order of magnitude" changes in net economic values of river transport as a consequence of the different development scenarios. If these changes are significant, further research studies may be required to derive more accurate and reliable estimates of the net economic value of river transport.

In addition, mitigation measures may also be required to divert IWT vessels around the hydropower dams. The capital investment required to construct the civil infrastructure (canals and locks), as well as the annual costs of operating and maintaining the navigation system, will be estimated by the International Economist and Navigation Experts for various dams. These capital and O&M cost will then be deducted from the incremental benefit stream. The incremental net benefit stream will then be used to estimate the NPV of incremental navigation benefits for each river reach/zone and the LMB as a whole.

(v) Development of reservoir fisheries

The hydropower reservoirs created in the LMB would provide an opportunity to develop both capture and culture fisheries. Within the proposed reservoirs, the annual production of fish will be estimated by the Fisheries Specialist and the phasing of reservoir fisheries development over a 20 year period will also be undertaken.

With regard to economic valuation, current market prices will be used adjusted by an economic conversion factor. Production and marketing costs will also be determined and these data will be then be used to estimate of annual net economic value of reservoir fish resources in the present and future situations. The economic NPV of reservoir fisheries production over a 50 year period will then be calculated.

(vi) Decline in capture fisheries

The annual economic losses associated with a decline in capture fisheries which can be directly related the construction of LMB dams will also be evaluated. The annual economic losses of capture fisheries will comprise the direct losses in terms of the decline in the net value of capture fisheries output that is likely to result from a barrier to fish migration (both downstream and upstream) as a consequence of both directly killing fish passing through the HEP turbines and stopping the migration of certain fish species to their breeding, spawning and feeding grounds. Changes in water levels in both the wet and dry seasons will also have an adverse impact on capture fisheries and this will be taken into account in the economic valuation of fish losses.

The expected loss of the annual capture fisheries catch will be estimated by the Fisheries Specialist. The type of fish species/guilds that will be affected will also be specified. Annual net economic values per ton will then be calculated for a number of zones/river reaches. Based on these data sets, annual net economic values will be estimated for the present, "future without" and "future with" development situations in order to determine the incremental economic value of fisheries losses over 50 years and the respective NPVs for each riparian country and the LMB as a whole.

(vii) Reduction of wetland areas and biodiversity

The economic losses associated with a reduction in wetland areas, as well as their composition in terms of biodiversity of ecosystems, which can be directly related to lower river flows in the wet season due to the construction of dams and other interventions, will be evaluated. The area of wetlands expected to be lost and the annual rate of decline will be estimated by the Environmental Specialists. The types of wetland likely to be affected and the location of specific wetland areas which are likely to be lost should also be mapped using the GIS.

The annual economic value of wetland areas likely to be lost at each location over a 30 year period will be estimated by applying unit values to different wetland types. The valuation of different types of wetlands will primarily be based on the wetland valuation study being conducted by the Environment Programme (EP). This recent study includes a wide range wetland types and covers the valuation of a number of wetland functions such as flood control, shoreline protection, groundwater recharge, water purification and biodiversity conservation. The Environmentalists in the scenario assessment team will also assist with the wetland valuation exercise based on an analysis of wetland values throughout South East Asia.

Furthermore, within the LMB, a number of wetland valuation studies have also been undertaken in recent years. For example, at That Luang Marsh (on the outskirts of Vientiane), some of the marsh has been converted to rice and vegetable cultivation and the remainder is covered with permanent and seasonal aquaculture ponds, shrub/grasslands and peat land. The marsh provides three major ecosystem functions that indirectly benefit the Vientiane population. These include flood control, domestic wastewater purification, and water storage/supply for irrigated agriculture outside the marsh area. The value of flood control can be measured by the annual value of flood damages avoided as a result of the regulatory function of the marsh. The economic value of sanitation and wastewater purification services provided can be measured by the cost of replacing these functions with engineered solutions. Lastly, the value of water storage for dry season irrigation of land can be measured by the incremental net value of irrigated rice production.

The economic value determined for these wetlands can then be used as a guide to the valuation of wetlands affected by the different development scenarios, i.e. benefit transfer valuation.

By contrasting the "future with" and "future without" annual value of wetland areas, the incremental annual wetland losses from the construction of UMB and LMB dams will then be derived over a 50 year period. The wetland loss streams will then be used to estimate the NPV of incremental wetland losses for each specific area and the LMB as a whole.

It should, however, be noted that protected areas with high environmental value, e.g. Ramsar sites and world heritage sites, would not be adversely affected as appropriate mitigation measures would be include in the development costs.

(viii) Increased riverbank erosion

The economic losses associated with increased riverbank erosion (such as loss of agricultural land and infrastructure) which can be directly related the construction of UMB and LMB dams through a reduction in sediment transport in the river systems will also be evaluated. The annual economic losses of riverbank erosion during the wet season will include both direct losses (e.g. agricultural land, forest, private property and public infrastructure) as well as indirect losses (e.g. costs of relocation and resettlement) within the LMB.

The area of land expected to be lost to riverbank erosion and the rate of erosion will be estimated by the Geo-morphologist. The location of specific areas which are likely to be eroded will also be mapped using the GIS.

Within areas vulnerable to erosion, information on the numbers of households and types of assets (e.g. land, houses, shops, schools, health centres, roads etc) which could be lost would be obtained from the GIS database and maps. The annual economic value of assets likely to be lost at each location over a 30 year period will be estimated by applying unit values to a wide range of assets. For different types of land use (i.e. agriculture, forest, wetlands etc), the present value (PV) of annual benefits over 50 years will be used, while replacement cost estimates will be used to value buildings and infrastructure.

With regard to indirect economic losses, the relocation and resettlement costs will be based on the unit costs of transporting goods and equipment from the houses, businesses and public facilities which are vulnerable to riverbank erosion.

By contrasting the "future with" and "future without" annual losses within the areas vulnerable to erosion, the incremental annual riverbank erosion losses from the construction of UMB and LMB dams will then be derived over a 50 year period. The annual loss streams will then be used to estimate the NPV of incremental riverbank erosion losses for each specific area and the LMB as a whole.

3.2.2 *Foreseeable Future Scenarios*

The foreseeable future scenarios comprise: (i) LMB 20 year plan scenario: definite future scenario plus planned water resource development including hydropower dams in LMB (mainstream and tributary) and irrigation development; (ii) LMB 20 year plan without mainstream hydropower dams; and (iii) LMB 20 year plan without mainstream hydropower dams in the lower LMB.

The characteristics of the proposed hydropower dams (both mainstream and tributary dams), together with the estimated expansion of the irrigated area within LMB and the options for flood management in the Mekong Delta, are outlined in Annex 1: Hydrological Assessment.

The economic assessment of the foreseeable future scenarios will focus on estimating the potential annual benefits from:

- hydropower development on the mainstream and tributaries in the LMB;
- planned expansion of irrigated area in NE Thailand, Lao PDR, Cambodia and Viet Nam;
- reduced flood losses and damage in the LMB;
- reduced saline intrusion in Mekong Delta;
- enhanced navigation and river transport (if significant); and
- fisheries development in LMB reservoirs.

However, the construction of hydropower dams and irrigation development will also have a number of adverse impacts which will also be evaluated in terms of economic losses. These adverse impacts include:

- significant decline in capture fisheries as a result of dam construction, particularly mainstream dams;
- increased riverbank erosion due to reduced river sedimentation; and
- decline in the wetland areas resulting from a reduction in flooding.

(i) Hydropower production

The economic assessment of the hydropower stations in LMB, which have been either been completed or are under construction plus the projects planned for implementation over the next 20 years, will be based on the benefit:cost analyses prepared for a wide range of hydropower projects by the Hydropower Specialist, as previous discussed under Section 3.2.1: Definite Future Scenario.

In order to clearly identify the benefits and costs associated with the construction of mainstream dams, the assessment of the foreseeable future scenario will evaluate alternative options with respect to hydropower development in the LMB. These options include: (i) full development (existing and planned), (ii) LMB tributary dams only, i.e. without mainstream dams; (iii) LMB tributary dams plus mainstream dams in upper LMB, i.e. without mainstream dams in the middle and lower LMB. For the various alternative options, the incremental levels of installed

HEP capacity and annual power generated, as well as the incremental net economic value of hydropower development, will be determined. The phasing of hydropower development will also be undertaken and this will include the number, type and location of dams which could be constructed over a 20 year period.

Although the economic analysis of individual hydropower stations in terms of the costs and benefits of energy production has been undertaken, this analysis excluded economic losses related to capture fisheries, reduction in wetland areas and increased riverbank erosion, as well as potential benefits of an expansion of the irrigated area, improved flood control, enhanced navigation and reservoir fisheries. These wider consequences of hydropower development will now be evaluated in the present economic assessment. Furthermore, the costs of resettling/compensating households displaced by reservoirs, as well as the costs of environmental mitigation measures, will also be estimated. Other mitigation measures such as the construction of re-regulation dams to reduce fluctuations in downstream flows will also be considered.

In addition, the economic benefits resulting from flood mitigation and irrigation development will also be assessed in relation to alternative dam operation strategies. This analysis will primarily focus on assessing the economic impact of different dam operation strategies with respect to flood risk reduction in the wet season as well as the water availability for irrigation development in dry season. The alternative dam operation rules to be analysed will be determined by the Hydropower Specialist.

(ii) Expansion of irrigated area

The expansion in the area of irrigated land in NE Thailand, Lao PDR, Cambodia and Viet Nam will be made possible by an increased supply of water during the dry season made available by increased storage capacity in the hydropower reservoirs. The irrigated area will be estimated from the BDP irrigation database and the location of the present and future irrigated areas will be mapped following the integration of the irrigation database into the GIS. The hydrological assessment will also determine whether sufficient water will be available for the planned expansion of the irrigated area. The diversion of river flows for irrigation could include pump transfer schemes.

The phasing of the irrigation development will also be undertaken and this will include planned areas within LMB that could be developed over a 20 year period. This phasing of future irrigated area will also take account of the likely development constraints such as the capital investment required from government and the availability of labour.

Within the proposed irrigated areas, cropping patterns (both rain fed and irrigated) will be derived for the present, “future with” and “future without” development situations. These cropping patterns (i.e. proportion of area under each crop in both the wet and dry season) will be derived by the Irrigation Agronomist based on existing cropping pattern data which are available in the irrigation database.

To estimate economic crop benefits per hectare for rice and non-rice crops under both irrigated and rain fed conditions, the following information will be needed: (i) present and future crop yields, (ii) seed, fertiliser and pesticide usage by crop, (iii) labour and machinery requirements by crop, and (iv) economic prices of crop outputs, inputs, labour, machinery and transport.

Following the collection of these data sets, annual crop budgets will be prepared for each crop type in the present, "future without" and "future with" situations. A crop budget will comprise the value of production per hectare (average crop yield multiplied by economic output price) less production costs per hectare (seeds, fertilisers, pesticides, labour, machinery and transport requirements multiplied by the respective economic input prices, wage rates and hire charges) in order to determine the annual economic benefits per hectare for each crop.

Annual crop benefits per hectare will then be derived for a range of rice and non-rice crops at various locations within NE Thailand, Lao PDR, Cambodia and Viet Nam benefiting from a planned expansion of the irrigated area. The annual crop benefits per hectare will then be applied to the respective crop areas within each of the rain fed and irrigated cropping patterns. In addition, the possibility of expanding rice-fish systems within irrigated areas will also be considered.

By contrasting the "future with" and "future without" annual net benefit streams for a combination of cropping patterns, the incremental annual crop benefits from a phased expansion of the irrigated area will then be derived over a 50 year period. The crop benefit streams will then be used to estimate the NPV of incremental crop benefits for the planned irrigation development areas within LMB.

The capital investment required to construct the irrigation/drainage infrastructure and to install the irrigation equipment (including water transfer schemes), as well as the annual costs of operating and maintaining the irrigation/drainage systems, will be estimated by the Economist and Water Resources Planner for different types of irrigation schemes. This will be based on data available from the irrigation database and irrigation project reports. The NPV of the capital and recurrent cost stream over a 50 year period will then be estimated for the planned development areas.

(iii) Reduced flood losses and damage in LMB

The annual economic benefits of reducing floods during the wet season due to the improved regulation of river flows in the LMB will also be evaluated. Furthermore, the alternative dam options (e.g. with and without mainstream dams) will result in different rivers flows and flooding regimes. Consequently, the impact on the economic benefits of flood reduction, which will result from the alternative mainstream dam options, will also be assessed.

The area of land benefiting from flood risk reduction in the LMB will be estimated from the assessment of hydrological changes resulting from the construction of the LMB dams. The location of specific areas directly benefiting from reduced flooding should be mapped using the

GIS database. Within areas where flood risk has been reduced, information on the numbers of households and types of land use will be obtained from the GIS database.

The annual economic value of direct and indirect benefits of flood mitigation, as well as the reduction in the annual flood benefits, will be derived from the FMMP-C2 study on flood damage and flood risk in focal areas. These values will then be applied to population and land use data within other locations of LMB benefiting from a reduction in flooding. Alternatively, the economic value of the annual flood risk reduction could simply be based on existing data collected on damage and losses from historic flood events and then annualised over a number of years.

The incremental annual benefits from flood mitigation will then be derived over a 50 year period by contrasting the "future with" and "future without" annual net benefit streams within the areas benefiting from flood mitigation. The flood reduction benefit streams will then be used to estimate the NPV of incremental flood reduction benefits for different parts of the LMB.

(iv) Reduced saline intrusion in Mekong Delta

The annual economic benefits of reducing saline intrusion, due to the increased river flows during the dry season, will also be evaluated. These benefits will include higher crop productivity and improved capture fisheries within areas in the Mekong Delta which currently experience saline intrusion.

The area of land that is likely to benefit from reduced saline intrusion will be based on the assessment of hydrological changes which will result from the construction of mainstream and tributary dams in the LMB. The location of specific areas directly benefiting from reduced salinity should be mapped using the GIS database. Within areas where salinity is likely to been reduced, information on the types of land use will also be obtained from the GIS database.

The annual economic value of crop benefits (based on information collected by FMMP-C2) will be applied to crop patterns benefiting from a reduction in saline intrusion. The annual economic value of capture fisheries will be estimated by the Fisheries Specialist and Riparian Economist. By contrasting the "future with" and "future without" annual benefit streams within the areas benefiting from a reduction in salinity, the incremental annual salinity reduction benefits will then be derived over a 50 year period and this will then be used to estimate the NPV of salinity reduction benefits .

(v) Enhanced navigation and river transport

If significant, the potential economic benefits for navigation and river transport due to an increase in the depth and duration of flooding during the wet season will also be assessed. These benefits mainly derive from an increase in the number of days per annum in which the river system is navigable due to an increase in the depth and duration of river flows during critical periods in the year. This increase in the navigable days will be due to the improved regulation of river flows by the existing and planned LMB dams.

The methodology used to estimate the NPV of incremental navigation benefits for each river reach/zone and the LMB as a whole will be the same as that being applied to the navigation assessment in the Definite Future Scenario and will include both the economic value of the incremental IWT cargo trade and mitigation measures (i.e. canals and locks) that may be required to divert IWT vessels around the hydropower dams.

