MEKONG RIVER COMMISSION SECRETARIAT

Office of the Secretariat in Vientiane
184 Fa Ngoum Road, Ban Sithane Neua,
P.O. Box 6101, Vientiane, Lao PDR
Tel: (856-21) 263 263 Fax: (856-21) 263 264

Office of the Secretariat in Phnom Penh
576 National Road, no. 2, Chak Angre Krom,
P.O. Box 623, Phnom Penh, Cambodia
Tel: (855-23) 425 353 Fax: (855-23) 425 363

mrcs@mrcmekong.org

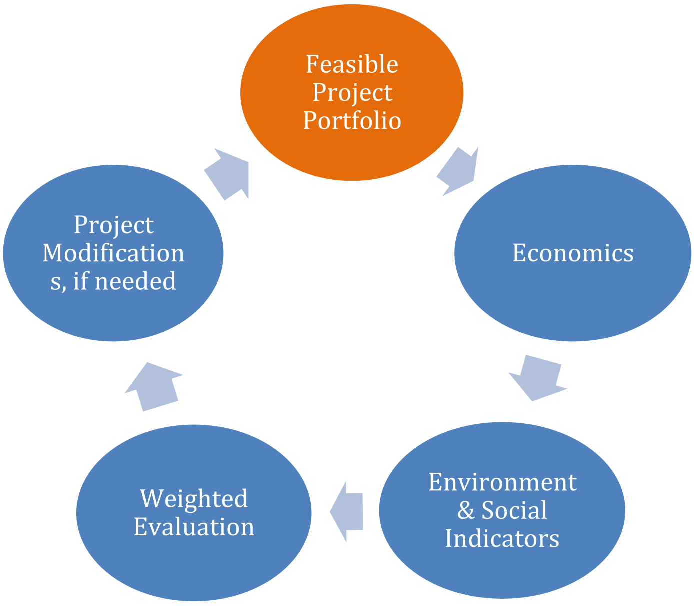
www.mrcmekong.org

MRC Initiative on Sustainable Hydropower (ISH)

GUIDELINES FOR THE EVALUATION OF HYDROPOWER AND MULTI-PURPOSE PROJECT PORTFOLIOS

ANNEX 1

ECONOMICS PRACTICE GUIDE



November 2015

MRC Initiative on Sustainable Hydropower (ISH)

Produced by	MRC Initiative for Sustainable Hydropower
Produced for	MRC Member Countries
ISH11 Project Team	Dr Armando Balloffet, Team Leader, Environmental Specialist Dr Bruce Aylward, Economist Dr Sarah Kruse, Economist Dr James Taylor, Social Specialist Mr Sok Bun Heng, Cambodia National Consultant Mr Lamphone Dimanivong, Lao PDR National Consultant Dr Warapong Tungittiplakorn, Thailand National Consultant Dr Tran Van Dat, Viet Nam National Consultant
MRCS ISH Staff	Voradeth Phonekeo, ISH Programme Coordinator Simon Krohn, ISH International Technical Officer Piseth Chea, Riparian Professional

**** NOTES:**

1. This Working Version has been reviewed by MRC member countries at Regional and National Meetings through 2014 and 2015. However, there is a need for ongoing and further discussion between MRC member countries on several aspects including the methods proposed for the multi-criteria analysis.
2. The economic valuation methods proposed here are based on international practice and research in the Mekong Region. The application of these methods by suitably qualified practitioners will require discussion with MRC member countries to ensure the valuation methods are suitable for the context of that particular application.

Abbreviations and Acronyms

ADB	Asian Development Bank
BDP	Basin Development Plan (of the MRC)
BCR	Benefit-Cost Ratio
CBA	Cost-Benefit Analysis
CDM	Clean Development Mechanism
CV	Contingent Valuation
EP	Environment Programme (of the MRC)
FAO	Food and Agriculture Organization of the United Nations
FP	Fisheries Programme (of the MRC)
GHG	Greenhouse Gases
GIS	Geographic Information System
GOL	Government of Lao PDR
HPST	Hydropower Planning Support Tool
IBFM	Integrated Basin Flow Management
ICEM	International Centre for Environmental Management
IDC	Interest During Construction
IKMP	Information and Knowledge Management Programme (of the MRC)
IPP	Independent Power Producer
ISH	Initiative on Sustainable Hydropower (of the MRC)
ISH02	The Guidelines Project of ISH
IUCN	International Union for the Conservation of Nature
LMB	Lower Mekong Basin
M&I	Municipal and Industrial
MRC	Mekong River Commission
MRC-BDP	Basin Development Planning Unit (of the MRC)
MRCS	Mekong River Commission Secretariat
MRD	Mekong River Delta
NMC	National Mekong Committee
NPV	Net Present Value
O&M	Operations and Maintenance
PV	Present Value
RAP	Resettlement Action Plans
UMD	Upper Mekong Development Scenario
US	United States of America
USD	United States Dollar
VAT	Value Added Tax
WTP	Willingness to Pay

Table of Contents

List of Figures

List of Tables

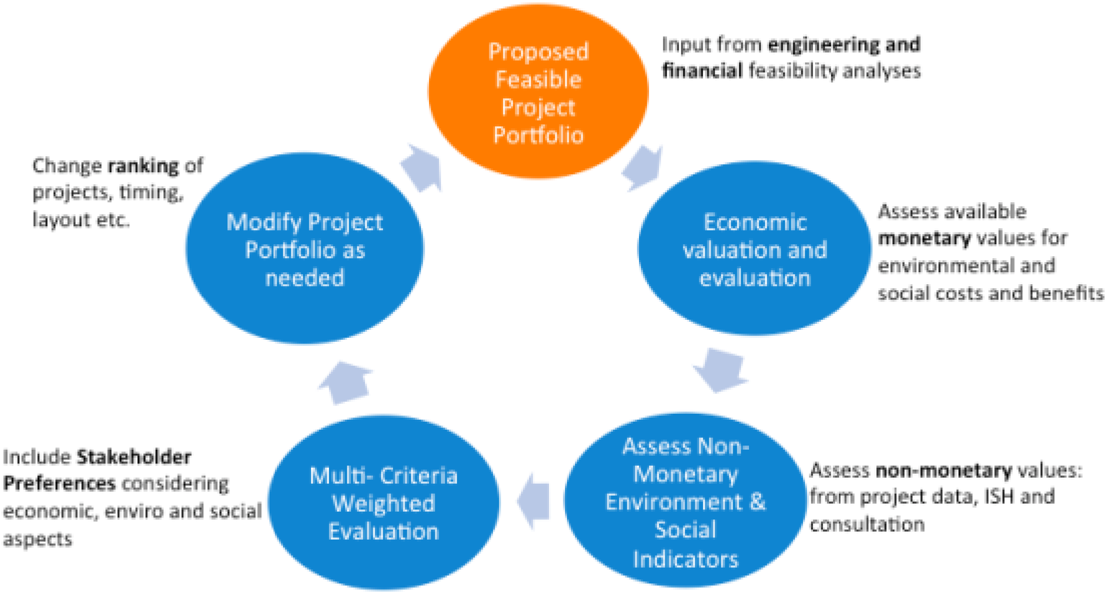
1 The Guidelines - Overview

The MRC's Initiative for Sustainable Hydropower (ISH) seeks to propose sustainable hydropower considerations which can be integrated into the planning and regulatory frameworks of member countries. The purpose and need for the Guidelines for the Evaluation of Hydropower and Multi-Purpose Project Portfolios (The Guidelines) developed under the ISH02 Project can be summarized as:

- *Current ways of planning hydropower schemes need to adequately take into account their wider social, economic and environmental implications. The key to integration of all costs and benefits into the national strategic planning approach is to identify credible values for these costs and benefits and then to "internalize" them into the normal economic analysis used to compare hydropower and multi-purpose options.*
- *Multi-purpose uses of dams need to be considered at the outset of project and basin planning.*

The Guidelines propose a portfolio planning process with associated tools for valuation and evaluation of hydropower and multipurpose dam project portfolios. Their objective is to assist Member Countries in their basin planning and energy/hydropower planning frameworks. The figure below illustrates the essential components of ISH02 Guidelines concept.

