The MRC
Basin Development Plan

Economic Valuation of Water Resources (RAM Applications)

BDP Library Volume 8

June 2005
Revised December 2005

Mekong River Commission

BDP

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Foreword

The BDP Library was compiled towards the end of Phase 1 of the BDP Programme. It provides an overview of the BDP formulation, together with information about the planning process and its knowledge base, tools and routines.

The library incorporates the essence of more than a hundred technical reports, working papers and other documents. It consists of 15 volumes:

1. The BDP planning process
2. Sub-area analysis and transboundary planning
3. Sub-area studies (including 13 sub – volumes)
4. Scenarios for strategic planning
5. Stakeholder participation
6. Data system and knowledge base
7. MRCS Decision Support Framework (DSF) and BDP applications
8. Economic valuation of water resources (RAM applications)
9. Social and environmental issues and assessments (SIA, SEA)
10. IWRM strategy for the Lower Mekong Basin
11. Monographs. March 2005
12. Project implementation and quality plan
13. National sector reviews
14. Regional sector overviews
15. Training

The work was carried out jointly by MRC and the NMCs with comprehensive support and active participation by all MRC programmes and more than 200 national line agencies. Financial and technical support was kindly granted by Australia, Denmark, Japan, Sweden and Switzerland.

The library has been produced for the purpose of the BDP and is intended for use within the BDP Programme. The work was done from 2002 to 2005, and some information may already have been superseded by new developments and new knowledge. The library does not reflect the opinions of MRC nor the NMCs.

It is hoped that the work will contribute to the sustainable development of water resources and water-related resources in support of the MRC vision of *'an economically prosperous, socially just and environmentally sound Mekong River Basin'.*

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Acronyms and abbreviations

ADB	:	Asian Development Bank
AFTA	:	ASEAN Free Trade Area
AIA	:	ASEAN Investment Area
AICO	:	ASEAN Industrial Co-operation Scheme
ASEAN	:	Association of South East Asian Nations
BDP	:	Basin Development Plan (of MRC)
DSF	:	Decision-Support Framework (of MRC)
EIA	:	environmental impact assessment
ESCAP	:	Economic and Social Committee for Asia and the Pacific (of the UN)
GDP	:	gross domestic product
HAI	:	habitat area index
HYV	:	high-yield variety (of rice)
IRRI	:	International Rice Research Institute
IWRM	:	integrated water resources management
IWT	:	inland waterway transport
LMB	:	Lower Mekong Basin (the Mekong Basin parts of Cambodia, Lao PDR, Thailand and Viet Nam)
LRMC	:	long run narginal cost
MRC	:	Mekong River Commission
MRCS	:	Mekong River Commission Secretariat
NA, n/a	:	not applicable
NMC	:	National Mekong Committee
O&M	:	operation and maintenance
RAM	:	Resource Allocation Model (of BDP)
RAOM	:	Resource Allocation and Optimization Model (now replaced by RAM)
SRMC	:	Short run marginal cost
TEV	:	total economic value
WTO	:	World Trade Organization
WTP	:	willingness to pay
WUP	:	Water Utilization Programme (of MRC)

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Executive summary

Water allocation

Effectively managing the available water resources in a river basin requires water to be allocated between various demand types and interests in a well-considered and equitable manner. Factors to be considered in developing guidelines for water allocation include:

- The range of demand types to be supplied with water and their locations within the river basin;
- Target levels of service for each type of demand and realistic water usage rates for each type of demand taking into account target levels of service;
- Anticipated quantity, quality and location of any effluents returned to the river system following its use for each demand type; and
- The impacts of the water usage and water returns on the availability of water at other locations.

Various basin simulation models are being developed by the MRC to help better understand the outcomes of changes to water availability and water demand in the Mekong Basin. These are all linked in terms of their inputs and outputs and when used in combination, they are able to provide a powerful planning tool that clearly shows the hydrological, environmental, social and economic impacts of both exogenous (e.g. global climate change) and human-induced changes to the river basin.

In addition to these hydrological basin-simulation models, the Basin Development Plan (BDP) has developed a hydrological-economic Resource Allocation Model (RAM). The primary purpose of resource allocation modelling is to provide a link between water resource use and associated economic returns in the Lower Mekong Basin at an aggregate (i.e. basin-wide) level. As a clearer picture of the way various major sorts of economic activities (e.g., agriculture, fisheries, hydropower, municipal and industrial demands, tourism, navigation, environmental uses, etc) are related to water demands emerges, the nature of major resource development opportunities and possible choices at the LMB level also becomes more explicit. The model outputs therefore provide a useful illustration, in economic terms, to planners and policy-makers of the nature of opportunities and possible choices regarding resource use and associated economic development opportunities in the LMB. Ideally, the RAM will be able to assist with identifying strategies for rational basin-wide economic growth in general and identifying 'win-win' resource-based development opportunities in particular.

The Resource Allocation Model (RAM)

The Resource Allocation Model has been developed to assist in the rational management of LMB water resources that are shared between the four riparian countries – from an economics perspective. Among the issues that are implied by the concept of *'management of a shared resource'* are

- the need to identify (and - where possible – quantify) the nature of economic benefits which come from various water-using activities
- the need to identify (and – where possible – quantify) where trade-offs between various alternative water-using economic activities may exist

- the desirability of identifying where complementarities in water-use exist (both within countries and across sub-areas and national borders) so that 'win-win' development opportunities can be formulated and promoted
- the need to understand how water resource use and the economic returns from that use are distributed throughout the LMB (i.e., to address issues of equity within LMB), and
- the need to understand how - and to what extent - the achievement of particular economic objectives may conflict with the objective of sustainable resource use (again, so that trade-offs can be identified and – economically informed - planning choices made).

It should be noted that the foregoing quite clearly implies the treatment of water as an economic good, as opposed to a social (or 'common property') good or resource. (This is discussed more, below). It is increasingly the case that water pricing policies in the national economies (e.g., for domestic water supplies, for irrigation) are based on market principles (e.g., estimated measures of water-related productivity, estimates of willingness to pay, long-run marginal costs of supply), indicating that water's true value to the riparian economies is recognized, and that its potential increasing scarcity – at least for certain uses and at the margin - is also increasingly being taken account of. This approach necessarily entails valuing water applied in its different uses, even if – at present –

- competition for aggregate water supply within LMB is relatively limited,
- financial prices and economic values for alternative water uses which are derived may be necessarily approximate (and hypothetical in some cases), and
- methodological issues (i.e., with separating out financial and economic price differentials across several countries with differing trade and tax regimes) abound.

The RAM is first and foremost a planning tool. The model shows the activity-based composition and the geographical distribution of economic benefits from any particular pattern of water use in the LMB, and the economic consequences of changes to that water resource use. It thus allows users to consider various development opportunities and to understand the structure of their costs and benefits vis-à-vis changes from that original situation. Essentially, it is an analytical tool for the rapid assessment of various development options; its overall technical and representational design is explicitly predicated on the existing economic and natural resource conditions, observed economic trends and potential developments outlined in an earlier document entitled "Economic Development and Water Resource Demands in the Lower Mekong Basin" (Ward, K. and Rowcroft, P., 2005).

Decisions about which opportunities to actually pursue of course remain the prerogative of national policy makers (and are subject to the 1995 Mekong Agreement), but the purpose of the RAM is to highlight the economic implications of any particular courses of action.

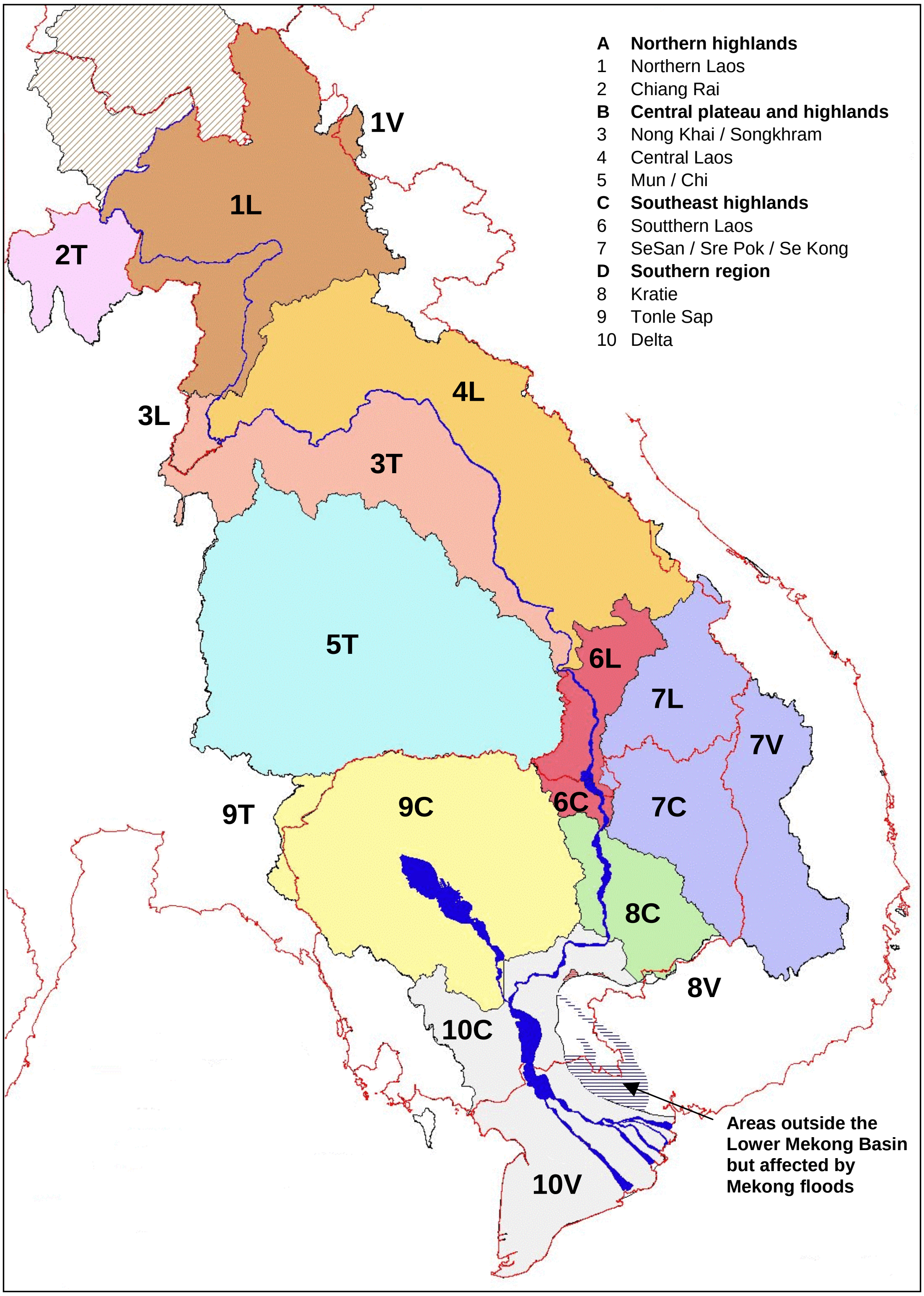
A full description of the RAM and its technical characteristics is contained in MRC (2003 and 2004). Briefly it may be noted here that

- the hydrological input to the RAM comes from the output of the Decision Support Framework (DSF) – a series of computer models linked to a database which is able to simulate the behaviour of the LMB river systems under different sets of assumptions regarding a range of environmental and development conditions
- a 'baseline' set of hydrological conditions is modelled from the DSF which is initially the input for RAM; future alternative sets of possible economic activities are constructed from this basis

- the RAM is built up on a sub-area basis, and thus affords analysis at this level – i.e., within the individual 10 sub-areas on a water-use basis and between/across sub-areas on a collective water use or individual water-use basis - and at a close approximation to the national level (i.e., as combinations of sub-areas, except where sub-areas are comprised of more than one national territory and some assumptions about returns to national territories have to be made), and
- major water-using demands have been identified, categorized and valued, as have major environmental impacts (descriptions of the various methodologies and data sources for these valuations are summarized in MRC-BDP (2005).

Potential future developments of RAM may include the integration of either (i) an optimization functionality (e.g., using 'What's Best?') and/or (ii) a quantitative risk modelling functionality (e.g., using '@Risk'). For ease and simplicity of use, and for greater transparency in access, these functions have presently not been included in the present design. However, it may be noted that RAM still contains the potential for de facto optimality - in the sense that users now themselves build development opportunities and can consider aggregate returns in different circumstances in a quest for maximisasion of economic values – and also that sensitivity testing – by applying ranges of values for key variables – can approximate the modelling of unknown outcomes.

Map of BDP sub-areas



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1 Introduction

The MRC Basin Development Plan (BDP) was instituted by the April 1995 Mekong Agreement. Following a series of preparatory studies, the BDP project document was approved by the MRC Council in October 2000. The BDP formulation (Phase 1) started in October 2001 and is scheduled for completion in July 2006.

The vision of the Basin Development Plan (BDP) is to contribute to acceleration of inter-dependent sub-regional growth by establishing a process and framework conducive to investment and sustainable development. To contribute to this vision, the BDP process being undertaken by the Mekong River Commission (MRC) should establish a planning framework for development programmes, capable of balancing efficient use of resources with protection of the environment and the promotion of social justice and equity.

There are two main outputs sought from the first phase of the BDP programme. First, the establishment of a more participatory form of basin planning than has previously existed in the Lower Mekong Basin for use in subsequent planning rounds. Second, an agreed short-list of high priority development projects with basin-wide or trans-boundary significance which have benefits that transcend national borders.

This paper presents the BDP Resource Allocation Model, a key tool for the planning process, together with applications that contribute to the knowledge base for the BDP.

1.1 Origin of document

The document is based on reports and working papers prepared between October 2003 and June 2005:

Beecham, Richard (2004): Developing inputs for Resource Allocation and Optimization Model. Technical Report 1, February 2004. Mekong River Commission, Basin Development Plan

MRC-BDP (2003): Development of Resource Allocation and Optimization Model. Final report on the development of the BDP RAOM. Prepared by Halcrow Group Ltd., October 2003. Mekong River Commission, Basin Development Plan

Rowcroft, Petrina (2004): The application of the Resource Allocation and Optimization Model to economic analysis of water-use trade offs within the Basin Development Plan. Resource document. February 2004. Mekong River Commission, Basin Development Plan

Rowcroft, Petrina (2005a): Resource Allocation Model (RAM), user guide. 21 June 2005. Mekong River Commission, Basin Development Plan

Rowcroft, Petrina (2005b): Methodologies and sources for valuation of water resource demands in the Lower Mekong Basin. 27 June 2005. Mekong River Commission, Basin Development Plan

Rowcroft, Petrina (2005c): Economic dimensions of water resource planning in the Lower Mekong Basin: An initial analysis based on the Resource Allocation Model (RAM). 29 June 2005. Mekong River Commission, Basin Development Plan

The present report has been compiled by extracts from the two last-mentioned references, which in turn build on the other ones listed above.

1.2 Basis and context

1.2.1 Link/relationship of subject to IWRM

The economic perspective of IWRM is emphasised by the 4th Dublin principle: *'Water has an economic value in all its competing uses and should be recognised as an economic good'.* The economics of water utilisation and water resource allocation is an essential IWRM discipline, both for traditional cost-benefit assessments and as a support for broader cross-sector and basinwide considerations.

The concept of Total Economic Value (TEV) for resource valuation is useful as a general reference in support of decisions that span across a variety of sectors and water uses.

1.2.2 Link/relationship of subject to BDP Inception Report

The Inception Report retains the stage-wise approach to BDP formulation that had been identified during the programme formulation:

Stage 1 - analysis of the LMB and of sub-areas

Stage 2 - analysis of development scenarios

Stage 3 - strategy formulation

Stage 4 - compilation of long-list of programmes and projects

Stage 5 - compilation of short-list of programmes and projects

The resource allocation analyses contribute to Stages 1 and 2, from where results are carried forward to Stage 3 and the following stages.

1.2.3 Link/relationship of subject to other BDP reports / activities

The analyses and findings presented in the present document are based on the development of tools and knowledge base that has taken place under the BDP during the regional and national sector reviews and the sub-area studies.

1.2.4 Link/relationship of subject to BDP's Logical Framework Matrix

In the BDP Logical Framework, the resource allocation analyses contribute comprehensively to

Output 2.4	Basin-wide strategies in general, and
Activity 2.4.1	Scenario review
Activity 2.4.2	Strategy components
Activity 2.4.3	Formulation of strategies

in particular. Also, the studies have provided valuable contributions to

Output 2.5	(long-list of programmes and projects).

1.3 Significance

1.3.1 Significance of subject for strategic planning

Between them, the studies provide aggregated information about baseline conditions, development trends as they appear at present, development needs and options, and an assessment of potential future developments.

This information is highly useful in connection with strategy formulation and identification of useful and practical development interventions.

1.3.2 Significance of subject for Mekong Basin

The main perspective of the BDP is IWRM at the basin scale, and the studies presented in the present report have been carried out in a basinwide perspective.

Hereby, they provide a basinwide economic overlay to the national and regional sector reviews that have been prepared in parallel.

This is one step towards an understanding of regional (and inter-sector) synergies and trade-offs that can contribute to a healthy regional development in its own right, as well as by adding value to the many development programmes at the national level.

Also, the resource allocation studies illustrate and emphasize one of the major development challenges in the Lower Mekong Basin, namely the need of improved efficiencies in all water-dependent production systems. Improved efficiencies - both the water efficiency itself and the economic efficiency of water utilization - are a key to the opportunities offered by the ongoing development towards lower trade barriers, as currently promoted by ASEAN, AFTA and WTO.

1.3.3 Significance of subject for MRCS / BDP 1

Together with the national sector reviews and the sub-area studies, the studies presented in the present report have formed a platform for scenario analysis of inter-sector dependencies (synergies and constraints), as well as for the preparation of a holistic, integrated IWRM Strategy[1] and for identification of viable development projects.

[1] In preparation (mid 2005)

2 Summary of approach

2.1 Resource allocation modelling in the Lower Mekong Basin

There are a number of issues that need to be addressed in order to effectively manage LMB water resources. These include the need to identify and relative costs and benefits and the tradeoffs and complementarities in water allocation among different water-using sectors and countries; and among the goals of efficiency, equity and sustainable resource use; and to determine the role of institutions and organizations in water allocation processes.

Until now, there has been little work done on empirical quantified valuation of natural resources within the LMB. However, rapid agricultural and economic development within the basin is resulting in increased competition among countries and water users for Mekong waters. This in turn generated the need for the establishment of institutional and water allocation mechanisms for the sustainable development of the river. Recent research has looked into developing an optimal water allocation regime for the Mekong through basin simulation models based on the original work of Ringler (2001a, b[1]).

Ringler (2001a) sought to address some of the issues outlined above through the development of an holistic, integrated economic-hydrologic model for the basin where water supply and demand is optimized using the economic objective of maximizing the net benefits of water use. The model is highly aggregated with country/regional-level water supply and demand, and economic benefit functions and solves for optimal water allocation at the basin level subject to a series of physical, system control, and policy constraints. The optimal allocation of water across water-using sectors is determined on the basis of the economic value of water in alternative uses.

For a more detailed description of the Ringler model and similar work being conducted in the Mekong Basin see the RAOM Resource Document (2004)2.

2.2 The BDP Resource Allocation Model (RAM)

Underpinning both the rules for maintenance of flows (see Section 1) and the BDP is the concept of finding a trade-off between development and environmental protection that is acceptable to all four countries. A trade-off must be defined in terms of the value of what is gained and what is lost. This requires an understanding of the hydrological, environmental, social and economic consequence of different water allocation regimes, including realistic environmental valuation.

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1 Ringler, C. (2001a) *Optimal Allocation of Water Resources in the Mekong River Basin: Multi-Country and Intersectoral Analyses*. PhD Dissertation. Bonn University. Peter Lang Verlag

Ringler, C. (2001b) Optimal *Water Allocation in the Mekong River Basin*. ZEF Discussion Papers on Development Policy No. 38, Center for Development Research, Bonn, May 2001, p. 50

2 MRC-BDP (2004) Resource Allocation and Optimisation Model (RAOM) Resource Document. BDP Discussion Paper by Petrina Rowcroft. Mekong River Commission: Phnom Penh

The BDP RAM is conceptually very similar to the Ringler model but differs in the following respects:

- It does not rely on complex programming language; it is MS-Excel based
- It is based on 10 sub-catchments (BDP sub-areas) whereas Ringler subdivided the basin into seven aggregated spatial units based on geographic/administrative boundaries
- It uses a combination of hydrological data imported from a rainfall-runoff model (LMB) and observed (gauged) stream flows at Chiang Saen for inflows from the Upper Mekong Basin
- It attempts to include instream demands and social and environmental impacts

The Resource Allocation Model (RAM) combines hydrological and economic data to allow users to explore feasible solutions for allocating water to meet different planning objectives. It is particularly useful as an analytical tool for assessing the significance of potential water allocation trade offs in quantitative terms. It also provides a means for evaluating alternative development scenarios using a standardized unit of measurement (i.e. money).

The BDP RAM was initially developed with an optimization component (using a What's Best? Excel add-on) and was known as the Resource Allocation and Optimization Model (RAOM). However, optimization was not a key model requirement and conflicted with the requirement to assess scenarios against a baseline and was thus removed.

The RAM has been developed to assist the BDP in scenario-based planning such that a number of combinations of external conditions and interventions can be modelled and their outcomes analyzed. It is not intended as a substitute for the more comprehensive Decision Support Framework (DSF)1 that has been developed under the Water-Utilization Programme (WUP) but is rather an analytical tool for the rapid appraisal of various development options. Unlike the DSF, the RAM facilitates identification and quantification of some of the main economic trade offs that will result from changes in water allocation patterns. Within the basin development planning process, it will be used in the context of the following sorts of questions:

1. What are the main economic activities (that rely on water from the Mekong) in the LMB?
2. Where are these activities located (on a sub-area basis)?
3. What is the significance (value) of these activities:
    (a) To the sub-area?
    (b) To the country?
    (c) To the basin as a whole?

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[1] The DSF has been developed under WUP-A as a series of computer models linked to a database. The DSF is able to simulate behaviour of the LMB river systems under different development conditions, and assist in predicting environmental and socio-economic impacts as a result of changes in those conditions. For a full description see MRC WUP-A (Jan 2002 and March 2002). The basin models underlying the DSF provide a quantitative description of changes in water flows under different conditions. Impact analysis tools have been developed in the DSF to assist in translating hydrological changes into environmental and socio-economic impacts. The DSF is thus intended for impact analyses, while the RAM is suited to both impact analysis and optimisation studies (MRC – 25 June 2003).

4. What are the internal and external driving forces that might result in changes to the intensity in which different economic activities are undertaken?

5. What are the major trade-offs (at LMB level) that will result from changes in the way that water is allocated among competing uses?

6. What is the economic significance (monetary value) of these trade-offs?

7. Who bears the costs/enjoys the benefits?

8. What activity-based development projects can add most economic value to the LMB without contravening water use rules (i.e. feeds into project selection)?

9. Apart from the extractive/revenue-earning economic activities, what can be said about the value of latent environmental resources or important ecological services?