(vi) Development of reservoir fisheries

The hydropower reservoirs created in the LMB would provide an opportunity to develop both capture and culture fisheries. Within the proposed reservoirs, the annual production of fish will be estimated by the Fisheries Specialist and the phasing of reservoir fisheries development over a 20 year period will also be undertaken.

With regard economic valuation, current market prices will be used adjusted by an economic conversion factor. Production and marketing costs will also be determined and these data will be then be used to estimate of annual net economic value of reservoir fish resources in the present and future situations. The economic NPV of reservoir fisheries production over a 50 year period will then be calculated.

(vii) Decline in capture fisheries production

The annual economic losses associated with a decline in capture fisheries which can be directly related the construction of dams on both the mainstream and tributaries within LMB will also be evaluated. For the various alternative options under the foreseeable future scenario, e.g. with or without mainstream dams, the annual economic losses of capture fisheries will comprise the direct losses in terms of the decline in the net value of capture fisheries output that is likely to result from a barrier to fish migration (both downstream and upstream) as a consequence of both directly killing fish passing through the HEP turbines and stopping the migration of certain fish species to their breeding, spawning and feeding grounds. Mainstream dams will have a significant impact on capture fisheries, so greater emphasis will be given to assessing the likely decline in capture fisheries production due to the construction of mainstream dams.

The expected loss of the annual capture fisheries catch will be estimated by the Fisheries Specialist. The locations which are likely to experience a reduction in fish production will also be mapped using the GIS. The type of fish species/guilds that will be affected will also be specified.

Although estimating the annual decline in capture fishery production in the LMB is likely to be problematic, information from a number of Fisheries Programme (FP) studies (including the modelling of the impact of hydropower stations on different types of fish guilds) will provide some indication of likely decline in yields of various types of fish guilds. In addition to estimating the present and future capture fisheries catch with hydropower development, it is also important to estimate the likely trend in capture fisheries production without the hydropower dams which will result from changes in market demand (due to population growth and increasing incomes) as well as issues relating to the sustainability of capture fishing. An estimate of the incremental capture fisheries losses over a 50 year period will then be estimated.

Some data relating to fish market prices, fishing costs (i.e. boats, fishing gear and labour) and marketing costs/margins are currently available in FP reports and other relevant reports. These data will therefore be used to provide an estimate of annual net economic value of the capture fish resources in present and future (with hydropower dams) situations. However, to expand and update the existing data sets, further market price and production/marketing cost data will be gathered by the Riparian Economist. Annual net economic values per ton will then be calculated for a number of zones/river reaches but, it should be noted, that the market prices and fishing costs will vary considerably among the different types of fish species/guilds as well as by location.

Based on these data sets, annual net economic values will be estimated for the present, "future without" and "future with" development situations in order to determine the incremental economic value of fisheries losses over 50 years and the respective NPVs for different parts of the LMB.

(viii) Reduction of wetland area and biodiversity

The economic losses associated with a reduction in wetland areas (as well as the composition in terms of biodiversity of ecosystems) which can be directly related to lower river flows in the wet season due to upstream dam construction, will be evaluated. For the alternative options under the foreseeable future scenarios, the area of wetlands expected to be lost over the foreseeable future and the annual rate of decline will be estimated by the Environmental Specialists. The types of wetland likely to be affected, and the location of specific wetland areas which are likely to be lost, will also be mapped using the GIS. With regard to mainstream dams, riverside gardens in areas vulnerable to inundation due to the construction of dams will also be included in the assessment.

The annual economic value of wetland areas likely to be lost at each location will be estimated by applying unit values to different wetland types. The wetland valuation procedure will follow the methodology outlined under the definite future scenario.

By contrasting the "future with" and "future without" annual value of wetland areas, the incremental annual wetland losses from the construction of dams under the alternative options, e.g. with and without mainstream dams, will then be derived over a 50 year period. The wetland loss streams will then be used to estimate the NPV of incremental wetland losses for each specific area and the LMB as a whole.

It should, however, be noted that protected areas with high environmental value, e.g. Ramsar sites and world heritage sites, would not be adversely affected as appropriate mitigation measures would be include in the development costs.

(ix) Increased riverbank erosion

The economic losses associated with increased riverbank erosion (such as loss of agricultural land and infrastructure) which can be directly related the construction of mainstream and tributary dams through a reduction in sediment transport in the river systems will also be evaluated. The annual economic losses of riverbank erosion during the wet season will include both direct and indirect losses within the LMB.

The area of land expected to be lost to riverbank erosion and the annual rate of erosion will be estimated by the Geo-morphologist. The location of specific areas which are likely to be eroded will also be mapped using the GIS. The methodology used to determine the annual economic value of assets likely to be lost at each location, as well as the relocation and resettlement costs, will be the same as that applied in the definite future scenario.

By contrasting the "future with" and "future without" annual losses within the areas vulnerable to erosion, the incremental annual riverbank erosion losses from the construction of mainstream and tributary dams, under alternative dam options, will then be derived over a 50 year period. The annual loss streams will then be used to estimate the NPV of incremental riverbank erosion losses for each specific area and the LMB as a whole.

With respect to the definite future scenario, the economic benefits resulting from flood mitigation and enhanced navigation will also be assessed in relation to alternative dam operation strategies. This analysis will primarily focus on assessing the economic impact of an different dam operation strategies in relation to flood risk reduction in the wet season as well as the water availability for irrigation purposes in dry season. The alternative dam operation rules to be analysed will be determined by the Hydropower Specialist.

3.2.3 Mekong Delta Flood Management Scenario

FMMP, Component 2: Structural Measures and Flood Proofing (FMMP-C2) have been studying flood management options in the Cambodian and Viet Nam flood plains as well as other locations within the LMB. While all flood management schemes are important, it is evident that only those in the Cambodian and Viet Nam flood plains have particular significance at the basin level due to the potential trans-boundary impacts between Cambodia and Viet Nam.

For the foreseeable future scenario, the proposed flood management measures to be implemented in the Mekong Delta over the next 20 years will comprise 9 scenarios under 3 options, namely:

Option 1: Development in Cambodia only

This scenario comprises of early flood protection and full flood protection in Cambodia. The planned projects are as follows:

- West Bassac: full flood protection in Zones 1 and 3, and early flood protection in Zone 2; and
- East Mekong: full flood protection in Zones 2 and 3, and early flood protection in Zone 1, but no flood protection for Zone 4.

Option 2: Development in Viet Nam only with 4 scenarios as follows:

- Canal enlargement in Long Xuyen Quadrangle and Plain of Reeds;
- As above with rotation percentage of 20% full flood protection area;
- As above with rotation percentage of 30% full flood protection area; and
- As above with rotation percentage of 50% full flood protection area.

Option 3: Combination of Option 1 and Option 2.

The characteristics of the proposed options for flood management in the Mekong Delta are further discussed in Annex 1: Hydrological Assessment.

The economic assessment of the Mekong Delta flood management scenario will focus on estimating the potential annual benefits from:

- reduced flood losses and damage in the Mekong Delta; and

- crop intensification and expansion of irrigated area in Mekong Delta.

However, the construction of flood mitigation and irrigation/drainage infrastructure could also have a number of adverse impacts which will also be evaluated in terms of economic losses. These adverse impacts include:

- decline in capture fisheries due to flood mitigation measures;

- loss of wetland areas resulting from a reduction in flooding, and

- increased saline intrusion as a consequence of irrigation development.

(i) Reduced flood losses and damage in Mekong Delta

Under the foreseeable future scenario, the benefits and costs associated with the flood mitigation and management measures planned for the Mekong Delta over the next 20 years will be evaluated. Flood mitigation benefits will primarily include lower crop losses as well as reduced damage to private property and public infrastructure. Furthermore, the indirect benefits of mitigating flooding as well as the decline in the annual benefits of flooding will also be evaluated.

The area benefiting from the proposed flood management measures in the Mekong Delta, the annual economic value of direct and indirect benefits of flood mitigation, as well as the reduction in the annual flood benefits, will be estimated by FMMP-C2 as part of the current study of alternative flood mitigation options.

The incremental annual benefits from flood mitigation will then be derived by contrasting the “future with” and “future without” annual net benefit streams within the areas benefiting from flood mitigation. The flood reduction benefit streams will then be used to estimate the NPV of incremental flood reduction benefits in the Mekong Delta.

For the flood management measures proposed, the capital investment required to construct flood mitigation infrastructure, as well as the annual costs of operating and maintaining the flood management system, will be estimated by FMMP-C2. Furthermore, the costs of resettling/compensating households displaced by structures, as well as the costs of environmental mitigation measures (such as fish passes), will also be estimated. The NPV of the capital and recurrent cost streams over a 50 year period will then be calculated for the proposed areas.

(ii) Crop intensification and expansion of irrigated area in Mekong Delta

In addition to benefits derived from a reduction in flood damages, flood management measures in the Mekong Delta will also provide an opportunity to intensify crop production in the wet season (through a change in cropping pattern) and dry season (through the provision of irrigation water). The annual economic benefits of crop intensification and irrigation development will therefore be derived for a range of rice and non-rice crops (see methodology in Section 3.2.2: Foreseeable Future Scenario, Expansion of Irrigated Areas).

The expansion of the irrigated area will be estimated by FMMP-C2 as part their current study on flood mitigation options. The location of the present and future irrigated areas should be mapped following the incorporation of data from FMMP-C2 into the GIS. The phasing of the irrigation development will be undertaken over a 20 year period.

Within the areas benefiting from improved flood management and irrigation development., cropping patterns (both rain fed and irrigated) will be determined for the present, “future with” and “future without” development situations. These cropping patterns will be derived by the Irrigation Agronomist based on existing cropping patterns available from FMMP-C2.

Annual crop benefits per hectare will then be estimated for a range of rice and non-rice crops benefiting from crop intensification in the wet season and a planned expansion of the irrigated area in the dry season. The annual crop benefits per hectare will then be applied to the respective crop areas within each of the rain fed and irrigated cropping patterns. In addition, the possibility of expanding rice-fish systems, as well as the further development of aquaculture production, within the benefited areas will also be considered.

The incremental annual benefits from crop intensification and irrigation development in the Mekong Delta will then be derived over the foreseeable future by contrasting the “future with” and “future without” annual net benefit streams within the benefited areas. The crop production benefit streams will then be used to estimate the NPV of incremental crop production benefits within the development areas.

For the proposed areas within the Mekong Delta, the capital investment required to construct the flood mitigation infrastructure and install the irrigation equipment, as well as the annual costs of operating and maintaining the flood management and irrigation system, will be estimated by FMMP-C2. Furthermore, the costs of resettling/compensating households displaced by structures, as well as the costs of environmental mitigation measures (such as fish passes), will also be estimated. The NPV of the capital and recurrent cost streams over a 50 year period will then be calculated for the development areas.

(iii) Decline in capture fisheries production

The annual economic losses associated with a decline in capture fisheries which can be directly related the construction of flood mitigation infrastructure in the Mekong Delta will also be evaluated. For the alternative flood management options, the annual economic losses of capture fisheries will mainly comprise the direct losses in terms of the decline in the net value of capture fisheries output which is likely to result from a barrier to fish migration. The expected loss of the annual capture fisheries catch will be estimated by the Fisheries Specialist. The type of fish species/guilds that will be affected will also be specified.

Although estimating the annual decline in capture fishery production in the Mekong Delta is likely to be problematic, information from a number of Fisheries Programme (FP) studies will provide some indication of likely decline in yields of various types of fish guilds. Annual net economic values per ton will then be calculated with data available from FMMP-C2.

Based on these data sets, annual net economic values will be estimated for the present, “future without” and “future with” development situations in order to determine the incremental economic value of fisheries losses over 50 years and the respective NPVs.

(iv) Reduction of wetland areas and biodiversity

The economic losses associated with a reduction in wetland areas, which can be directly related to the construction of flood mitigation measures, will be evaluated. For the alternative flood management options, the area of wetlands expected to be lost and the annual rate of decline will be estimated by the Environmental Specialists. The types of wetland likely to be affected and the location of specific wetland areas which are likely to be lost should also be mapped using the GIS.

The annual economic value of wetland areas likely to be lost will be estimated by applying unit values to different wetland types. The wetland valuation procedure will follow the methodology outlined under the definite future scenario.

By contrasting the “future with” and “future without” annual value of wetland areas, the incremental annual wetland losses from the construction of dams under the alternative options will then be derived over a 50 year period. The wetland loss streams will then be used to estimate the NPV of incremental wetland losses for the development areas.

(v) Increased saline intrusion

If significant, the annual economic losses associated with saline intrusion, due to the increased irrigation development within the Mekong Delta, will also be assessed. The area of land that is likely to experience saline intrusion in the future will be based on the assessment of hydrological changes resulting from the construction of flood mitigation infrastructure. The location of vulnerable areas should be mapped using the GIS database. Within areas where salinity is likely to increase, information on the types of land use will also be obtained from the GIS database.

The annual economic value of crop benefits (based on information collected by FMMP-C2) will then be applied to crop patterns likely to experience increased salinity. By contrasting the "future with" and "future without" annual loss streams within the vulnerable areas, the incremental annual salinity losses will then be derived over a 50 year period and this will then be used to estimate the NPV of salinity losses.

3.2.4 Long term development scenarios

The assessment for the long term scenarios will present a discussion of the economic assessments undertaken for the definite future scenario and the foreseeable future scenarios (including hydropower dams, irrigation schemes and flood management infrastructure in the Mekong Delta planned for implementation over the next 20 years), as well as other potential water resource developments that could be undertaken in the long term (50 years). The long term water resource developments would include hydropower dams in the LMB tributaries, intra or inter basin diversions, and flood management infrastructure along the mainstream.

Two long term scenarios are envisaged: (i) continued development scenario reflecting the plausible extension of the currently planned water resources developments in LMB (based on the screening of projects in the hydropower and irrigation databases) as well as other water demands related to increasing population and economic development, and (ii) very high development scenario to represent the full potential of hydropower development, irrigated agriculture and flood management which would include significant diversions from the mainstream, controlled diversion of flood water to Tonle Sap Lake and regulation of the outflow from the Great Lake.

Unlike the quantitative analysis which will be undertaken for the definite future and foreseeable future scenarios, the economic assessment of the long term scenarios will be mainly qualitative in nature and no attempt will be made to estimate incremental net economic benefits or NPVs. It is, however, expected that the economic assessment will highlight:

- economic growth opportunities provided by a range of developments in the water resources sector;

- capital investment and recurrent costs of the major interventions (e.g. hydropower dams, irrigation infrastructure and flood management works);
- economic losses associated with adverse environmental and social impacts, with particular reference to capture fisheries and wetland areas;
- equitable distribution of net economic benefits between riparian countries;
- equitable distribution of benefits and losses between different income groups within the riparian countries, and compensatory measures for communities suffering loss of income and livelihoods;
- medium and long term changes in river and coastal morphology;
- long term economic impact of climate change particularly with respect to anticipated changes in agricultural and fisheries production systems throughout the LMB as well as the impact of sea level rise on coastal production systems and livelihoods;
- economic impact of structural changes in the LMB economy in terms of incomes, employment, livelihoods and poverty within different sectors of the rural and urban economies; and
- issues related to future sustainability of water resource developments in relation to the dynamics of wider and long term economic, social and environmental changes, e.g. population growth, development of the industrial and service sectors, diversification of employment opportunities and urbanisation.