Figure 1 The Portfolio Planning Concept



It is important to note that "portfolio planning" here is taken in its broadest sense. This means that any set of projects that meet a planned purpose could constitute the portfolio of projects for evaluation with the Guidelines. For example, a portfolio might include:

- all planned hydropower projects in a country;
- all planned hydropower projects in the Mekong;
- all planned hydropower projects in a sub-basin of the Mekong; or
- a suite of alternatives for a single site or a single cascade of dams on a river.

The idea behind the Guidelines is that including, quantifying and valuing as many of the costs and benefits in an agreed upon and standardized way that promotes sustainability would add value to the decision-making process. **The Guidelines will not provide "the" answer for decision makers.**

Rather they represent a tool that informs stakeholders and decision-makers enabling improved decisions. The Guidelines – consistent with the approach recommended by the World Commission on Dams (2000) – then are ultimately a multi-criteria decision support tool supported by sound financial and economic analysis.

The Guidelines consist of the documents and tools as illustrated in Figure 2. The components of the guidelines are as follows:

The Guidelines Process document (the Main Report): Provide the "process" for implementing the Guidelines including all the instructions and step-by-step activities.

Practice Guide on Economic Evaluation and Valuation for Hydropower and Multi-Purpose Dams (Annex 1 to the Main Report): Provides a process for the monetization of technical, engineering, environmental and social characteristics of the dams being assessed. It is understood that not all impacts can be expressed in monetary terms. **This document.**

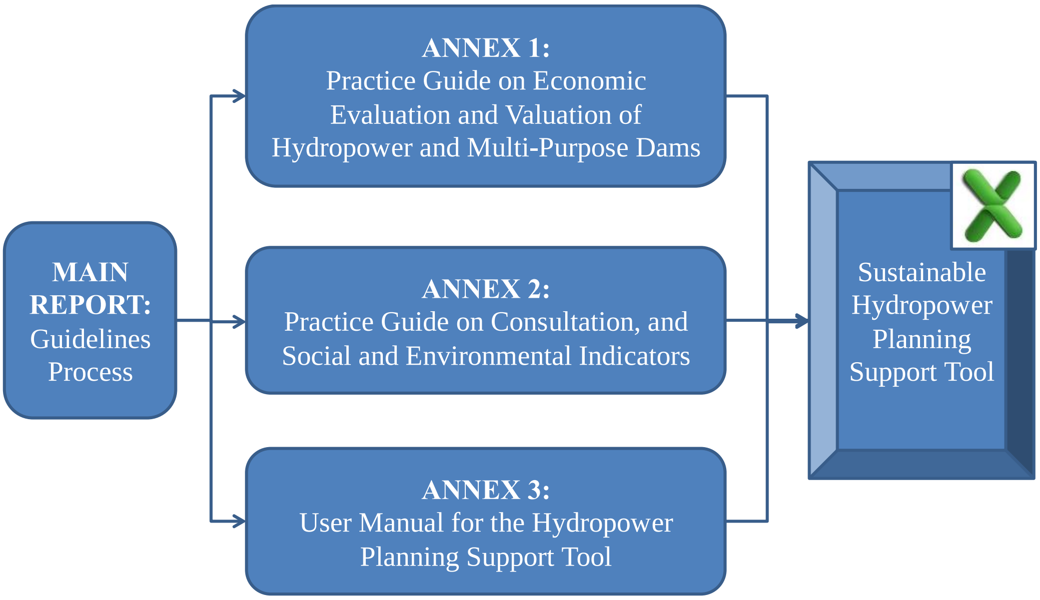
Practice Guide on Valuation of Non-Monetary Indicators for Hydropower and Multi-Purpose Dams (Annex 2 to the Main Report): Provides a recommended approach for selecting, scoring and weighting of a set of social and environmental indicators that represent impacts that are not valued in monetary terms; and also provides guidance on consultation and participation processes to elicit these values from stakeholders and stakeholder representatives.

The Hydropower Planning Support Tool: User's Manual (Annex 3 to the Main Report): The HPST User Manual provides guidance on how to enter and upload data into the HPST, how to customize applications of the HPST to particular circumstances (the type of analysis as per above); and explains the results that the HPST provides.

Sustainable Hydropower Portfolio Planning Support Tool. The HPST is contained in two spreadsheet files. The HPST Project Data Workbook is where project data is entered and refined according to protocols in the User Manual. The project data is then uploaded into the HPST Basin Workbook. This workbook takes the project data, the default parameters, and stakeholder weightings and generates a series of outputs. Outputs of this model include prioritization of projects, total net present value of all (or some) of the dams being assessed in financial and economic terms, normalized scores and ranking of projects on social and environmental criteria, and ranking of projects using a risk-weighted benefit-cost ratio. A set of standard modifications and customization to the Basin Workbook can be made by users and stakeholders following guidance provided in the HPST User Manual. Additional customization is possible by modifying the underlying algorithms and formulae in the workbook.

The Guidelines were developed in collaboration with member countries. Stages in the development included a series of national and regional consultations with member countries, including a case study in the Srepok Basin (Viet Nam and Cambodia) to test the Guidelines process and develop the HPST.

Figure 2 Guidelines for Hydropower and Multi-Purpose Planning



This document constitutes Annex 1 to the Main Report and represents the draft final version of the Economics Practice Guide circulated for review and comment to the MRC and member countries.

The document begins with two overarching sections. The first sets forth the approach to economic analysis of project impacts and provides an overview of the process the Guidelines team took in identifying which impacts would be valued in economic terms in the HPST. The next section provides the evaluation methods and decision criteria deployed in the financial analysis, the economic analysis and the multi-criteria analysis of the HPST. This includes the standard financial and economic evaluation criteria of net present value and benefit-cost ratio, as well as the risk-weighted benefit-cost ratio deployed in the multi-criteria analysis.

The guidance sections for the HPST then follow. Each section walks through each impact and how it is (or is not) valued and incorporated into the HPST. For each impact this includes, as relevant, the following information:

- Brief description of the impact.
- Review of methods and data from the LMB literature review.
- Methods and data as relevant from other literature.
- The HPST valuation approach including methods and data.
- Directions for additional work and future research

Appendices to the Annex include additional background on economic valuation methods (Appendix 1) and a literature review of prior economic analyses of LMB dams in the MRC context (Appendix 2).