Once various issues have been identified through the RAM, these can then be subjected to more detailed investigation and analysis.

Economic activities modelled in RAM

The RAM models seven water-related economic activities / impacts in the LMB. The relevance of these dimensions to water use planning are discussed more fully in a paper entitled "Economic Development and Water Resource Demands in the Lower Mekong Basin" (MRC-BDP, 2005)1. The activities considered are:

(a) Extractive uses

Irrigated agriculture

Hydropower

Municipal & industrial use

Tourism

(b) Instream demands

Fisheries

Wetlands

Navigation

(c) Environmental impacts

Flooding

Saline intrusion

Production functions for wetland productivity and navigation have not yet been derived but work on the valuation of these activities has begun in collaboration with the MRC Navigation and Environment Programmes.

For the purposes of the model, each activity is explicitly linked to some form of water demand, whether extractive (e.g. agriculture and M&I) or instream (e.g. wetlands, fisheries). In some cases the relationships between productivity (or economic outcome) and water

[1] MRC-BDP (2005) Economic development and water resource demands in the Lower Mekong Basin. MRC Discussion Paper (Draft) by Keith Ward and Petrina Rowcroft. February 2005. Mekong River Commission: Vientiane.

availability are fairly well known (e.g. crop water requirements for agriculture, hydropower, M&I) but in some instances, these relationships are complex and not yet well understood and have had to be modelled based on a number of simplifying assumptions (see sections on flooding and saline intrusion) or entered as constraints (see sections on fisheries, wetlands and navigation).

Outputs from RAM

Various development-planning scenarios have been formulated and run through the RAM. Hydrological and environmental impacts are assessed as deviations from the baseline situation. In each case, the parameters of interest are:

- The value of water (in each scenario, including the current baseline situation) to the whole LMB
- The value of water to individual sub-areas
- The relative water-related values of each of the economic activities modelled
- The value of water-related environmental goods (fisheries and wetlands) and services (navigable channels) that may be threatened by changes to flow levels
- The economic costs of flow-related damages (i.e. flooding and saline intrusion)

Some preliminary results and analysis are presented in BDP Planning Scenario Economic Summaries (MRC-BDP, June 2005)1.

2.3 Economic valuation

As noted above, the RAM is being developed as a conceptual, analytical tool that can be used to assess the significance of potential water allocation trade offs in quantitative terms. It also provides a means for evaluating alternative development scenarios using a standardized "unit of measurement", i.e. money.

For the model to be used with confidence in comparing and quantifying the economic impacts of hydrological and development scenarios and in guiding decision-makers towards an economically optimal allocation of water, it is important that the values assigned to the different water uses are comparable (i.e. valued in common units) and that all items can be valued at their value in use or opportunity cost to society.

> Opportunity costs are the benefits foregone by using a limited resource for one purpose instead of for its next best alternative use (Gittinger, 1996)

Markets generate the relative values of all traded goods and services as relative prices which makes them very useful for comparison as not only are they co-measurable but also some indication of their current relative scarcity value is provided (Hanley and Spash, 1993). However, the use of market prices alone is sometimes not sufficient for analyzing the real

[1] BDP (2005) *BDP Planning Scenario Economic Summaries: Preliminary Results*. BDP Discussion Paper by Petrina Rowcroft and Keith Ward. Mekong River Commission

trade-offs to society as they do not always reflect the total economic value (TEV) of a particular good or service.

Total Economic Value (TEV) is used to define features in terms of their direct and indirect use and non-use values (see figure 1 below). Using the concept of TEV allows us to include values for benefits that may not have market prices (i.e. they are generally not bought or sold, e.g. ecological services and heritage value) and to examine the environmental and social impacts of development options

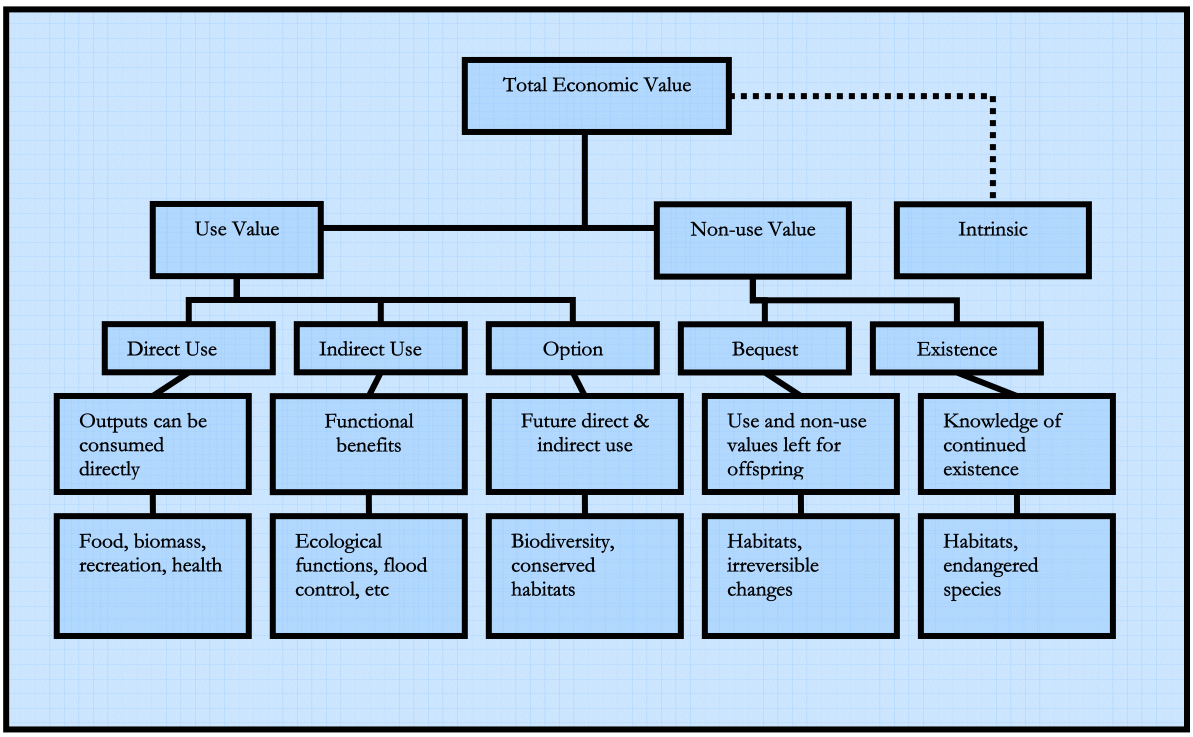
Sometimes, consumers will be willing to pay more than the market price for a particular good or service because its private value to them is much higher. This may be because the resource has a non-use value that is not typically expressed in the market place or conveys some form of positive externality.

Externalities are unintended, unpriced impacts of developments. They may be positive where benefits are realised or negative where costs are borne by third parties

Economic benefits of domestic, industrial and agricultural water demands are generally straightforward to quantify, as their values are expressed in the market place. However, economic benefits of environmental water demands are more difficult to quantify, as their values are generally not expressed through market processes.

Markets generate the relative values of all traded goods and services as relative prices which makes them very useful for comparison as not only are they co-measurable but also some indication of their current relative scarcity value is provided (Hanley and Spash, 1993).

Figure 2.1: TEV framework



Monetary valuation

Monetary valuation is useful for the reasons outlined above:

- Comparability – it is a "standardized unit of measurement" which is well understood
- Convertibility – US$ can be easily 'translated' into local currency values which may make them more meaningful to those living in different parts of the basin

In the RAM, all monetary values are expressed in terms of net benefits (i.e. revenues minus costs). This is to account for the fact that prices (set by local, regional and sometimes global markets) are not necessarily good indicators of the true value of a good or service because they do not always account for the value of resources used up in the production of goods and provision of services.

Financial vs economic values

All monetary values in the RAM are also expressed as economic, rather than financial, values as far as possible. Economic valuation requires that all values are expressed in terms of their opportunity costs to society. The main differences between economic and financial values are highlighted in the box below.

Financial values	Economic values
Accounting measures (direct cash flows) Usually expressed in nominal (ie constant price) terms	Reflect actual resource use (including opportunity costs of time, money and labour) Exclude transfers (e.g. taxes and subsidies) which are simply a reallocation of resources among groups in society, rather than an actual resource use Include externalities (unintended environmental and social impacts of a particular activity) Use real (present day) values to account for past/future cost-benefit streams

Economics, RAM and decision-making

Economic valuation thus provides an important input to decision-making. It provides decision-makers with realistic, comprehensible and comparable information about the nature and significance (in quantitative terms) of decisions regarding the allocation of water (a) among competing water demands, (b) among sub-areas and (c) among countries in the LMB.

The RAM is a particularly powerful tool in this regard in that it provides an interface between hydrology and economics in a way that explicitly links the two and allows users to experiment with and compare various allocations. For the purposes of Basin Development Planning in particular, resource allocation modelling helps integrate and coordinate national planning by identifying:

- patterns of water use that maximize economic benefits basin-wide

- other basin-wide patterns of water use which may be considered desirable to achieve particular policy objectives (e.g. environmental protection, poverty reduction, etc)
- where national development plans may compete/conflict with one another in terms of water use
- where there may be opportunities for transboundary development of water resources in such a way as to reduce unit costs and increase aggregate benefits, and
- where transboundary trade-offs between alternative water uses may be made in order to minimize cross-border conflicts and maximize the collective benefits
- the environmental costs – in very broad terms - of particular development options, both basin-wide and at sub-area level

3 The economic dimensions of water use planning

In the Lower Mekong Basin context, water has historically been – and largely still is - first and foremost treated as a 'common property' (i.e., social) good. Water is recognized as being essential for sustaining life and as a commodity to which people and the aquatic environment have right of access; it has been traditionally recognized less as an economic good, despite the fact that its use has a major impact on the creation of wealth and the wellbeing of the population. However, generalized disappointment during the last century over the failure to meet basic needs for water for all people, and also given the need to stem the trend of water quality deterioration through the failure of traditional command-and-control regulatory approaches in many places, have led to rethinking of international, regional, national and local water priorities and policies.

Countries and regions now differ markedly with respect to the degree to which they treat water as either a social or economic good. Countries with strong free-market tendencies that emphasize private ownership mostly emphasize its economic value, while others emphasize its social characteristics. Overall, however, consideration has come more and more to be given to the potential value of applying economic tools and principles in water resource management. The International Conference on Water and the Environment (Dublin, 1992), concluded, among other things, that water has an economic value in all its competing uses and should be recognized as an economic good.

Increasingly, the need to assess the economic value of water in its alternative uses is being more widely recognized, and almost without exception there is an increasing interest worldwide in using economic instruments (e.g., prices)

- to increase allocative efficiency (i.e., by letting those who can use it most productively demonstrate this by paying for it),
- to effect desired behavioural change among water users (e.g., to avoid waste), and
- to use water as a catalyst for the generation of wealth and prosperity.

This applies within the LMB as much as anywhere, and clear moves (i.e., policy changes) in this direction are already apparent in Thailand (farmers in the Central Plains and elsewhere have recently been objecting to the imposition of fees for water access in a context where its supply had been treated as a free good, for example).

Many of the trends described in "Economic Development and Water Resources Demands in the Lower Mekong Basin" (Ward and Rowcroft, 2005) will add to the pressure for the treatment of water as an economic good, and therefore for its pricing to be made much more explicit to both policy-makers and consumers. In this sense, RAM is an attempt to embed this thinking within the BDP and MRC planning context, even though it may be a relatively crude instrument at present

For simplicity and manageability in the RAM context, the economic dimensions of water use planning have been restricted to nine major uses / impacts. These are as summarized in the following table: there are four economic demands of an extractive nature (i.e., they require abstraction of water from the stream and do not return it all to the flow or significantly delay its return), three in-stream economic demands (i.e., they require flow but do not abstract water from the stream), and two environmental economic impacts of water distribution patterns.

Table 3.1: Water uses and impacts

	Water use / impact type	Water use or impact
1	Extractive economic demands	Agriculture (dry and wet season, irrigated)
		Hydropower
		Municipal and industrial use
		Tourism use
2	In-stream economic demands	Fisheries
		Wetlands
		Navigation (including river-based tourism)
3	Environmental impacts	Flooding
		Saline intrusion

Collectively, the definition of these various dimensions of water resource use and impact in the LMB constitutes a reasonable approximation of resource and economic reality at an aggregate (i.e., basin-wide and between sub-areas) level, and allows a number of key planning issues to be addressed at that same level of thinking and analysis.

The extractive economic demands are modelled in terms of functional relationships between volumes of water applied and amounts of economic values generated. The technical parameters of these relationships (e.g., irrigation water efficiency, hydropower efficiency, composition of municipal and industrial and tourism water demands) are not yet documented; the basis of economic valuation of the various outputs is summarized in *"Methodologies and Sources for the Valuation of Water Resources Demands in the Lower Mekong Basin"* (Rowcroft, 2005).

The in-stream economic demands for water are not yet all integral parts of the model. Where relationships are modelled, the technical requirements are somewhat approximate as the relationship between water flow and the maintenance of river condition / biological diversity etc generally is still being investigated by the Integrated Basin Flow Management - IBFM – programme.

Rather, the model records the magnitude of deviations in flow, compared to the baseline, for each month and in each sub-area. The user, together with relevant experts, can then assess whether these changes are likely to be significant given the presence of wetlands, fish spawning/feeding areas and navigation activities in any of the sub-areas.

This approach is taken for two reasons. Firstly, because in many situations explored by RAM the competition between extractive and in-stream uses does not result in the constraint being violated (i.e., competition for water is not too severe. Secondly, because modelling functional relationships between (i) in-stream water flows and fisheries output/fisheries values, (ii) in-stream water flows and navigation values, and (iii) in-stream water flows and wetlands preservation values proved to be highly contentious in the absence of reliable, comprehensive and agreed data sets. The analytic process has thus been oriented around identifying those situations in which conflicts between extractive and in-stream uses *might potentially occur* at a sub-area level, and then looking at the implied trade-offs (e.g., between increasing dry season irrigated agriculture and reduced fish/wetland/navigation value) on a case-by-case basis (with site/sub-area-specific values being applied for the in-stream water uses at that point). This approach allows users and planners to understand what is being gained (e.g., in terms of increased hydropower value or agricultural output) and then to identify/gather information locally and think quite specifically about what is likely to be lost by the pursuit of a particular development possibility.

The approach to the environmental economic impacts (of flooding and of saline intrusion) has been to value these as consequences of particular water distributions. The analytical approach has been to consider these as economic costs – and thus they are subtracted from the total economic net worth under any particular situation being studied/modelled with RAM. The consideration of these two impacts in this way allows the costs of flooding to be explicitly identified (and thus the desirability or otherwise of employing flood mitigation measures to be assessed – in economic terms), and the trade-off between up-stream economic water-using activities adding economic value and the down-stream costs of increased saline intrusion (in the Mekong Delta) to be made explicit (similarly allowing choice to be made about whether costs outweigh benefits, although here with potential transboundary/cross-national border implications).

Finally, it should be noted here that the activity and impact valuation within RAM is attempted largely in *economic* rather than *financial* prices, in that market prices for some outputs (e.g. tourism and municipal and industrial water demands) and impacts (e.g., wetland preservation) have had to be inferred in the absence of markets for these goods. Where financial prices have been observed and applied (e.g., for agricultural outputs and for hydropower generation) the treatment of their non-market externalities (e.g., the social costs incurred in hydropower schemes of resettling communities) are made explicit; non-priced inputs (e.g., family labour applied on agriculture) have been valued at their opportunity costs. Remaining differences in financial and economic values as a result of tax and trade policies, national exchange rate management (and as are observable through national standard conversion factors/shadow exchange rate factors etc) are minimal in the LMB countries and have not been applied (the present level of 'broad-brush'/basin-wide analysis under RAM does not justify applying this level of detail at present). For these reasons, the rest of this analysis is discussed in terms of *economic* prices.

4 Valuation of extractive economic demands

4.1 Irrigated agriculture

4.1.1 Summary and rationale

The largest water user by far in the basin is irrigated agriculture. It is estimated (FAO, 1999) that water withdrawals for irrigated agriculture account for 94% of total withdrawals in Cambodia, 82% of withdrawals in Laos, 91% of withdrawals in Thailand and 86% of withdrawals in Viet Nam. Agricultural water demand is therefore arguably the most important component in the model, and one of the highest value users and is therefore likely to play a major role in determining levels of availability for other users. The agricultural sector is critically important to the LMB economy. Over 40% of the basin's land area is devoted to agriculture (MRCS, 2003a) and agricultural activities provide the livelihoods of the majority of the basin's population which has grown by nearly 50% since 1980 and is projected to increase at a similar rate for at least the next 20 years, placing increasing pressure on the land for extra production (Nesbitt, 2003). Overall, 75% of the region's population is estimated to be dependent upon agricultural crops, fisheries, livestock or forestry (MRCS, 2003a).

Yields from crop production in the LMB are generally considered low by international standards, and there is scope for increasing the scale, intensity and efficiency of production. Crop production in the LMB is limited by a number of factors including flooding, poor soils, poor access to markets, high input costs, pests and disease and agricultural labour shortages. Access to water is a major constraint to increasing crop yields in the LMB. While there is presently sufficient water in the Mekong to meet the crop water requirements of the Basin, there is a shortage of water distribution systems (Nesbitt, 2003). Abstractions for agriculture are, however, beginning to increase rapidly as riparian governments promote agricultural production by subsidizing the installation of irrigation infrastructure. Furthermore, growing agricultural water demands will be forced to compete with increasing demands from other water-using sectors, particularly tourism and municipal & industrial. Irrigation schemes continue to be installed or improved in each of the four countries to improve production (Nesbitt, 2003). Such changes could significantly enhance rural incomes and national macroeconomic performance. Increasing commercialisation of production, expansion and intensification of irrigation and the diversification of rice-based production systems into alternative crops with greater financial returns are all important trends in this direction.

It is therefore essential that planning efforts recognize this trend if efficient water utilization practices are to be encouraged to ensure an equitable distribution of an increasingly precious resource.

4.1.2 Valuation basis

For the purposes of the RAM, the value of water used for irrigation can be broadly estimated by determining the value of irrigated crop harvests. Note that the model does not take account of other agricultural uses of water, e.g. livestock production.

For each sub-basin a maximum of four crop patterns can be modelled. These "patterns" may be a single crop (e.g. wet season rice) or can be a "basket" of crops with similar crop water requirements (see Table 1 for the crops included in the baseline planning scenario). Where more than one crop type is represented (i.e. a basket), then the value of that cropping pattern has been calculated using a weighted average of the relative areas and outputs per square kilometre of each

Table 4.1: Main crop types modelled in RAM baseline scenario

Sub-area	Crop 1	Crop 2	Crop 3	Crop 4
1	Wet season rice	Dry season rice	Vegetables	Maize
2	Wet season rice	Dry season rice	Maize	Soy
3	Wet season rice	Dry season rice	Maize	Kenaf
4	Wet season rice	Dry season rice	Vegetables	Maize
5	Wet season rice	Dry season rice	Soy	Kenaf
6	Wet season rice	Dry season rice	Vegetables	Maize
7	Winter rice (Viet Nam)	Wet season rice (Laos)	Dry season rice (Viet Nam Central Highlands)	Coffee
8	Wet season rice (early)	Wet season rice (mid)	Dry season rice	Coffee
9	Wet season rice (early)	Wet season rice (mid)	Dry season rice	Soy
10	Spring/autumn rice (Viet Nam)	Wet season rice (autumn/winter)	Wet season rice (winter)	Dry season rice (winter/spring)

Data

Agricultural water demands have been incorporated into RAM based on calculated crop water requirements (see DSF manuals for further details) and crop areas for irrigated crops. Data on crop production areas and crop yields was obtained primarily from national statistical yearbooks and from information contained in the DSF. Crop production costs were not widely available and thus estimates of the approximate returns to production were based on limited information from reports containing farm production budgets. Crop prices – at point of first sale - were obtained from price bulletins, agricultural marketing surveys and the FAO Agricultural Database.

The full list of information sources is shown in the reference section.

Wherever possible, provincial level data was used but where this was not available, average national data was used. Provincial and national data on cropping areas was converted to sub-area level using the relative proportions of each province in each sub-area.

Assumptions

In the absence of detailed agricultural production data the following key assumptions have been made:

Farmgate prices were obtained wherever possible but where only market prices were available, farmgate prices7 have been estimated as approximately 70% of market prices (accounting for transport, storage and retail costs). Also, although a large share of production is for subsistence, particularly in Laos and Cambodia, using economic prices for all irrigated

7 The term "prices received by farmers" as used here, should in theory refer to the national ***average*** of individual commodities comprising all grades, kinds and varieties. These prices are determined by the farm gate or first-point-of-sale transactions when farmers participate in their capacity as sellers of their own products.

crops is justified on the basis that farmers would otherwise need to acquire these products in the market.

Yields for each different crop type are uniform within provincial boundaries. Where provincial data was not available, average national yields were used.

Production costs are 85% of farmgate prices for commodities (field crops) and 75% for fruit and vegetables. This takes into account both the direct costs of crop production and the opportunity cost of family labour and land.

For every set of assumptions, an alternative set has been formulated and will be routinely tested in the RAM to assess how sensitive the findings are to each set of assumptions. In the case of agriculture, the following alternative assumption has been made:

Production costs are 75% of farmgate prices for commodities (field crops) and 60% for fruit and vegetables.

Modelling

To estimate the value of water used for irrigation requires a specification of a function for net profits from irrigation, which accounts for both seasonal and geographical variations in the profits accruing from each crop type. Such a function is derived based on the returns to irrigated agriculture once input, transport and marketing costs have been accounted for. The aggregate net benefit value for all crop types across each basin then provides an approximation of the value of water to agricultural users[8].

The crop water requirements for each cropping pattern have been estimated (using data contained in the DSF) and have been added to the model. The economic value of each cropping pattern has then been calculated as follows:

$$BA = (PA * QA) - (CA)$$

Where:

BA	=	the net benefits (US$) to agriculture per square kilometre for each cropping pattern
PA	=	the average farmgate price[9,10] (US$) per tonne for each cropping pattern
QA	=	the yield (tonnes per km^2) of each crop
CA	=	the production cost (US$) per square kilometre for each crop type/cropping pattern

8 The model calculates crop water requirements on the basis of crop areas. Thus if there is insufficient water for a given crop area, rather than allocate less water to each cropping unit (so that yields decline rather than area), the model will show an infeasible solution.

9 For cropping patterns where more than one crop type is specified, average farmgate prices are calculated on the basis of the relative harvested areas and yields of each crop type.

10 Where crops are not sold on the market, it is assumed that they are kept for subsistence use. Implicit in this assumption is that if the crops were not grown, they would be purchased at the market, most likely at a higher cost than subsistence production.

Information from the model may then include things like:

- Value added by water to irrigated agriculture in the LMB as a whole
- Value added by water to irrigated agriculture in each sub-area
- Potential trade-offs between sectors, sub-areas and/or countries as a result of an expansion in agricultural water demands
- Comparison of productivity (irrigation and profitability) for different crop types (per unit area) in different sub-areas
- Identifiable limits to expansion of various cropping types
- Value added by water to irrigated agriculture compared to value added by water in other activities at sub-area and basin-wide levels.