The long term water development scenarios within the LMB will also be assessed in the context of the overall structure and dynamics of the national economies of the riparian countries, particularly with respect to the energy, agriculture, fisheries and other natural resource sectors, as well as navigation and water supply (domestic and industrial). An assessment will therefore be made of the overall macro economic trends and development forecasts, as well as the national economic development policies, at both regional and national level.

The contribution of each development scenario to economic growth, poverty reduction and employment opportunities within the riparian countries will also require evaluation. Finally, this analysis will take account of the strategic development plans within each country particularly in relation to the water sector.

4 Data requirements for economic assessment

4.1 Overview

The economic assessment of BDP development scenarios will require comprehensive and reliable data sets. Economic impacts will mainly arise as a consequence of altered river flows and barriers to fish migration primarily resulting from hydro-power development. This will causing changes in environmental conditions which in turn have impact upon the people living in the locations affected by these changes.

The main sources for economic data are government statistics, ad hoc economic studies and data collection surveys. In recent years, a significant effort has been made to assemble data sets to support economic assessments, but further data collection is still required.

Data collection comprises the gathering of all documents, maps and databases available from the various MRC programmes as well as other relevant information obtainable from the four riparian countries. Where possible, it is also important to ensure that the latest data is available in a geo-referenced format which can be used to generate information at specific locations (e.g. districts, zones/river reaches etc).

Once established and quality assured, the data sets would be placed on BDP database and would be freely accessible. It is important that, as part of the quality assurance, the level of accuracy of the data is also clearly shown in order to provide planners with a guide to the validity of conclusions that can be drawn from the results of the economic assessment. Finally, it is essential that the data sets are: (i) transparently assembled, (ii) consistently used by the scenario assessment team, and (iii) archived by IKMP for future used by BDP and other MRC programmes.

The main data requirements for the economic assessments are summarised below and detailed in Tables 4.2 to 4.8.

Hydropower

- Hydropower generating parameters at each site;
- Operating rules of existing and proposed hydropower dams;
- Installed capacity (MW) of existing and proposed hydropower stations;
- Capital investment and annual recurrent costs (as well as construction periods);
- Cost of resettlement and relocation of displaced households;
- mitigation measures (e.g. fish passes, re-regulation dams);
- Economic net benefits of energy generated under assumed operating rules.

Irrigated Agriculture

- Existing, planned and potential irrigable area by locality;
- Irrigated/rainfed cropping patterns and crop yields by locality;
- Mapping of irrigated area and crop production;
- Capital investment and annual recurrent costs of irrigation development;
- Incremental net economic benefits per hectare of irrigated land by crop.

Fisheries

- Decline in capture fisheries production due to dams creating barriers to fish migration;
- Relationship between flow/flood conditions and capture fish production by location;
- Existing and future production of aquaculture, reservoir fisheries and rice-fish systems;
- Incremental net economic benefits of capture fisheries production;
- Economic net benefits of aquaculture and reservoir fisheries production.

Navigation and river transport

- Minimum safe draughts required for different categories of boats;
- Incremental cargo transported by river reaches;
- Economic net value of incremental cargo transported.

Flood management in Mekong Delta and other areas of LMB

- Flood damage (both direct and indirect) by depth and duration of flooding;
- Mapping of economic value of flood damage/losses in flood prone areas;
- Economic benefits of flooding, e.g. increased crop yields and capture fisheries;
- Capital and annual recurrent costs of flood management works in Mekong Delta;

Saline intrusion in Mekong Delta

- Economic net benefits of mitigating saline intrusion;
- Mapping of economic value of mitigating saline intrusion;

Wetland areas

- Land use mapping of different types of wetland areas (including river gardens);
- Economic value of wetland types per unit area.

Riverbank erosion

- Economic losses associated with increased riverbank erosion;
- Mapping of land and settlements vulnerable to riverbank erosion.

4.2 Hydropower data

The data required for the economic assessment of hydropower development within the LMB for the various development scenarios are outline in Table 4-1 below.

Table 4-1 Data required for economic assessment of hydropower development

Data Type	Unit	Data Source	Comment/Responsibility
Dependable HEP capacity: Existing and future development of dependable capacity of HEP stations (with and without mainstream dams) over 20 years within LMB by riparian country.	MW	Hydropower database	Data available (estimated by Hydropower Specialist)
Annual HEP production: Present and future annual HEP production (with and without mainstream dams) within LMB by riparian country.	GWh	Hydropower database	Data available (estimated by Hydropower Specialist)
Energy exports/imports: Present and future annual energy exports and imports, as well as power trade prices, within LMB by riparian country.	GWh US$ per MWh	Hydropower database	Data available (estimated by Hydropower Specialist)
Capital costs: Development costs (EPC and IDC) of HEP stations and transmission lines by riparian country	US$ million	Hydropower database	Data available (estimated by Hydropower Specialist). *N.B. Cost estimates for mainstream dams to be revised by SEA team*
Operation & maintenance costs: Annual O&M costs of HEP stations and transmission lines by riparian country	US$ million	Hydropower database	Data available (estimated by Hydropower Specialist)
Employment: Labour required for the construction and annual O&M of HEP stations and transmission lines over 20 years by riparian country	person years	Hydropower sector review	To be estimated by Riparian Economist in association with Hydropower Specialist
Operating rules: Operating rules for existing, planned and proposed hydropower stations in riparian countries, as well as existing and planned Chinese HEP stations.		Hydropower sector review	To be determined by Hydropower Specialist
Resettlement Costs: Costs of resettlement and compensation for households displaced by reservoirs and structures	No. households US$ per household		To be estimated by Riparian Economist and Social Scientist
Environmental Mitigation Costs: Costs of mitigation of adverse environmental impacts, e.g. fish passes for capture fisheries.	US$ million per HEP station	Fisheries programme	To be estimated by Fisheries Specialist (based on mitigation measures undertake for other HEP projects)

4.3 Irrigated agriculture data

The data required for the economic assessment of irrigation development within the LMB for the various development scenarios are outline in Table 4-2 below.

Table 4-2 Data required for economic assessment of irrigation development

Data Type	Unit	Data Source	Comment/Responsibility
Irrigated areas: Present, planned and potential area for existing and new irrigation schemes over 20 year period within LMB by riparian country	ha	BDP irrigation database	Database completed and available GIS mapping required by GIS Specialist
Irrigated cropping patterns: Proportion of area under each crop (rice and non-rice) for variety of irrigated cropping patterns within each riparian country[1/]	% of cultivated area	BDP irrigation database	Database completed and being linked to irrigated areas Irrigation Agronomist to derive future irrigated cropping patterns
Rain fed cropping patterns: Proportion of area under each crop (rice and non-rice) for variety of rain fed cropping patterns within each riparian country	% of cultivated area	Based on existing cropping patterns available in BDP database	To be derived by Irrigation Agronomist GIS mapping required by GIS Specialist
Crop yields: Present and future annual crop yields (with & without irrigation project over 30 years) for different rice and non-rice crops within each rain fed and irrigated cropping pattern	tonne per ha	District level govt. statistics within each country BDP Irrigation Sector Review - National Reports	District level crop yield data needs to be collected from national statistics by Riparian Agronomist Future with and without project crop yields to be derived by Irrigation Agronomist
Crop inputs: Present and future (with & without project) use of seed, fertilisers and pesticides for different rice and non-rice crops within each rain fed and irrigated cropping pattern	kg per ha	Govt statistics within each riparian country	Present crop inputs to be estimated by Riparian Agronomist based on national statistics Future with and without project crop inputs to be derived by Irrigation Agronomist
Labour and machinery requirements: Present and future (with & without irrigation projects) labour and machinery/equipment requirements for different rice and non-rice crops within each rain fed and irrigated cropping pattern	person days per ha machinery hours per ha	Irrigation and agricultural project reports	Present labour and machinery requirements by Riparian Agronomist based on available data Future with and without project estimates of labour and machinery to be derived by Irrigation Agronomist
Output and input prices: Farm gate and market prices for farm produce (rice and non-rice crops), seeds, fertilisers, pesticides, as well as rural wage rates and hire charges for machinery/equipment and transport within each riparian country.	US$/tonne US$/person day US$/ mach. hour US$/tonne/ km	Govt statistics within each riparian country. World Bank commodity price projections	Financial prices to be collected by Riparian Economist. Economic prices to be derived by International Economist.

Data Type	Unit	Data Source	Comment/Responsibility
Capital costs: Costs of civil works and equipment for different types of irrigation/drainage scheme, e.g. gravity and pumping (low lift , high lift) by riparian country	US$ million per ha	Irrigation database (some projects) Irrigation project reports	To be estimated by International Economist in association with Water Resources Planner
Operation & maintenance costs: Annual O&M costs of different types of irrigation scheme, e.g. gravity, pumping (low lift , high lift) by country	US$ per hectare	Irrigation project reports	To be estimated by International Economist in association with Water Resources Planner
Employment: Labour required for the construction and annual O&M of irrigation projects by country	**person years**	**Irrigation project reports**	To be estimated by Riparian Economist

[1/] Irrigated crops (from Irrigation Water Use Assessment, 2005) comprise:

NE Thailand:

TW1	Wet season rice (regions 1, 2 and 4),
TW2	Wet season rice (regions 3 and 7),
TW3	Wet season rice (region 5 and 8),
TD1	Dry season rice (region 1, 2, 5 and 8),
TD2	Dry season rice (region 3),
TD3	Dry season rice (region 4),
TD4	Dry season rice (region 7)
TO	Non-rice crops (maize, cassava, fruit & vegetables)

Lao PDR:

LW1	Wet season rice (north and central)
LW2	Wet season rice (south west)
LD1	Dry season rice
LV	Vegetables

Cambodia:

CW1	Wet season rice (early)
CW2	Wet season rice (late)
CD1	Dry season rice (early)
CD2	Dry season rice (late)

Viet Nam:

VW1	Wet season rice (summer/autumn)
VW2	Wet season rice (autumn/winter)
VW3	Wet season rice (single rice crop)
VW4	Wet season rice (highland)
VD	Dry season rice (winter/spring)

4.4 Fisheries data

The data required for the economic assessment of the impact on capture and culture fisheries within the LMB for the various development scenarios are outline in Table 4-3.

Table 4-3 Data required for economic assessment of impact on LMB fisheries

Data Type	Unit	Data Source	Comment/ Responsibility
Capture fisheries production: Present and future annual capture fisheries catch (with and without HEP dams) over 20 year period within LMB by fish guild, location and riparian country	tonnes	Fisheries programme data and reports	To be estimated by Fisheries Specialist
Reservoir fisheries production: Present and future annual fisheries production (with and without HEP dams) over 20 year period within LMB reservoirs	tonnes	Fisheries programme data and reports	To be estimated by Fisheries Specialist
Aquaculture fisheries area: Present and future annual aquaculture fisheries area within LMB by riparian country	ha	Fisheries programme data and reports	To be estimated by Fisheries Specialist
Aquaculture fish yields: Present and future annual fish yields for different aquaculture systems, such as (i) high input fish, (ii) low input fish, and (iii) coastal shrimp.	tonne per ha	Fisheries programme data and reports	To be estimated by Fisheries Specialist
Capture fisheries labour: Number of fishers in present and future (with and without HEP dams) over 20 years within LMB by zone/river reach.	person years	Fisheries programme data and reports	To be estimated by Riparian Social Scientist and Economist in association with Fisheries Specialist
Aquaculture and reservoir fisheries input and labour costs: Present and future capital and annual recurrent costs of inputs, labour and equipment for different reservoir, aquaculture and rice-fish systems	US$ per ha	Fisheries programme reports, e.g. "Financial analysis of aquaculture & fishery activities in LMB" (2002)	To be estimated by Riparian Economist in association with Fisheries Specialist
Output prices and marketing costs: Landed/farm gate and market prices as well as marketing/transport costs and marketing margins for different types of fish produced by capture, reservoir and aquaculture systems within each riparian country.	US$ per tonne	Fisheries programme Govt statistics within each riparian country	Financial prices and costs to be collected by Riparian Economist. Economic prices and costs to be derived by International Economist.

4.5 Navigation data

The data required for the economic assessment of navigation and river transport within the LMB for the various development scenarios are outline in Table 4-4 below.

Table 4-4 Data required for economic assessment of impact on river transport

Data Type	Unit	Data Source	Comment/ Responsibility
Annual number of days river is navigable: Based on minimum safe draught requirements for different classes of vessel, present and future (with and without LMB water resource developments) annual number of days river is navigable as a result of changes in river flows by river reach/zone and country	days	Navigation programme	To be estimated by Navigation Programme experts based on the hydrological assessment
Annual IWT cargo volume: Present and future (with and without LMB water resource developments) annual volume of IWT cargo trade over 30 year period by zone/river reach and riparian country	million tonnes	Navigation programme Govt statistics in each country	To be estimated by International Economist in association with Navigation Programme experts
Annual IWT cargo value added: Gross value, transport costs and value added per tonne of cargo transport by IWT	US$ per tonne	Navigation programme Govt statistics in each country	To be estimated by International Economist in association with Navigation Programme experts
Mitigation costs: Capital and annual O&M costs for different mitigation measures such as construction of canals and locks to divert river transport around mainstream dams	US$ million	Navigation programme	To be estimated by International Economist in association with Navigation Programme experts

4.6 Wetlands data

The data required for the economic assessment of the impact on wetlands areas (including river gardens) within the LMB for various development scenarios are outline in Table 4-5 below.

Table 4-5 Data required for economic assessment of impact on wetland areas

Data Type	Unit	Data Source	Comment/ Responsibility
Wetlands areas: Present and future area (with and without LMB water resource developments) of different types of wetland ecosystems[1/] over 20 year period by riparian country	ha	Environment programme (EP) GIS land use database and maps	To be estimated by Environmental Specialists using GIS data and mapping GIS mapping required by GIS Specialist
Annual value of wetland: Present and future annual values of different types of wetlands over 20 year period	US$ per ha	EP study on wetland valuation Wetland valuation database. Recent wetland valuation studies from SE Asia	To be estimated by International Economist in consultation with Environmental Specialists.

Data Type	Unit	Data Source	Comment/ Responsibility
River garden areas: Present and future area (with and without mainstream dams) of river gardens over 20 year period by river reach and riparian country	ha	GIS land use database and maps	To be estimated by Environmental Specialists using GIS data and mapping
Net value of river gardens: Present and future annual values of river gardens over 20 year period	US$ per ha	Wetland valuation database	To be estimated by Riparian Economist

[1/] Wetland ecosystems comprise (i) Mekong River and tributaries, (ii) rapids and deep pools, (iii) beaches, banks and bars, (iv) riverine flooded forest and floodplains, (v) lakes and ponds, (vi) marshes, swamps and grassland, (vii) rice fields, (viii) mangrove forests, and (ix) estuaries and deltas.