2 Approach to Economic Analysis used in the Guidelines

This section provides background material to set the stage for the subsequent guidance sections on valuation of individual impacts. First is a brief overview of the conceptual approach underpinning the Guidelines approach to analysis of hydropower and multi-purpose impacts. Second, is a discussion of how these impacts can be evaluated in economic terms or included in a multi-criteria analysis through the use of social or environmental indicators (the indicators themselves are developed in Annex 2). A more detailed explanation of the methods for valuing these impacts is provided in Appendix 1 to this Annex. The next two sub-sections ground this general framework in the Mekong context. Based on literature reviewed a categorization of individual impacts is proposed and explained. The results of a literature review of prior economic analyses in the MRC context are then used to identify which impacts have been valued in economic terms in prior studies. The literature review summary is provided in Appendix 2 to this Annex. This leads to the final sub-section which lays out, using the same impact categories, how each value is treated in the HPST, i.e., whether it is included or excluded from the HPST, and if included whether it is included in the economic analysis or in the social and environmental indicators.

2.1 Conceptual Framework for Valuation and Evaluation of Hydropower Dams

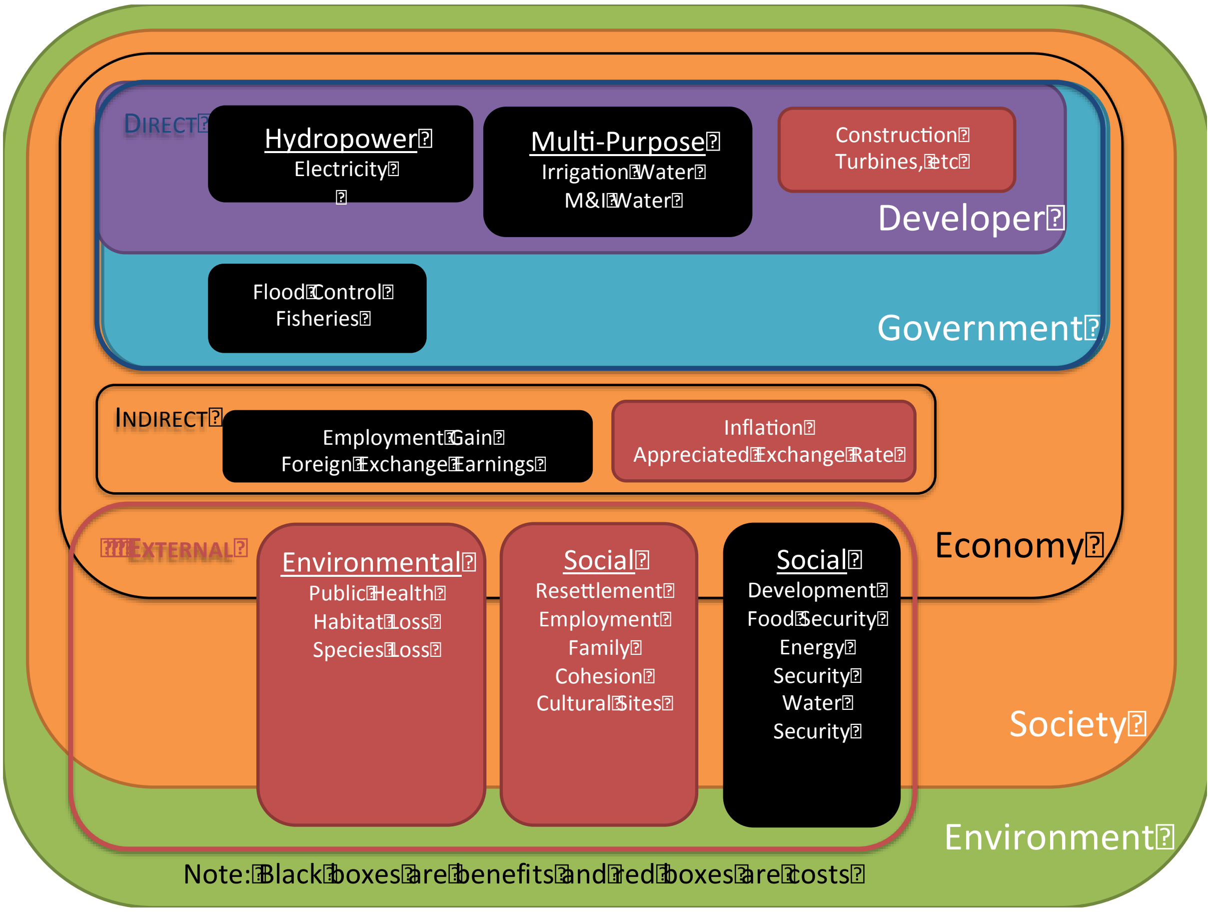
Evaluation of hydropower dams for planning purposes is premised on the idea of constructing an adequate representation of the existing situation, which is then altered over time by one or more projects. The construction and operation of these projects create a large number of impacts, some positive and some negative. These impacts affect a wide range of societal actors that are conceptualized as a set of nested actors ranging from the developer, to government, to economy, to society, and finally the environment. In Figure 3 an effort is made to draw out the potential types of impacts associated with hydropower projects and to show how they may be classified as direct, indirect or external. The types of impacts are categorized and defined as follows.

Generally the **direct impacts** are considered those of construction and the resulting services provided, including but not limited to electricity, irrigation water, municipal and industrial (M&I) water, flood control and fisheries. Where the government is not the developer, then the benefits of those project services that can be managed and captured – such as electricity, irrigation water and M&I water – may be managed for the benefit of the developer; whereas those that are more diffuse such as reservoir fisheries and flood control may be managed by government for the benefit of the economy and society.

The **indirect costs and benefits** are conceptualized here as the indirect effects that accrue to the economy (or regional economic effects). These are secondary impacts from changes in quantities and prices as the direct impacts of the project ripple through the economy (i.e. through associated markets). These include what may be lumped as the macroeconomic impacts including items such as employment gains, multiplier effects, foreign exchange issues, etc.

The **external impacts** are taken here to be the environmental and social impacts that have a series of social, environmental and economic consequences. The idea behind the current Guidelines Project is that many of these impacts can be expressed in terms of their economic impact, i.e., in monetary terms. So for example, that the economic impact of a loss in ecosystem services may be expressed in terms of its impact on the economy and, hence, contrasted directly with the net benefits from the power supply or other multi-purpose aspects of a project.

Figure 3 Impacts of Dam Projects



In order that the Guidelines serve planning purposes and be **practical and replicable** with information available at the planning level, the HPST examines only the direct and external impacts. Indirect economic impacts such as increases or decreases in employment due to changes in prices and quantities that emerge following construction of an infrastructure project are not addressed in the HPST. This is consistent with the practice in the region. The literature review found no analyses of this nature associated with hydropower projects. Indeed developing these impacts as costs and benefits and adding them to the direct costs and benefits is not generally advisable (Aylward et al. 2001). In theory positive or negative impacts along these lines could be included as non-monetised indicators. However, the knowledge base for doing this in the region is not sufficiently developed to make this practical at this point in time.

A further consideration in developing the HPST is that at the planning stage detailed EIAs, SIAs and CIAs may not be available. Similarly, detailed costs social and environmental mitigation plans may not be available. The HPST is therefore designed to estimate the direct and external impacts of hydropower and multi-purpose facilities.

2.2 Financial and Economic Evaluation: Monetizing Impact Costs and Benefits

The financial and economic evaluation process consists of the analysis of how a project or series of projects leads to impacts on individual economic actors and, ultimately, the economy as a whole. Financial evaluation pertains to the monetary interests of the project proponent (or developer). Economic evaluation should strive to value and incorporate into the economic evaluation the impacts on not just developers, but other stakeholders, so as to represent the net impact of the project on the economy. Cash flow and financial analysis are used to assess impacts as felt by particular actors (gains and losses) but need to be properly adjusted in order to represent the impact to the economy (and not just an individual or firm). The general process of economic valuation (regardless of the type of impact) involves a series of three logical steps, as follows:

1. Identify Impacts (positive and negative) – qualitative description of the cause and effect of the project in terms of social, economic and environmental impacts (including hydropower and multipurpose impacts).