Rice-shrimp systems

In coastal areas in the Mekong delta, saline water intrusion into inland areas during the dry season has limited the availability of freshwater for around 300,000 ha of agricultural land. As a result, local farmers have had to adapt their traditional agricultural activities, particularly rice production in the dry season, through the introduction of high-yielding varieties, chemical fertilizers and improved irrigation systems (Be and Dung, 1999). However, the higher production costs associated with rice monoculture in brackish water areas means that the returns to rice production do not generally generate enough income to cover the living expenses of farming households.

As a result, integrated rice-shrimp systems have rapidly extended around the brackish water areas of the Mekong delta largely because of the high profits associated with shrimp production (Be and Dung, 1999). In recent years, the high export prices of shrimps have encouraged farmers to shift from the integrated rice-shrimp system to shrimp monoculture. There are, however, a number of questions around the environmental sustainability and economic viability of such systems, especially where the environmental costs have not been accounted for by private farmers.

The value of economic returns from integrated rice-shrimp systems in the Mekong delta have been calculated based on data contained in a published study on the economic and environmental impacts of rice-shrimp farming systems in the Mekong delta (Be and Dung, 1999).

The gross value of rice-shrimp farming is estimated based on the sum of the gross returns from each of rice and shrimp farming11 in the delta. Gross returns are in turn a function of the respective yields (kg/ha) of rice and shrimp in areas under the integrated system and the prices received by farmers for each product. The net returns are then simply calculated by subtracting the production costs (seed, fertilizer, derris, chemicals, machinery, hired labour, tax and other costs) from the gross value. These costs do not include the environmental, construction or family labour costs associated with rice-shrimp production. Applying a GDP deflator to the result gives the value of net returns in 2002 prices.

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11 There are three systems of shrimp farming in the Mekong delta: natural shrimp, tiger shrimp and a combination of natural and tiger shrimps. Sometimes a combination of crabs or shrimp and crabs are farmed. The analysis accounts for these by using a weighted value according to the proportion of households practising each type of shrimp farming system relative to the total number of households practising shrimp farming in the study site.

Data issues and sensitivity testing

Once the present value (baseline) has been established, various hydrological and development scenarios can be modelled to show (a) their impact on the supply of water available for irrigated agriculture, and (b) the economic impacts of one, or a combination of any, of the following scenarios:

- Changes in the ***availability of water*** for irrigation
- Changes in the ***irrigation efficiency*** of crop types (e.g. through the introduction of new varieties)
- Changes in the ***yield*** of crop types (e.g. through the introduction of HYVs)
- Changes in the ***value*** per hectare of crop types
- Changes in the ***irrigated land area*** devoted to each crop type
- Changes in the ***cropping pattern*** for any given irrigated area
- Changes in ***relative prices*** for any of the crop types

The productivity of irrigation water (US$/m3) depends on both the profitability of the crop (ratio of production costs to farmgate prices) and its irrigation efficiency. In order to test the sensitivity of the model results to the underlying assumptions about agricultural productivity, some of the assumptions around the factors affecting agricultural efficiency have been changed and the outcomes analyzed. These factors include:

- Irrigation efficiency of modeled crop types (crop water requirements)
- Crop yield improvements (e.g. through introduction of high-yield varieties)
- Changes to crop returns

Table 4.2: Summary RAM inputs for baseline scenario, irrigation – assumption set 1

Sub-area		Crop 1	Crop 2	Crop 3	Crop 4
1		Wet season rice	Dry season rice	Vegetables	Maize
	Output (t/ha)	3.17	3.84	6.34	2.26
	Net value (US$/sq km)	5,077	5,801	36,824	2,264
2		Wet season rice	Dry season rice	Maize	Soy
	Output (t/ha)	3.04	3.27	3.87	1.53
	Net value (US$/sq km)	4,746	4,546	4,450	5,047
3		Wet season rice	Dry season rice	Maize	Kenaf
	Output (t/ha)	2.09	4.12	3.87	1.55
	Net value (US$/sq km)	7,140.22	5,604.74	4,546	4,026

Sub-area		Crop 1	Crop 2	Crop 3	Crop 4
4		Wet season rice	Dry season rice	Vegetables	Maize
	Output (t/ha)	3.29	4.38	7.10	2.39
	Net value (US$/sq km)	5,272	6,642	41,548	2,396
5		Wet season rice	Dry season rice	Soy	Kenaf
	Output (t/ha)	2.07	3.27	1.53	1.55
	Net value (US$/sq km)	3,466.02	4,413	5,047	4,026
6		Wet season rice	Dry season rice	Vegetables	Maize
	Output (t/ha)	3.10	4.10	5.06	2.39
	Net value (US$/sq km)	4,259	5,249	25,955	3,404
7		Winter Rice (Viet Nam)	Wet season rice (Laos)	Dry season rice	Coffee
	Output (t/ha)	2.81	2.50	4.83	1.15
	Net value (US$/sq km)	7,546	6,011	7260	16,850
8		Wet Season Rice (early)	Wet Season Rice (mid)	Dry Season Rice	Coffee
	Output (t/ha)	1.90	1.90	3.10	0.81
	Net Value (US$/sq km)	2,482	2,482	3,830	24,615
9		Wet Season Rice (early)	Wet Season Rice (mid)	Dry Season Rice	Soy
	Output (t/ha)	1.90	1.90	3.10	1.53
	Net Value (US$/sq km)	3,531	3,531	3,547	5,047
10		Spring/Autumn Rice (Viet Nam)	Wet Season Rice (Autumn / Winter)	Wet Season Rice (Winter)	Dry Season Rice (Winter/Spring)
	Output (t/ha)	4.00	4.00	3.05	4.35
	Net Value (US$/sq km)	12,190	15,930	4711	7,479

Note: The value of the double crop is estimated as 1*WS rice crop + 1*DS rice crop

Table 4.3: Summary RAM inputs for baseline scenario, irrigation – assumption set 2

Sub-area		Crop 1	Crop 2	Crop 3	Crop 4
1		Wet season rice	Dry season rice	Vegetables	Maize
	Output (t/ha)	3.17	3.84	6.34	2.26
	Net value (US$/sq km)	8,462	9,668	58,918	3,774
2		Wet season rice	Dry season rice	Maize	Soy
	Output (t/ha)	3.04	3.27	3.87	1.53
	Net value (US$/sq km)	15,820	15,154	14,834	16,822
3		Wet season rice	Dry season rice	Maize	Kenaf
	Output (t/ha)	2.09	4.12	3.87	1.55
	Net value (US$/sq km)	9,034	9,341	4,450	6,711
4		Wet season rice	Dry season rice	Vegetables	Maize
	Output (t/ha)	3.29	4.38	7.10	2.39
	Net value (US$/sq km)	8,787	11,071	66,477	3,993
5		Wet season rice	Dry season rice	Soy	Kenaf
	Output (t/ha)	2.07	3.27	1.53	1.55
	Net value (US$/sq km)	5,777	7,355	8,368	6,669
6		Wet season rice	Dry season rice	Vegetables	Maize
	Output (t/ha)	3.10	4.10	5.06	2.39
	Net value (US$/sq km)	9,345	14,040	57,520	11,496
7		Winter Rice (Viet Nam)	Wet season rice (Laos)	Dry season rice	Coffee
	Output (t/ha)	2.81	2.50	4.83	1.15
	Net value (US$/sq km)	12,577	9,232	12,100	28,084
8		Wet season rice (early)	Wet season rice (mid)	Dry season rice	Coffee
	Output (t/ha)	1.90	1.90	3.10	0.81
	Net value (US$/sq km)	3,557	3,557	5,376	71,793
9		Wet season rice (early)	Wet season rice (mid)	Dry season rice	Soy
	Output (t/ha)	1.90	1.90	3.10	1.53
	Net value (US$/sq km)	4,984	4,984	5,912	8,368

Sub-area		Crop 1	Crop 2	Crop 3	Crop 4
10		Spring/Autumn Rice (Viet Nam)	Wet season rice (Autumn / Winter)	Wet season rice (Winter)	Dry season rice (Winter/Spring)
	Output (t/ha)	4.00	4.00	3.05	4.35
	Net value (US$/sq km)	20,317	26,549	7,852	12,465

The full calculations behind each of these values are detailed in a set of Excel Workbooks available from the MRCS BDP.

4.2 Hydropower

4.2.1 Summary and rationale

Hydropower is an important resource of the Mekong Basin. The GMS is endowed with substantial energy reserves, but they are unevenly distributed between the member countries. Lao PDR, Myanmar, Yunnan and Viet Nam have the energy resources to be self-sufficient but Thailand is energy deficient and will increasingly rely on imports in spite of considerable oil, gas and lignite reserves (Maunsell, 2004). Cambodia is also dependent on imported energy. Within each county there is also a lack of balance in the mix of energy sources. Hydropower resources in Lao PDR, Myanmar, Yunnan and to some extent Viet Nam are abundant and exceed those countries' own demand. Good quality coal deposits occur in Yunnan and Viet Nam. Lignite deposits in Thailand are unlikely to be exploited further due to a combination of economic and environmental reasons unless cost-efficient emission control technologies are advanced. There are substantial recoverable reserves of natural gas, mainly from offshore fields in Myanmar, Thailand and Viet Nam. Oil production in the GMS is limited.

Hydropower has the potential to satisfy growing national and regional energy needs. For some countries in the region, it is one of the main exploitable natural resources. As such, hydropower represents at present, and potentially even more so in the future, a major source of export earnings. It has the potential to contribute to economic development in a sustainable way when planned and implemented properly.

Estimates of the hydropower potential of the LMB vary, depending on the applied feasibility criteria. MRC estimates put the hydropower potential of the Basin at some 30,000 MW[12]. Of this, 13,000 MW are on the mainstream, 13,000 MW in Lao tributaries, 2,200 MW in Cambodian tributaries, and 2,000 MW in Viet Nam tributaries. To date, 11 schemes have been completed in the LMB, with all tributary projects totaling some 1,600 MW, or 5% of the potential.

The MRC Hydropower Development Strategy views least-cost planning in a basin-wide context as the optimal sequence of developing the hydropower resources in the Basin. However, it notes further that it can – and should - be given the broader perspective of least-cost planning in relation to alternative energy sources, where the full environmental and social costs of the different alternatives are reflected in the final selection. In the GMS, alternatives to hydropower for the supply of the large quantities of power needed to meet

12 Estimates from an inventory by MRC in 1970-80s, reviewed in 1998, and based on studies at various levels of detail.

increasing regional demand will primarily be thermal generation based on coal, oil or natural gas (MRCS – Hydropower Development Strategy, 2001).

The lowest-cost hydropower potential is located in Laos while the main markets are Thailand, increasingly Viet Nam, and the more distant markets of Malaysia and Singapore. As a result of this unequal distribution of supply and demand, there is substantial potential for power trade between all countries (including Myanmar and southwest China) (Crousillat, 1998; MRCS-HDS, 2001).

The primary markets for Lao PDR are Thailand and Viet Nam. These markets are large compared with the potential supply from Lao PDR and trade is therefore constrained by price rather than demand. Opportunities are also influenced by other factors including:

- Relative costs of hydropower and thermal generation;
- Progress in establishing regional 500 kV transmission interconnections;
- Timing and nature of power market reforms within GMS countries;
- Availability of, and competition for, capital;
- Progress of large hydropower developments in neighbouring countries.

4.2.2 Valuation basis

The relationship between volumes of water used and power generated is variable and complex, depending upon the technical design of individual hydropower stations (in particular amount/extent of storage required, head etc, as well as age/efficiency of turbines).

Data

Data was obtained from a review of a number of recent studies on the power sector in the region including:

– Nam Theun 2 Project Economics Interim Summary Report (World Bank, 2004)

– Nam Theun 2 Project Economic Analysis (World Bank, 2005)

– Environmental and Social Impacts of the Nam Theun 2 Hydropower Project (Laplante, 2005)

– Nam Theun 2 Regional Economic Least-Cost Analysis (Vernstrom, 2005)

– Laos Power System Strategy Study (ADB, 2002)

– Power System Development Plan for Lao PDR (Maunsell, 2004)

– Laos Hydropower Development Strategy Study (World Bank, 1999)

– Thailand Power Development Plan (presentation)

– Fueling Viet Nam's Development: New Challenges for the Energy Sector (World Bank, 1998)

Valuation

The economic value of power generated by any particular hydropower station within the LMB is also highly variable, depending upon *(inter alia):*

– The proximity of the generation site to the place of consumption (and hence transmission/distribution costs)

– Whether power is domestically-consumed or exported; and

– Whether the power produced substitutes for existing supplies or is incremental to national production. In the case of the LMB, we assume that all hydropower supplies are incremental to existing supplies.

The relevant "cost of supply" for neighbouring countries is the marginal cost, the cost of meeting an increment of load at different times of the day/year and at different voltage levels. If the load must be supplied over an extended period (i.e., years), its value is given by the system long run marginal cost (LRMC), which includes the incremental cost of both capacity and energy required to serve the load without interruption. If no long-term commitment is required, however, its value is given by the system short run marginal cost (SRMC), which includes only the cost of fuel and variable O&M required for generating units operating at the margin during different hours of the day and seasons of the year (Maunsell, 2004).

For international power trade, the LRMC, adjusted for the cost of transmission, is the best proxy for the value of a firm power purchase or sale, and SRMC, similarly adjusted, is the best proxy for the value of a non-firm transaction. Specifically, the relevant marginal cost must be adjusted in the case of exports, since the buying country will expect to pay no more than its own marginal cost at the point where additional load is required. Likewise, marginal cost must be adjusted for imports, since the selling country will expect to receive its full marginal cost at the point of generation plus any cost for transmission to the buyer (Maunsell, 2004).

However, in order to run the RAM, some simplifying assumptions must be made to existing data on a range of hydropower developments (existing and planned) within LMB to generate some hypothesis about the value of water in this application. Any applied values will be subject to later refinement and sensitivity-testing in any event.

Approximate values for hydropower generation have been derived based on the following information for each plant:

Average (firm and non-firm) economic generation costs (c/kWh). Wherever possible, the financial cost estimates have been taken from the Lao Power Sector Development Strategy (Maunsell, 2004). The estimates in this study are average generation costs that have been weighted for primary and secondary energy production and adjusted to account for some social and environmental impacts. The study only covers hydropower dams in Laos. For dams not included in the study and where financial generation costs are available, an adjustment factor of 1.2 (see Nam Theun 2 Project Economics Summary Report, p.6) has been applied to convert from financial to economic costs. The Viet Namese dams all have the same cost-benefit structure because of a lack of information. The financial costs of the Yali dam have thus been used for all dams in Viet Nam.

Average transmission and distribution costs (c/kWh). Information from the Nam Theun 2 Project Economics Summary Report suggests that transmission and distribution costs are around 40% of average economic generation costs for hydropower sold from Laos to Thailand and 200% for power produced and sold for domestic consumption in Laos13. However, data on the relative proportions of power generated for export compared to power generated for domestic consumption is not readily available for other LMB dams. For

[13] These estimates are based on data provided in the Nam Theun 2 Project Economics Summary Report (2004).

this reason, the blanket assumption that transmission and distribution costs are 45%14 of economic generation costs has been applied to all dams in Laos other than Nam Theun 2. For Viet Nam, it is assumed that transmission and distribution costs are 30% of economic generation costs.

A composite willingness-to-pay measure based on relative national WTP values and weighted according to the amount of power from each station that is either sold for export or produced for domestic consumption. In the case of Viet Nam, no information on WTP for power was readily available thus WTP was calculated using the Lao WTP and adjusted by the ratio of Lao GDP to Viet Nam GDP.

Modelling

Within the RAM, hydropower stations are either "on", in which case net benefits are a function of some predetermined average output (in kWh) based on their physical output capacity, or "off" in which case there are no net benefits. Thus, when a particular hydropower station is set to "on", the net benefits are calculated as follows:

BH = (PH * QH) – (CH * QH)

Where:

BH	=	Net benefits (US$/kWh) from hydropower production
PH	=	WTP (US$/kWh)
QH	=	Hydropower output (kWh per year)
CH	=	Total economic generation, transmission and distribution costs (US$/kWh)

Data issues and sensitivity testing

The information used in deriving the RAM hydropower values has come from review of a range of regional power sector studies. Inconsistencies exist between these studies although a stated objective of the Lao Power Sector Development Plan (Maunsell, 2004) was to reconcile them. Wherever possible, the Maunsell values have been used. The inconsistencies derive from differences in:

- methodology
- level of detail and effort
- study objectives
- parameter values, constraints and other assumptions.

In most cases disparities can be traced to differences in assumptions and parameters. For the Nam Theun 2 dam, data has come exclusively from the Nam Theun 2 Project Economics Report.

Inflating all the net benefits by 50% tested the sensitivity of RAM results to changes in net benefit values.

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14 This is roughly the resulting percentage if it is assumed that all hydropower dams are generating similar ratios of power for export to power for domestic consumption.

Table 4.4: Summary RAM inputs, hydropower

(Note that a maximum of four dams can be modelled in each scenario)

Dams modelled in the RAM	Country	Scenarios in which dam included	Ave annual output (GWh)	Ave economic generation costs (c/kWh)	Transmission / distribution costs (c/kWh)	Weighted WTP (c/kWh)	Assumption set 1: Net benefits (US$ '000/GWh)	Assumption set 2: Net benefits (US$ '000/GWh)
Nam Leuk	Lao PDR	None	230				37.40	56.10
Nam Ngum Baseline	Lao PDR	All	1,040	2.67	1.20	7.13	32.56	48.84
Nam Ngum 2	Lao PDR	None	2,310				32.56	48.84
Theun Hinboun	Lao PDR	All	1,620	2.00	0.90	7.13	42.24	63.36
Nam Nhiep 1	Lao PDR	None	1,362				25.29	37.94
Nam Theun 2	Lao PDR	Low High Irrigation	5,936	2.70	1.26	7.13	44.74	67.11
Nam Theun 3	Lao PDR	High	568	2.92	1.32	7.13	28.93	43.39
Houay Ho	Lao PDR	Baseline Low Irrigation	556	2.92	1.32	7.13	21.66	32.49
Yali Baseline	Viet Nam	Baselines	3,650	4.34	1.30	8.96	33.16	49.73
Yali Regulated	Viet Nam	Low High Irrigation	3,650	4.34	1.30	8.96	33.16	49.73
Plei Krong	Viet Nam	None	417				33.16	49.73
Kontum	Viet Nam	None	945				33.16	49.73
Xe Kaman 1	Lao PDR	High	1,925	2.34	0.70	7.13	33.77	50.65
Xe Kaman 3	Lao PDR	None	1,349				37.40	56.10
Se San 4a	Viet Nam	None	1,348				33.16	49.73
Se San 5	Viet Nam	High	1,795	4.34	1.30	8.96	33.16	49.73
Lower Se San & Lower Se Pok	Viet Nam	High	100	4.34	1.30	8.96	33.16	49.73

4.3 Municipal and industrial use

4.3.1 Summary and rationale

There is little information available on municipal and industrial water uses in the Mekong River Basin. Domestic water supply and sanitation is often seen as a national responsibility with few transboundary implications because domestic water supplies usually represent small volumes relative to total withdrawals. However, three aspects of domestic water use should make it a regional concern:

– Demand for domestic water use is universal;

– Wastewater disposal may contaminate water for downstream users; and

– Social and economic consequences of inadequate supplies are serious.

Domestic water use issues in the LMB have been reviewed in detail by Seager (2002). Some of the most important features are summarized below.

Access to safe supplies

Per capita daily water use shows a great variation among different economies and regions. Generally speaking, in developing regions of the world people use far less water per capita than those in the developed regions. In Africa, the average consumption standard is 47 l/p/c/d and in Asia, this figure increases to 85 l/p/c/d. The minimum amount of water required to meet basic needs varies depending upon what is included as "basic needs". The figures vary globally from 20 to 50 litres per person per day depending on the country or regional context.

Safe water is defined by UNICEF as a supply of water through household connection, public standpipe, protected dug well, protected spring or rainwater collection, with a minimum quantity of 20 litres/person/day within one hour of people's residences (UNICEF, 2002). Gleick (1996) estimates the total basic water requirement at 50 l/p/c/d for meeting four domestic basic needs: drinking, sanitation, bathing and cooking, independent of climate, technology and culture. Falkenmark uses the figure of 100 l/p/c/d for personal use as a rough estimate of the amount needed for a minimally acceptable standard of living in developing countries (Population reports 1998). For this reason, national goals have been used wherever possible, in the hope that these reflect more appropriately the actual needs of the LMB population.

The quality of water supply varies widely across the LMB. In most provinces in NE Thailand, over 90 percent of the population has access to safe water. In most Cambodian provinces, the proportion is less than 25 percent; in Lao PDR it is between 25 and 50 percent (Hook et al, 2003). Access to safe water may be more common in Lao PDR than in Cambodia because of greater numbers of people living in remote upland areas with access to unpolluted mountain streams. Also, during the dry season in Cambodia, the number of households with access to safe water declines in both urban and rural areas.

Urban supplies

Water supplying people in urban towns and cities originates mostly – about 85% - from the Mekong River and its tributaries, and represents only 0.04% of the annual discharge of the Mekong River. In 1995, ESCAP estimated that only one third of Vientiane's population was served by a public water supply. Water withdrawals are estimated at 55,000m3/day or 140 litres per capita per day. Only 2.5% of the piped water is used in industrial activities. It is believed that up to one third of the water is unaccounted for (i.e. it does not reach the end user). About 60% of the population of Phnom Penh was connected to the public water supply system in 2000 (Ringler, 2001).

Rural supplies

It was estimated that in 2002, about 60% of the rural population in Lao PDR had potable water from a public tap, or hand pump or spring; no houses had piped water connections. The goal is to reach the figure of 90% by 2020. The government target is to provide 35 litres/per person/per day.

Industrial demands

Industrial water demand varies widely from enterprise to enterprise and from country to country based upon location conditions. Industrial water demand is often considered under the following headings (MRC-BDP, 2003):

- Cooling water demand: usually abstracted directly from, and returned to, rivers with little overall loss.
- Major industrial demand: factories using 1,000-20,000 m3/day or more for such industries as paper making, chemical manufacture, iron and steel production, oil refining etc. Such supplies are often obtained from private sources.
- Large industrial demand: factories using 100-500 m3/day for food processing, vegetable washing, drinks bottling, ice making, chemical products etc. These supplies are frequently drawn from the public supply.
- Medium to small industrial demand: factories are using less than 50 m3/day comprising many types are making a wide range of products. The majority will take their water from the public supply.

In 2001, the major industrial water use in Cambodia was associated with garment manufacturing in and around Phnom Penh. The water use requirements were estimated at 75,000m3/day or about 27 MCM/year. Freshwater requirements for industrial purposes were estimated in 1996 about 47-55 MCM/year for Phnom Penh, and up to 2 MCM/year for each provincial town (CNMC, 2003).