4.7 Flood mitigation data

The data required for the economic assessment of flood mitigation measures within the Mekong Delta, as well as other parts of the LMB, for the various development scenario are outline in Table 4-6 below.

Table 4-6 Data required for economic assessment of flood mitigation measures

Data Type	Unit	Data Source	Comment/Responsibility
Flood water level reduction along mainstream: Location, maximum flood level for each development scenario.	m	IKMP hydrological model results	Tables showing maximum flood water level by scenario and location. Distance (km) between locations. (Hydrologist)
Existing maximum extent of flood inundation: Map and excel file by districts/provinces.	ha	IKMP and MRC database	GIS Specialist and Hydrologist
Extent of flood inundation: Map and excel file by districts/provinces for each development scenario.	ha	IKMP, hydrological model results	Identify area inundated 0-0.5m and more than 0.5m. (GIS Specialist and Hydrologist).
Flood damage assessments in focal areas: Location, extent and type of flood damages	various	FMMP_C2	Location of focal areas and demonstration projects carried out under FMMP_C2. (Riparian Economist)
Areas benefiting from flood mitigation measures: Location, extent and type of land use of areas benefiting from flood mitigation measures in Mekong Delta as well as reduced flooding from HEP dams by riparian country	ha	FMMP-C2: (Structural Measures and Flood Proofing)	Database and mapping of areas benefiting from flood mitigation in Mekong Delta based on results from FMMP-C2 (Riparian Economist) For other parts of LMB, population and land use data required for areas where flooding is reduced. GIS land use mapping required by GIS Specialist

Data Type	Unit	Data Source	Comment/Responsibility
Population benefiting from flood mitigation measures: Number and location of households and businesses benefiting from flood mitigation measures in Mekong Delta by riparian country	number of HHs	FMMP-C2	Database and mapping of populations benefiting from flood mitigation based on results from FMMP-C2 (Riparian Economist). GIS population mapping required by GIS Specialist
Direct and indirect losses and damage due to flooding: Present and future values (with and without flood mitigation) of annual damage to agriculture, property and public infrastructure due to floods in Mekong Delta and other parts of LMB over 20 year period by country.	US$ million	FMMP-C2 for Mekong Delta Historic annual flood losses and damage records by area for other parts of LMB	Estimates to be based on results from scenario assessments undertaken by FMMP-C2 (Riparian Economist)
Annual benefits of flooding: Present and future values (with and without flood mitigation measures) of different types of annual benefits from flooding (e.g. increase crop yield/lower fertiliser costs, reduced pollution and increased capture fisheries) over 20 year period by riparian country	US$ million	FMMP-C2	Estimates to be based on results from scenario assessments undertaken by FMMP-C2 (Riparian Economist)
Increases in net agricultural benefits resulting from changes in cropping pattern: Present and future (with & without flood mitigation) annual net agricultural benefits from different rice based cropping patterns including irrigated cropping in dry season over 20 years by riparian country	US$ per ha	FMMP-C2	To be determined by Irrigation Agronomist and Riparian/International Economists based on data provided by FMMP-C2 on existing cropping patterns
Increases in net benefits from aquaculture: Present and future (with and without flood mitigation) annual net benefits from aquaculture production due to flood mitigation measures	US$ per ha	District statistics on aquaculture production in Mekong Delta (Viet Nam and Cambodia)	To be determined by Fisheries Specialist and Riparian Economist
Reduction in capture fisheries: Present and future annual value of capture fisheries catch (with and without flood mitigation) over 20 years in Mekong Delta by country	US$ per ha	FMMP-C2 Capture fisheries yield data (from FP reports)	To be estimated by Fisheries Specialist and Riparian/International Economists based on available capture fisheries data
Capital Costs: Costs of civil works and equipment for different types of measures to mitigate flooding by riparian country	US$ per ha	FMMP-C2	Estimates to be based on data from FMMP-C2 (International/Riparian Economists)
Operation & Maintenance Costs: Annual O&M costs of different types of measures to mitigate flooding by riparian country	US$ per ha	FMMP-C2	Estimates to be based on data from FMMP-C2 (International/Riparian Economists)
Resettlement Costs: Costs of resettlement and compensation for households displaced by structures	US$ per ha	FMMP-C2	To be estimated by Riparian Economist based on data from FMMP-C2
Environmental Mitigation Costs: Costs of mitigation of adverse environmental impacts, e.g. fish passes for capture fisheries, biodiversity conservation.	US$ per ha	Fisheries programme Environment programme	To be estimated by Fisheries Specialists and Environmentalists

4.8 Saline intrusion data

The data required for the economic assessment of the impact on saline intrusion within the LMB for various development scenarios are outline in Table 4-7 below.

Table 4-7 Data required for economic assessment of impact on saline intrusion

Data Type	Unit	Data Source	Comment/ Responsibility
Areas affected by saline intrusion: Location, extent and type of land use in coastal areas affected by saline intrusion[1/] in present and future (with and without water resource developments) by riparian country	ha	IKMP District level govt. statistics (Vietnam)	To be estimated by IKMP based on hydrological assessment and GIS mapping GIS land use mapping required by GIS Specialist
Changes in crop productivity: Present and future (with and without water resource developments) annual changes in crop yield due to saline intrusion in the LMB over 20 year period by riparian country	tonne per ha	FMMP-C2 District level govt. statistics (Vietnam)	To be estimated by Irrigation Agronomist
Annual net value of crop production: Present and future net value of annual changes in crop productivity over 20 year period by riparian country	US$ per ha	FMMP-C2	To be derived by Riparian/International Economists
Changes in capture fisheries: Present and future net value of annual capture fisheries catch resulting from saline intrusion over 20 year period within affected areas by riparian country	US$ per ha	Fisheries Programme	To be estimated by Fisheries Specialist and Riparian Economist

1/ In areas affected by salinity, duration of saline intrusion and salt concentration will also be taken into account.

4.9 Riverbank erosion data

The data required for the economic assessment of the impact on riverbank erosion within the LMB for each of development scenarios are outline in Table 4-8.

Table 4-8 Data required for economic assessment of impact on riverbank erosion

Data Type	Unit	Data Source	Comment/ Responsibility
Areas affected by riverbank erosion: Location, extent and type of assets, e.g. land, property and infrastructure, expected to be lost to riverbank erosion within vulnerable areas in present and future (with and without water resource developments) by riparian country	ha	IKMP	To be estimated by Geo-morphologist using GIS. Database and mapping of land use types vulnerable to riverbank erosion based on GIS
Population vulnerable to riverbank erosion: Number and location of households and businesses vulnerable to riverbank erosion in LMB by riparian country	number of HHs	IKMP	Database and mapping of populations vulnerable to riverbank erosion based on GIS
Value of assets vulnerable to riverbank erosion: Present and future unit value of land, property and infrastructure vulnerable to riverbank erosion in the LMB over 20 year period by riparian country.	US$/ha US$/property US$/km infra-structure	District level govt. statistics	To be estimated by Economists
Relocation and resettlement costs: Relocation and resettlement costs per household in areas affected by riverbank erosion	US$ per HH		To be estimated by Economists

5 Work programme

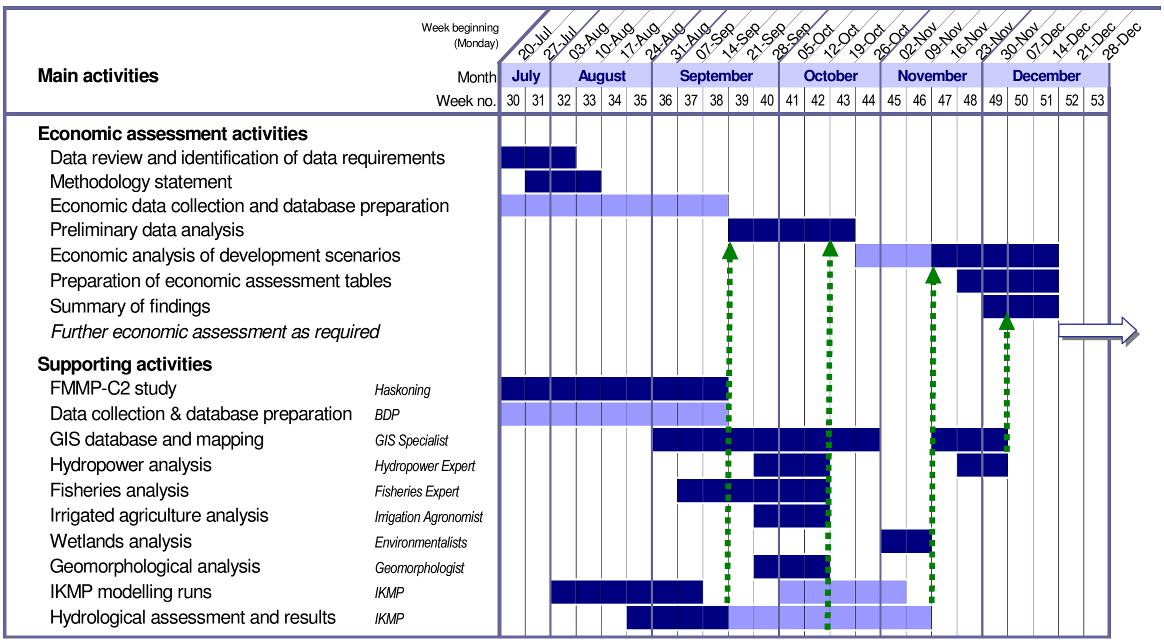
A work programme has been prepared to:

- specify the main tasks of the economic assessment up to December 2009;
- outline the schedule for the economic assessment within the given time frame; and
- identify the timing of key supporting activities and establish linkages to the economic assessment.

Following a review of the findings of the economic assessment and the preparation and submission of an interim consultation document in February 2010, it is envisaged that a draft assessment report will be prepared in March 2010.

The work programme for the economic assessment activities, as well as linkages to the supporting activities, is summarised in Figure 5-1 below. The schedule of staff inputs which corresponds to activities in the work programme is given in **Error! Reference source not found.**.

Figure 5-1 Work programme for economic assessment of BDP development scenarios



Draft

Mekong River Commission

Basin Development Plan, Phase 2

Economic, environmental and social impact assessment of basin-wide water resources development scenarios

Assessment methodology

Annex 5
Fisheries assessment

October 2009

Economic, environmental and social impact assessment of basin-wide water resources development scenarios

Assessment methodology

Main report	Overview
Annex 1	Hydrological assessment
Annex 2	Environmental assessment
Annex 3	Social assessment
Annex 4	Economic assessment
Annex 5	**Fisheries assessment**

Contents amendment record

This report has been issued and amended as follows:

Issue	Revision	Description	Date	Signed
1	0	Draft to BDP team for comment	6 October 2009	ASH
2	1	Draft prepared for 2nd Regional Stakeholder Consultation and Dialogue of Basin Development Plan Programme, Phase 2	7 Oct 2009	

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Tables

Figures

Glossary

ADB	Asian Development Bank
AIFP	Agriculture, Irrigation and Forestry Programme
BDP	Basin development programme
BDP1	BDP Phase 1
BDP2	BDP Phase 2
DSF	Decision support framework
EP	Environment Programme
FMMP	Flood management and mitigation programme
FP	Fisheries Programme
HP	Hydropower Programme
IBFM	Integrated basin flow management
IQQM	Discharge modelling software
ISIS	Proprietary river modelling software
IKMP	Information and knowledge management programme
IWRM	Integrated water resources management
LMB	Lower Mekong Basin
MRC	Mekong River Commission
MRCS	Mekong River Commission Secretariat
NMC	National Mekong Committee
NP	Navigation Programme
PIN	Project Identification Note
PDS	Project Description Sheet
PNPCA	Procedures for Notification, Prior Consultation and Agreement
PWUM	Procedures for Water Use Monitoring
RTWG	Regional technical working group
SWAT	Open source hydrological modelling software
ToR	Terms of reference
WB	World Bank
WUP	Water utilisation programme
WUP-A	WUP component for DSF development

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1 Introduction

1.1 Purpose of the report

The purpose of this report is to provide a description of the proposed methodology to assess likely outcomes of the basin development scenarios on future yields of fish and other aquatic animals (OAA) in the LMB to support the economic and social assessments.

1.2 Report structure

Chapter 2 describes the context of the fisheries assessment in relation to the scenarios to be assessed and the specific development objectives, key issues and indicators relating to the fisheries sector. Details of the likely impact pathways on the fisheries sector arising from these activities are also described and the opportunities and threats that these present.

Chapter 3 details the methodology that will be applied to assess the readily quantifiable impacts. A qualitative assessment will examine additional impacts on fish yield that may arise from changes to hydrological conditions (flows, depths, inundated areas) and water quality (e.g. dissolved gas concentrations, temperature, salinity) upstream and downstream of the dams; and changes to sediment transport, which cannot be readily quantified.

Chapter 4 summarises the data required for the assessment.

2 Development scenarios, fisheries indicators and key issues

2.1 Basin-wide scenarios and assessment framework

Following the MRC Technical Note (23 March 2009) on 'Scoping and Planning of the Assessment of Basin-wide Development Scenarios", the LMB development scenarios to be assessed comprise four situations: (i) baseline situation; (ii) definite future situation; (iii) foreseeable future situation; and (iv) long-term future situation. These are to be assessed in under nine categories of scenario as illustrated in Table 1 below.

Table 1 Summary of the Development Scenarios

	Title	Time horizon	Runs		Interventions
			85-00	CC	
1	**Baseline scenario**	Baseline (1985-'00)	1		Year 2000 infrastructure including existing HEP dams
2	**Upper Mekong Dam scenario (UMDS)**	Definite future over next 5-10 years	1		Baseline plus 6 existing, under construction and planned HEP dams in Upper Mekong Basin
3	**Definite future scenario (DFS)**		1		UMDS plus 25 additional HEP dams in LMB and updated flood measures in delta
	Foreseeable future situation (FSS)				
4	LMB 20-year plan scenario	Foreseeable future over next 20 years	1	1	DFS plus 11 LMB m/stream dams and planned tributary dams etc
5	LMB 20-year plan without mainstream dams		1		As above, excluding 11 LMB dams
6	LMB 20-year plan with 6 m/s dams in upper LMB		1		As above plus 6 LMB dams in upper LMB
	LMB 20-year plan with 9 m/s dams		1		As (5) excluding Ban Kum and Pakchom
7	**Mekong delta flood management scenario**	Baseline (1985-'00)	6		Baseline plus 6 different options for flood control in Cambodia and Viet Nam
	Long term future				
8	LMB long-term development scenarios	Long term future over next 50 years	1	1	LMB 20-year scenario plus all feasible infrastructure developments in LMB
9	LMB very high development scenarios		1	1	As above extended to full potential infrastructure developments
10	**Further scenarios**		2	1	To be determined by BDP assessment team
			17	4	

The composition of these scenarios is fully described in Annex 1.