2. Quantify Impacts – where feasible, document the cause and effect in quantities, i.e., number of displaced persons, kilos of fish production lost/gained, cultural sites inundated.

3. Value Impacts – where feasible and appropriate, document the costs and benefits represented by the quantities of impacts, i.e., the costs of resettlement, the value of fish production lost/gained.

It is important to note that for a large hydropower project with a long list of impacts, this logical progression cannot be followed to completion for every impact that is identified. The Guidelines are directed at the planning level and thus even a full listing of all the identified impacts, such as occurs with an environmental or social impact analysis may not be practical. Nor is it feasible to quantify and value all such impacts at the planning level, or even in detailed project evaluation.

Instead, as described further in the next sub-sections, the approach is to identify, quantify and value the most significant impacts. In the Guidelines the term "value" is used broadly and applies to both monetary valuation through financial and economic analysis and the scoring or quantification of impacts in terms of social or environmental indicators. A challenging aspect of the Guidelines then is to try and capture the most significant indicators in a **practical and replicable** manner. Although the HPST is designed to be a stand-alone model that accounts for the major impacts, future applications may necessarily have to modify the structure as the HPST when it is applied in new contexts and stakeholders wish to add additional impacts into the analysis.

That said the process pursued in developing the Guidelines is to first identify which significant impacts can be valued in economic terms and which cannot. Those that cannot or should not be valued in economic terms are then taken up to see if they can usefully be "valued" using available social and environmental indicators (as explained in Annex 2).

2.3 Impact Framework for the Mekong

At the outset of the Guidelines Project a literature review on economics was conducted in the context of the MRC and hydropower dams. A number of studies were found that provided material results in terms of valuation methods and/or valuation estimates for the direct and indirect costs and benefits of large dams in the LMB (Maunsell and Lahmeyer International 2004a; LaPlante 2005; Hall and Leebouapao 2005; Yermoli 2009; ICEM 2010c; MRC-BDP 2011; MRC-BDP 2010b). The valuation efforts of these studies are summarized in Appendix 2 of this annex and are deployed as relevant in the various valuation sections in this Annex. The review of existing studies of Mekong hydropower developments assists in defining what a range of agencies, consultants, and academics have been capable of actually accomplishing in this respect. This review assists in developing two important structural inputs for developing the Guidelines:

1. Enumerating the types of direct and external impacts of hydropower development in the LMB, including multipurpose elements.

2. Assessing which impacts have been valued in monetary terms and the adequacy of the data and methods employed.

Turning to the first of these products, the table below organizes the impacts examined by these studies and their assessment of impacts according to the approach set forth in the table provides a description of the type of impact, and explains the impact and whether it is likely to have positive or negative economic impact. Consistent with the approach specified above, the impacts are segregated into direct and external impacts. While the separation is not always abundantly clear, the intent is that "direct impacts" refers to the productive benefits that are the explicit objective of the project proponent (and their government partners when the project is privately financed). Thus hydropower, irrigated agriculture, flood control, navigation and reservoir fisheries are included as direct impacts. This category includes not just the benefits but also the investment and operational and maintenance (O&M) costs associated with the dam and developing the productive uses of water. The external costs are the negative or positive impacts that the development of the project entails more widely on the environment and society. Table 1 below presents the classification deployed in the Guidelines, which groups external impacts into three groups based on location of the impact and then enumerates them into sub-types as applicable:

- Local external impacts, including:
    - On human populations (e.g. employment, local economic development, resettlement, loss/changes in in livelihood)
    - Inundation of land
- Downstream hydrological impacts, including:
    - Agriculture development or loss
    - Fisheries (reservoir, wild capture, etc.)
    - Sediment and Bedload changes
- Other (diffuse or global) ecosystem services, including:
    - Biodiversity
    - Greenhouse gas emissions
    - Bioprospecting
    - Recreation and tourism
    - Watershed protection

Note that the "inundated lands" category is used to denote cases where studies have estimated the economic value of lands the use of which are completely changed by dam development (typically through direct inundation or displacement/resettlement of local populations). Such changes in land use can be assessed by valuing individual goods and services or by assessing a single value per hectare. The inundated lands category refers to those cases where studies pursued the latter approach.

Table 1. List and Description of Impacts of Hydropower and Multi-purpose Projects

CATEGORY		DEFINITION	IMPACT
Direct Impacts			
	Dam & hydropower construction	Dam and hydropower infrastructure.	Financial and economic costs to the proponent, both capital and O&M.
	Multipurpose construction	Additional infrastructure to meet multipurpose needs such as irrigation systems, water conveyance and treatment systems, levees, locks, etc.	Financial and economic costs to the proponent, both capital and O&M.
	Resettlement	Land lost to create reservoirs and project structures will necessitate the relocation of households and villages and on-going development assistance.	Financial costs to the proponent, both capital and O&M. Note that resettlement may itself create a second round of additional impacts if those resettled cannot adapt and prosper in the new location, or if their resettlement displaces or dislocates other groups already residing in the new location (this leads to more external impacts as per below that may in turn lead to higher than expected resettlement costs if the proponent or government intervenes to address these).
	Environmental mitigation	Efforts sponsored by the project proponent or the government to directly reduce foreseen environmental impacts of the project by investment and expenditure on environmental protection or compensatory projects.	Financial costs to the proponent (or government), both capital and O&M.
	Hydroelectric power	Water that is diverted/stored by the project and passes through turbines to generate electricity.	Financial and economic benefits from local, national or export power sales.
	Irrigated agriculture	Agriculture that is reliant on a supply of water from sources other than direct rain. Irrigated agriculture, primarily rice production, is the largest user of water in the LMB and diverts approximately 10% of mean annual flow for	Financial and economic benefits from the development of irrigation projects, in the form of increased productivity of existing irrigated lands (e.g. in the form of a second crop per year) as well as the opportunity to develop additional production in new agricultural areas.

CATEGORY			DEFINITION	IMPACT
			the entire basin.	
		Water supply	Potable water for domestic, municipal and industrial uses.	Financial and economic benefits from the provision and sale of potable water.
		Flood control	The ability to control river flow to minimize risk or realization of flooding.	Greater regulation of river flows will help mitigate flooding during the wet season. Direct financial and economic benefits include decreases in property & infrastructure damage, lower crop losses, decreased risk of wage loss and relocation, etc.
		Navigation	At least four key categories of water transport can be identified: subsistence users, passenger transport, cruises and freight transport.	Reregulation of flow regime creates financial and economic benefits to improved flow and depth in the dry season. Potential losses could occur for small boat/subsistence users.
		Fisheries - reservoir	Capture fisheries that may develop in the reservoirs created by hydropower dams.	Financial and economic benefits resulting from increases in area available for reservoir fisheries. Note that the net fisheries benefits depends on the external impacts of diminution in pre-existing fisheries.
External Impacts – "Local"				
	Human Population			
		Culture	Individuals, communities and regions of great ethnic and cultural diversity populate the LMB region, including a strong indigenous presence. For many of these groups, the Mekong River, its tributaries, and its resources have historical, religious, mythical and cultural values.	Negative impacts as hydropower development has the potential to affect culture in a variety of ways: loss of culturally important sites, loss of historically important sites, and decreased access to traditional foods, among others.
		Health	Physical and mental well being of the LMB population.	Mixed Impacts associated with induced improvements in infrastructure (e.g. installation of health clinics) or negative impacts due to environmental deterioration, in-migration and other population changes (e.g. decreases in fish for consumption, HIV-AIDs, increase in disease vectors).