Industrial water demands have not been directly accounted for in the model. Relative to municipal demands, industrial demands are very low and in many cases are satisfied through groundwater supplies.

Estimates of basic municipal and industrial water demand in each of the LMB countries, based on population, are shown in Table 2. In reality, demands beyond those that satisfy basic needs will vary according to a number of factors including income, other socio-economic factors and any efforts by the riparian governments to institute cost recovery measures (e.g. water charging).

Table 4.5: Basin population and municipal and industrial water withdrawals 2000 and 2020

Country	Basin population 2000	Water demand for M&I (million m3) 2000	Basin population 2020	Water demand for M&I (million m3) 2020
Cambodia	10,570,188	42	16,238,388	64
Lao PDR	4,956,981	77	7,481,013	117
Thailand	22,846,875	1,362	26,967,375	1,607
Viet Nam	17,033,866	1,387	21,817,222	1,776

Sources: Population Division of the UN Department of Social and Economic Affairs; MRCS (2003); WRI; Ringler (2001).

The World Resources Institute estimated total withdrawals per capita in each of the four Mekong countries as follows:

Table 4.6: Per capita water withdrawals

Country	m3 per year	m3 per day (equivalent)	Litres per capita per day
Cambodia	3.3	0.01	9
Lao PDR	10.4	0.03	28
Thailand	35.76	0.1	98
Viet Nam	48.84	0.13	134

Note: Figures for Cambodia and Lao are 1987 estimates. For Thailand, 1995 and for Viet Nam, 1990

4.3.2 Valuation basis

The entire basin population is assumed to benefit from domestic and/or industrial water withdrawals from the Mekong, although only a share of the population is connected to public supply systems. Rather than using data from National Water Supply Authorities, which reflects only those number of people connected to a public supply system and usually limited to urban areas only, withdrawals for M&I uses have been estimated using both sub-area population data and national targets for basic needs requirements. This is consistent with the demand forecasting used in the DSF.

In Viet Nam, the National Strategy for Rural Water Supply and Sanitation (2000) aims to provide 85% of rural inhabitants with access to safe water at the level of 60 litres per capita per day and 70% of families with good standard latrines by 2010.

In Cambodia, the government is committed to achieving the long-term goal of providing access to clean drinking water and environmental sanitation for the entire population, but has not yet set specific targets.

In Lao PDR, the Sector Investment Plan for water supply sets national targets to provide safe water supply for 80% of the population by 2000; access to sanitary toilets for 50% of the rural population; and sewerage reticulation for Vientiane, Luang Prabang, Pakse and Savannakhet by 2003.

In Thailand, the Provincial Water Authority has responsibility for water supply and sanitation outside Bangkok. Regional Water Supply Authorities have committed to provide at least 10 villages per year in each supply area with potable water.

The following standards have been used as minimum per capita daily requirements:

Table 4.7: Basic water demands

Country	RAM baseline	Low development / Irrigation development	High development
Cambodia	32 l/cap/day	150 l/cap/day	150 l/cap/day
Lao PDR	64 l/cap/day	100 l/cap/day	100 l/cap/day
Thailand	115 l/cap/day	200 l/cap/day	200 l/cap/day
Viet Nam	60 l/cap/day	150 l/cap/day	150 l/cap/day

Note: The baseline figures are the ones used in the DSF and the World Bank Mekong Water Resources Assistance Strategy.

For the purposes of RAM, municipal water demands have been conceptualized in the same way as crops i.e. that there are minimum water requirements for each person living in the LMB that have to be met. However, unlike crops which can be substituted (i.e. different cropping patterns or crop types) or abandoned altogether in times of severe water shortages, municipal demands have to be met in order to satisfy basic human needs. In order to meet this criterion, where water availability in any sub-area is insufficient to meet the demands of the population in that sub-area, the model has been set to show a warning, thus ensuring that the user is aware of potential violations of the basic water requirement. Where more than one country shares the same sub-area, a weighted average requirement of the countries is used.

Estimating benefits

A number of different studies were consulted for estimates of WTP for municipal water supplies. The estimates presented in these studies were sometimes very different as the quality of water and/or service being valued varied widely (e.g. piped supplies vs standpipes, treated vs non-treated water, etc).

Table 4.8 below shows house connection prices versus informal vendor prices (in US$) in selected cities in each of the four member countries. These provide some indication of the prices that people are willing to pay for domestic water supplies.

Whereas water vendors charge up to US$14.6/m3 for water in Vientiane, charges by the Water Supply Authority are usually far less, ranging from US$0.04-0.24/m3 (see Table 5), following a block rate tariff scheme (ADB, 2004).

Because of the uncertainties around the level of service that households were obtaining from private and/or informal sources, the benefits of municipal and industrial water are equated to an average WTP for water of US$0.14 per m3 (see Ringler, 2001, p.182).

Table 4.8: Water connection tariffs

City	Cost of water for domestic use (10m3 /month) in US$/m3 (2001 prices)	Price charged by informal vendors (US$/m3)	Ratio (vendor/connection)
Chiang Mai, Thailand	0.15	1.01	6.64
Ho Chi Minh City, Viet Nam	0.128	1.08	9.23
Phnom Penh, Cambodia	0.082	1.64	18.02
Vientiane, Lao PDR	0.033	14.68	135.92

Source: ADB (1997) Second Water Utilities Data Book and UNESCO

Estimating costs

Water has significant real costs of supply. Various kinds of costs are involved (Briscoe, 1996; Cotton et al, 1991; Winpenny, 1994; Herrington, 1987; Rogers, Bhatia and Huber, 1997; Webster, 1998):

- Supply costs (the capital and recurrent costs associated with the installation of the necessary infrastructure required to treat, transport and provide service levels, operation and maintenance costs of this infrastructure and the depreciation costs which accrue over the life of the project as parts need to be repaired or upgraded).
- Opportunity costs (the value of water in its next best alternative use). The size of the opportunity cost depends on the value of the water in its highest alternative current-use value.
- Environmental costs (both direct and indirect, relating to the abstraction, distribution and use of the resource)

Together, the opportunity and supply or use costs make up what is commonly referred to as the 'economic cost' of water.

Table 4.9 shows average tariffs and unit production costs for three LMB water supply authorities.

Table 4.9: Average tariff and unit production costs for LMB water authorities

Country	Average tariff (US$/m3)	Unit production cost (US$/m3)
Cambodia (Phnom Penh)	0.244	0.082
Lao PDR (Vientiane)	0.042	0.033
Viet Nam (Ho Chi Minh City)	0.183	0.128

Source: ADB (2004) Water in Asian Cities

For the purposes of RAM, the costs of water provision for M&I uses is estimated as US$0.05/m3 (Ringler, 2001, p114) which lies within the range of the unit production costs of each of the water supply authorities shown in the table above.

Based on the above, the net benefits of municipal water supplies have been estimated as US$0.09 / m3. This figure is applied to all sub-areas within the basin.

Modelling

Net benefits are calculated as:

Bm = QLMB(Pm - Cm)

Where:

Bm = net benefits from municipal and industrial use (US$/m3)

Qm = quantity demanded/supplied (m3) which is a function of sub-area population and the daily per capita requirement

Pm = gross benefits from municipal and industrial use, measured by WTP (US$/m3)

Cm = costs of supply (US$/m3)

Data issues and sensitivity testing

The published data shows a large discrepancy between the prices that vendors are able to charge for water, reflecting either a wide variation in the willingness to pay of households in different cities or errors in the information. While it can reasonably be expected that WTP for similar levels of service will vary slightly across households in different countries, there is little evidence to suggest that the factors affecting effective demand (measured by WTP) should be so different between the LMB countries, assuming that the levels of service being offered by the vendors are comparable. The estimate used in the model comes from a series of WTP studies conducted in the United States and may underestimate the value of clean water to households in the LMB. For this reason, the sensitivity of the model results to an inflated WTP value has been tested.

It can reasonably be expected that rising levels of income and education, associated with development, will also increase the demand for water. Thus all future planning scenarios use a higher per capita BWR than the baseline. The modelled future requirements are shown above in Table 4.7.

Tourism demands

Tourism is an important, and growing, source of foreign exchange in the LMB economies. Furthermore, it is also a large water user and therefore ought to be accounted for in water allocation planning. For the purposes of the RAM model, tourism demands are modeled separately from municipal demands to (a) reflect the fact that tourism demands are exogenously determined i.e. they are not related to population growth in the LMB (b) allow for both high and low growth tourism scenarios and what high growth tourism in one sub-area (e.g. around Siem Reap) may mean for downstream basins and (c) to allow clear analysis of the trade-offs that may need to be made between other extractive sectors and tourism. The valuation of tourism demands is described in the section that follows.

Table 4.10: Summary RAM inputs for all scenarios, municipal and industrial water uses

Parameter	Assumption set 1	Assumption set 2
WTP for water	0.14 US$/m^3	1.00 US$/m^3
Costs of production	0.05 US$/m^3	0.03 US$/m^3
Net benefits to M&I	0.09 US$/m^3	0.97 US$/m^3

4.4 Tourism

4.4.1 Summary and rationale

The tourism industry has been developing rapidly since the early 1990s and has become an increasingly significant source of revenue for the LMB countries. In part recognition of this, tourism has been identified as one of the key sectors the six GMS countries have pledged to promote as part of their regional economic cooperation programme. Furthermore, the potential of tourism is increasingly being recognized in the economic development policies of all LMB countries, targeting both domestic and international demand. For example, an explicit objective of the Viet Nam National Administration of Tourism is "to develop the tourism industry into a spearhead economic sector" such that tourism will contribute at least 5% of GDP by 2005 and 6-8% by 2010 with revenues for 2005 and 2010 of US$2-2.5 billion and US$4-4.5 billion respectively. The tourism industry in Thailand has played an important role in national economic development for a number of years. Tourism, with its multiple backward and forward linkages, is also an increasingly important contributor to the less developed economies of Laos and Cambodia.

The significance of tourism to each of the national economies is illustrated in the table below.

Table 4.11: Economic contribution of tourism

GDP contribution (%)			
Country	*2001*	*2002*	*2012 projected*
Cambodia	9.18	9.27	11.51
Lao PDR	9.73	9.35	12.69
Thailand	12.95	11.95	12.04
Viet Nam	6.71	6.49	7.38
Southeast Asia	8.51	8.15	8.93

Source: World Travel and Tourism Council (2002)

4.4.2 Valuation basis

There are two perspectives from which the tourism value of water in the LMB can be analyzed. The first is to approximate the value of water to tourism by looking at the value of water-related tourism assets such as Tonle Sap Great Lake, boating channels that facilitate waterborne transport and recreation, Khon Phapeng Falls and the Irrawaddy Dolphin. It is, however, extremely difficult to assess the value of tourism that can be attributed directly to the presence of the Mekong and its associated assets and more particularly, how tourism numbers to these identified assets may be influenced by water levels. For this reason, the values of water-related tourism assets have not been included in the model. However, if it is assumed that tourism numbers are in some way related to the presence of the Mekong River, then it can also be assumed that if river levels were to drop such that the tourism-related assets were adversely affected, then tourism numbers would also fall. To some extent, the river-based value of tourism has been captured in the navigation and wetlands constraints: if water levels are below some predefined minimum level, tourist passenger boats will not be able to navigate, important wildlife habitats may be lost and the tourism value of the Mekong will decline.

The second approach is based on the recognition that one of the most important requirements for the development of tourism facilities is an adequate and continuous supply of safe water for drinking and other domestic and recreational uses. This is the approach used in the model.

Detailed data on per capita water use for tourism is difficult to obtain. However, in 2000, it was estimated that per capita water use in Luang Prabang was approximately 3 times greater than in most other towns in Lao PDR (MRCS, 2002). This observation is attributed to the large number of tourists visiting the town and provides an indication of the significance of exogenous tourism demands on water resources.

The tourism industry is a large water user and should therefore be accounted for in water allocation planning. As noted earlier, for the purposes of the RAM tourism water demands are separated from municipal and industrial demands to facilitate analyses of the trade-offs between tourism and other water-dependent sectors such as agriculture and to make the clear distinction between endogenous (i.e. population growth) and exogenous demands.

Data sources and assumptions

Tourism statistics for the LMB countries have been obtained from a variety of sources:

- Tourism Authority of Thailand (TAT) and the Office of National Statistics
- Viet Nam Tourism
- Cambodia Ministry of Tourism
- BDP National Sector Overviews and Sub-area Studies for Cambodia, Laos, Thailand and Viet Nam
- World Travel and Tourism Council

These sources include data on:

- The numbers of tourists to each country and/or provinces within countries. Where provincial tourism data was unavailable, visitor numbers to different parts of each country were estimated according to assumptions around the proportion of total tourist days in particular areas (as a percentage of total average length of stay in each country)
- The average length of stay of tourists in each country. This is currently around 5-7 days15
- Expenditure per tourist per day

The following estimates were also used in deriving the tourism value of water:

- Water use per capita per tourist is 300 litres16 per day (this includes drinking, bathing, laundry and recreational demands)

15 Based on Cambodia Ministry of Tourism (2003), TAT (2004)

16 The European Environment Agency (2001) estimated that in Europe each tourist consumes 300 litres of freshwater per day. Luxury tourists can utilise up to 880 litres per day. UNEPTIE (2003) notes that if the order of magnitude of global water consumption can be estimated, European averages could be taken as conservative as water efficiency in Europe may be higher than elsewhere.

– Tourists spend, on average, US$0.01 per litre or $3 per day on water

In this way, we can think of tourists in the same way as irrigated crops i.e. that they have specific water requirements. In the model, the user can then run scenarios which allocate small, medium and large quantities of water to tourism (by changing the number of tourists to each sub-area) and assess the outcomes in terms of that they mean in terms of both (a) the total economic benefits from water allocated to tourism in each case and (b) the significance of the trade-offs between tourism and competing water demands. The trade-offs are likely to be particularly apparent around Tonle Sap where tourism and agriculture are potential water rivals.

Using the assumptions outlined above and data from the national tourism authorities of each country, the following deductions can be made about the role and value of water to the tourism sector in each country:

Table 4.12: Tourism value of water

Country	Tourism value added by water per year (US$)	Average tourism value added by water per day (US$)
Cambodia	18,829,385	51,587
Lao PDR	12,128,814	33,230
Thailand	258,552,000	708,362
Viet Nam	55,187,748	151,199

The total value-added of water generated by tourism is highest for Thailand and lowest for Lao PDR (see Table 4.12). This largely reflects the relative numbers of tourists to each country each year.

In each country, the returns per unit of water from allocating water to an alternative use (i.e. away from tourism) must be greater than US$1 per 100 litres in order to make economic sense. However, social, political and environmental considerations will also play a role in determining an optimal allocation of water between sectors.

If Cambodia chose to allocate water away from tourism and towards agriculture in Siem Reap province and this reallocation meant that there was insufficient water to meet the current demands of tourism in the area, then the present water-related value of each tourism day lost would be in the region of $34,000[17].

As planners, we are interested in knowing how an increase or reduction in tourist numbers will affect total water demand and what this might mean for alternative and especially competing water uses. Thus we can analyze the impacts of any number of additional tourists in terms of the opportunity costs of water. For example, if each tourist requires 300 litres of water per day and only 300 litres of water per day were available, then only 1 tourist per day could be supported.

17 Calculated based on the assumption that 65% of the total number of tourist days is spent in Siem Reap province.

Modelling

Following from the above, the water-related benefits from tourism in any sub-area can be expressed as:

VWT = DT * EWT

Where:

VWT	=	Value of water allocated to tourism (US$)
DT	=	Number of tourist days per year
EWT	=	Expenditure per tourist per day on water (US$)

And where:

DT = NT * ST

Such that:

NT	=	average number of tourists per year, based on recorded visitor numbers or assumptions around the proportion of visitors to particular basin areas
ST	=	average length of stay (days) per tourist

And where:

EWT = US$3 [18]

Data issues and sensitivity testing

Reliable and/or recent provincial level data on staying visitor numbers was not available for Cambodia, Laos or Viet Nam at the time of writing. Sub-area data was derived by:

(a) estimating the relative proportions of total tourist time (% of tourist days in each country each year) spent in different parts of each country; and

(b) translating provincial data (where it exists) to sub-area level based on the relative area of each province contained in the sub-area.

These assumptions may lead to over- or under-estimation of the number of tourists to the LMB and/or to particular sub-areas. The sensitivity of the model results to changes in tourism numbers will therefore be assessed. Provincial tourism data for Thailand was accessed through the website of the Tourism Authority of Thailand.

We may also wish to test:

– what happens when tourist water requirements are increased/decreased

– where thresholds lie – i.e. at what point (number of tourists) water shortages may become a problem

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18 The European Environmental Agency estimated that on average, tourists require 300 litres per person per day. If total expenditure on water per tourist per day is estimated at around US$3, then this gives a value of water of US$0.01 per litre.

It is assumed that tourism will continue to be a high-growth sector in the LMB. For the purposes of the BDP planning scenarios, tourism numbers are expected to increase by 50% under a low development scenario and to double under a high development scenario.

Summary data inputs for RAM

Table 4.13: Assumptions related to water demand for tourism

	Parameter	Assumption Set 1	Assumption Set 2	Unit
1/	Per capita consumption of water per day	300	300	litres
2/	Ave expenditure on water per day	3	6	US$
	Value of water per litre	0.01	0.02	US$
	Value of water per cubic metre	10	20	US$
3/	Average length of stay per tourist in Cambodia	7.98	7.98	days
	Average length of stay per tourist in Lao PDR	6	6	days
	Average length of stay per tourist in Thailand	7.98	7.98	days
	Average length of stay per tourist in Viet Nam	7	7	days
4/	Proportion of tourists to Cambodia visiting Siem Reap Province	65	65	%
	Proportion of tourists to Cambodia visiting Phnom Penh	30	30	%
	Proportion of tourists to Cambodia visiting Kratie/Mondulkiri/Stung Treng	2	2	%
	Proportion of tourists to Cambodia visiting Kampong Cham	0.5	0.5	%
	Proportion of tourists to Lao PDR visiting Champasak/Sekong/Attapeu	2.8	2.8	%
	Proportion of tourists to Lao PDR visiting Luang Prabang	65	65	%
	Proportion of tourists to Lao PDR visiting Vientiane	30	30	%
	Proportion of tourists to Viet Nam visiting Central Highlands	2	2	%
	Proportion of tourists to Viet Nam visiting Mekong Delta	2	2	%

Under Assumption Set 2, the average expenditure on water per tourist has been doubled. Daily water consumption remains the same under both assumption sets.

5 Valuation of instream economic demands

5.1 Fisheries

5.1.1 Summary and rationale

The Mekong River Basin hosts one of the most diverse freshwater fisheries in the world, with over 1,200 recorded fish species and a diverse fauna of other freshwater animals. The Mekong fishery is enormously important both commercially and for subsistence livelihoods throughout the LMB. Based on studies by the MRC Fisheries Program, it is currently estimated that average consumption of fish and other aquatic products (OAP) in the LMB is about 36 kg/person/year. Around 2.6 million tonnes of fish and aquatic products are caught or cultured in the LMB each year, with an estimated value at first point of sale of just over $1,900 million. Up to two-thirds of the LMB's population are involved in fishing at least part-time or seasonally. Preserving the Mekong fishery is central to food security in the region.

Seasonal peaks in the Mekong catches have stimulated the development of a large industry which produces dried and fermented fish products, fish sauce and paste. This processing industry adds value to the catch, provides employment and spreads the economic and nutritional benefits of the catch over the full year.

The value of fisheries production in the LMB is very difficult to estimate because the relative proportions of fish, processed fish products and other aquatic animals are not well described, and the average prices of these different products in different regions are not known (MRC-Fisheries, 2002). Nevertheless, an approximate idea of the value of the fishery can be obtained by applying fish prices to the total yield of fish, fish products and other aquatic animals. Phillips (in press) has estimated the average farm gate price for cultured fish to be in the region of US$1.05 per kg and Aeron-Thomas (in press) estimates a first hand sale price of US$0.68/kg for capture fish. For reservoir fisheries, the conservative value of US$0.68/kg is used because although the fish are produced by both aquaculture and capture fisheries, the relative proportions cannot be easily estimated. This results in an estimate of US$1,921 million for the value of the fishery. This is for the first sale price only, and so does not include any estimate of the multiplier effects of the fish trade.

Based on this information, baseline fish consumption and gross value in each LMB country have been estimated as shown in the table below.

Table 5.1: Fish consumption as a measure of yield in the LMB

Country	Fish consumption (tonnes per year)	Value of fisheries (US$ millions)
Cambodia	682,150.00	496.14
Laos	182,700.00	132.88
Thailand NE	932,300.00	678.08
Viet Nam Delta	844,850.00	614.48
Lower Mekong Basin	2,642,000.00	1,921.58

5.1.2 Valuation basis

Standard functional forms for the evaluation of the relationship between water flows and the value of fish production are not readily available. However, productivity is known to be a function of multiple factors including:

- fishing practices
- total fishing effort
- river flows
- barriers to river migration
- access to and from floodplain habitats and habitat changes

Recent advances have, however, been made in modelling how fisheries productivity may be affected by changes in hydrological flow levels (MRC, 2005) using indicators relating to habitat availability and migration.

The area flooded each year and the duration for which it is inundated is one of the most important factors relating to the sustainability of the Mekong fisheries. For the area downstream of Kratie, for which flooded areas can be simulated, this can be captured in a single index (MRC, 2005) called a Habitat Area Index (HAI).

The HAI is computed as the product of area inundated to more than 0.5m and the number of days this area is inundated in each year. Areas flooded less than one month (30 days), and/or more than six months (183 days) are excluded. This total area – duration is representative of total amount of habitat that is available to fish over the year; the more habitat available, the more fish that can survive, grow and/or reproduce. Changes in habitat availability can be expected to have direct consequential impacts on the productivity of capture fisheries downstream of Kratie, including Tonle Sap.

The HAI is used to estimate the changes in annual yields (catch) downstream of Kratie.

Upstream of Kratie, changes in fisheries productivity are estimated using a stream length index as a surrogate for the unknown area of floodplain habitat in each tributary reach. This follows from the fact that for many species, the migrations undertaken at the commencement of the wet season are an essential component of an annual breeding cycle, the success of which is determined by at least the following two factors:

- the ability to move upstream along the Mekong mainstream and tributaries, without impediment by physical barriers; and
- the extent of inundation in the wet season 'destination' areas towards which the migrations are directed

Further details on the development of both the HAI and effective length indices can be found the report entitled "Modelled impacts of scoping development scenarios in the Lower Mekong Basin" (MRC, 2005). Importantly, the potential additions to fish yield from new reservoir fisheries (i.e. as a result of storage development) are not included at present, even though they may compensate to some extent for the reduction in upstream fish yields. It is believed that the potential increases in yields from reservoir fisheries in the new dams are generally less than 10% of the decreases in the capture fisheries and therefore do not adequately compensate for the lost productivity.