The same MRC Technical note also set out an assessment framework to assist the countries in examining the trade-offs between scenarios and in subsequently determining an appropriate basin-wide development strategy. The framework provides for triple-bottom line assessment of each scenario within an overall objective of promoting sustainable and equitable development. The assessment of fisheries as described in this Annex is primarily to address the evaluation of productivity changes in the fisheries sector, recognising that in doing so this will provide valuable insights to other parts of the assessment, notably in relation to the assessment of dependency within the basin of livelihoods on capture fisheries (see Main Report for full list of assessment indicators).

Table 2 Specific development objectives, issues and fisheries indicators

Specific development objective	Issue	Indicator
Economic development		
1.5 Maintain productivity of fishery sector	Capture fisheries and aquaculture production	Incremental annual average capture fish availability Incremental annual average aquaculture production Net incremental economic value
Social development		
3.4 Increased employment generation in water related sectors	Incremental sustainable employment from water resource interventions	Incremental number of people engaged in fisheries

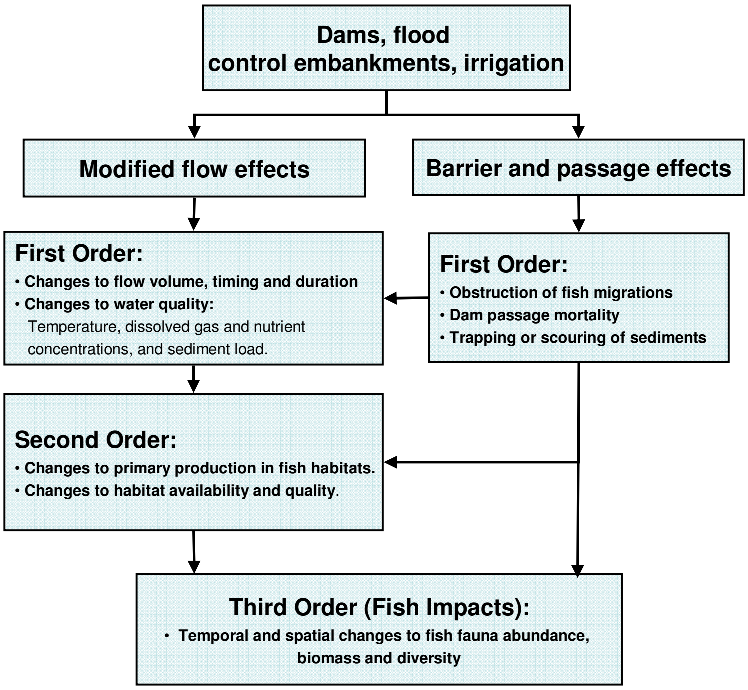
Pro-active development of aquaculture is not included as an intervention in the scenarios. However the assessment will evaluate the opportunities presented by the many new reservoirs associated with dams and hydropower included in the scenarios. The impacts on brackish aquaculture under different scenarios will be considered under the environmental assessments.

2.2 Basin development and fisheries: Threats and Opportunities

The major threats to river fish resources arising from the future development of the basin are dams and flood control embankments but water abstractions for irrigation schemes or consumption also threaten downstream fish habitat availability. With a rapidly expanding population in the region, increasing rates of exploitation (fishing pressure) have also been identified as a threat to the sustainability, diversity and value of the resource.

Dams and flood control embankments deny or diminish fish access to critical habitat for feeding, reproduction and survival. Dams in particular also have the potential to reduce population survival rates as adult fish and their progeny incur mortality passing through dam turbines, by-pass structures, or over dam spillways when returning to downstream feeding and refuge habitat (see Figure 1).

Figure 1 Dam and flood control impact pathways on fisheries resources (Modified from Halls & Kshatriya (2009).



The combination of diminished survival rates and spawning success can lead to significant reductions in exploitable fish biomass and species extinctions as reported in river basins throughout the world (see WCD 2000; Welcomme 1985 and Welcomme & Halls 2001; Halls 1998 for reviews).

Flow changes caused by these structures can impact upon fish populations and fish communities by disrupting and diminishing spawning behaviour and success, and by reducing growth and survival rates arising from diminished feeding and refuge opportunities and exposure to unfavourable environmental (water quality) conditions (ibid.).

Opportunities for fisheries may also arise from basin development. These include the creation of reservoirs behind storage dams that can be used to culture stocked fish and the expansion of irrigated wetlands that support productive rice-field fisheries and fish culture systems. Salinity changes in the delta may also offer scope to expand or sustain the culture of high value species such as the giant river prawn *Macrobrachium rosenbergii.*

2.3 Overview of potential impacts to fisheries arising from basin development

2.3.1 Dams

Large dams are typically constructed for hydropower generation but they may also serve to divert water for irrigation and other consumptive uses. Dams are typically characterised as either storage or run-of-river type – the latter having no significant live storage.

Dams have both barrier (and passage) and modified flow effects on fish populations and subsequent impacts on fishery yield (Table 3).

Dams deny or diminish fish access to critical[1] habitat for spawning, feeding and refuge but also have the potential to reduce population survival rates as adult fish and their progeny incur mortality passing through dam turbines, by-pass structures, or over dam spillways when returning to downstream feeding and refuge habitat. The combination of diminished survival rates and spawning success can lead to significant reductions in exploitable fish biomass and species extinctions as reported in river basins throughout the world (see WCD 2000; Welcomme 1985 and Welcomme & Halls 2001; Halls 1998 for reviews).

Migratory species may accumulate in the forebay area above dams as well as below spillways and turbine outlets and suffer increased predation rates arising from the disorientation effects of dam passage and the numerical response of predators to prey density. Dams also have the capacity to trap sediments directly as a consequence of their physical presence (barrier effect), and because they retard flows upstream leading to increased deposition of sediment in their reservoirs or upstream areas which can choke spawning substrates of gravel and sand spawners. Similar hydrological processes can impact on the transport of pelagic fish eggs and larvae (ichthyoplankton) to downstream nursery and feeding areas whereby the reservoirs acts as a permanent 'sink' diminishing recruitment in the population. Diminished transportation rates to sheltered or nursery habitat can also increase exposure to predation for these life stages. Reduced flushing rates may result in accumulation or low dilution of toxic wastes or anoxic conditions leading to fish mortalities. Excessive water depths may cause drowning and loss of spawning substrates.

New reservoir habitats created upstream of storage dams in tributaries may however support productive fisheries for both indigenous and exotic fishes suited to lentic conditions as well as some other animals including shrimps (see Review in Hortle and Penrrong 2009). Typical fish yields from reservoirs are examined in Section 3.6. Stabilized water levels (shift from pulse regulated to stable system dynamics) favour phytoplankton-based primary production particularly if retention times in reservoirs are high.

Storage dams with stable water levels may experience vertical stratification of the water column diminishing mixing and forming cold anoxic deep water. Reduced mixing can lower primary production as nutrient re-cycling rates are lowered. Thermal refuges and habitats in deep areas (and pools) may no longer be accessible causing the elevated mortality rates and the loss of stenothermal species. Sudden breakdown (overturn) of the theremocline can cause fish kills as cold anoxic waters are released from depth.

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[1] Critical habitats are areas crucial to the survival of particular species, populations and ecological communities.

Table 3 Summary of typical impacts of dams in river systems

Cause	Effects
Barrier and passage effects	
Obstruction of fish migrations.	Fish denied access to critical upstream spawning habitat. Accumulation of migrant species below dams. Increased rates of predation on migrating species in vicinity of dams both in forebay, below spillways and turbine outlets (numerical response of predators to prey density).
Elevated mortality rates arising from passage through turbines and other structures e.g. spillways.	Increases in both direct (turbine blade strike rapid pressure changes) and indirect mortality (increased predation arising from disorientation following passage) leading to reduction in fish biomass.
Interruption of downstream sediment transport.	Diminished primary and secondary (including fish) production downstream of dam. Reduction in abundance of non-visual predators and omnivores within the fish community in preference to pelagic planktivores and visual predators.
Formation of closed aquatic systems.	Opportunities for aquaculture and reservoir fisheries.
Modified flow effects: Upstream / reservoirs	
Decreased flow velocity	Potential increases in phytoplankton-based primary production if retention times in reservoirs are high supporting secondary production including fish. Shifts from reophilic to lentic communities in reservoir upstream and in controlled reaches downstream.
Decreased flow velocity	Deposition (sinking) and mortality of ichthyoplankton in reservoirs diminishing recruitment downstream. Delayed downstream (passive) migrations of juvenile stages potentially increasing mortality rates (increased exposure to predation). Reduced flushing rate results in accumulation or low dilution of toxic wastes or anoxic conditions leading to fish mortalities.
Increased water depth	Drowning and loss of spawning substrates. Loss of some species including psammophils and lithophils.

Cause	Effects
Changes to water temperature.	Changes to growth and mortality rates.
Stabilized water levels (shift from pulse regulated to stable system dynamics).	Reduction of allocthonous inputs and nutrients from ATTZ causing reductions to primary production and secondary production. Changes in species composition favouring pelagic planktivors, sight feeding carnivores and tributary species.
Vertical stratification of the water column (thermocline and anoxic layers).	Thermal refuges and habitats in deep areas (and pools) no longer accessible. Elevated mortality rates and loss of stenothermal species. Reduced mixing lowers productivity. Sudden breakdown (overturn) of the theremocline can cause fish kills as cold anoxic waters are released from depth.
Increased sediment deposition upstream of dam arising from low flow conditions.	Sedimentation (choking) of spawning habitats. Decline in lithophils and psammophils. Changes in density of vegetation usually favouring phytophils. Changes to benthos leading to restructuring of fish community toward illiophages.
Increased water transparency.	Can favour phytoplankton production thereby increasing production for some species.
Large fluctuations in water levels in impounded rivers/reservoirs.	Disruption of spawning through inappropriate stimuli or unnatural/unpredictable short-term changes favouring species with more flexible spawning behaviour. Stranding and dessication of eggs, larvae and other life stages.
Modified flow effects: Downstream	
Diminished and delayed flows (discharge) during wet season.	Decline in habitat availability (area and duration) for feeding, shelter and reproduction. Diminished reproductive success due to insufficient or delayed stimuli for migrations and reproduction. Changes to salinity concentrations in deltas may change species relative abundance of stenohaline and euryhaline species but overall effects on yields are uncertain.

Cause	Effects
Rapid (short-term) fluctuations in water levels (hydropeaking).	Diminished reproductive success due to insufficient or inappropriate stimuli for migrations and reproduction favouring species with more flexible spawning behaviour. Stranding of eggs, juveniles and adults and elevated mortality due to unpredictable flood patterns. Diminished reproduction in nest building species due to overly rapid rises in water levels.
Increase in dry season flows (permanently elevated dry season water levels).	Diminished local primary and secondary production arising from the permanent loss of seasonally flooded forests and other riparian vegetation. Loss of organic inputs and reduced nutrient re-cycling due to diminished ATTZ. Potential loss of shelter and spawning habitat for fish. Flood level re-defined (raised).
Reduced sediment transport downstream.	Diminished primary and secondary production resulting from reduced nutrient transport.
Release of deep cold, nutrient-rich but often anoxic waters (localised impact)	Loss of stenothermal species. Delayed and diminished spawning. Encourages tailwater fisheries in immediate downstream vicinity of dam (may simply reflect a re-distribution of fish rather than increase to overall abundance/biomass). Creation of hypoxic conditions below dams causing sudden fish kills.
Release of oxygen and nitrogen super-saturated water from spillway or dam crest during high water periods (localised impact).	Diminished survival rates arising from prolonged exposure to saturated waters.

Large fluctuations of water in reservoirs may raise mortality rates among species by stranding and may also disrupt spawning activity through inappropriate stimuli or unnatural/ unpredictable short-term changes favouring species with more flexible spawning behaviour.

Dams can significantly modify the flood pulse affecting primary and secondary production, and fish habitat quality and quantity in downstream locations. Fish yields are consequently impacted. Diminished and delayed flows (discharge) or rapid short-term fluctuations in water levels caused by hydro-peaking can also affect reproductive success due to insufficient or delayed stimuli for migrations and reproduction favouring species with more flexible spawning behaviour. Rapid and unpredictable water level fluctuations can also raise stranding-related mortality. Overly rapid rises in water levels can diminish reproduction in some species e.g. nest builders.

Reduced transport of nutrient-rich sediment may affect primary and secondary production in downstream locations. Release of deep cold nutrient rich waters may encourage tailwater fisheries in the immediate downstream vicinity of dam. This may simply reflect a re-distribution of fish rather than an increase to overall abundance or biomass in the system. The release of deep cold anoxic waters may cause mortalities and delay or diminish spawning in some species. Changes to salinity concentrations in deltas may change species relative abundance of stenohaline and euryhaline species but overall effects on yields are uncertain.

2.3.2 *Flood control projects including flood control drainage and irrigation (FCDI) schemes*

Levees and flood control embankments are linear dams designed to increase the height of the existing natural levee and thereby prevent water spreading laterally onto the floodplain. Flood control projects often enclose areas of floodplain within dykes to control flooding thereby enabling activities such as rice and fish culture, irrigated agriculture and grazing for cattle to take place (Welcomme 1985).

Projects may include systems to control floodplain inundation to maximise agricultural production and a safe environment for their inhabitants. These are often referred to as Flood Control Drainage and Irrigation Schemes. Flooding within FCDI schemes is usually controlled by sluice gates built into the embankments. Local rainfall is often an important source of flooding and some schemes are also equipped with pumps to control water levels when gravity drainage is not possible.

Flood control projects obstruct lateral migrations of fish between the main channel and the floodplain and modify the flood pulse). They also interrupt sediment transport potentially effecting primary (and secondary) productivity (Table 4). The net effect is typically a reduction in fish yield, value and diversity (Halls et al 1998; 1999).

2.3.3 *Irrigation Projects*

Because of their relatively small individual size and their location outside or on the margins of the flood zone, irrigation projects without full flood protection tend to have less impact on fisheries compared to FCDI or flood protection works that can both significantly modify hydrological conditions in the flood zone and obstruct fish migrations, impacting on fish yield and diversity (Halls et al 1998; 1999). Most small scale irrigation projects are located outside of the flood zone and comprise ponds and reservoirs intimately connected with surrounding rice fields forming the rain-fed 'ricefield landscape'.

Pumps and weirs may be used to abstract or divert water from river channels. The expansion of the 'ricefield landscape' by irrigation development will impact on yields of floodplain river fisheries by depriving them of water through the many small-scale diversions into fields and by obstructing fish migrations. These losses, may however be compensated for **to some extent** by the additional catches of the more restricted suite of fish, mainly blackfish from rice fields, and small irrigation reservoirs (Khoa et al., 2005). The extent of compensation for any losses will also depend upon fisheries and agricultural management practices (Hortle & Penroong 2009).