CATEGORY			DEFINITION	IMPACT
		Infrastructure	Fixed physical structures such as buildings, roads, bridges, mines, irrigation lines & pumps, among others.	Negative impacts due to permanent loss of existing infrastructure with the development of reservoirs and other project structures. Other infrastructure may be at increased risk due to changes in river hydrology. Note that reduced flooding risk is included above as a direct benefit.
		Displacement and dislocation	Land lost to create reservoirs and project structures will physically displace individuals and communities, and lead to social and economic dislocation (absent resettlement and mitigation).	Negative impacts including loss of home/village, loss of livelihood, loss of access to traditional food sources, loss of community and culture, negative health impacts from changes in water quality or food availability, and increased social stress.
		Inundated lands		
		Developed land	Developed land is defined as land used by humans for purposes such as agriculture, aquaculture, gathering & harvesting, residence, etc.	Some permanent loss would occur with the development of hydropower reservoirs and other project structures.
		Forestland	A variety of systems, defined by their primary cover – trees, but each with its own functions and unique range of goods and services.	Some permanent loss would occur with the development of hydropower reservoirs and other project structures.
		Wetlands	A class of complex systems, defined by the level of water saturation in the soil, but each with its own functions and unique range of goods and services.	Some permanent loss would occur. In others, changes in distribution and area associated with changes in flow and flooding. These impacts will affect, in turn, the quantity and quality of wetland ecosystem services provided.
External Impacts – Downstream Hydrological				
	Causal Factors			
		Altered flow regime	Change in daily, seasonal or yearly flow regime with installation of storage capacity and hydropower use (i.e. for peak power).	Mixed but largely negative impacts on downstream productive activities and the environment as covered below for agriculture, fisheries and other services.

CATEGORY			DEFINITION	IMPACT
		Change in nutrient and sediment transport	Change in sediment capture by hydropower projects may alter sediment content of tributary or mainstream flow.	Negative impacts as sediment deposition occurs behind reservoirs instead of reaching downstream to support channel, delta and estuarine geomorphology downstream. Some of these impacts may be accounted for with changes to productive activities and the environment (as covered above) but the long-term impacts on geomorphology, land subsidence, saline intrusion, etc. are not well understood.
			Change in upstream and downstream land use and sediment capture by hydropower projects may alter nutrient content of tributary or mainstream flow.	Mixed but largely negative impacts on productive activities and the environment as covered above for agriculture, fisheries and ecosystem services, possible negative impacts on water supply due to increased nutrient loading and water treatment costs.
		Change in fish and aquatic biodiversity passage	Dams represent an impediment to the movement of fish and other aquatic biodiversity.	Negative impacts as dams (with or without passage provisions) restrict access of migratory fish to spawning, rearing and other habitat.
	Impacted Production			
		Fisheries		
		Aquaculture	Cultivation of aquatic animals, primarily fish, for consumption.	Mixed Impacts. It is not clear whether gains in aquaculture would be a direct result of hydropower development or of increased investment in aquaculture. Also, hydropower development may also generate external costs if it alters extent or productivity of existing on-site or downstream aquaculture.
		Marine	Marine fisheries, defined as those in the marine waters of the Delta and nearby sea.	Negative impacts may occur with reduced flow of sediment and nutrients from the Mekong River into the Mekong Delta.
		River/lake	Wild capture fisheries on the Mekong River and its tributaries.	Negative impacts may occur as a result of changes in hydrological conditions, loss of migration routes, and alterations of annual floodplain inundation and recession patterns, among others.
		Agriculture		

CATEGORY	DEFINITION	IMPACT
Riverbank gardens	Gardens planted in riverbank exposed by receding water – used for both income and sustenance.	Negative impacts to riverbank gardens may occur in different ways: permanent inundation, changes in sediment/nutrient deposition, and/or changes in water depth/quality.
Recession/rain-fed (Tonle Sap)	Agriculture, particularly rice, which is planted in the edges of water bodies (e.g. Tonle Sap) as floodwaters recede.	Negative impacts may occur as reduced area available for recession rice production results from changes in annual flooding.
Paddy (Delta)	Agricultural production, primarily rice, in the MRD.	Mixed impacts as (a) reduced nutrient loading and decreased sediments may negatively impact production, and (b) increased dry season flow and reduced saline intrusion may have positive benefits for paddy production by increasing the number of hectares on which to farm.
Riparian & aquatic vegetation	Local populations use a variety of riparian and aquatic plant species, both for personal use and for income.	Negative impacts as changes in flow, flooding and general river hydrology may impact the quality/quantity and/or the regional population’s ability to access and harvest wild species.
Bedload: sand & gravel	Sand and gravel includes a variety of materials used for construction and building that are extracted from rivers.	Extraction of sand & gravel occurs for construction purposes in the rivers of the LMB and the availability and location of this bedload will be altered by the capture of bedload by dams and the change in flow regime caused by hydropower projects.
External Impacts – Other Ecosystem Services (may be upstream, on-site, downstream or regional/global)		
Biodiversity	LMB flora and fauna. The Mekong River has some of the highest levels of biodiversity found in any river system in the world.	Primarily negative impacts as large hydropower projects affect upstream, on-site and downstream habitat, harvest, and migration endangering species and leading to extirpation and/or extinction.
GHG emissions	Greenhouse gas emissions from energy production.	Mixed Impacts as (a) hydropower generally emits fewer GHG emissions than fossil fuel dependent sources and (b) this decrease may be offset by GHG emissions from tropical reservoirs.
Bioprospecting	The potential for medical or pharmaceutical applications derived from biodiversity.	Loss of wetlands/forestland to inundation and project structures, and changes in river hydrology are likely to impact regional species; however, it may be difficult to assess how

CATEGORY		DEFINITION	IMPACT
			such impacts might affect the option value for regional species.
	Recreation and tourism	The LMB is already a popular regional and international tourist destination and tourism to the region is expected to continue to grow.	Mixed impacts as dams and reservoirs can be a recreation/tourism attraction, but it is more likely that hydropower development and associated large scale habitat modification and biodiversity loss would affect both perception and willingness to pay for recreation/tourism activities associated with the Mekong River.
	Watershed protection	Displacement or relocation of communities from valley bottoms up into the watershed may lead to deforestation, loss of soil cover and higher rates of erosion.	Negative impacts due to loss of on-site soil productivity and potential loss of reservoir productivity and length of life

2.4 Mekong Studies on Valuation of Impacts

The assessment of the extent to which the identified impacts of hydropower projects are valued in economic terms in the Mekong studies is compiled in Table 2. Each study's examination of specific impacts can be characterized as to whether the impact was (a) not identified or included, (b) identified but considered only in qualitative terms, (c) identified and quantified in physical terms but not valued in economic terms, or (d) identified, quantified and valued. A further qualification here is that in some of the studies there is discussion of how an impact would be valued, but no effort to do so is present. A further classification of the studies can be made as to whether the study considered the baseline level of value derived from the resource (denoted "B" in the table) and the impact of changes due to dams ("I"), or just one or the other of these.