The changes in fisheries productivity upstream and downstream of Kratie under each scenario have been estimated as follows (MRC, 2005):

Table 5.2: Estimated changes in fishery productivity

Scenario	Upstream of Kratie	Downstream of Kratie
Low development	-2%	-5%
Irrigation	-2%	-5%
High development	-15%	-10%

These productivity losses have been indirectly incorporated into the RAM by applying them to the baseline consumption figures shown in Table 9 above. Note that for the purposes of modelling in RAM, where fish values have been derived on a national basis, these productivity losses have been assigned to the countries as follows:

- Laos and NE Thailand are considered as being upstream of Kratie
- Cambodia and Viet Nam are considered as being downstream of Kratie

The resulting fisheries net benefits under each scenario are then derived as described below.

The economic benefits from fish production in each country are calculated using the total value of LMB fisheries (US$1,921 million in the baseline[19]) apportioned to each country on the basis of relative LMB population and further adjusted for relative national consumption levels. Hence:

VFNAT = [PopNAT / PopLMB * VFLMB] * [CONNAT / CONLMB]

Where:

VFNAT	=	Adjusted value of national fisheries production (US$)
PopNAT	=	National basin population (millions)
PopLMB	=	Total LMB population (millions)
VFLMB	=	Value of LMB fisheries production (US$)
CONNAT	=	Average national fish consumption per capita per year (kg)
CONLMB	=	Average LMB fish consumption per capita per year (kg)

Production costs have been estimated as follows for each of the assumption sets:

Assumption set 1: 30% of sales value for capture fisheries and 80% for aquaculture

Assumption set 2: 60% of sales value for capture fisheries and 75% for aquaculture

These costs are then weighted based on the relative production ratios of capture and reservoir fisheries and aquaculture.

19 See Sverdrup-Jensen (2002)

The production costs are subtracted from the adjusted national benefits to obtain national net benefits. These national benefits are then converted to sub-area level based on the area (km2) of each country (province) represented in each sub-area.

Because of the possibly contested ecological relationship that has been derived (through the HAI and stream length ratio), the RAM has also been set up so that it can flag areas where average changes from average baseline flows exceed any given level (e.g. 10%) in any given month. As expert knowledge about the relationship between productivity and flow levels increases, the possible implications for fisheries productivity in each of the wet and dry seasons in particular sub-areas as a result of flow changes can be assessed.

In addition to the changes in productivity accounted for in the economic impacts, particular attention is also given to the value of changes in productivity downstream of Kratie, again using the HAI. The purpose of this is to facilitate comparison between social and environmental net benefits as a result of each planning scenario in order to highlight particular trade-offs (e.g the cost-savings as a result of reduced flooding compared to the loss in fisheries value as a result of reduced habitat area).

The downstream impacts on fisheries have been valued, using the HAI, as follows:

– annual fish productivity per hectare is estimated to be around 243kg/ha. This is a high-end estimate based on work near Phnom Penh by Dubeau et al[20] (see Beecham and Cross, 2005).

– The value of capture fisheries is estimated to be around US$0.68 per kg.

– Using this information, a value per km2 per day is calculated

– This value is then multiplied by the area-duration (i.e. the HAI) in each scenario to obtain average total fisheries net benefit values downstream of Kratie.

– The difference in value between the baseline and each planning scenario then represents the change in net benefits.

Data issues and sensitivity testing

The valuation of fisheries in the LMB is subject to a number of methodological debates centred around whether catch or consumption should be used as the basis for measuring yield. Even based on consumption alone, there is a wide range of estimates of average per capita consumption and hence total fisheries value.

Because of the difficulties in obtaining reliable, or at least consistent, data on the value of fisheries in the LMB, the endpoint values of the per capita consumption range (ie low and high) for the total value of fisheries in each country (and hence sub-area) will be reported in the analysis. The individual values will not, however, need to be tested in the model as the trade-offs with other sectors or sub-areas cannot be quantified without a known flow-productivity relationship.

[20] Dubeau, P., Poeu, O. and Sjorslev, J. (2001) Estimating Fish and Aquatic Animal Productivity /Yield per Area in Kampong Tralach: An Integrated Approach. http://www.mekonginfo.org/mrc_en/doclib.nsf/ByCat_Fisheries?OpenView&Start=1&Count=30&Expand=5.2#5.2

Table 5.3: Summary RAM inputs, fisheries, assumption set 1

Parameter	Baseline value	Low / irrigation development	High development	Unit
Total value LMB fisheries	1,921.58	1,894.25	1,688.87	million US$
Proportion capture fisheries	80.00	80.00	80.00	%
Proportion aquaculture	20.00	20.00	20.00	%
Price capture fisheries	0.68	0.68	0.68	US$/kg
Price aquaculture fisheries	1.05	1.05	1.05	US$/kg
Price reservoir fisheries	0.68	0.68	0.68	US$/kg
Production costs as proportion of farmgate sales value for capture fisheries	30.00	30.00	30.00	%
Production costs as proportion of farmgate sales value for aquaculture	80.00	80.00	80.00	%
Net value LMB fisheries	1,174	1,150	1,025	million US$
Net benefits - SA 1	38.87	38.17	33.43	million US$
Net benefits - SA 2	38.18	37.42	32.45	million US$
Net benefits - SA 3	104.85	102.75	89.12	million US$
Net benefits - SA 4	37.82	37.10	32.34	million US$
Net benefits - SA 5	262.98	257.72	223.54	million US$
Net benefits - SA 6	12.21	12.03	10.69	million US$
Net benefits - SA 7	227.16	224.79	203.99	million US$
Net benefits - SA 8	44.59	44.14	40.13	million US$
Net benefits - SA 9	160.28	158.59	143.80	million US$
Net benefits - SA 10C	62.97	62.34	56.67	million US$
Net benefits - SA 10V	184.07	175.03	159.12	million US$

Table 5.4: Summary RAM inputs, fisheries, assumption set 2

Parameter	Value	Low / irrigation development	High development	Unit
Total value LMB fisheries	1,921.58	1,894.25	1,688.87	million US$
Proportion capture fisheries	80.00	80.00	80.00	%
Proportion aquaculture	20.00	20.00	20.00	%
Price capture fisheries	0.68	0.68	0.68	US$/kg
Price aquaculture fisheries	1.05	1.05	1.05	US$/kg
Price reservoir fisheries	0.68	0.68	0.68	US$/kg
Production costs as proportion of farmgate sales value for capture fisheries	60.00	60.00	60.00	%
Production costs as proportion of farmgate sales value for aquaculture	75.00	75.00	75.00	%
Net value LMB fisheries	724	709	709	million US$
Net benefits - SA 1	23.97	23.54	20.61	million US$
Net benefits - SA 2	23.54	23.07	20.01	million US$
Net benefits - SA 3	64.66	63.36	54.96	million US$
Net benefits - SA 4	23.32	22.88	19.95	million US$
Net benefits - SA 5	162.17	158.93	137.85	million US$
Net benefits - SA 6	7.53	7.42	6.59	million US$
Net benefits - SA 7	140.08	138.62	125.80	million US$
Net benefits - SA 8	27.50	27.22	24.75	million US$
Net benefits - SA 9	98.84	97.80	88.68	million US$
Net benefits - SA 10C	38.83	38.44	34.95	million US$
Net benefits - SA 10V	113.51	107.94	98.13	million US$

5.2 Wetland productivity

5.2.1 Summary and rationale

Instream flows for environmental uses are minimum amounts of water necessary to maintain a river or stream's instream functions and values. The instream flow functions and values examined here are for wetlands, including the maintenance of the overall river ecology.

According to the 1971 Ramsar Convention, wetlands are "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static, flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six metres".

Wetlands are estimated to cover between 6 and 12 million hectares of the entire LMB (Ringler, 2001). Moreover, the entire Mekong Delta can be considered a wetland area, including the floodplain between the Mekong and the Bassac, the Plain of Reeds, the Ha Tien open floodplain, the Melaleuca forests, and the tidal floodplains.

Wetlands are an important source of nutrition, income, firewood, construction material, and water supply in the Mekong River Basin. In addition to the direct use value related to harvest of fish and other marketable goods, the LMB wetland system also produces important indirect, non-marketable use values in the form of flood control and groundwater recharge. The biodiversity also has an economic value in the genetic material present in the system and economic non-use value related to the existence of the biological richness of the system.

5.2.2 Wetland classification

There are essentially two types of wetlands identified in the LMB – saltwater and freshwater. Saltwater wetlands are sub-divided into marine/coastal and estuarine wetlands. Freshwater wetlands include riverine, palustrine (marshes/swamps) and lacustrine wetlands.

Although various different classifications of wetlands exist, the most generally applied one is that provided by the Ramsar Convention on Wetlands. It divides wetlands into three main categories of habitat: (1) marine/coastal wetlands, (2) inland wetlands, and (3) man-made wetlands. Marine and coastal wetlands include estuaries, inter-tidal marshes, brackish, saline and freshwater lagoons, mangrove swamps as well as coral reefs and rocky sea shores. Inland wetlands are areas as lakes, rivers, streams and creeks, waterfalls, marshes, peatlands and flooded meadows. Lastly, man-made wetlands include canals, aquaculture ponds, water storage areas and sometimes wastewater treatment areas.

5.2.3 Wetland values

Even the broad classification described above demonstrates the substantial diversity of wetlands. Each of the wetland types has different characteristics and functions which in turn result in different values for different types. A common typology of values (use and non-use) is that developed by Dugan (1990) and shown in the table below.

As can be seen from this table, wetlands have a wide variety of functions, uses and attributes. Primary wetland functions include water supply, flow control (mainly for flood control), prevention of saline water intrusion in coastal areas into both surface and groundwater, shoreline protection, erosion control, windbreak, sediment retention, nutrient retention, toxicant removal, and water transport. Important on-site wetland products include animal, plant and mineral products (e.g. fish, timber and peat for fuel and construction); and off-site products, which are produced by the wetlands but migrate or transported to other sites (e.g. dissolved nutrients, migratory fish and birds).

Other wetland benefits include their use as a gene bank for commercial exploitation and maintenance of wildlife populations and significant habitat for the lifecycle of important plants and animal species that might be threatened by extinction. Wetlands also contribute to the maintenance of existing processes and natural systems (e.g. floodplains assure the maintenance of microclimates) and can prevent the development of acid sulphate soils. Finally, some wetlands are suitable for tourism and recreation, have aesthetic significance or are associated with religious and spiritual beliefs and activities. Natural wetlands are thus highly productive systems and benefits from wetland products are often significantly higher per unit area compared to any other land use (Davies and Claridge, 1993). All of these uses are present in some form in the Mekong River Basin.

Wetlands and mangrove forests in the Mekong Delta form a buffer between land and sea, trap river-borne sediment brought with floods, have a primary function in soil conservation and coastal protection, provide a habitat for flora and fauna, serve as spawning and nursery grounds for fish; and provide important wintering areas for migratory birds. However, these areas are under threat. In the Delta and elsewhere, wetland trees are cut for fuelwood, charcoal and construction material. Mangrove forests have been converted to agricultural areas and shrimp production, and have been lost to drainage activities and excavation work for canals (MRC, 1997).

Table 5.5: Typology of wetlands values

Key: ○ Absent or exceptional; ● Present; ■ common and important value of that wetland type.
Source: After Dugan (1990)

	Lakes	Estuaries (without mangroves)	Mangroves	Open coasts	Floodplains	Freshwater marshes	Peatlands	Swamp forests
Functions								
Groundwater recharge	■	○	○	○	■	■	●	●
Groundwater discharge	●	●	●	●	●	■	●	■
Flood control & flow regulation	■	●	■	○	■	■	●	■
Shoreline stabilisation, erosion control	○	●	■	●	●	■	○	○
Sediment / toxicant retention	■	●	■	●	■	■	■	■
Nutrient retention	●	●	■	●	■	■	■	■
Biomass export	●	●	■	●	■	●	○	●
Storm protection/windbreak	○	●	■	●	○	○	○	●
Microclimate stabilisation	●	○	●	○	●	●	○	●
Water transport	●	●	●	○	●	○	○	○
Recreation /tourism	●	●	●	■	●	●	●	●
Information – research, education and monitoring	●	●	●	●	●	●	●	●
Maintenance of ecosystem stability and integrity of other ecosystems	●	●	●	●	●	●	●	●
Storage and recycling of human and organic waste	●	●	■	●	●	■	■	■
Maintenance of migration and nursery habitats	■	●	●	●	■	●	○	●
Products								
Forest resources	○	○	■	○	●	○	○	■
Wildlife resources	●	■	●	●	■	■	●	●
Fisheries	■	■	■	●	■	■	○	●
Forage resources (food, fuelwood, medicine, construction materials)	○	●	●	○	●	●	○	○
Agricultural resources	●	○	○	○	■	●	●	○
Water supply	■	○	○	○	●	●	●	●
Genetic resources	●	●	●	●	●	●	●	●
Energy	○	○	○	○	○	○	■	○
Attributes								
Biological diversity	■	■	●	●	■	●	●	●
Uniqueness to culture or heritage	●	●	●	●	●	●	●	●

Wetlands are most commonly valued by evaluating each of the characteristics of the system. The Total Economic Value (TEV)[21] of wetland resources provides a useful framework for such a valuation approach. TEV comprises direct use value, indirect use value, option value, and existence value (see Table 10 for an example of TEV for a mangrove). Many functions are characteristic of specific wetlands (as shown in the box below) within specific regions and thus the relative importance of the individual components of TEV for a given wetland area are site-specific and depend on the wetland type.

Economic values are usually distinguished as use and non-use values. Economic use values of wetlands comprise the direct use of a wetland's goods, such as the consumption of fish for food, trees for fuelwood or as building material, and water for drinking, cooking and washing. Use values also include the indirect use of a wetland's services, such as water retention capacity (including man-made for irrigation or energy production) and nutrient recycling. Lastly, option value can be distinguished as a use value – this is the value of a wetland to humans to preserve an environment as a potential benefit for themselves in the future.

The non-use value of a wetland refers to the non-instrumental value, not associated with use. This includes existence value – a recognition of the value that of the very existence of wetlands.

The relative values that a particular wetland type provides depend on its characteristic processes. For instance, a coastal wetland's processes are often dominated by the daily tidal cycle, whilst a floodplain wetland is dominated by the freshwater hydrology of a river. Very different habitats arise in these areas and the associated ranges of values that can be provided, are correspondingly different. Furthermore, human interaction with the environment is very diverse and thus there are many specific values that can be realised by different individuals and stakeholder groups. These can be categorized according to the way that humans interact and benefit from them. The principal types are described in the box below.

21 See Figure 2.1 for a schematic of TEV

Components of Total Economic Value (TEV)

Direct use value

Direct use values are the values derived from the direct use or interaction with a wetland's resources and services. Direct use values include both consumptive uses of a wetland's resources (e.g., fuelwood collection, hunting, and fishing) and non-consumptive uses of a wetland's 'services' (e.g., recreation, tourism, and in-situ research and education). Direct use of wetlands could involve both commercial and non-commercial activities. Non-commercial activities are often very important for the subsistence needs of local populations.

Indirect use value

Indirect use values are the indirect support and protection provided to economic activity and property by the wetland's natural functions, or regulatory 'environmental' services. For example, the storm protection function of a wetland system may protect agricultural production, infrastructure, properties, and even human lives. Groundwater recharge might replenish aquifer supplies in the area used for domestic agricultural and industrial purposes in other regions.

Option value

Option value is a type of use value in that it relates to future use of wetlands. Option value arises because individuals may value the option to be able to use a wetland some time in the future. Thus there is an additional 'premium' placed on preserving a wetland system and its resources and functions for future use. Option value may be particularly important if one is uncertain about the future value but believes it may be high, and if current exploitation of the wetland or its conversion to other uses results in irreversible effects. For example, wetland resources may be underutilized today but may have a high future value in terms of scientific, educational, commercial and other economic uses. Similarly, the environmental regulatory functions of the wetland ecosystem may become increasingly important over time as economic activities develop and spread in the region.

Bequest values are a special category of option values. Such values arise from individuals placing a high value on the conservation of wetlands for future generations to use. The motive is the desire to pass something on to one's descendants. Bequest values may be particularly high among the local populations currently using or inhabiting a wetland in that they would like to see their way of life and culture that has 'co-evolved' in conjunction with the forest passed on to their heirs and future generations. Option and bequest value are difficult to assess as their estimation involves some assumptions concerning future incomes and preferences, as well as technological change.

Non-use values

Non-use values are derived neither from current direct nor indirect use of the wetland. There are individuals who do not use the wetland but nevertheless wish to see them preserved 'in their own right'. These 'intrinsic' values are often referred to as existence values. Existence value is derived from the pure pleasure in something's existence, unrelated to whether the person concerned will ever be able to benefit directly or indirectly from it. Existence values are difficult to measure as they involve subjective valuations by individuals unrelated to either their own or other's use, whether current or future. However, several economic studies have shown the 'existence value' of ecosystems constitutes a significant percentage of total economic value.

Table 5.6: TEV of a mangrove resource (Koh Kong, Cambodia)

Use values		Non-use values	
Direct value	*Indirect value*	*Option value*	
Timber	Shoreline / riverbanks	Future use	Cultural and aesthetic
Firewood	Stabilization		Spiritual and religious
Woodchips	Groundwater recharge and discharge		
Charcoal	Flood and flow control		
Fisheries	Storage and recycling of human waste and pollutants		
Forest resources: food, medicine, construction materials, tools, dyes; wildlife	Maintenance of biodiversity		
Agricultural resources	Provision of migration habitat		
Water supply	Provision of nursery and breeding grounds for fish		
Water transport	Nutrient retention		
Genetic resources	Prevention of saline water intrusion		
Tourism and recreation			
Human habitat			
Educational, historic and scientific information			

Source: Bann (2003)

5.2.4 Quantification of LMB Wetland Benefits

Until very recently there have been relatively few efforts at quantifying wetland benefits in the LMB. Where studies have been undertaken, they have typically focused on direct benefits and have been limited to small wetland areas. It is only in the past two years that significant resources have been directed at examining the TEV of entire wetland ecosystems such as Tonle Sap.

Ringler (2001) modeled the net benefits from wetlands as a function of wetland area and yield with potential wetland damage related to deviation of actual flows from representative monthly flows in both directions – severe/abnormal flooding and drought. Wetland benefits were thus modeled as a declining function of increasing flow deviations from normal flows.

Whilst the physical relationship between wetland area and flow levels may be intuitive, it is less clear how individual wetland values respond to changes in flows. Some wetland types are more sensitive to changes in flows than others. (pers comm., MRCS-EP) and some of the functions and products in particular may be affected by changes in the timing and volume of flows.

Wetland values for RAM

To avoid the specification of potentially contentious relationships, wetlands are considered in a similar way to fisheries and navigation. That is, the net benefits are not modelled as a function of flow; rather the monthly deviations from baseline flow levels for each sub-area are noted and the possible implications for wetlands in each of these sub-areas are considered on a case-by-case basis by wetland specialists. Where wetland productivity (where productivity refers to the TEV) is expected to change substantially, then the model user can investigate the total value of the wetland potentially at risk in that sub-area using benefits transfer estimates appropriate for the dominant wetland class in that sub-area.

Value data

Due to limited resources, estimates for the RAM have been drawn from existing wetland valuation studies and then applied to the LMB through a process of benefits transfer.

Benefits transfer provides a means of estimating monetary values for environmental resources without performing relatively time consuming and expensive primary valuation studies. It involves the prediction of the value of a wetland, given the knowledge of its physical and socio-economic characteristics. This requires information on specific characteristics of each wetland, such as wetland type, wetland area and latitude, as well as imputed information on per capita income and population density[22].

The values used in the benefits transfer have been drawn from a number of sources including:

- A global wetland study which provides median values for different wetland types across continents (Schuyt and Brander, 2004);
- Site-specific wetland studies in Laos (IUCN); and
- Various wetland valuation studies conducted by researchers at EEPSEA

The studies consulted display an extremely high range of values, from US$14/ha in Viet Nam to almost US$2,000/ha in Lao PDR (fisheries excluded). Freshwater marshes and mangroves tend to yield the lowest values per hectare while the values of freshwater woodlands are considerably higher.

Since the basis of all the wetland valuation studies are different, the values used for RAM are those from a meta-analysis of 17 valuation studies of Asian wetlands (Schuyt and Brander, 2004). Wetland value functions were estimated by regressing the standardized wetland values on a number of explanatory variables including wetland type, income per capita, population density and wetland size. The results of the meta-analysis are presented in Table 5.7.

These values should broadly correspond to "representative" wetland classes in each of the sub-areas and may be adjusted to take account of known site-specific factors. At the time of writing, wetland mapping for the basin on a sub-area basis had not been completed. Using GIS, an overlay map can be created using both sub-area shape files and wetland maps. For each sub-area, a dominant wetland class and its appropriate values (excluding fisheries and rice production) can be identified. It is envisaged that the wetland mapping and wetland valuation components of the MRC Environment Programme's wetlands project will contribute significantly to this process.

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22 Population density is an indicator of the demand for wetland goods and services. Higher populations may also correspond to a higher pressure on the biodiversity, scientific, socio-cultural and other important wetland values including the integrity o f ecological services provided by the wetland.

Table 5.7: TEV of Asian wetlands by wetland type

Wetland type	US$/ha
Mangrove	19
Unvegetated sediment	202
Salt/brackish marsh	23
Freshwater marsh	15
Freshwater woodland	228
Average	188

It is important to note at the outset that the wetland values derived are likely to be very conservative estimates. This is because many wetland functions are typically not included in economic valuation studies. Most valuation studies tend to focus on the use values of wetlands, as these values are relatively easy to estimate using market prices. It should, thus be kept in mind that wetlands should not be conserved or managed based on their use values alone. Some wetlands may have high biodiversity, ecological and socio-cultural values; values that may not necessarily be easily expressed in monetary terms but which should nevertheless be integrated into decision-making processes. The values used for the purposes of RAM are intended to demonstrate that wetlands are economically valuable entities that provide goods and services upon which many communities and local and regional economies depend.

5.3 Navigation

5.3.1 Summary and rationale

The Mekong River has significant navigation potential and has long been used as a main transport route for travel, trading and for providing access to natural resources and social facilities. Furthermore, river transport is often the only means for communication and transport during peak annual floods especially since alternative transport modes seldom meet trade requirements (MRC Navigation Strategy, 2003). Comparative costings of inland waterway transport (IWT) with road and rail transport suggest that the economic operating costs of IWT within the region are about one sixth those of road trucks and about one third those of trains. Further, the Mekong River and its associated waterways are estimated to carry nearly two-thirds of all cargo tonnage in the Mekong Delta of Viet Nam, nearly half of all cargo tonnage between Thailand and the Lao PDR and nearly one third of all domestic cargo tonnage within Lao PDR.

There is a common interest among the MRC member countries in increasing levels of international trade and regional integration and it is believed that shipping is one of the most cost-effective ways to achieve this. Waterborne transport also contributes to economic diversification, provides employment opportunities and can supply a positive balance of payments. Waterborne transport has distinct advantages over other transport modes: it is cheap, holds large cargo capacity, relieves road congestion and maintenance, and is attractive to tourists.

Article 9 (Freedom of Navigation) of the 1995 Agreement for the Sustainable Development of the Mekong River Basin (MRCS, 1995) provides the mandate for the MRC to promote and co-ordinate water transportation and to encourage freedom of navigation in the LMB. However, the extent to which water transportation for trade can be encouraged, is largely dependent on the availability of suitable shipping channels.