Table 4 impacts to fish and fisheries arising from flood control structures and embankments for other uses

Cause	Effects
Lateral migrations (active and passive) between floodplain and main channel obstructed.	Loss of floodplain-dependent migratory species that seasonally utilise the floodplain for reproduction, feeding or shelter including reductions to yield.
Reductions to flood extent and duration inside poldered areas.	Diminished habitat availability and therefore fish productivity of floodplain resident species or species that can survive within remaining habitats inside flood control scheme (polder).
Delayed flooding inside polders	Diminished spawning success and growth (fish production).
Disrupted nutrient exchange (sediment transport and deposition).	Poor recruitment, general reduction in primary and secondary production including fish.
Induction of water through pumps for irrigation and flood control.	Fish mortalities resulting from passage through turbines and pumps particularly juveniles.
Irrigation may increases aquatic habitat availability, particularly rice fields.	Increased rice-field fish yields
Increased use of pesticides and fertilizers required for HYV's of crops grown inside polders.	General degradation of fisheries
Increases to river discharge as flow is constrained to main channel.	Egg and early life stages swept past suitable nursery habitat. Upstream spawning migrations hampered by excessive flows. Spawning beds destroyed by down cutting (erosion) of river bed.

3 Assessment methodology

3.1 Outline of proposed methodology

The assessment will attempt to quantify the likely 'new' yield of fish that might be expected under each development scenario. Many potential impacts may arise to the fisheries sector as a result of development activities. Only some impacts can be readily quantified given existing knowledge, data and models. Other potential impacts will be highlighted and described, and where possible quantified in terms of likely scale and direction of change.

The quantitative assessment will include fish yield losses arising from:

- Barrier impacts of dams and flood control schemes.
- Flood modification impacts in the flood zone arising from water storage above dams and abstractions for irrigation.

and gains arising from:

- Reservoir fisheries above tributary dams.
- Irrigation projects.

3.2 Scope of the assessment

3.2.1 *Spatial Scope*

The spatial scope of the assessment is defined as being:

- All aquatic fish habitats where changes to yield would be expected as a result of the diminished access to these habitats or arising from changes to hydrological conditions within them due to development activities.

Impacts will be reported at the national level.

3.2.2 *Resource Scope*

The assessment will include impacts to wild caught fish and other aquatic animals (OAA) commonly included in reported fisheries yields (e.g. frogs, snails, small shrimp).

The assessment excludes potential national level development plans for the aquaculture sector because these have not been defined for any of the development scenarios but locally autonomous small-scale (informal) aquaculture development in reservoirs will be included because most reservoirs are stocked.

The assessment excludes unplanned or unspecified mitigation measures (e.g. fish pass facilities in flood control embankments).

3.2.3 *Development scope*

Three major development sectors are included:

- Hydropower
- Irrigation (and other abstractions for domestic and industrial water supply)
- Flood Control (overlaps irrigation)

The impacts of a growing basin population will be included in the assessment. In the base case, future fish yield is assumed to be unaffected by the growing basin population (potential fishing pressure) because:

- Management may effectively control growing fishing pressure.
- Alternative livelihoods opportunities may grow.
- Uncertainty surrounding existing levels of exploitation.

Sensitivity tests to this key assumption will be made reflecting both an increasing and a declining situation in underlying fisheries yield.

3.2.4 *Impacts Scope*

The magnitude of impacts of basin development varies through space and time. Some may be local whereas others will be felt basin-wide. Some will have a more profound impact than others. On the basis of the available information the quantitative assessment described in this section includes only those impacts highlighted in Table 5, Table 6 and Table 7.

These represent the readily quantifiable impacts. Other impacts to fisheries which are harder to quantify arising from the 1st and 2nd order impacts listed in these tables will be examined in qualitatively.

Table 5 Summary of first and second order impacts relevant to fisheries associated with dams. Impacts highlighted yellow are included in assessment. Remaining impacts are ranked in approximate order of importance

Dams	1st and 2nd Order Impacts
Barrier and passage effects	Obstruction of fish migrations and passage mortality (if applicable).
	Interruption of downstream sediment transport.
	Formation of reservoirs in tributaries upstream of dams.
Modified flow effects: Upstream / reservoirs	Increased flooded area.
	Increased dry season water levels
	Decreased flow velocity.
	Increased sediment deposition due to low flow conditions.
	Rapid (short-term) fluctuations in water levels (hydropeaking)
	Stabilized water levels (no flood pulse).
	Vertical stratification of the water column.
	Increased water depth.
	Changes to water temperature.
	Increased water transparency.
Modified flow effects: Downstream	Diminished and delayed floodplain inundation
	Increased dry season water levels
	Diminished and delayed flows (discharge) in channel.
	Reduced sediment transport downstream.
	Rapid (short-term) fluctuations in water levels (hydropeaking).
	Changes to salinity in delta regions.
	Release of deep cold, nutrient-rich but often anoxic waters.
	Release of gas super-saturated water.

Table 6 Summary of first and second order impacts relevant to fisheries associated with flood control and flood control drainage and irrigation (FCDI) schemes in the flood zone. Impacts highlighted yellow are included in assessment. Remaining impacts are ranked in order of importance

Flood control schemes (FCDI) Inside flood zone)	1st and 2nd Order Impacts
Barrier and passage effects	Obstruction of fish migrations between floodplain and main channel.
	Interruption of sediment transport to floodplains.
	Passage mortality via pumps for irrigation and flood control.
Modified flow effects:	Diminished and delayed flooding inside poldered areas
	Increases to river discharge as flow is constrained to main channel.
	Increased use of pesticides and fertilizers for HYV's of crops.

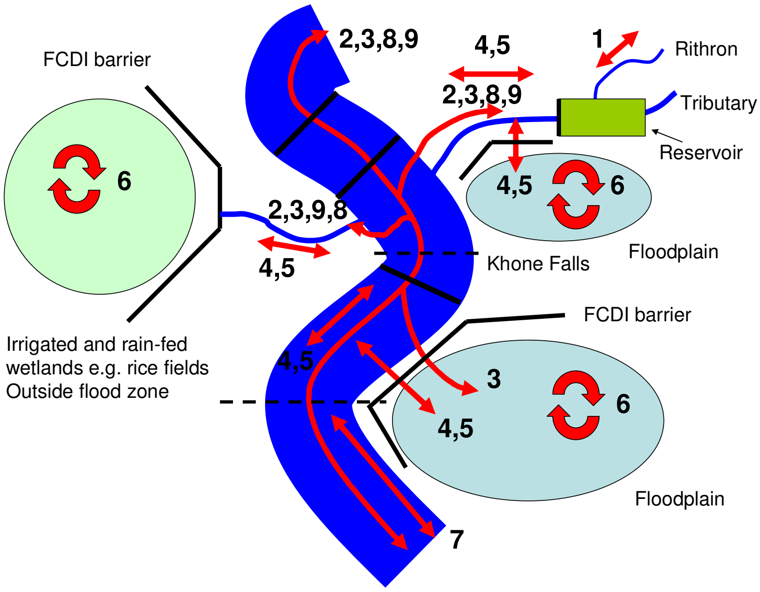
Table 7 Summary of first and second order impacts relevant to fisheries associated with irrigation projects outside the flood zone. Impacts highlighted yellow are included in assessment. Remaining impacts are ranked in order of importance

Irrigation Projects (Outside of flood zone)	1st and 2nd Order Impacts
Barrier and passage effects	Obstruction of fish migrations between project and river system.
	Passage mortality via pumps for irrigation.
Modified flow effects:	Increased area of 'ricefield landscape' i.e. small ponds, reservoirs, and surrounding ricefields forming the irrigation project.
	Downstream reductions to flow by irrigation abstractions or diversions from channels WITHIN the floodzone or connected to the river system.
	Increased use of pesticides and fertilizers

3.3 Fish Guilds – a framework for assessing opportunities and threats

For impact assessment purposes, it is useful to identify major categories or ***guilds*** of fish inhabiting the lower Mekong basin that exhibit similar migratory behaviour. The guild framework helps facilitate the identification of species within the assemblage that are most likely to be impacted by basin development. Halls & Kshatriya (2009) identified 10 guilds of fish in the Mekong (Table 8) based upon their migrations or exchanges of life history stages between critical habitat (Figure 2). These represent variants or aggregations of the environmental guilds proposed by Welcomme *et al.* (2006).

Figure 2 Typical migrations of the 9 freshwater guilds among and within the main wetlands



Halls & Kshatriya (2009) identified 233 species of fish in the Mekong belonging to these 10 guilds representing 55 families. This included 19 marine species belonging to 16 families. Twenty-two species of blackfish belonging to 9 families were identified. A further 42 species belonging to 17 families were found only in the Vietnamese delta. The remaining 150 species were identified as *whitefish* belonging to guilds 1-5, 8 and 9.

Fifty-eight *whitefish* species were assigned to the highly migratory guilds (Guilds 2, 3, 8 & 9). They include 5 of the 11 Mekong fish species threatened by extinction according to the IUCN 'Red List' (http://www.redlist.org): the Mekong giant catfish (*Pangasianodon gigas*), the Mekong stingray (*Dasyatis laosensis*), Jullien's barb (*Probarbus jullieni*), the Laotian shad (*Tenualosa thibaudeaui*) and the Thicklip barb (*Probarbus labeamajor*).

A further 26 species belonging to the 'floodplain spawner' guild were identified. This guild is at risk mainly from longitudinal (flood control embankments) barriers obstructing spawning migrations but also from lateral (dams) obstructing refuge migrations.

Table 8 Fish guilds in the Mekong proposed by Halls & Kshatriya (2009)

Guild	Habitats utilised	Typical characteristics
1. Rithron resident guild	Rithron	Resident in rapids torrents, rocky areas and pools in the rithron. Generally insectivrous, algal scrapers or filter feeders, small in size, lithophilic or phytophilic with extended breeding seasons and suckers or spines to maintain position in the flow. Limited migrations.
2. Migratory main channel (& tributaries) resident guild	Marine to Rithron	Long distance migrants spawning in the main channel (sometimes in rithron) upstream of adult feeding habitat in the main channel. May migrate to refuges (deep pools) in the main channel during the dry season. Pelagophilic members have drifting pelagic egg or larval stages returning to adult habitat utilising backwaters and slacks as nurseries. Adults do not enter floodplain and may be piscivorous. Lithophilic members may be anadromous with fry resident at upstream site for a certain period and may occupy upstream floodplain. May also include psammophils (sand spawners). Members vulnerable to overexploitation and tend to disappear when river is damned preventing longitudinal upstream migration. May respond favourably to fish passage facilities. Includes anadromous species.
3. Migratory main channel (& tributaries) spawner guild	Floodplains to Rithron	Spawn in the main channel, tributaries or margins upstream of floodplain feeding and nursery habitat often with pelagic egg or larval stages. Pelagophilic, lithophilic, phytophilic (in floodplain margins) or psammophilic. Adults and drifting larvae return to floodplains to feed and therefore impacted by flood control embankments preventing lateral migrations between the main channel and the floodplain. May migrate to refuges (deep pools) in the main channel during the dry season. Tend to disappear when river is damned preventing longitudinal migrations to spawning and refuge habitat.

Guild	Habitats utilised	Typical characteristics
4. Migratory channel refuge seeker guild	Floodplains to potomon	Undertake migrations from floodplain feeding and spawning habitat to refuges (deep pools) in the main channel during the dry season. Predominantly phytophils. Differ from main channel spawner in that spawning occurs on the floodplain with main channel used as refuge during dry season. Threatened when river is damned preventing longitudinal migrations to refuge habitat in main channel or flood control embankments preventing lateral spawning and refuge migrations.
5. Generalist guild	Floodplains and potomon	Limited non-critical migrations in mainstream. Highly adaptable to habitat modification. Often repeat breeders or breed during both wet and dry seasons sometimes with nests and parental care. Rheophilic or limnophilic; often tolerant of low dissolved oxygen concentrations. May be semi-migratory often with sedentary local populations. Benthic members are predominantly lithophils and psammophils and occupy centre of main channel with intolerance to low dissolved oxygen. May seek refuge in deep pools during dry season. The riparian zone members typically occur amongst the vegetation of main channel and fringing floodplains. May undertake lateral migrations to floodplain to occupy similar habitats during flooding. Often tolerant and low D.O. and exhibit wide range of breeding behaviour but predominantly phytophils. This guild is especially well represented in most rivers.
6. Floodplain resident guild (Blackfish)	Floodplains	Limited migrations between floodplains pools, river margins, swamps, and inundated floodplains. Tolerant to low oxygen concentrations or complete anoxia. Often repeat breeders, phytophils, nest builders, parental care or live bearers.
7. Estuarine resident guild	Estuary	Limited migrations within the estuary in response to daily and seasonal variations in salinity. Brackish water guild euryhaline and usually confined to brackish part of system. Freshwater estuarine guild includes stenohaline species that inhabit freshwater part of estuarine system.

Guild	Habitats utilised	Typical characteristics
8. Semi-anadromous guild	Estuary and lower potomon	Enters fresh/brackish waters to breed. Enters freshwaters as larvae/juveniles to use the area as a nursery, either obligate or opportunistic. Impacted by river mouth dams that stop migration into the river.
9. Catadromous guild	Marine to Rithron	Reproduction, early feeding and growth at sea. Juvenile or sub-adult migration to freshwater habitat often penetrating far upstream. Members vulnerable to overexploitation and tend to disappear when river is damned preventing longitudinal upstream migration. May respond favourably to fish passage facilities (e.g. salmonids).
10. Marine guild	Estuary	Enters estuaries opportunistically.

3.4 Baseline yields

The estimates of yield from the fish consumption survey described by Hortle (2007) will be used as the baseline for the assessment.

These country-specific fish yield estimates will be sub-divided into the 9 guild categories described in Section 3.3 based upon the proportions of each guild observed in catch surveys undertaken in each country.

3.5 Estimation of barrier and passage effects

Species vulnerable to barrier and passage impacts in the basin will include those which undertake obligatory migrations to survive or to complete their lifecycle. Species belonging to Guilds 2, 3, 8 and 9, that undertake significant longitudinal migrations within the mainstream and tributaries will be particularly vulnerable to mainstream and tributary hydropower dams (Table 9). Lateral migrations of guild 4 would be impacted by flood control projects and embankments of FCDI schemes and tributary reservoirs. Given its flexible behaviour, it is assumed that Guild 5 would not be impacted by barriers to migrations, instead adapting to the conditions within the dam, flood control compartment or reservoir. Similarly, because of their sedentary nature and ability to withstand harsh environmental conditions, blackfish species (Guild 6) are also hypothesised not to be impacted by barriers.