Not unexpectedly the primary direct benefits of dam projects – hydropower and irrigation – are valued in almost all the studies reviewed. The coverage of external impacts on the other hand is less common. This can be said looking across the rows as well as looking down the columns (i.e. by study). No doubt, blank and lightly shaded cells in the table are in part due to the difficulty of valuing these impacts. In some cases it is important to note that no impact was identified. This may mean there was an impact and it was simply not identified, or it could mean that for the purposes of the study (i.e. the project that was being evaluated) there was no impact. For example variation between the tributary valuation of Laplante (2005) and the study of mainstream dams by ICEM (2010c) can be expected simply due to the different context of the projects.

The table also notes the extent to which each study valued baseline levels of the good or service and/or the impact associated with changes due to hydropower development. With regard to the focus of each of the studies, Yermoli (2004), Laplante (2005) and MRC-BDP (2011; 2010b) take a classic approach by simply examining the impacts. The Hall and Leebouapao (2005) study is incomplete with respect to impacts due to its early termination, but provides useful information about baseline values. The ICEM study reports provide considerable information about baseline conditions and impacts, although this information is not directed towards the traditional costs-benefit analysis criterion of NPV. Thus, the information is scattered about in the main report and the underlying technical reports and the impacts are not summed and grouped as proposed in this Guidelines project. The MRC-BDP scenario work covers both baseline and impact information (MRC-BDP 2011).

In sum, much as anticipated in the rationale for the Guidelines Project, the existing literature on the Mekong suggests that much effort has been devoted to the valuation of direct impacts, while the attention devoted to the external impacts is limited and varies from study to study. This reinforces the utility of developing a comprehensive impact framework and set of recommendations for valuing impacts in the Guidelines.

Table 2. Coverage of Values by the Mekong Literature

Key

Not identified	
Methods Only	M
Qualitative Valuation	░
Quantitative Valuation	▒
Valuation	█

				Maunsell & Lahmeyer (2004)	**Hall & Leebouapao (2005)**	**Laplante (2005)**	**Yarmoli (2009)**	**ICEM (2010)**	**BDP Tech 13 (2010)**	**BDP Phase 2 (2011)**
			Baseline (B) and/or Impact (I) Focus	**B & I**	**B**	**I**	**I**	**B & I**	**I**	**B & I**
DIRECT IMPACTS			Dam & hydropower construction	█	█		█	█	█	█
			Multipurpose construction						█	█
			Resettlement & development assistance	█		▒	▒	█		
			Environmental mitigation	█			█	░	█	█
			Hydroelectric power	█	█	█	█	█	█	█
			Irrigated agriculture	█	█	█		█	█	█
			Water supply	█	█	░				█
			Flood control		M			░		█
			Navigation		M	░		█	█	█
			Fisheries - reservoir		▒			█	█	█
EXTERNAL IMPACTS	**"Local"**	Human Population	Culture			░		░		
			Health	█		░		░		
			Infrastructure	█		░				
			Displacement and dislocation	█		▒		▒		▒
		Inundated lands	Developed land	█		█				█
			Forestland	█		█		▒	█	█
			Wetlands	█	M			█	█	█
	Downstream	Causal Factors	Flow regime	(see fisheries and agriculture)						
			Nutrient transport					█		█
			Sediment transport	█		░		▒		░
			Fish passage							
		Fisheries	Aquaculture		▒				█	█
			Marine					▒		
			River / Lake	█	█			█	█	█
		Agriculture	Riverbank gardens		█	█		█	█	█
			Recession/rain-fed (Tonle Sap)						█	█
			Paddy (Delta)						█	█
			Riparian & aquatic vegetation			░		▒		
		Other	Bedload: sand & gravel		█			█		
	Other Ecosystem Services		Biodiversity	█	░	░		░	█	░
			GHG emissions			█		█		
			Bioprospecting			█				
			Tourism & recreation			█		█		
			Watershed protection		░					█

2.5 HPST Approach to Valuation of Impacts

Based on the review of the literature the initial draft Guidelines suggested which impacts could and should be valued in monetary terms as part of the Guidelines, which impacts could not or should not be valued and which might be valued (Ballofet, Aylward, and Taylor 2014). While there are a number of impacts that are quite feasible to value in monetary terms, there are equally a number – such as biodiversity and cultural impacts – that are not appropriate to value in monetary terms. The case study of the Srepok River Basin assisted the team in making a final decision as to which impacts could be valued in monetary terms in a practical and replicable manner through the HPST. The case study also provided guidance on how those impacts not valued in monetary terms could be incorporated through the environmental and social criteria.

Table 3 presents a synopsis of the approach to valuation taken in the HPST. The table lists each impact and whether it is accounted for in financial or economic terms, and whether it is then valued through the environmental or social criteria. While the intent was to avoid overlap, given the multi-functionality of some of the environmental and social indicators, the table shows it is not possible to avoid overlap. Every effort was made to minimize the extent of the overlap in order to avoid unnecessary double counting of an impact in the multi-criteria analysis.

A brief summary by main category of impact follows.

Direct Impacts: Hydropower and Multi-Purpose. Unfortunately, the dams that were assessed in the Srepok case study for the Guidelines did not feature multi-purpose aspects, for those built or those in planning. In some sense then the basin was not atypical of the Mekong, however this feature of the case study did not assist in developing reliable methods for valuing the costs and benefits of multi-purpose projects. As a result simple valuation routines were included in the HPST for a few of the most tractable multi-purpose areas such as irrigation, water supply and reservoir fisheries. But these routines were not fully tested through the case study approach and may need refinement in future applications.

External Impacts: “Local” impacts. Local impacts include impacts on the human population and inundated lands. In addition to inundated lands there will be other impacts immediately upstream and downstream of a dam in terms of impacts on land, water, ecology and social/economic systems. Developing replicable approaches to develop monetary measures for the cultural and health impacts was not possible, and seemed inappropriate to the ISH02 team. These impacts are thus passed to the social impacts for inclusion in the HPST. Impacts on infrastructure, land and displaced/dislocated populations were quantified and valued in monetary terms.

It is important to emphasize that in the case of human displacement and dislocation a comprehensive and exact measure of economic value is not possible to achieve and may be an improper use of economic valuation tools. For this reason these are also included in the social criteria. That said, it may be feasible to place a cost figure on this impact that would reflect the maximum potential economic loss due to displacement and dislocation. In other words there is always a risk of the worst outcome with these projects and that entire communities are disadvantaged in perpetuity. It is feasible to place a value on this, understanding that no monetary value can necessarily represent the potential in terms of human cost. The potential benefit of this approach is to quantify the economic risk to human populations in a way that allows a worst-case explicit inclusion of this important impact into the economic analysis. While incorporating these sorts of economic values into policy decisions can be a difficult and controversial procedure, most policies and project decisions are in fact based on either an implicit and unquantified assessment of these costs, or in many countries an explicit economic assessment of the risk to human life and welfare of alternative courses of action. To this end a replicable approach is built into the HPST that enables users to estimate these costs.