Two types of factors affect the volume and efficiency of navigation along the Mekong. First are national and international rules pertaining to customs, immigration and navigation logistics. Second, is the hydraulics of river flows, i.e. the depths and velocities that result from the interaction of the physical channel form at a particular location and prevailing river flow. Whilst high velocities increase power consumption and hence cost for upstream river transport, most notably during the wet season, it is shallow water depths that physically prevent vessels from transiting a river reach at all (MRC, 2005). Navigation can therefore be considered as a competing water demand (in-stream) and for this reason is considered in the RAM analyses.

5.3.2 Trade benefits of river transportation

Water transport plays an important role in navigable reaches. The importance of the Mekong River and its tributaries as a transport artery for member countries can be summarized as follows:

- It has significant trade benefits in terms of the volume and value of trade flows made possible by river transportation;
- It contributes to poverty alleviation; and
- It is often the sole practical means of transport for remote, riverine communities

In 2001, trade valued at an estimated US$4,700 million was transported in the LMB on the Mekong River and its associated waterways. The trade volumes within and between countries in the region can be broken down as follows:

Table 5.8: Trade volumes and values associated with IWT

Country	Volume (million tonnes)	Value (million US$)
Cambodia	0.5	235
Lao PDR	0.7	-
Viet Nam (Mekong Delta), excluding trade with Cambodia	21.8	4,000
Thailand and Lao PDR (cross-border trade)	1.5	350
Thailand and China (Yunnan)	0.4	88

Source: MRC Navigation Strategy Resource Document, 2003; data is for 2001.

As the only landlocked country in the LMB and with road development constrained by topography, Lao PDR in particular has realised substantial benefits from the Mekong River as the main conduit for its international trade flows. Total navigable waterways amount to 7,484km (Ringler, 2001, p72). In 2001, the value of the export, import and transit trade flowing through the country's river customs checkpoints opposite Thailand is estimated to have amounted to $348.52 million, or 44%, of a total trade value of $795.49 million. River customs checkpoints account for an even greater share of the value of Lao PDR's exports – about 64 per cent – since export flows tend to be dominated by logs, timber products and other agricultural commodities such as coffee. All of these are well adapted to transport by river, and would cause substantial damage to roads if transported over land.

In Cambodia, navigable waterways have been estimated at 3,700km. The reach from Viet Nam to Phnom Penh is particularly important for the country for commercial transport. Most of the larger canals in the Viet Nam Mekong Delta are used for navigation. The connection between Phnom Penh and Siem Reap via the Tonle Sap River and lake is also important for tourism. Navigation is less important in Thailand where the road and rail network is highly developed. As described above, trade between Laos and Thailand is, however, still highly dependent upon the river.

5.3.3 Valuation basis

It is difficult to establish a clear relationship between river flows and the value of riverborne transport. While it is generally the case that higher flows in the dry season facilitate the passing of larger boats, it is not clear how total volumes (passengers and cargo) might be altered as a result of changes in flow. Two smaller boats might be able to replace one larger boat, for example. In any one reach of the Mekong, the typical dry season flow has lead to the use of vessels that are capable of navigating it most, but not all, of the time. Thus river reaches that have shallow river depths in the dry season are typically used by smaller vessels than in deeper reaches; larger ones being uneconomic due to long periods when they can not be used.

In many reaches of the Mekong, navigation of goods and people is subject to restriction in the dry season as the depth of water approaches and becomes less than the safe depth for the size of vessels using that reach. However, only in one area, the Khon Falls, does navigation remain impassable at all flows and at all times of year for any sized vessel. The safe depth is a function of the average vessel's (loaded) tonnage and design, which define its "safe draught", i.e. the depth of the vessel below the water surface, plus a safety allowance. The safety allowance in the Mekong is typically 0.5m.

Differences in vessel design, used upstream and downstream of Kampong Cham, results in the different safe draught – tonnage relationships, presented in MRC (2005). The Navigation Programme has interpreted these safe draft requirements for each major reach of the Mekong. The maps below show the current limits of navigation in terms of minimum depths and corresponding maximum vessel size. The minimum depths are determined by the lowest low water (LLW) level.

A particular constraint to the definition of a flow-value relationship is the lack of intra-country data on passenger numbers, cargo volumes and values or the relative costs and benefits of alternative, mostly land-based, forms of transport. The serious lack of origin-destination information of trade and traffic flows of all modes of transport makes it quite difficult to assess which river stretches are currently important or have high potentials to become important in future. But, based on the available reports, the stretch between China and Thailand (Chiang Saen and Chiang Khong) and Lao PDR (Luang Prabang, or even Vientiane) is likely to show an increase in trade flows.

In light of these difficulties, the value and trade-offs associated with navigation potential are presently considered outside of the model, in a similar way to wetlands. Instead of valuing incremental changes in flow, the model has been set to show, for every scenario, what the mean monthly deviations in flow (compared to the baseline) are for each sub-area. These deviations then allow one to compare water levels with safe minimum drafts to see where navigation potential might be compromised. The value of navigation in sub-areas that experience significant flow changes, can then be further investigated.

Figure 5.1: Navigation potential upstream of Kampong Cham (2003)

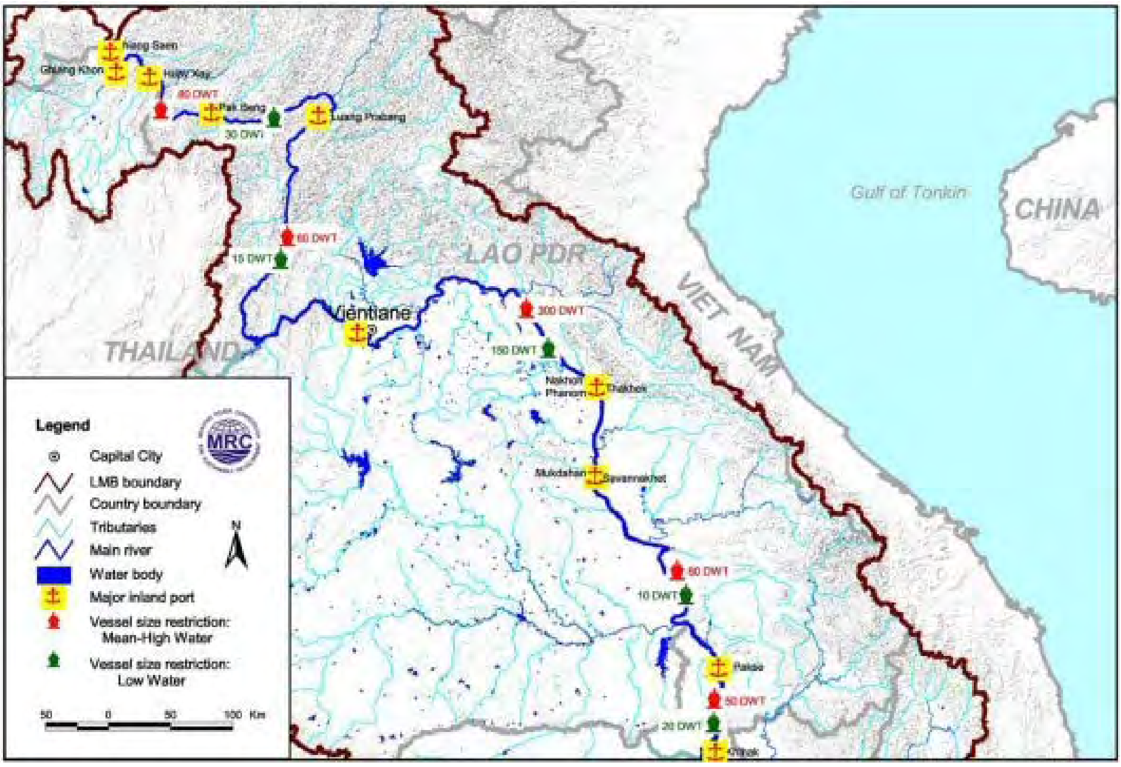
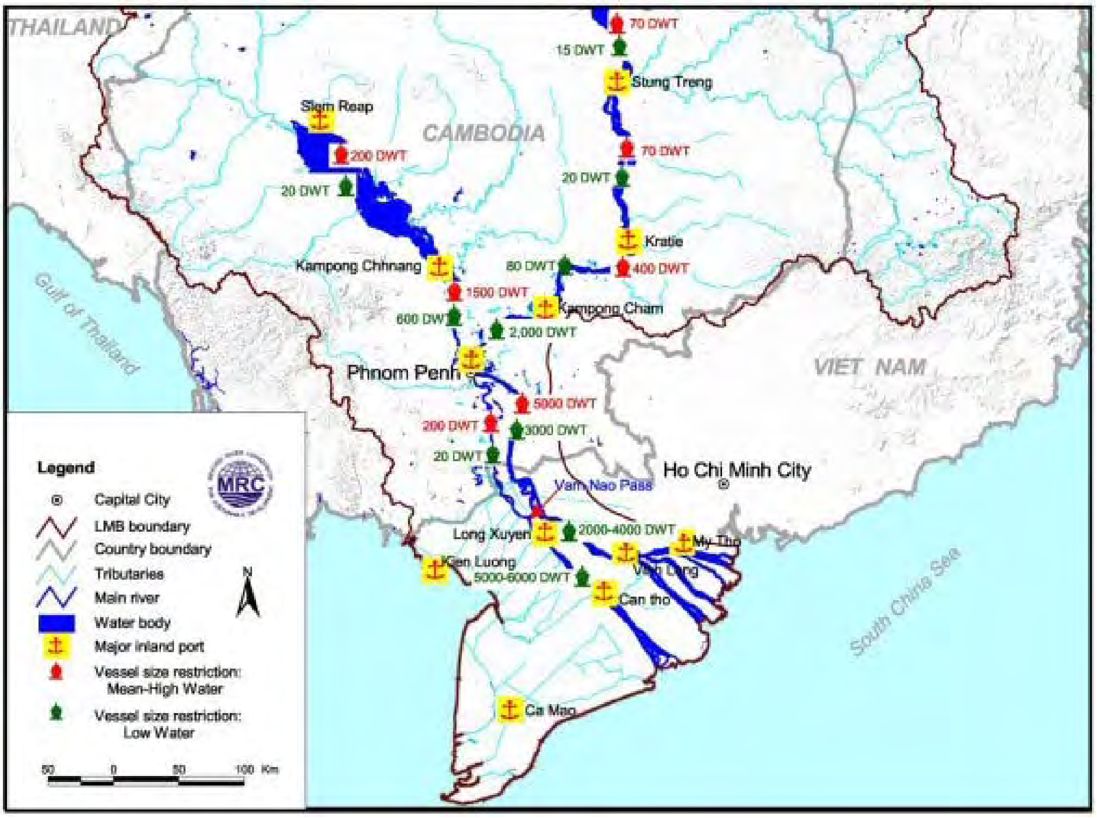


Figure 5.2: Navigation potential downstream of Kampong Cham (2003)



The gauge height corresponding to lowest water levels (i.e. the minimum depth) has been computed (see MRC, 2005) by assuming that the lowest low water (LLW) levels (i.e. the minimum depth) at the critically shallow sections within a reach, correspond to the LLW levels at the stream flow monitoring stations. Using the relationships established by the MRC Navigation Program between vessel class and minimum safe draft requirements for each river reach and the computed gauge heights, the average annual number of days that these navigation requirements are met can be calculated. This information can be used as a starting point for estimating the changes in value associated with changes in navigation potential.

Preliminary information on the value of navigation in the Lower Mekong Basin has been obtained primarily from:

- MRC Navigation Programme (pers comm.)
- MRC Navigation Strategy (2003) and Navigation Strategy Resource Document (2003).

6 Environmental impacts

6.1 Flood damages

6.1.1 Summary and rationale

Floods are a recurring event in the Lower Mekong Basin resulting in loss of life and property, causing damage to agriculture and rural infrastructure, and disrupting social and economic activities. At the same time, flooding of the mainstream and tributaries of the Mekong River is an important source for the wealth of biodiversity, abundance of fish and soil fertility in the basin. Flood management and mitigation has thus become a priority issue at the national and regional levels, particularly in the aftermath of the disastrous floods of 2000 and 2001 (MRC, 2003).

Most people living along the Mekong floodplains have adapted their lives to seasonally high river flows and flooding. They take advantage of the benefits the floods provide to agriculture and fishing. However, sometimes the floods are unexpected or extreme and cause loss of life, agricultural production losses and damage to property and infrastructure.

Flooding may produce not only immediately apparent effects but also continuing after-effects. The valuation of flood costs and benefits should therefore reflect the full socio-economic and environmental effects both at the time the event occurs but also for the duration of the period during which it produces both direct and indirect impacts.

6.1.2 Valuation basis

Despite the generally beneficial effects of the natural flood regime, severe flooding events over the past few years have resulted in significant economic and social costs to communities living in and near the Mekong floodplains. It is the economic costs borne by households as a result of severe flooding that are the focus of flood impact valuation in RAM.

Peak annual depths and flood durations less than 0.5 m are generally not of real concern to people, as access is not significantly impeded and duration is very short. In addition, even small embankments can easily block such shallow flooding, thus limiting the extent of flooding. The short durations and shallow depths also make these areas of limited utility to fish. Therefore, as a general indicator the 0.5m level is adopted for comparison of maximum flood and flood durations between scenarios. The derivation of flood depth-duration curves and flood extent is described more fully in MRC (2005).

Recent studies have looked at both the costs and benefits of Mekong floods. The damage estimates tend to be primarily financial in nature and often severely underestimate the total economic losses (e.g. disruption to livelihood activities, disease, resettlement costs, etc) incurred as a result of severe flooding. The economic benefits of regular floods have not yet been quantified. Sources of data for the RAM valuation include:

- National contributions to the annual Mekong Food Forums
- BDP sub-area studies
- WWF Living Mekong Initiative discussion papers
- MRC DSF Outputs from ISIS model simulations

Model and data limitations have restricted the analysis of flooding impacts to the total area below Kratie, rather than to individual sub-areas. The losses to households are calculated as follows:

(a) The number of households in the flood-affected area of the LMB is calculated as:

HHFLOOD = (AREAFLOOD / AREALMB) * (POPLMB / Ave HH size[23])

Where:

HHFLOOD	=	Number of households in the flooded area
AREAFLOOD	=	Total LMB area flooded (km2); calculated from DSF
AREALMB	=	Total LMB area (km2)
POPLMB	=	Total LMB population

(b) It is then assumed that only 25%[24] of households in the flooded area are actually detrimentally affected by the flooding

(c) The total costs borne by urban and rural flood-affected households in the LMB is then estimated as:

FCT = [(0.8 * 51) + (0.2 * 510)] * 1.5

Where:

FCT	=	FLOODCOSTSTOTAL = Total costs of flood damages to households in the LMB
0.8	=	Proportion of rural households in the LMB (MRCS-BDP, 2003)
0.2	=	Proportion of urban households in the LMB (MRCS-BDP, 2003)
51	=	Total costs borne by flood-affected households in rural areas (Gupta et al, 2004)
510	=	Total costs borne by flood-affected households in urban areas (estimated on the basis of Gupta et al, 2004)
1.5	=	Conversion factor from financial to economic prices

6.1.3 Data issues and sensitivity

Floods may cause direct damages (to assets), indirect losses (the flow of production of goods and services) and macroeconomic effects (the performance of the main macroeconomic aggregates of the affected country).

The type of flooding will have different effects depending on whether flooding takes place slowly or quickly. Slow evolution results in minimal fatalities and injuries, damage to crops and both medium and long-term effects on nutrition. Flash floods cause many fatalities, some injuries, destruction of homes and immediate and long-term consequences for food security. The extent of agricultural losses primarily depends upon the time of year that a

23 Estimated to average around 5.5 for the LMB (MRC-BDP, 2003).

24 This estimate will undergo sensitivity testing

flood occurs and the duration of flooding. For crops, the value of losses will also depend on the crop growth stage.

Generally the costs of damage to property or due to lost output are the main source of costs. However, the costs of flood mitigation measures may also be significant (Silva and Pagiola, 2003).

As noted earlier, data availability and the precision of the model limit the level of analysis to the basin as a whole. However, it is possible to predict what the total impact of flooding in each sub-area might be using the method described above.

Further shortcomings to the data used is that it does not reflect the social losses (beyond the household) of damages to public infrastructure such as roads, telecommunications, schools and public health facilities. Loss of agricultural productivity is expressed as a financial value is thus only partly accounted for at the household level. Losses to future earnings as a result of the long-term effects of flood damage (e.g. loss of equipment, washing away of topsoil, etc) are not considered.

However, there is insufficient data available to estimate the total economic value of flood damages. The estimates used in the model do, however, provide an adequate indication of the magnitude of losses incurred by households in the LMB. Sensitivity analyses can be conducted on the number of affected households in the basin and value of flood damages.

Table 6.1: Summary RAM inputs, flood damages

Parameter	Value
LMB Area (km2)	795,000
LMB Population (2000)	55,407,910
Ave Household Size	5.5
% Urban	20
% Rural	80
Total costs borne by urban households (US$)	51
Total costs borne by rural households (US$)	510

6.2 Saline intrusion

6.2.1 Overview

Seawater intrusion has been a perennial problem in the Viet Nam Delta during the dry season. The recent rapid increase in dry-season irrigated agriculture, fuelled by the doi moi policy has severely increased water shortages and the resulting saltwater intrusion in the delta. Out of an average 2,000m3/sec of dry-season flows, it has been estimated that at least 1,500m3/sec are needed to combat saltwater intrusion (NEDECO, 1993a, cited in Browder 1998).

The massive freshwater flows, which inundate much of the Mekong Delta during the wet season, nourish the Delta's highly productive and essential rice crops (Vo-tong Xuan, 1993;

Tran Thanh Be, 1994; Vo Quang Minh, 1995). The Delta has been called Viet Nam's rice-basket, which emphasizes its economic and social importance to Viet Nam (Tran Thanh Be, 1994). During the dry season, the Mekong River flows are so low that sea waters intrude into the lower reaches of the River, producing brackish water conditions that are unsuitable for rice growth. At present approximately 2 million hectares of land are subject to dry season salinity with saline water extending 50 km inland (Vo Quang Minh, 1995). Increasing diversions of upstream Mekong flows for dry season irrigation, both in Viet Nam and in countries upstream, threaten to exacerbate saltwater intrusion into productive lands.

In a portion of the salt-affected area, some innovative farmers have adapted to the fluctuating freshwater-brackish water environment by evolving a rice-shrimp rotation system to maximize returns through both rice and high-value, extensive or semi-intensive shrimp production (Vo-tong Xuan, 1993). The sustainability of this system is unknown, but sedimentation during the saline phase decreases the land area available for production by up to 4% pa (Tran Thanh Be, 1994). In addition, the area suitable for the rice-shrimp system is limited and is smaller than the area impacted by dry-season saline water intrusion. Both rice and fish production are extremely important to Viet Nam's economy and national well-being. At present, dry season saline intrusion limits rice production and global prices for shrimp are volatile.

6.2.2 Data

The following studies were consulted for information on saline intrusion.

- Partial Review of Salinity Intrusion in the Mekong Delta, Viet Nam.
- Possible Impacts of Saline Water Intrusion Floodgates in Viet Nam’s Lower Mekong Delta
- Study of Salt Water Intrusion, Land Use and Rice Production in the Coastal Plain of the Mekong Delta

6.2.3 Valuation Basis

Salinity intrusion is a particular issue in the Viet Namese part of the Mekong delta. The economic impacts of saline intrusion are calculated on the basis of the losses to agricultural (rice) productivity in areas where some predefined salinity threshold (0.4g/litre) is exceeded[25].

The following steps have been followed to estimate the economic value of these losses:

- The iSIS model in the DSF uses the flow and water level results from the hydraulic simulation and tidal and salinity measurements from 1998 to simulate a time series of salinities in the Mekong Delta at hourly time steps. The results from this simulation should be able to give an indication of the relative effects of the different scenarios.
- The area of rice production and its value (see Section 4.1) in the Mekong Delta is known
- The assumption that around 4% of rice production is lost as a result of saline intrusion is applied

25 Empirical studies show that 4g/l is the maximum level of salinity that can be tolerated before paddy productivity is affected (To Quang Toan, 2003).

– The resulting value of *lost* rice production is calculated. When compared to the baseline, this value provides an indication of the extent of losses or gains incurred respectively as a result of an increase or decrease in the area affected by saline intrusion.

6.2.4 Data and modeling issues

Two main issues with the configuration and operation of the iSIS model have been identified (MRC, 2005). These will have an impact on salinity results before the absolute salinity levels can be considered reliable.

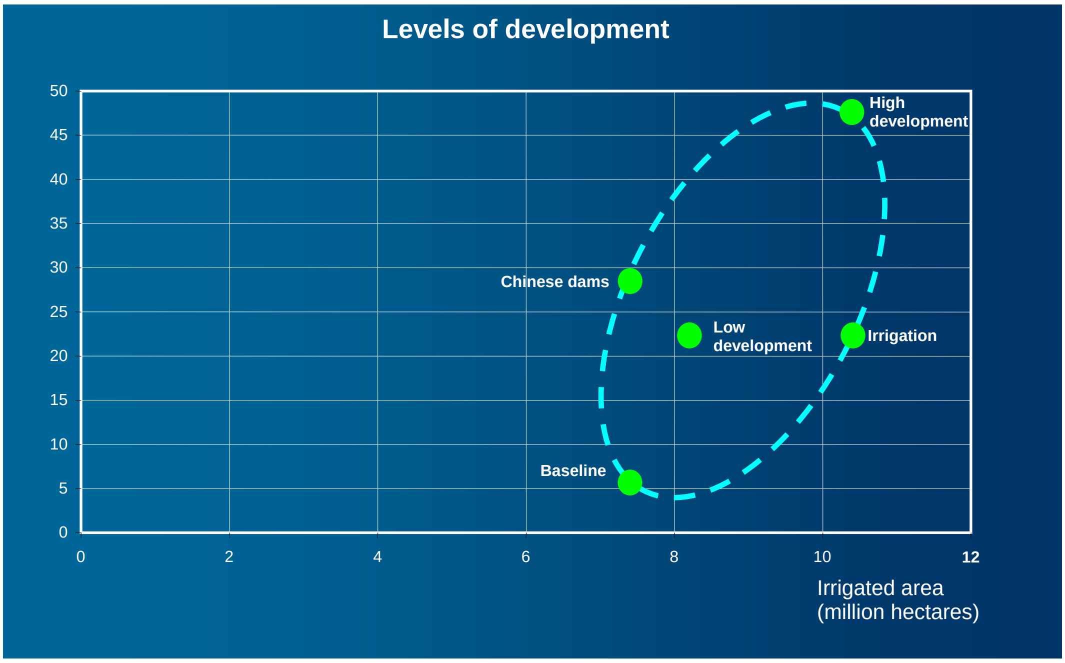
- The first is that the configuration and operation of salinity intrusion barriers needs to be updated to reflect current conditions. Salinity intrusion barriers in the region about Tra Vinh have not yet been included in the configuration. Also, the operation of the salinity intrusion barriers, that is when they are opened and closed, does not necessarily take into consideration the operation of these to cater for brackish water requirements of shrimp farms.
- The second key issue is that the irrigation diversions had to be averaged over a 90-day period to make the hydraulic simulation stable.