Table 9 Matrix summarising the hypothesised barrier and passage impact (and flow effect) locations for each guild (for all 11 mainstream dams scenario). M/S – mainstream; MC – Main channel; RES - Reservoir; ARES - Above reservoir; TC - Tributary channel

LOCATION OF IMPACTS

		BARRIER EFFECTS								FLOW (FI/HAI) EFFECTS*							
TRIB DAMS		MAIN CHANNEL			TRIBUTARY					MAIN CHANNEL			TRIBUTARY				
					BELOW			ABOVE					BELOW			ABOVE	
		MC	F/PLAIN FCDIs		TC	F/PLAIN FCDIs		RES	ARES	MC	F/PLAIN FCDIs		TC	F/PLAIN FCDIs		RES	ARES
M/S DAM	GUILD		OUT	IN		OUT	IN				OUT	IN		OUT	IN		
ABOVE	1	✖	-	-	-	-	-	-	✖	✖	-	-	-	-	-	-	✖
	2	✓	-	-	✓	-	-	-	-	-	-	-	-	-	-	-	-
	3	✓	✓	✓	✓	✓	✓	✓	✓	-	-	-	-	-	-	-	-
	4	✖	✖	✓	✖	✖	✓	✓	-	✓	✓	-	✓	✓	-	-	-
	5	✖	✖	✖	✖	✖	✖	✖	✖	✓	✓	✓	✓	✓	✓	✖	✖
	6	-	✖	✖	-	✖	✖	✖	-	-	✓	✓	-	✓	✓	✖	-
	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	8	✓	-	-	✓	-	-	✓	✓	-	-	-	-	-	-	-	-
	9	✓	-	-	✓	-	-	✓	✓	-	-	-	-	-	-	-	-
LOWEST DAM																	
BELOW	1	-	-	-	-	-	-	-	✖	-	-	-	-	-	-	-	✖
	2	✓	-	-	✓	-	-	-	-	-	-	-	-	-	-	-	-
	3	✓	✓	✓	✓	✓	✓	✓	✓	-	-	-	-	-	-	-	-
	4	✖	✖	✓	✖	✖	✓	✓	-	✓	✓	-	✓	✓	-	-	-
	5	✖	✖	✖	✖	✖	✖	✖	✖	✓	✓	✓	✓	✓	✓	✖	✖
	6	-	✖	✖	-	✖	✖	✖	-	-	✓	✓	-	✓	✓	✖	-
	7	✖	✖	✖	✖	✖	✖	✖	✖	✓	✓	✓	✓	✓	✓	-	-
	8	✓	-	-	✓	-	-	✓	✓	-	-	-	-	-	-	-	-
	9	✓	-	-	✓	-	-	✓	✓	-	-	-	-	-	-	-	-

*AFTER ACCOUNTING FOR BARRIER EFFECTS

Key

✓	Impact expected
✖	Impact not expected
?	Impact may be expected depending upon availability of waterbodies and habitats remaining
-	Species or habitat combination not expected in these locations

3.5.1 *Mainstream and tributary dams*

Halls & Kshatria (2009) concluded that the likelihood of populations of species belonging to Guilds 2,3,8, & 9 remaining viable in the basin is small should their spawning adults have to cross a dam to access their spawning habitat. This conclusion was drawn under the assumption that all spawning habitat is located above the lowermost dam (Sambor) included in their study. Other assumptions concerning the distribution of spawning habitat in relation to the position of dams were not examined.

Whilst the distribution of spawning habitat in the basin remains uncertain, the assumption that all or most of the spawning habitat of the four guilds lies above Sambor is not unlikely and therefore the calculation of lost yield straightforward. The baseline yield for each country is simply reduced by the yield attributable to these species.

However, for Scenario No. 6 which excludes 5 mainstream dams in the middle and lower part of the basin, the lowermost dam in the system would be then become Pak Chom. The assumption that all spawning habitat lies above this dam may not be deemed realistic.

Since it was decided that the population dynamics model described by Halls & Kshatriya (2009) would not be employed for this assessment or to explore other assumptions concerning the distribution of spawning habitat in the basin, an alternative simple approach is described below where lost yields of highly migratory fish (Guilds 2,3,8,9) are simply estimated in proportion to the estimated lost spawning habitat area above the proposed location of the Sambor dam. Assuming that the Sambor dam corresponds to the lowermost range of the spawning habitat for these guilds ensures that the study approaches are consistent. In reality, spawning habitat may exist below Sambor. The conclusions of Halls & Kshatria (2009) remain unchanged and both sets of results should be considered as part of the assessment.

A simple barrier effects model.

The aggregated yield of highly migratory species belonging to guilds 2, 3, 8 & 9 in the basin is assumed to vary linearly with the available spawning habitat (ASA). The available spawning habitat is assumed to occupy the entire area of the main channel and its tributaries. Yield is zero when the ASA is zero.

Yield arising from the construction of hydropower dams (both in the mainstream and tributaries) is therefore estimated to be lost in proportion to the loss of available spawning habitat. This model assumes that spawning habitat of equal quality exists throughout the basin in the main channel and its tributaries, and that spawning fish will utilise the available habitat (regardless of its upstream position in the basin) at some constant (unchanging) density corresponding to the baseline conditions. It also assumes a linear relationship between stock size and recruitment (i.e. no density-dependent effects).

NB The model predictions will be consistent with those of Halls & Kshatria (2009) if all spawning habitat is assumed to lie upstream of the lowermost (Sambor) Dam.

It is assumed that fish ladders or passes will not be effective (zero passage of fish) and therefore the available spawning habitat is estimated as the total channel area (mainstream and tributaries) downstream of the lowest mainstream dam.

When the mainstream forms a boarder between two countries, the area of the main channel area is divided equally between the two countries and added to the available area in the tributaries of each country.

Other assumptions concerning the distribution of ASA by country can be examined based upon for example expert judgement or informed by the results of surveys such as the Fisheries Programme 'Ichthyoplankton survey' (Ingthamjitr & Roitana 2009).

The predicted (new) yield of highly migratory guilds in each country under each scenario is simply the product of the baseline yield, the proportion of total spawning habitat in the basin above the lowermost dam, and the proportion of spawning habitat in the country not impacted i.e the proportion below lowest dam.

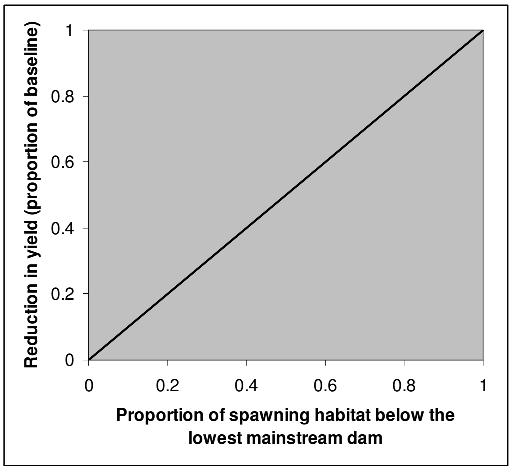


Figure 3 Estimated reduction in yield of guilds 2,3,8,9 expressed as a proportion of baseline yield plotted as a function of the proportion of spawning habitat below the lowest mainstream dam and above Sambor

The modification of the habitat upstream of reservoir dams is hypothesised to also impact on the migrations of Guild 4 particular for reservoirs without floodplains (see Table 9). Reductions in yield for Guild 4 due the barrier effects of reservoirs are assumed to vary in proportion to the proportion of the total flooded (flooded zone) area in each country impacted by the tributary reservoir (Figure 4).

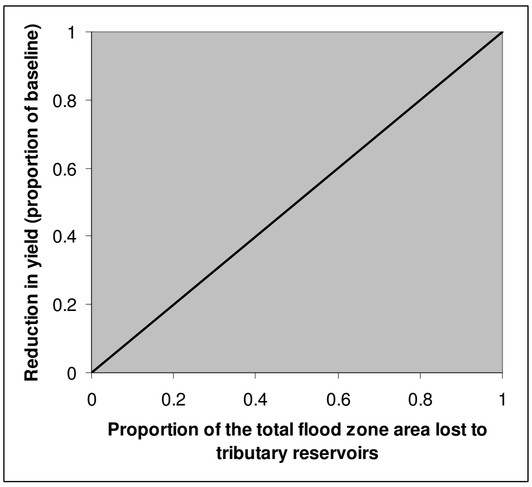


Figure 4 Estimated reduction in yield of Guild 4 expressed as a proportion of baseline yield plotted as a function of the proportion of the baseline flood zone area in tributary reservoirs

3.5.2 *Flood Control and Flood Control Drainage and Irrigation (FCDI) Projects*

Flood Control Drainage and Irrigation (FCDI) Projects are planned for both Cambodia and Vietnam. The most significant are included in Scenario 7: 'Mekong Delta Flood Management Scenario'. The schemes are designed to provide early (no flooding until 1st August) or full flood protection and regulation using embankments, pumps and regulators. Combined, the 4 projects aim to control flooding and salinity over 4,600 km2 of floodplain inside the flood zone. These projects have the potential to have both barrier and modified flow (flood-pulse) impacts on fisheries.

It is hypothesised that FCDI projects will impact on Guild 4 by obstructing lateral migrations between the floodplain and the main channel for spawning and refuge seeking respectively. Reductions in yield for Guild 4 due the barrier effects of FCDI projects are assumed to vary in proportion to the proportion of the total flooded (flooded zone) area in each country impacted by the FCDI (Figure 5).

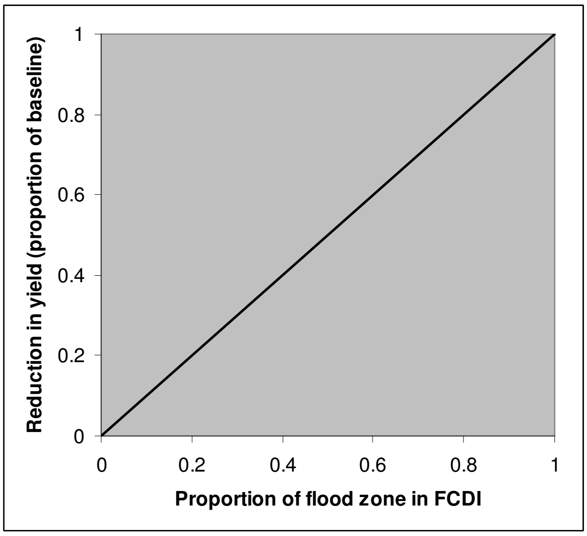


Figure 5 Estimated reduction in yield of Guild 4 expressed as a proportion of baseline yield plotted as a function of the proportion of the flood zone in FCDIs

For scenarios including only the 6 mainstream (Lao) dams in the upper part of the basin, yields from Guild 3 are adjusted in the same way because their access to downstream feeding habitats is hypothesised to be obstructed by the flood control embankments (Table 9).

Depending upon the extent of habitat availability during the dry season, Guild 5 may also be impacted. The estimated FCDI impacts may therefore be conservative.

3.6 Reservoirs fisheries

Dams on tributaries modify (reduce) the flood-pulse in the system and therefore impact on the yield of fish within the flood zone. Tributary dams also act as barriers to fish migrations impacting on species belonging to Guilds 2,3,4,8,9. Estimation of the barrier effects of tributary dams on the yield of these Guilds is described in Section 3.2.4. Estimation of the flow modification effects on fish inhabiting the flood zone downstream of tributary dams is described in Section 3.7.

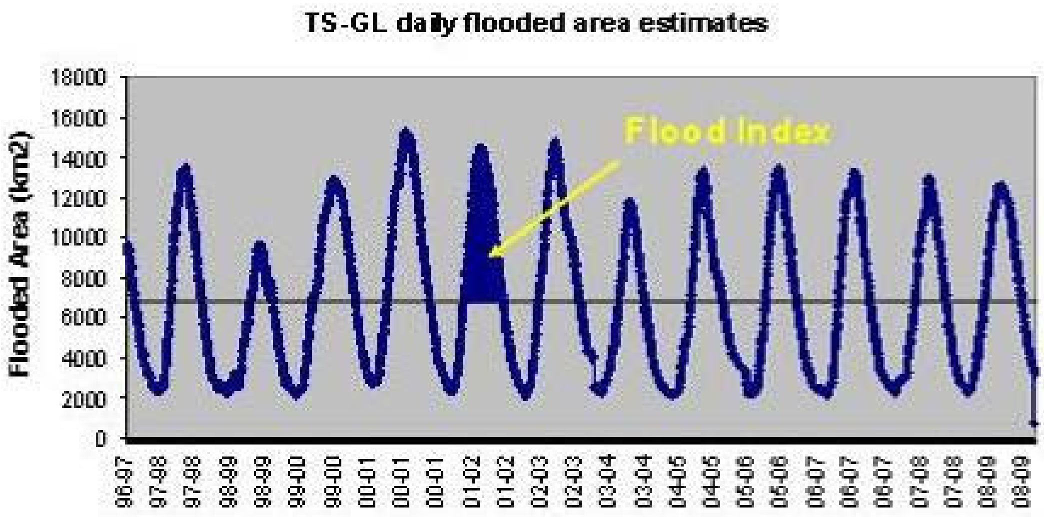
However, many reservoirs in the LMB formed by dams support productive fisheries for both indigenous and exotic fishes as well as some other animals including shrimps (see Review in Hortle and Penrrong 2009). Most species persisting in reservoirs probably belong to the very diverse Guilds 5 which include Bagrid and silurid catfish, many species of carps and the planktivorous freshwater herring, *Clupeichthys aesarnensis*. Guild 6 – the blackfish also persist in reservoirs. Fewer species persist in smaller reservoirs due to fewer niches and less diverse (spawning) habitat. The most productive reservoirs are small, shallow, nutrient-enriched, stocked with exotics species, and heavily fished. Yield per unit area declines exponentially with reservoir size (Hortle and Penroong 2009).

Based upon a review of reservoir yields in the LMB, Hortle and Penroong (2009) estimate that the mean yield across all sizes of reservoirs is likely to average at least 200 kg/ha/year. The 'new yield' from reservoir fisheries is estimated simply as the product of the total new reservoir maximum surface area and the areal yield estimate i.e. 200 kg/ha. To avoid 'double counting', the yield of Guild 5 & 6 is first reduced in proportion to area of the flood zone in the tributary 'lost' to the reservoir.

3.7 Estimation of modified flow (flood pulse) effects

All species are hypothesised to respond to changes to the extent and duration of the flood pulse due to its influence on primary and secondary production, and trophic (food chain) effects.

Figure 6 Illustration of the estimation of the flood index based upon the daily water levels at Kompong Luong in the Great Lake. The quadratic expression (provided by IKMP) provides estimates of the flooded area of the lake based upon the water level. The Flood Index is the sum of the daily flooded areas above the mean flooded area for the time series.



Changes to the extent and duration of the flood pulse are described by a flood index – simply the sum of the flooded area on day d ($Area_d$) above the mean flooded area (Welcomme 1979; Halls 2008):

$$FI = \sum_{d} Area_d$$

For scenarios when all 11 mainstream dams are included, flood index effects will only apply to guilds 4,5,6,7 because the remaining guilds are unlikely to persist given the minimum upstream passage success requirements of installed fish passes (Table 9).

However, if only the cascade of the 6 mainstream dams in upper part of the LMB are to be constructed, then it is hypothesised that flood index effects would be experienced by all the guilds except the rithron resident Guild 1 and in all locations except in and above storage reservoirs behind tributary dams (Table 10).