Downstream Hydrologic Impacts. With respect to downstream impacts, these are largely caused by changes to the flow and sediment regime, as well as to fish migration, that result from dam construction. These changes in hydrology impact downstream productive activities, primarily agriculture and fisheries. Based on the literature review it was found that many of the economic valuation efforts to date are rudimentary at best and based on assumptions that are often not documented clearly. A further issue is that these impacts may be quite different in nature and extent depending on which subbasin of the Mekong River is selected for analysis. The approach taken in the HPST was to apply productivity (see Section 13.2.1) valuation methods to the principal impacts observed in the Guidelines Srepok Basin case study. Given the need to attempt this from “scratch” i.e., without reference to existing economic estimates a number of potential impacts were not included. These are shown in blue in the table below and include downstream impacts on river gardens, aquaculture and marine systems. The routines that are developed focus primarily on impacts to the productivity of the Tonle Sap and the Mekong Delta. Application of the HPST to subbasins much further upstream on the Mekong River might require further work to assess impacts on the mainstream river itself.

Other Ecosystem Services. This category includes a number of impacts that hydropower projects have on upstream communities, on the national economy, or on global issues, like climate change. As such these impacts are often hard to define, or to generalize about, in relation to specific hydropower projects. This applies not just to monetary valuation but also to the environmental and social criteria. At present the HPST includes only the external impacts of hydropower reservoirs on climate change. General biodiversity impacts are taken up via environmental indicators. The remaining items: biodiversity prospecting, tourism and recreation, and watershed protection were judged too minor or variable in extent for inclusion in a practical and replicable manner.

In the subsequent sections of this Annex a category-by-category and impact-by-impact explanation is provided of how the HPST accounts (or does not) for these impacts in financial and economic terms. Each impact includes, as relevant, the following information (in sub-sections):

- Brief description of the impact.
- Review of methods and data from the LMB literature review.
- Methods and data as relevant from other literature.
- The HPST valuation approach including methods and data.
- Directions for additional work and future research

Before turning to these sections, we provide a brief explanation of the evaluation methods used in the valuation and summing up of impacts in monetary terms.

Table 3. Chart of Impacts and Approach taken to Valuation

Category			Impact	Included in Monetary Valuation?		Included in non-Monetary Indicators?	
				Financial	**Economic**	**Environmental**	**Social**
DIRECT IMPACTS			Dam & hydropower construction	🟩	🟩	▨	▨
			Multipurpose construction	▨	🟧	▨	▨
			Resettlement & development assistance	🟩	🟩	▨	▨
			Environmental mitigation	🟩	🟩	▨	▨
			Hydroelectric power	🟩	🟩	▨	▨
			Irrigated agriculture	▨	🟧	▨	▨
			Water supply	▨	🟧	▨	▨
			Flood control	▨	🟦	▨	▨
			Navigation	▨	🟦	▨	▨
			Fisheries reservoir	▨	🟧	▨	▨
EXTERNAL IMPACTS	**"Local"**	Human Population	Culture	▨	🟦		🟩
			Health	▨	🟦		🟩
			Infrastructure	▨	🟩		
			Displacement and dislocation	▨	🟩		🟩
		Inundated lands	Developed land	▨	🟩	🟩	
			Forestland	▨	🟩	🟩	
			Wetlands	▨	🟩	🟩	
	Downstream	Causal Factors	Flow regime	▨	🟩	🟩	
			Sediment transport	▨	🟩		
			Nutrient transport	▨	🟩		
			Fish passage	▨	🟩	🟩	
		Fisheries	Aquaculture	▨	🟦		
			Marine	▨	🟦		
			River / Lake	▨	flow and passage	🟩	
		Agriculture	Riverbank gardens	▨	🟦	🟩	
			Recession/rain-fed (Tonle Sap)	▨	nutrients only		
			Paddy (Delta)	▨	nutrients only		
			Riparian & aquatic vegetation	▨	🟦	🟩	
		Other	Bedload: sand & gravel	▨	🟩		
	Other Ecosystem Services		Biodiversity	▨	🟦	🟩	
			GHG emissions	▨	🟩		
			Bioprospecting	▨	🟦		
			Tourism & recreation	▨	🟦		
			Watershed protection	▨	🟦		

Key to Inclusion of Impacts in HPST	
Monetary Valuation	
Fully integrated	🟩
Limited inclusion	🟧
Not included	🟦
Not applicable	▨
Non-Monetary Valuation	
Indicator included	🟩
Indicator not included	

3 Evaluation Methods and Decision Criteria

The various financial and economic valuation efforts in the HPST rely on expressing values in commensurate units, i.e., in units that can be compared directly to each other. The decision criteria employed in the HPST include net present values and the benefit-cost ratio. These are each explained below, but first the basic parameters of evaluating a stream of economic costs or benefits over time are described. Further information on this topic can be obtained from standard texts on corporate finance or cost-benefit analysis (Brealey and Myers 1988; Jenkins, Kuo, and Harberger 2011b).

3.1 Parameters for Evaluation: Time Horizon and Discounting

Any hydropower project will realize financial expenditures and revenues, or economic costs and benefits, over a succession of years. In order to compare and contrast projects or project portfolios, it is important that the analysis include costs and benefits over an appropriate and relevant time horizon, which refers to the number of years across which quantitative and monetary estimates of project impacts are measured.

With project impacts and their monetary evaluation occurring over many years, there is a need to take account of what is generally called “the time value of money.” In other words, USD 50 of expenditure in Year 1 of a project is not equal to USD 50 of expenditure in Year 10 of the project. This initial amount, if invested in the market for the interim years, should be of some higher value in Year 10. The starting value is increased each year by some percentage, for example, according to the interest rate it earns in other investments. This interest rate, compounded over the time horizon, can be used to equate costs and benefits that occur in different periods. Used in reverse, i.e., used to take a future value and bring it back to a value in the present, it is called a discount rate by economists.

The general relationship between a future value of a cost or benefit, *FV*, and its present value, *PV*, can be expressed as follows:

$$PV = \frac{FV}{(1+r)^t}$$

where:

r = discount rate; and

t = the time period in which the future value occurs.

This expression reflects the discounting applied to any future value in period t.

Generally, in comparing alternatives, all future values are brought back to the present and summed in order to have comparable values. This process is called discounting and underpins the concept of net present value and benefit-cost ratios, as explained next.

3.2 Net Present Value

The net present value, *NPV*, of a stream of costs and benefits is represented by the following equation:

$$NPV = (B_{t=0}-C_{t=0})/(1+r)^0 + (B_{t=1}-C_{t=1})/(1+r)^1 + \ldots + (B_t-C_t)/(1+r)^t$$

where:

C = total cost in a given time period;

B = total benefit in a given time period;

r = discount rate; and

t = the end period of the project in years from the present.

So $(B_{t=1} - C_{t=1})$, for example, refers to total net benefits received one year from the present.

The expression $(1 + r)^t$ reflects the discounting of future costs and benefits.

Since the NPV incorporates the opportunity cost of capital, as represented by the discount rate, the decision-making rule is that a project with a positive NPV is worth undertaking and a project with a negative NPV is not worth undertaking. Of course, interdependencies between projects, particularly those linked together in terms of hydrology, flow, and storage, like hydropower, may require more complex assessment or decision criteria.

3.3 Benefit-Cost Ratio

The benefit cost ratio for a project, *BCR*, is a composite indicator derived from the present value of the costs of the project and the present value of the benefits of the project:

$$BCR = \frac{NPV\ of\ Benefits}{NPV\ of\ Costs}$$

The decision rule is that projects with a BCR greater than or equal to a value of 1 are worth undertaking. If the BCR of a project is less than 1 it is not worth undertaking. The BCR does not always lead to the correct decision, but it is useful in the HPST context because it provides a unit-less indicator that can be normalized and used in conjunction with similar indicators from the environmental and social analysis and deployed together in the multi-criteria analysis.