6.2.5 Sensitivity testing

The RAM can be adjusted to show what the resulting values would be if:

(a) the average productivity loss factor (%) were changed; or

(b) average rice yields or prices were changed



7 Economic summaries of BDP planning scenarios

7.1 Planning scenarios

The purpose of this chapter is simply to start describing the value added by water in the LMB by country, by activity and by various design and resource allocation assumptions using the planning scenarios that are currently being discussed within the MRC.

Four planning scenarios have been tested using the RAM:

(i) Baseline

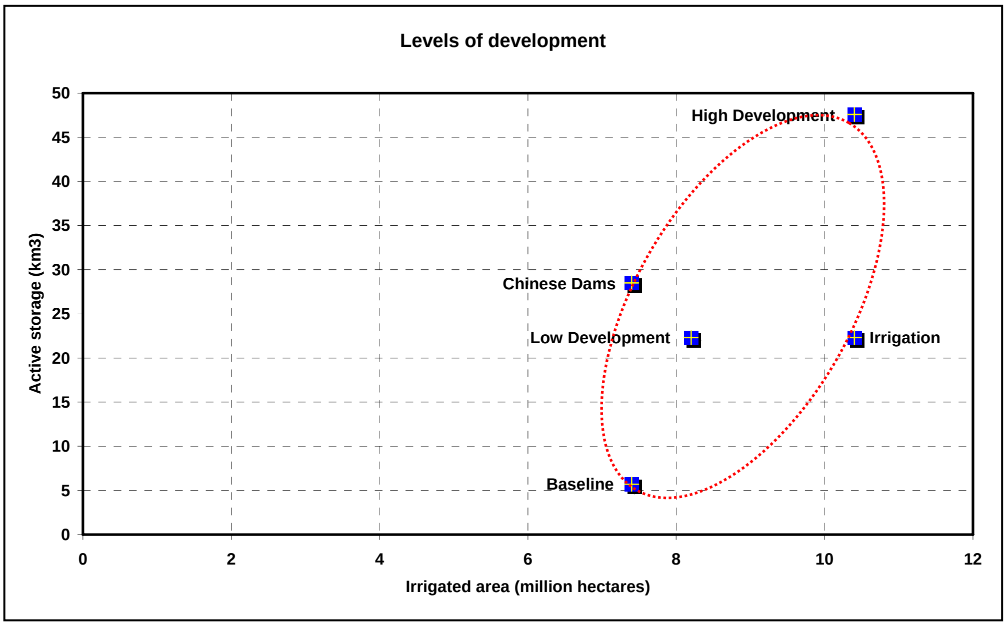
(ii) Low development

(iii) Irrigation

(iv) High development

These are broadly consistent with the scenarios run through the Decision Support Framework (DSF) developed under the Water Utilization Programme (WUP) and were formulated specifically to allow consideration of combinations for low and high development in hydropower and irrigation (see Figure 7.1).

Figure 7.1: Levels of irrigation and hydropower development modelled



A brief description of, and rationale for, each scenario follows below:

The baseline provides a reference point against which each of the other three scenarios is compared. It depicts the situation in the year 2000 with respect to the level of development, climatic conditions and resulting hydrological flow regime. The level of development includes physical characteristics such as land use, irrigated areas, dams and embankments as well as operational characteristics of the dams at that time. The climatic evaluation period used is 1985-2000 as this the longest period for which there is sufficient basin-wide data and incorporates the known range of climatic conditions in the LMB. All scenarios are simulated using the same climatic data set.

The purpose of the low development scenario is to estimate the likely changes in flow and nature of impacts that would result from a level of development that is nearly assured in the Lower and Upper Mekong Basin. This includes dams that are currently under construction and/or water resources developments that are at an advanced stage of technical and financial planning.

The irrigation scenario is being used to predict the likely changes in flow and the nature of impacts that would result if water resources development in each of the Mekong Basin countries was limited to expansion in irrigation and water supply only. It is assumed that hydropower development would not proceed beyond that which is included in the Low Development scenario (e.g. as a result of economic of community pressures). The intention of such a scenario is to highlight the potential stresses in dry season flow that may occur where releases from regulating storages do not supplement natural flow.

The purpose of the high development scenario is to estimate the changes in flow and impacts that would result following developments in irrigation, water supply and hydropower.

The particular design assumptions, including valuation sets, used in each of the RAM scenarios are summarized in Section 7.3.

The RAM and DSF scenarios differ in the following respects:

(i) For all scenarios other than the baseline, the RAM considers the impacts of potential development pathways 15 years hence (i.e. 2020). The DSF impacts are assessed at different points in time.

(ii) The RAM includes tourism as a specific water demand.

(iii) The RAM examines fisheries in terms of both a directly productive water use and as an environmental asset that is potentially affected by changes in flow levels.

The remainder of this chapter focuses on describing the likely economic impacts resulting from each of the planning scenarios. Section 7.2 summarizes the RAM findings using the current design and valuation assumptions. These results are presented graphically in Section 7.3. Section 7.4 describes the nature and significance of some of the environmental and social impacts that have been modelled including flooding, saline intrusion and fisheries productivity. Section 7.5 briefly outlines some of the environmental and flow-related issues in each of the constituent sub-areas and what the implications of some of these flow changes may mean for instream and environmental uses e.g. navigation, fisheries and wetland productivity. Section 7.6 is a summary of the underlying design and valuation assumptions.

The reader is cautioned against quoting these particular findings without reference to the valuation assumptions detailed in "Valuation Methodologies and Sources for Valuation of Water Resources Demands in the Lower Mekong Basin"[26]. Further refinements to the valuations (and underlying assumptions) continue to be made as new data and knowledge

[26] Rowcroft (2005b): Valuation methodologies and sources for valuation of water resources demands in the Lower Mekong Basin. Technical report for the Basin Development Plan by Petrina Rowcroft. Mekong River Commission, Vientiane. (Comprehensive extracts of this publication are included in the present report as Chapters 2-6)

about the nature of the relationships between productivity and hydrological flow becomes available.

The purpose of this study – and subsequent RAM documents produced under BDP Phase 1 – is not so much to provide definitive answers about the value of water in different uses but more to demonstrate the potential of resource allocation modelling in integrated water resources management (IWRM) (see Appendix A).

7.2 Summary results

This section highlights some of the key findings that are presented in more detail in the tables and charts that follow in Section 3. For each scenario, two sets of valuation assumptions were tested allowing us to see the sensitivity of the overall results to changes in the underlying assumptions. The results for each valuation set are presented consecutively for the sake of clarity.

Under **assumption set 1:**

- The present total valued added by water in the LMB countries in the major productive activities is about US$2.1 billion per year. In the High Development scenario, this increases by around 21% to US$2.5 billion. This might be considered a relatively modest change on an annualized basis over a 15-year period (i.e. to 2020) but may be partly explained by our implicit assumption that fisheries productivity declines with higher levels of development.

- On national bases, the biggest country gain, both in absolute and relative terms in a move to High Development accrues to Lao PDR which more than doubles its value added by water, largely as a result of hydropower development. The largest beneficiary country at present is Viet Nam which gains relatively little in a move from the Baseline to High Development scenario. Value added by water in Thailand grows by just over 5% while Cambodia gains around 10% but starts off from a low base.

- Under a high development scenario, Viet Nam remains the highest beneficiary country in relative terms. This can be partly explained by the significant value added by water in domestic uses as a result of the high population density. Cambodia becomes the smallest beneficiary country under a High Development scenario as the value added by water in irrigation expansion and in meeting growing domestic and tourism demands is not commensurate with the value added by water in hydropower development in Laos and Viet Nam. Cambodia also suffers fisheries losses due the reduction in habitat area. The pressures on fisheries productivity from over-fishing have not been investigated in this model.

- On a per capita basis, the change for the population of Lao PDR is by far the greatest (40%), almost ten times more than that of any other country. The change in value added per capita in Thailand is relatively small suggesting that even large-scale diversions for small-scale rice irrigation are not going to result in widespread economic growth.

- In terms of activity composition, fisheries is by far the most “productive” use of water and remains so across all planning scenarios. Value added by water in fisheries is almost more than double the next highest use (i.e. irrigated agriculture). In a move from the Baseline to a High Development scenario, agriculture’s basin-wide share increases by just 1%, belying the fact that returns to rice-based agriculture are very low. Hydropower makes up almost one quarter of total value added by water in the LMB under the High Development Scenario while the relative value of fisheries drops from over 50% to 40%.

- Not all sub-areas benefit in a move to the high development scenario and the scale of changes ranges from reductions in value added by 3% in Kratie (as a result of fisheries losses) to gains of 169% in Central Laos. The large gain in Central Laos can largely be attributed to large-scale hydropower development.

- In moving to a high development scenario, the area affected by serious flooding is reduced by around 20% resulting in cost savings of around US$41million. Fisheries value below Kratie decreases by around US$7 million due to a reduction in habitat area while there are positive net benefits to agriculture in the region of US$0.3 million as a result of a decrease in the area affected by saline intrusion.

Under assumption set 2:

- The present total valued added by water in the LMB countries in the major productive activities is about US$3.8 billion per year. In the High Development scenario, this increases by around 35% to US$5.1 billion.

- On national bases, the biggest country gain, both in absolute and relative terms in a move to High Development accrues to Lao PDR which again more than doubles its value added by water, largely as a result of hydropower development. Viet Nam and Thailand gain 24% and 20% in value added respectively while Cambodia benefits by around 34%, largely as a result of the high value added by water in domestic consumption which is assumed to increase significantly (on a per capita basis) over the next 15 years.

- Under a high development scenario, Viet Nam remains the highest beneficiary country in relative terms. Laos, which starts off from the lowest base, gains significantly and overtakes Cambodia in relative standings.

- On a per capita basis, the change for the population of Lao PDR is by far the greatest (69%). Thailand experiences the smallest changes in value added per capita while the modest changes in Cambodia suggest that promoting the expansion of irrigation for low value crops is not, on its own, an effective poverty reduction strategy.

- In terms of activity composition, domestic use is by far the most "productive" use (just under half) of water under this set of assumptions and remains so across all planning scenarios. In a move from the baseline to a high development scenario, agriculture's basin-wide share decreases by 2% while hydropower's share doubles.

- Under this set of assumptions, all sub-areas benefit in a move to the high development scenario although the scale of gains varies widely from 6% in Kratie to 175% in Central Laos.

- The environmental and social impacts remain largely the same under the different assumption sets as their valuation basis has not changed significantly. The higher returns to rice production result in slightly higher net benefits (US$0.5 million) due to the reduction in area affected by saline intrusion.

The comparative outcomes under each set of valuation assumptions are made clear in the tables and charts that follow.

7.3 Value added by various productive uses in the LMB

(Tables and charts)

7.3.1 Assumption set 1

Table 7.1: Value change, by scenario and by country, assumption set 1

	Value added by water (US$ millions)				Change (baseline to high)	
Country	*Baseline*	*Low development*	*Irrigation*	*High development*	*Value added %*	*US$ per capita*
Cambodia	356	381	399	391	10	2.1
Laos	279	551	561	569	104	39.0
Thailand	569	596	648	602	6	1.1
Viet Nam	904	930	932	992	10	4.1
TOTAL	2,107	2,458	2,540	2,553	21	6.0

Figure 7.2: Comparative total value added by water to the LMB economy, by scenario, assumption set 1

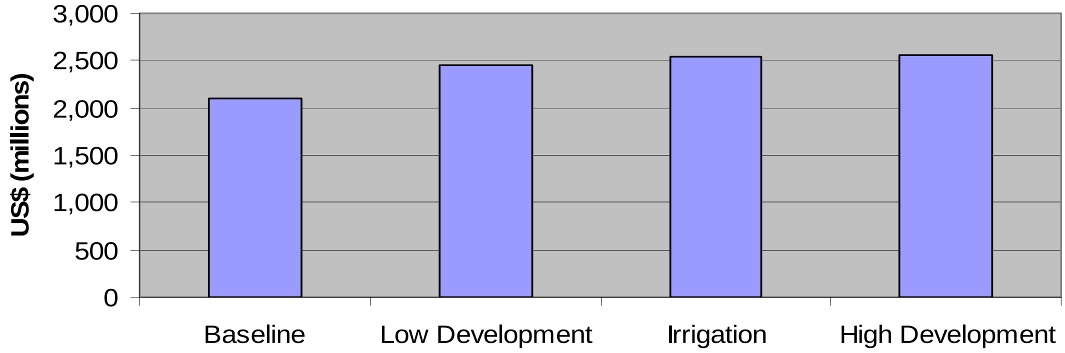


Figure 7.3: Comparative total value added by water by LMB country, assumption set 1

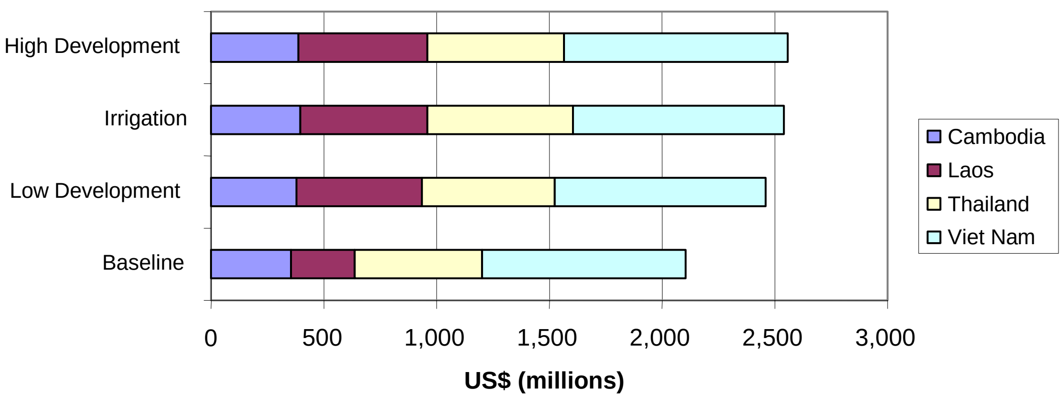


Figure 7.4: Value added by water in different uses in the LMB, assumption set 1

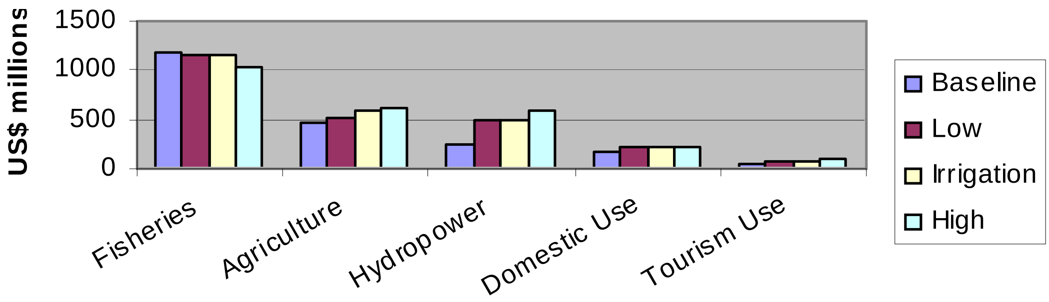


Figure 7.5: Composition of value added by water in different activities (LMB) - baseline, assumption set 1

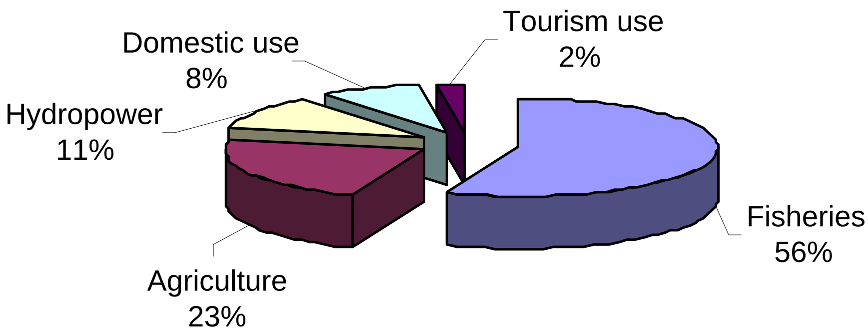


Figure 7.6: Composition of valued added by water in different activities (LMB) - high development, assumption set 1

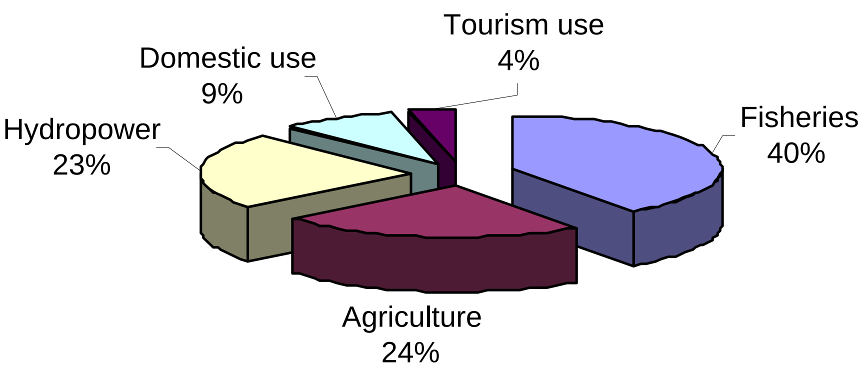
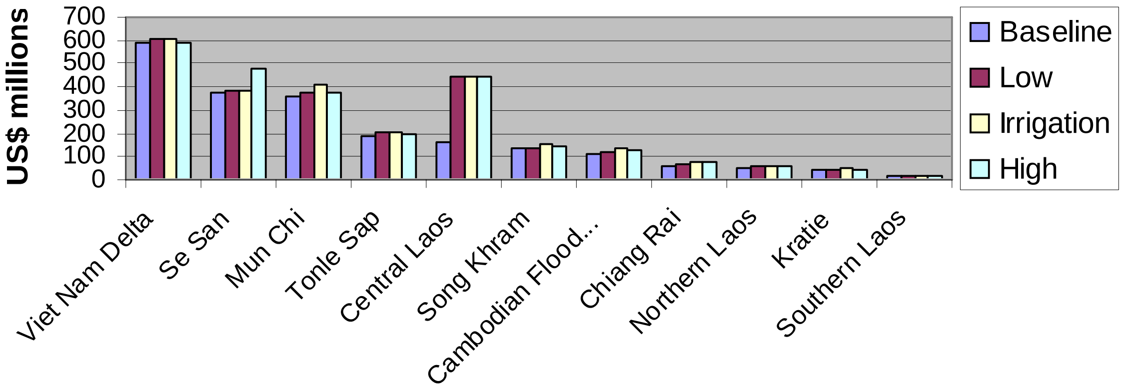


Table 7.2: Value change, by scenario and by sub-area, assumption set 1

		Value added by water (US$ millions)				Change (baseline to high)	
	Sub-area	*Baseline (US$ millions)*	*Low (US$ millions)*	*Irrigation (US$ millions)*	*High (US$ millions)*	*%*	*US$ per capita*
1	Northern Laos	53	59	60	60	13	3.0
2	Chiang Rai	62	70	73	73	18	6.1
3	Song Khram	136	140	156	143	5	1.2
4	Central Laos	165	440	447	444	169	73.2
5	Mun Chi	361	374	408	374	4	0.7
6	Southern Laos	16	18	19	18	12	2.2
7	Se San	377	381	383	478	27	26.9
8	Kratie	46	46	48	44	-3	-3.1
9	Tonle Sap	191	201	205	197	3	0.9
10	Cambodian Floodplain	108	123	135	132	22	3.0
11	Viet Nam Delta	593	606	606	590	0	-0.1
	Total	2,107	2,458	2,540	2,553	21	6.0

Figure 7.7: Total value added by water use by sub-area (all scenarios), assumption set 1



7.3.2 Assumption set 2

Table 7.3: Value change, by scenario and by country, assumption set 2

	Value added by water (US$ millions)				Change (baseline to high)	
Country	*Baseline*	*Low development*	*Irrigation*	*High development*	*Value added %*	*US$ per capita*
Cambodia	533	674	703	717	34	11.3
Laos	408	880	896	923	126	69.1

Thailand	1,284	1,476	1,564	1,544	20	8.8
Viet Nam	1,618	1,887	1,891	2,010	24	18.0
TOTAL	3,844	4,917	5,053	5,195	35	18.0

Figure 7.8: Comparative total value added by water to the LMB economy, by scenario, assumption set 2

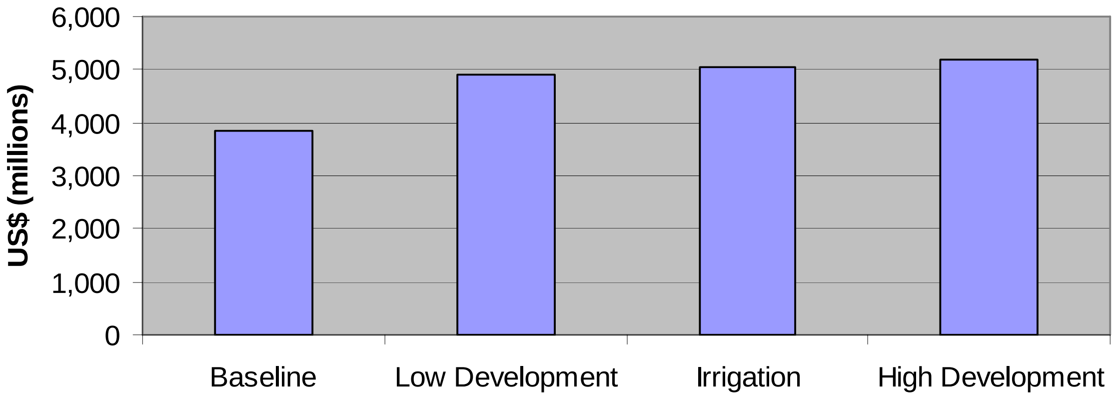


Figure 7.9: Comparative total value added by water by LMB country, assumption set 2