Table 10 Matrix summarising the hypothesised barrier and passage impact (and flow effect) locations for each guild if only the cascade of 6 mainstream dams in upper part of the LMB are constructed. M/S – mainstream; MC – Main channel; RES - Reservoir; ARES - Above reservoir; TC - Tributary channel

LOCATION OF IMPACTS

TRIB DAMS		BARRIER EFFECTS								FLOW (FI/HAI) EFFECTS*							
		MAIN CHANNEL			TRIBUTARY					MAIN CHANNEL			TRIBUTARY				
					BELOW			ABOVE					BELOW			ABOVE	
		MC	F/PLAIN FCDIs		TC	F/PLAIN FCDIs		RES	ARES	MC	F/PLAIN FCDIs		TC	F/PLAIN FCDIs		RES	ARES
M/S DAM	GUILD		OUT	IN		OUT	IN				OUT	IN		OUT	IN		
ABOVE	1	✗	-	-	-	-	-	-	✗	✗	-	-	-	-	-	-	✗
	2	✓	-	-	✓	-	-	-	-	-	-	-	-	-	-	-	-
	3	✓	✓	✓	✓	✓	✓	✓	✓	-	-	-	-	-	-	-	-
	4	✗	✗	✓	✗	✗	✓	✓	-	✓	✓	-	✓	✓	-	-	-
	5	✗	✗	✗	✗	✗	✗	✗	✗	✓	✓	✓	✓	✓	✓	✗	✗
	6	-	✗	✗	-	✗	✗	✗	-	-	✓	✓	-	✓	✓	✗	-
	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	8	✓	-	-	✓	-	-	✓	✓	-	-	-	-	-	-	-	-
	9	✓	-	-	✓	-	-	✓	✓	-	-	-	-	-	-	-	-
LOWEST DAM																	
BELOW	1	-	-	-	-	-	-	-	✗	-	-	-	-	-	-	-	✗
	2	✓	-	-	✓	-	-	-	-	✓	-	-	✓	-	-	-	-
	3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	-	-	-
	4	✗	✗	✓	✗	✗	✓	✓	-	✓	✓	-	✓	✓	-	-	-
	5	✗	✗	✗	✗	✗	✗	✗	✗	✓	✓	✓	✓	✓	✓	✗	✗
	6	-	✗	✗	-	✗	✗	✗	-	-	✓	✓	-	✓	✓	✗	-
	7	✗	✗	✗	✗	✗	✗	✗	✗	✓	✓	✓	✓	✓	✓	-	-
	8	✓	-	-	✓	-	-	✓	✓	✓	-	-	✓	-	-	-	-
	9	✓	-	-	✓	-	-	✓	✓	✓	-	-	✓	-	-	-	-

Key

*AFTER ACCOUNTING FOR BARRIER EFFECTS

✓	Impact expected
✗	Impact not expected
?	Impact may be expected depending upon availability of waterbodies and habitats remaining
-	Species or habitat combination not expected in these locations

It is also assumed that all guilds will respond to flood index effects in the same manner as observed for the Tonle-Sap Great Lake System exploited by the Cambodian Dai Fishery (see Halls 2008). Based upon daily catch rate estimates for this fishery over a 12 year period, a statistical model (GLM) was fitted (Figure 7) to predict how fish abundance, indicated by CPUE, responds to the flood index (FI). The model predicts that reductions

to the FI caused by the storage of water behind dams or water abstractions will result is approximately proportional reductions in fish abundance (CPUE) and therefore fish yield (

Figure 8).

Figure 7 (a) ln transformed observed and predicted catch rates (CPUE). Municipality, month, and lunar quarter were treated as fixed factors in the model with FI as the covariate, p<0.001, R2=0.66. (b) Back-transformed observed and predicted monthly yields, and the observed FI.

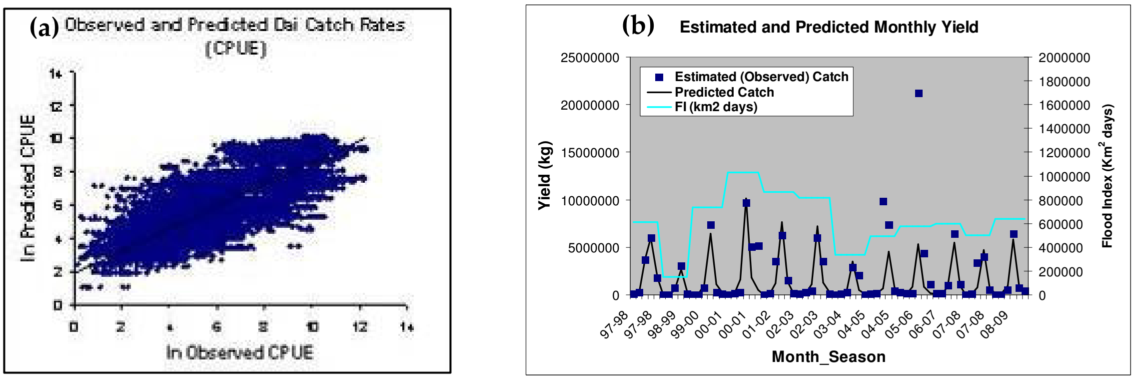
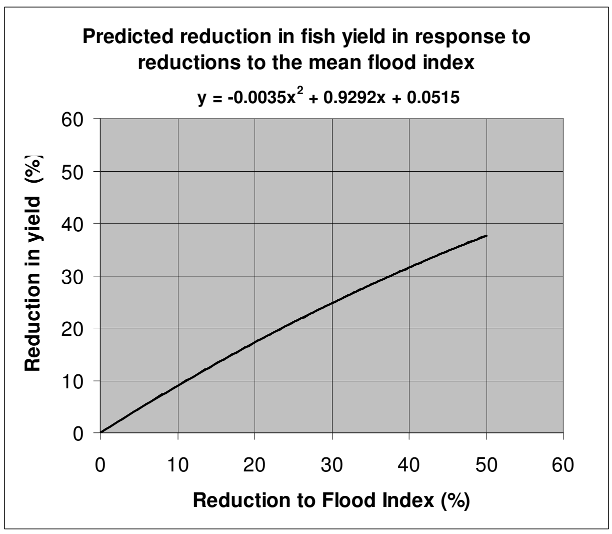


Figure 8 GLM model predicted reductions in yield plotted a as a function of reductions to the flood index. The model is approximately linear over the range of observations expected for the assessment (shaded red).



For each Scenario, the model illustrated in

Figure 8 is applied to each guild in the locations summarised in the hypothesis matrix (Table 10) weighted by the flooded area over which changes to the flood index occur to estimate the new yield of each guild. The flooded area used for this weighting excludes the flooded zone lost to reservoirs, areas upstream of reservoirs that are no longer influenced by the flood pulse, and areas within FCDI or flood control schemes which will have their own unique flood indices.

It may be appropriate to estimate several FIs for each country corresponding to different flood cells or zones. In this case, an average FI value is estimated for each country weighted by the flooded area over which the FI is observed.

For the trans-boundary Guilds 2, 3, 8 and 9, the mean FI derived for each country is weighted according to the proportion of the total flood zone in the basin lying in each country.

Yields of Guild 4 in each country (outside FCDI or flood controlled areas including reservoirs) are adjusted using the FI model applied with any necessary area weightings to account for spatial variation in the FI within the country described above.

The remaining Guilds 5 & 6 may occur both inside and outside FCDI schemes and any controlled flood areas. For each country, the yields of these two guilds are adjusted according a mean FI estimated for the areas lying inside and outside FCDI schemes weighted by the flooded area in each of the two areas.

The yield from Guild 7 is adjusted according the new FI for the Vietnamese Delta estimated for each scenario with any necessary area weightings if two or more FI estimates for the delta are made.

3.8 Irrigation Projects

These are considered separately from FCDI projects because of their small individual size and their location outside or on the margins of the flood zone. Because of these features they tend to have less impact on fisheries compared to FCDI or flood protection works that can both significantly modify hydrological conditions in the flood zone and obstruct fish migrations, impacting on fish yield and diversity (Halls et al 1998; 1999). Most small scale irrigation projects are located outside of the flood zone and comprise ponds and reservoirs intimately connected with surrounding rice fields forming the rain-fed 'ricefield landscape'. Pumps and weirs may be used to abstract or divert water from river channels.

The yield of fish and OAA from the unstocked ricefield landscape has been conservatively estimated as 50-100 kg/ha/year, approximately 20 % comprising OAA (Hortle & Penroon 2009). Common species of fish comprising the catch belong to the blackfish category (Guild 6) including air-breathing fishes such as snakeheads *Channa striata*, walking catfishes *Clarias* species and swamp eels *Monopterus albu* that can tolerate the extreme environmental conditions where water levels may fluctuate rapidly and in which the water is often hot and deoxygenated.

Other aquatic animals include snakes, crabs, shrimps, amphibians, molluscs and insects. Yields are favoured by inundation of ricefields to greater depths and for longer duration (see e.g. (Khoa et al., 2005), and where farmers maintain ponds as dry-season refuges (Angporn et al., 1998). Small water-bodies are often stocked and also support feral fishes; i.e. stocked species or aquaculture escapees that have established wild breeding populations.

The expansion of the 'ricefield landscape' by irrigation development will impact on yields of floodplain-river fisheries by depriving them of water through the many small-scale diversions into fields and by obstructing fish migrations.

These losses, may however be compensated for **to some extent** by the additional catches of the more restricted suite of fish, mainly blackfish (Guild 6) from rice fields, and small irrigation reservoirs (Khoa et al., 2005). The extent of compensation for any losses will also depend upon fisheries and agricultural management practices (Hortle & Penroong 2009).

Losses of water downstream of irrigation projects are included in modified flow impacts (see Section 3.7). Losses due to the barrier effects of irrigation schemes cannot be quantified for this assessment due to the large number of individual and often nested projects for which little information exists. The size, location and extent of barriers remains unclear. "The irrigation sector is complex and poorly understood…there is very limited information on the details of the existing irrigation schemes" (Young 2009). Irrigation projects that employ weirs to divert water into ricefields are reported to have lower yields than those employing pumps or reservoirs (Lorenzen et al 2004).

The 'new yield' from the expansion of the 'ricefield landscape' by irrigation development is assumed to be expected only for blackfish (Guild 6). This 'new yield' is estimated simply as the product of the additional irrigation project area and the mid-range of the areal yield i.e. 75 kg/ha.

4 Data Requirements

For each scenario, including the baseline, the following data are required:

Table 11 Data requirements for the Fisheries Assessment (Quantitative element).

Category	Data Type	Scale	Unit	Source	Comments
Barrier impacts of dams in mainstream and tributaries: Guilds 2,3,8,9.	Total channel area (or length) below the lowest mainstream dam and below the lowest dam in each tributary.	By riparian country	km^2 or km	IKMP/BDP	Mainstream area to be divided equally between countries that share the mainstream.
As above but for alternative assumption concerning distribution of spawning habitat.	As above but between the lowest mainstream dam and the position of Sambor dam1.	By riparian country	km^2 or km	IKMP/BDP	Mainstream area to be divided equally between countries that share the mainstream.
Barrier impacts of dams of Guild 4 in tributaries	Total flooded area (floodplain area) above the lowest dam in each tributary.	By riparian country	km^2	IKMP/BDP	
Barrier impacts of flood control projects (FCDI) on Guild 3 and 4.	Total area of the maximum flood zone within FCDIs or controlled flood zones.	By riparian country	km^2	IKMP/BDP	
New reservoir fisheries: Guilds 5 & 6.	Total area or reservoirs in tributaries.	By riparian country	km^2	IKMP/BDP	Maximum area of reservoirs to be used for estimation.
Reservoir 'correction factor' for lost yield of guilds 5 and 6.	Total area of the flood zone (tributary and associated floodplain area) above the lowest dam in each tributary.	By riparian country	km^2	IKMP/BDP	
Flood modification effects on the Guilds	Weighted mean FI	By riparian country	km^2 days	IKMP/BDP	Weighted by area of separately calculated 'flood cells' if used in hydrological model. Flooded areas exclude areas inside FCDIs and upstream of the lowest dam on each tributary.
Flood modification effects on Guilds 2,3,8,9.	Mean maximum flooded area below lowest m/s dam (if present) excluding areas within FCDI projects and tributaries above the lowest dam on each tributary.	By riparian country	km^2	IKMP/BDP	Required for the estimation of a basinwide FI weighted by flooded area corresponding to the migratory range of guilds 2,3,8,9.

Category	Data Type	Scale	Unit	Source	Comments
Flood modification effects on Guilds 3, 4.	Mean maximum flooded area excluding areas within FCDI projects and tributaries above the lowest dam on each tributary.	By riparian country	km^2	IKMP/BDP	Required to estimate the proportion of the mean maximum flooded area inside FCDIs.
Flood modification effects on Guilds 5, 6 inside FCDIs	Mean % reduction to FI inside FCDIs	By riparian country	%	IKMP/BDP/ FMMP	Advice from FMMP required.
Irrigation project fisheries	Total command area of irrigation projects.	By riparian country	Km^2	Irrigation Database	Excludes irrigation areas within FCDI Projects.

[1] Assumed to correspond approximately with the lowermost limit of spawning habitat for Guilds 2,3,8,9.

Table 12 Data requirements for the Fisheries Assessment (qualitative element).

Category	Data Type	Scale	Unit	Source	Comments
Sediment transport impacts on primary production and fisheries resources	Mean suspended sediment concentrations upstream and downstream of mainstream and tributary dams.	By riparian country but will be determined by location of dams.	mg/l	IKMP/BDP	Estimates required for both wet season and dry season.
	Mean rates of sediment deposition or erosion upstream and downstream of dams in the main channel and floodplains.	By riparian country but will be determined by location of dams.	mm/year	IKMP/BDP	Estimates required for both wet season and dry season.
	Predicted changes to rates of sediment deposition and erosion (net transport) inside flood control areas (FCDI)	For the 4 main FCDI Projects included in Mekong Delta Flood Management Scenario.	mm/year	IKMP/BDP	Estimates required for both wet season and dry season.
Changes to water depth	Change in mean, max. and min. channel depth upstream and downstream of mainstream and tributary dams.	Determined by location of dams.	m	IKMP/BDP	Estimates required for both wet season and dry season.

Category	Data Type	Scale	Unit	Source	Comments
Changes to flows	Change in mean, max. and min. channel discharge upstream and downstream of mainstream and tributary dams.	Determined by location of dams.	m^3/sec	IKMP/BDP	Estimates required for both wet season and dry season.
Changes to inundated areas	Change in mean, max. and min. inundated channel areas upstream and downstream of mainstream and tributary dams.	Determined by location of dams.	Km^2	IKMP/BDP	Estimates required for both wet season and dry season.
Daily water level fluctuations	Estimates of mean, min. and max. daily water levels upstream and downstream of mainstream and tributary dams.	Determined by location of dams.	m	IKMP/BDP	Estimates required for both wet season and dry season.
Water quality changes	Predicted changes to mean, max. min. water quality parameters (e.g. DO, temperature, and nutrients) upstream and downstream of mainstream and tributary dams.	Determined by location of dams.	mg/l; degrees centigrade;	IKMP/BDP	Estimates required for both wet season and dry season.
Salinity effects	Predicted monthly mean salinity concentrations in the river channels, floodplains and inside FCDI projects of the delta.	By lowest spatial resolution e.g. 1 km^2 grid cells.	mg/l	IKMP	Data most appropriately summarised by maps and tabular summaries.

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