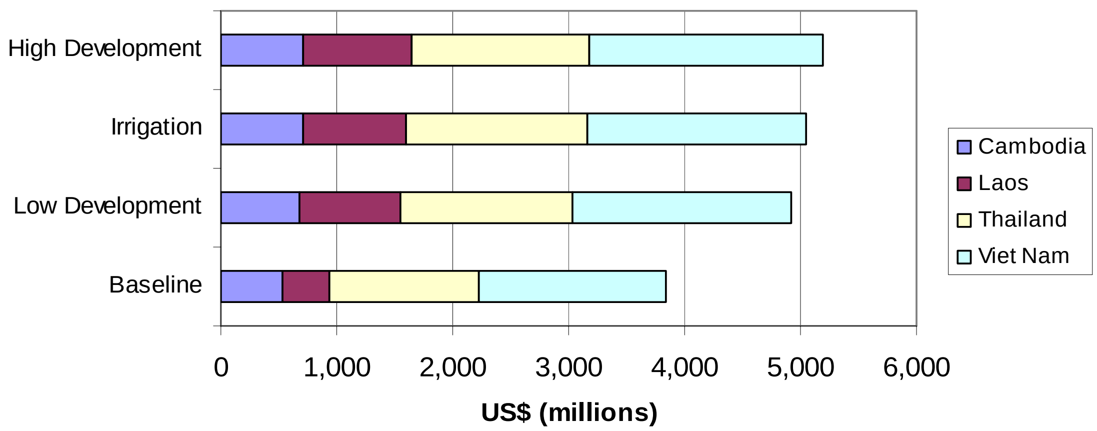


Figure 7.10: Value added by water in different uses in the LMB, assumption set 2

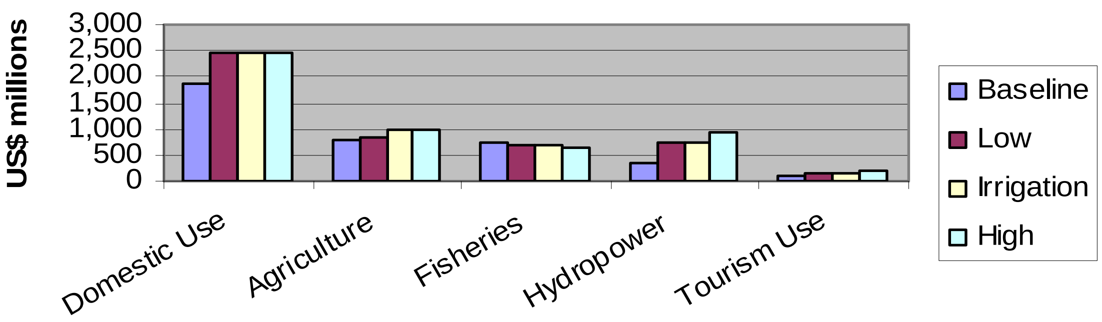


Figure 7.11: Composition of value added by water in different activities (LMB) - baseline, assumption set 2

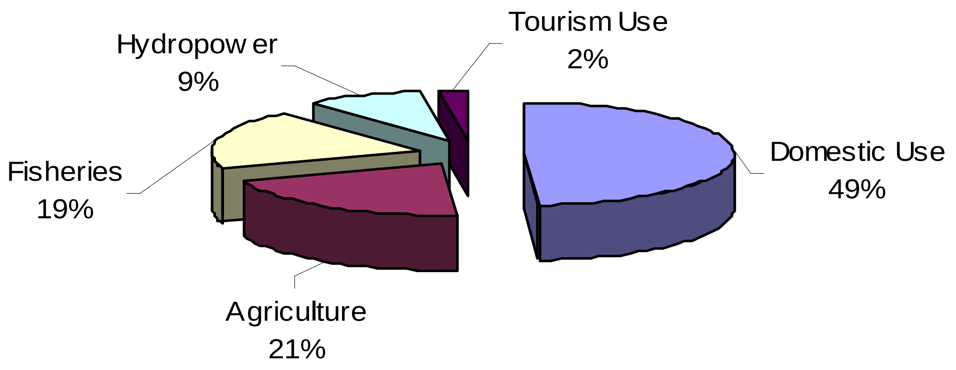


Figure 7.12: Composition of valued added by water in different activities (LMB) - high development, assumption set 2

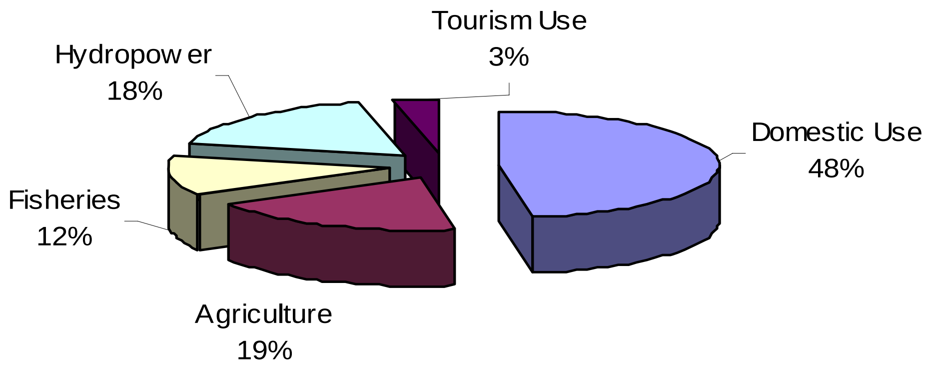
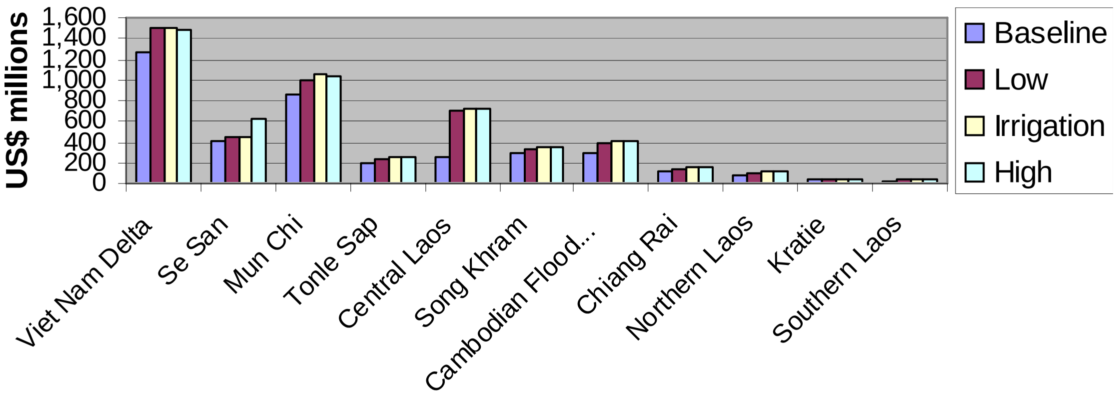


Table 7.4: Value change, by scenario and by sub-area, assumption set 2

		Value added by water (US$ millions)				Change (baseline to high)	
	Sub-Area	*Baseline (US$ millions)*	*Low (US$ millions)*	*Irrigation (US$ millions)*	*High (US$ millions)*	*%*	*US$ per capita*
1	Northern Laos	75	106	107	113	49	16.7
2	Chiang Rai	121	146	151	158	31	20.5
3	Song Khram	288	329	355	348	21	10.1
4	Central Laos	261	708	719	719	175	120.0
5	Mun Chi	866	990	1,046	1,026	18	8.6
6	Southern Laos	24	33	36	35	48	13.4
7	Se San	419	450	454	616	47	52.1
8	Kratie	34	35	39	36	6	4.5

9	Tonle Sap	198	241	246	251	27	7.8
10	Cambodian Floodplain	286	384	404	405	41	14.7
11	Viet Nam Delta	1,270	1,496	1,496	1,487	17	9.6
	Total	3,844	4,917	5,053	5,195	35	18.0

Figure 7.13: Total value added by water use by sub-area (all scenarios), assumption set 2



7.4 Environmental and social impacts below Kratie

Table 7.5: Value of environmental and social impacts

Value of environmental and social impacts: Difference between baseline and high development scenarios		
Impact	*Baseline to high (US$ millions)*	*Comments*
Flood Damages	41	Under the high development scenario the area of flooding below Kratie is reduced by around 20%. With a static baseline population this would result in economic net benefits of some US$41million. If it is assumed that the population living in areas affected by flooding increases at the same rate as the population growth rate, then the economic net benefits of a reduction in flooded area (under the high development Scenario) are in the order of US$62 million.
Fisheries production	-7.4	Under the high development scenario, the fish habitat area below Kratie decreases by about 8%. Based on estimates of fish productivity and habitat availability, the cost of this decline is valued at around US$7m annually
Saline intrusion	0.3	The high development scenario results in a reduction in the area affected by saline intrusion in the Viet Nam delta by 4%. The estimated benefits of this are in the region of US$300,000

Value of environmental and social impacts: Difference between baseline and high development scenarios		
Impact	*Baseline to high (US$ millions)*	*Comments*
Wetland productivity	Not yet calculated	Wetland productivity - and hence economic benefits - are expected to rise with increased flow levels up to some maximum level of flow (at which point wetland productivity actually declines). Once wetlands in the LMB have been mapped, values can be applied to provide an indication of the expected value of changes in productivity as a result of changes in water flows.

7.5 Possible environmental / water issues

Table 7.6: Possible environmental /water issues (basinwide and by sub-area)

Sub-area	Possible issue
Lower Mekong Basin	The High Development scenario results in significant (up to 70%) changes in flows in the upstream parts of the LMB during the dry season. Developments in the Upper Mekong Basin in particular result in significantly increased dry season flows (December to June). The largest reductions in flows are experienced in the early wet season, before upstream storages reach their capacity and start releasing water.
Northern Laos	Experiences up to 25% reduction in baseline flows during the wet season. Average dry season flows are increased by up to 50%. Fisheries are an important component of the sub-area economy and may be adversely affected where productivity is sensitive to changes in baseline flow of anything more than 2%.
Chiang Rai	Experiences up to 30% reductions in baseline flow for 2 months during the wet season and significant increases in flow (up to 70%) in the dry season.
Song Khram	Reductions in baseline flow of 9-20% in the wet season and an average increase of 28% during the driest month of the year
Central Laos	Wet season flows decline by up to 15% while dry season flows increase by around 25%. Fisheries productivity in this sub-area may be affected
Mun Chi	Similar to Central Laos.
Se San	Experiences less than 10% reduction in baseline flows, on average
Southern Laos	Reduction in flows of no more than 13% during the wet season. Dry season flows increase by more than 10% in all months. Important wetland sites around Attapeu and Stung Treng may be affected where they are sensitive to even small changes in flow levels.
Kratie	No more than a 10% reduction in flows during the wet season but average dry season flows increase by as much as 27% during the driest time of the year (around March) May have implications for fisheries and important flagship species e.g., Irrawaddy dolphin?
Tonle Sap	No changes greater than 10%. Wet season flows are expected to decline by between 2 and 9% in the wet season and to increase by no more than 8% during the dry season The decline in wet season flows may have implications for wetland and particularly fisheries productivity around the Great Lake
Cambodian Floodplain	Experiences reductions in flow (of no more than 8%) for 11 months of the year. Flows increase by around 2% in the early wet season May have implications for navigation and fisheries productivity. The area affected by severe flooding decreases
Viet Nam Delta	Similar flow changes to the Cambodian floodplain. May have implications for navigation. Saline intrusion becomes less extensive.

7.6 Design assumptions summary

Table 7.7: Summary of design assumptions

Scenario summary	Baseline	Low development	High development
Upper Mekong Basin Dams	None	Xiowan	Xiowan and Nuozhadu
Diversions	None	Inter-basin diversion from Chiang Rai tributary Intra-basin diversion from Mun Chi tributary	Inter-basin diversion from Chiang Rai tributary Intra-basin diversion from Mun Chi tributary Intra-basin diversion from Mun Chi mainstream
Population	Baseline (2000)	Medium growth (2020)	Medium growth (2020)
Domestic water consumption (litres per capita per day)	Based on MRC (2004) data on per capita water demands: Laos – 64, Thailand – 115, Cambodia – 32, Viet Nam – 66	Laos – 150, Thailand – 200, Cambodia – 100, Viet Nam – 150	Laos – 150, Thailand – 200, Cambodia – 100, Viet Nam – 150
Tourism use	300 litres per tourist per day Tourism numbers based on year 2002 national tourist statistics	300 litres per tourist per day 75% increase in tourist numbers from baseline	300 litres per tourist per day 100% increase in tourist numbers from baseline
Irrigated areas	Total irrigated area of 74,655 km2 allocated among sub-areas on the basis of the data contained in the DSF	Total irrigated area of 82,717 km2 allocated among sub-areas on the basis of the projections used in the DSF	Total irrigated area of 104,287 km2 allocated among sub-areas on the basis of the projections used in the DSF
Hydropower	4 dams modelled: Nam Ngum, Theun Hinboun, Houay Ho, Yali	5 dams modelled: Nam Ngum, Theun Hinboun, Nam Theun 2, Yali	8 dams modelled: Nam Ngum, Theun Hinboun, Nam Theun 2, Nam Theun 3, Yali, Xe Kaman 1, Se Kong 5, Lower Se San & Lower Sre Pok

A description of the Resource Allocation Model in terms of the specific assumptions made, inputs used and modelling techniques applied to its development is detailed in:

– MRC (2003) Final report on the development of the BDP RAOM. Mekong River Commission: Phnom Penh; and

– MRC (2004) Developing inputs for Resource Allocation and Optimization Model. Technical Report for the BDP by Richard Beecham. Mekong River Commission: Phnom Penh.

Table 7.8: Environmental impacts

Environmental impacts			
	Baseline	*Low development*	*High development*
Fisheries	Consumption as a measure of yield based on year 2000 baseline population	Consumption as a measure of yield based on year 2020 medium growth population	Consumption as a measure of yield based on year 2020 medium growth population
Saline intrusion	Measured as 4% of total baseline irrigated rice production area in the Viet Nam Delta	Measured as 4% of total low development irrigated rice production area in the Viet Nam Delta	Measured as 4% of total high development irrigated rice production area in the Viet Nam Delta
Flood damages	Baseline population (2000)	Medium growth population - 2020	Medium growth population - 2020

The valuation basis for each of the extractive demands, instream uses and environmental impacts included in the model are more fully described in "Methodologies and Sources for the Valuation of Water Resource Demands in the Lower Mekong Basin" (MRC-BDP, June 2005).

7.7 Valuation basis summary

Table 7.9: Valuation basis summary

	Assumption set 1	Assumption set 2
Irrigated agriculture	• Revenues = farmgate prices • Production Costs = 75% of revenues for fruit & vegetables; 85% of revenues for commodities (field crops)	• Revenues = farmgate prices • Production Costs = 60% of revenues for fruit & vegetables; 75% of revenues for commodities (field crops)
Domestic & industrial use	• Revenues = WTP for water = US$0.14 per m^3 • Costs = US$0.05 per m^3	• Revenues = WTP for water = US$1per m^3 • Costs = US$0.03 per m^3
Tourism	• Net benefits = expenditure on water per day (US$3 per tourist per day)	• Net benefits = expenditure on water per day (US$6 per tourist per day)
Hydropower	• Revenues = weighted WTP of power sales to Thailand/Laos/Viet Nam • Production costs = weighted average generation costs for various hydropower dams (Lao Power Sector Strategy Study)	• Net benefits = 50% higher than Assumption Set 1
Fisheries	• Revenues = value at point of first sale weighted according to relative capture (consumption) of reservoir, capture and culture fisheries • Production costs = 20% of sales value for capture fisheries and 70% of sales value for aquaculture	• Revenues = value at point of first sale weighted according to relative capture (consumption) of reservoir, capture and culture fisheries • Production costs = 60% of sales value for capture fisheries and 75% of sales value for aquaculture

Further details of the value estimates used in each case can be found in "Methodologies and Sources for the Valuation of Water Resource Demands in the Lower Mekong Basin" (MRC-BDP, June 2005).

8 Issues and priorities

The purpose of this study – and subsequent RAM documents produced under BDP Phase 1 – is not so much to provide definitive answers about the value of water in different uses but more to demonstrate the potential of resource allocation modelling in IWRM.

The results of this analysis provide a starting point for further discussion about the distribution and significance of various water-related activities and impacts. The results are expected to feed into the formulation of an IWRM Strategy for the Lower Mekong Basin and to guide subsequent further thinking about water resource use planning and management for MRC more widely.

9 Solutions

From a methodology point of view, there is much that can be done to further refine the descriptions and further the RAM analyses. In particular:

Valuation basis

The results presented in this paper are based on a particular set of valuation and modelling assumptions. These values and assumptions can be further refined as better data and more knowledge becomes available, allowing for a more realistic specification of production functions.

Environmental and instream demands

Conduct further investigation into the nature of trade-offs between directly productive activities (e.g. irrigation, hydropower and municipal extractions) and environmental impacts in terms of their distribution and magnitude.

Agricultural value added

Examine the range of options for adding economic value through changes in cropping patterns and composition (e.g. by changing crop areas, crop types, crop water efficiencies, etc).

Planning implications

Consider the implications of the findings for the BDP, for national-level water use planning and allocation, and for the MRC.

10 Findings and recommendations/ lessons learnt

Findings of the analyses may briefly be summarized as follows:

- At the basin level, fisheries generate the highest value added under the present set of valuation assumptions.
- Agriculture remains an important contributor to Gross Domestic Product (GDP) in each of the four countries but the value added by water in this sector is only about 25% (compared with over 50% in fisheries). The relatively low value added of agriculture is largely due to a combination of low yields (particularly in Laos and Cambodia), low market prices (through market competition) and high input costs

(land, labour, seedlings, etc). This suggests that allocating water to rice-based agriculture is not an economically efficient option at a basin-scale. At a local scale, however, the important contribution of agriculture to rural livelihoods and food security cannot be ignored. What the RAM tells us though, is that perhaps the most effective interventions should not focus solely on making irrigation water available, but rather on creating a more enabling environment that allows poor farmers access to fertile land, affordable high-yielding varieties, extension services and fair markets.

- Fisheries generate significant income for the basin but productivity in the floodplains is threatened by hydropower development, which changes the timing of flows and blocks migration routes. The resilience of fish to these impediments is not yet well known.
- Domestic water demands are expected to rise as the basin population continues to grow and as per capita demands increase as a result of better education about the benefits of clean water and sanitation and rising levels of disposable income, particularly in urban areas. The total value of water allocated to municipal uses will rise commensurately but the marginal value may also increase through moves to treat water as an economic, rather than a purely social, good.
- Hydropower will become an important source of value added in the basin, and particularly to the economy of Lao PDR. It can reasonably be expected that increased availability of cost-effective sources of clean energy will drive further economic growth and development in the basin. The impacts on current poverty levels at a more local level are less clear.
- Tourism is another important source of value for the LMB. At present, the RAM only looks at the value of extractive uses but the water "environment" (e.g. navigable rivers, waterfalls, lakes) also provides significant tourism benefits.

11 Relevance

11.1 Relevance for NMCs and/or line agencies

The studies presented in this document provide a useful perspective to the national sector development planning, both by illustrating (and offering quantitative estimates) of options and constraints, and by placing the national development initiatives in a basinwide context. The regional and sub-area analyses describe the basin-scale relations that can expand the scope of the national development efforts, and (via the subsequent planning activities) add value to these efforts.

11.2 Relevance for MRCS and/or BDP Phase 2

Just like sub-basin and national level development planning, basinwide planning must build - not on full knowledge about the future - as required by the theoretical *'rational'* model for decision-making - but on *'the best knowledge available'.* While present trends can deceive, as the development sometimes proceeds stepwise rather than gradual, and while any prediction will accordingly be uncertain, due to new challenges and new opportunities, the decision basis should incorporate such knowledge as is available at the time when decisions must be made.

The analyses and recommendations presented in the present document provide valuable information to other MRC programmes and a good starting point for BDP Phase 2.

12 Concluding general outlook

The RAM has been developed as a tool to allow users to identify trade-offs arising as a result of water allocation decisions and then to evaluate the significance of these trade-offs in quantitative terms, using economic values as a yardstick. Apart from providing the means to describe various trade-offs in comparable and meaningful terms, economic valuation also contributes to a better understanding of the importance of water to the basin-wide economy.

Unlike all other resources currently available to MRC in general and BDP in particular, the RAM explicitly links water usage to economic outcomes. As a clearer picture of the way various major sorts of economic activities (e.g., agriculture, fisheries, hydropower, municipal and industrial demands, tourism, navigation, environmental uses, etc) are related to water demands has emerged, the nature of major resource development opportunities and possible choices at the LMB level is also becoming more explicit. Ideally, the RAM will be able to assist with identifying strategies for rational basin-wide economic growth in general and identifying 'win-win' resource-based development opportunities in particular.

The next step will be to refine the values and functions for modelling the various environmental and instream water demands – wetland productivity, flooding, saline intrusion and navigation. Further analyses can then be conducted using the RAM to show, for example:

- The nature of trade-offs, in terms of their location and value, between directly productive activities (e.g. irrigated agriculture, hydropower, etc) and instream and/or environmental demands
- How the nature of trade-offs changes under different valuation assumptions

Ultimately, the analyses facilitated by the model should be able to assist with:

- Providing a picture of overall value-added by water in all its uses under varying sets of assumptions (including depiction of alternative future 'scenarios')
- Better integration and co-ordination of national planning efforts
- Identifying where MRC efforts (as a source of techno-economic advice, as an 'honest broker' between countries) should be best located to assist countries to employ 'win-win' national development planning, and
- Identifying and justifying specific development opportunities (national and transboundary) which may be worthy of promotion

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Appendix A: RAM rationale and applications

	RAM: A summary of rationale and applications
Rationale	The primary purpose of resource allocation modelling is to provide a link between water resource use and associated economic returns in the Lower Mekong Basin at an aggregate (i.e., basin-wide) level. This link is not made in any other of the various hydrological and modelling tools employed by MRC. Basin-wide resource allocation modelling affords a level of analysis which is supra-national and uniquely the preserve and remit of MRC. Resource allocation modelling can provide a picture of overall value-added by water in all its uses under varying sets of assumptions (including depiction of alternative future 'scenarios'), and allows • analysis of the benefits of the major extractive uses of water (in terms of understanding their relative importance to LMB and national GDPs, and identifying possible development opportunities and potential conflicts between them), • analysis of the relationships between these extractive uses and the major in-stream uses of water (in terms of possible conflicts and complementarities/opportunities) • analysis – in economic terms - of the relationships between directly productive activities which use water and key environmental conditions in the LMB, and • analysis of the distribution of economic costs and benefits from sets of actual or potential activities on a geographical basis (i.e., between sub-areas and nations) within LMB
Applications for Integrated Water Resource Management Strategy for LMB	At a strategic level, resource allocation modelling helps integrate and co-ordinate national planning by: • identifying that pattern of water use which maximises economic benefits basin-wide • identifying other basin-wide patterns of water use which may be considered desirable to achieve particular policy objectives (e.g., poverty reduction, geographical equity, environmental protection etc) • identifying where national development plans may compete/conflict with one another in water use • identifying where there may be opportunities for transboundary development of water resources (reducing unit costs, increasing aggregate benefits), and • identifying where transboundary trade-offs between alternative water uses may be made (minimising cross-border conflicts, maximising collective benefits)
Applications for MRC's Strategic Plan	For the purposes of MRC's operations, resource allocation modelling • assists in identifying where MRC efforts (as a source of techno-economic advice, as an 'honest broker' between countries) should be best located to assist countries to employ 'win-win' national development planning, and • assists in identifying and justifying specific development opportunities (national and transboundary) which may be worthy of promotion (e.g., through solicitation for international or local funding)
Applications for IBFM programme	In relation to the MRC IBFM programme, resource allocation modelling • assists in identifying, quantifying and valuing the environmental costs of particular development options, both basin-wide and at sub-area level