3.4 Normalisation of Indicators

In the multi-criteria analysis, the environmental and social indicators are normalized before ranking and combining with the economic BCR. This means scaling disparate scores or values to values between 0 and 1, which is achieved by setting the maximum value in the data set of total indicator scores, D, for all project scores to a value of 1. All other values are then set as proportions of the maximum value so that the normalized score, *N*, of the indicators score for any project, S_P, is simply equal to the variables score S_p divided by the maximum value in the data set:

$$N_p = \frac{S_P}{MAX[D(S_P)]}$$

3.5 Risk-Weighted Benefit-Cost Ratio

In the HPST, the multi-criteria analysis concludes with the use of a risk-weighted benefit-cost ration, BCR_{RW}. This is simply calculated for all projects, *P*, as follows:

$$BCR_{RW} = \frac{BCR_P}{N_P}$$

4 Financial Valuation of Hydropower

For the Guidelines a financial analysis of each hydropower project or portfolio is included for a number of reasons:

- The financial NPV is a useful indicator of the ability to be financially self-sufficient; generally hydropower projects/portfolios are unlikely to move forward if the revenues do not cover the costs, including the cost of capital to the project proponent.
- A number of the financial parameters are inputs into the economic analysis; an economic analysis can be thought of as a financial analysis broadened to include the costs and benefits to other stakeholders and/or as a financial analysis modified to reflect the marginal opportunity costs of inputs/outputs to the economy as a whole and not just their market cost/benefit to the proponent.
- It is instructive to compare the financial attractiveness of a project with its economic returns and its environmental and social indicator scores.

In the HPST the following components of the financial analysis are included, as explained below:

- Capital costs;
- Resettlement costs;
- Environmental mitigation costs;
- Power revenues;
- Annual operations and maintenance costs; and
- Taxes and other fees.

Note that interest during construction is an important element of the financial projections but is not included in the calculation of financial profitability. This as typical decision-making criterion such as net present value and internal rate of return represent efforts to see if the project is worth it to the proponent given their cost of capital.

In order to estimate the last item, taxes and other fees, it is necessary not just to estimate the expenditure and revenue components, but also to develop a set of financial projections for each project. This requires information on loan parameters, tax rules, tax rates, etc. As the goal of the HPST is to enable comparisons across projects from a planning perspective, many of these parameters are generalized across the four LMB countries. As such, the financial analysis does not attempt to replicate the specific loan rates, for example, of this project or that project. Rather the same parameters are used for all projects so that the financial worth of each project can be compared on a level playing field.

4.1 Time Horizon and Discount Rates

Financial analysis reflects the revenue and expenditures made by the project proponent. As most projects in the LMB are developed currently with private project finance along the BOOT (Build-Own-Operate-Transfer), the time horizon should reflect the length of life of the concession period. Review of legal/regulatory information and project documentation suggests that this is typically a 30-year period, effective from the commissioning date. Some concessions may be longer depending on negotiations between the host country and the project proponent. In Lao PDR, concessions may vary, but the base concession is 25 years (AF-Mercados EMI 2013). Where the regulatory regime allows variable concession life, the length of the concession may be varied in order to arrive at a project that satisfies both the private proponent and the government. However, as indicated previously, the intent of the financial analysis is not to reflect such real world negotiations over project particulars, but instead to provide a standardized examination of a portfolio of projects for planning purposes. For this reason, 30 years is selected for each of the countries as the appropriate time horizon.

As with the time horizon, it is important to use a single discount rate for each country in order to standardize the analysis for planning purposes. Data on discount rates was sought from national sources and from project documentation. Generally, a 10% rate seems to be the default value, with the exception of Thailand, where a 12% rate was provided. Typically, discount rates will be higher in faster growing economies.

As the time horizon and discount rates are key parameters in the HPST, they may be easily modified as described in the HPST User Manual. It is best practice to carry out sensitivity analysis with a number of parameters but particularly the discount rate given that it may have a large impact on capital-intensive investments like dams. Sensitivity analysis examines the effect that a reasonable range of discount rates might have on the economic profitability of a project is established. Given the 10% to 12% rates a +/- of 2% to 5% might be used in the sensitivity analysis. The goal is to see if a lower or higher rate makes the project unattractive.

Table 4. Financial Analysis: Time Horizon and Discount Rate

PARAMETER	UNIT	General	Cambodia	LaoPDR	Thailand	Viet Nam
Financial Analysis						
Time Horizon	Yrs		30	25	30	30
Discount Rate	%		10%	10%	12%	10%

4.2 Capital Costs

Estimating the capital costs of large hydropower projects is a complex exercise well beyond the scope of the Guidelines and the HPST. As a result, the HPST employs existing estimates of capital costs for projects. These may be early feasibility design, or actual figures. A general source of estimates for capital costs is the MRC Hydropower Database (Yermoli 2009). However, for most projects examined by the guidelines, there likely will be and existing study that includes a cost estimate. If there is no cost estimate, it is really not practical to include the project in an application of the Guidelines. The methods for entering cost data into the Data Workbook of the HPST are specified in the HPST User Manual (see Section 3).

A number of potential sources of project costs, such as the MRC database, may present cost figures as single figures that include interest during construction (IDC) or as two figures, being the IDC plus the actual capital cost of the project (for example as engineering, procurement and construction, or EPC, costs). The HPST thus includes the necessary calculations to spread costs over the number of construction years in the project and to estimate IDC. The cost spread applied to all projects is provided below in Table 5. The percentage spread of capital costs is based on the profile of the one Srepok Basin case study dam for which a six-year spread of investment was available, as well as the general principle of achieving a level expenditure of funds across the project, with a ramp up and ramp down year, and with the highest expenditure years being towards the end of the project.

Table 5. Spread of Capital Costs across Construction Period

Construction Cost Spread	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10
Years of Construction: 1	100%									
Years of Construction: 2	50%	50%								
Years of Construction: 3	30%	40%	30%							
Years of Construction: 4	20%	30%	30%	20%						
Years of Construction: 5	15%	20%	25%	25%	15%					
Years of Construction: 6	10%	15%	20%	20%	25%	10%				
Years of Construction: 7	5%	10%	15%	20%	20%	20%	10%			
Years of Construction: 8	5%	10%	10%	15%	15%	15%	20%	10%		
Years of Construction: 9	5%	10%	10%	10%	15%	15%	15%	15%	5%	
Years of Construction: 10	5%	10%	10%	10%	10%	10%	15%	15%	10%	5%

4.3 Resettlement Costs

The inundation of lands to create hydropower reservoirs and land lost to project structures (e.g. physical plant and transmission lines) may necessitate the relocation of households and villages. It has been shown that, in addition to moving from one place to another, there may be other indirect impacts on resettled peoples such as loss of livelihood, loss of access to traditional food sources, loss of community and culture, negative health impacts from changes in water quality or food availability, and increased social stress, among others (MRC-BDP 2010h; ICEM 2010c).

In addition to providing for resettled individuals' income and residence, there may also be a need for on-going economic and social assistance to adequately compensate these individuals and allow for successful adaptation to their new location. Such resettlement and assistance programs would generally have the objective of leaving local and affected populations better off than before the project, in other words creating economic and social development opportunities rather than merely trying to mitigate, or "reduce", the impacts of such projects.

The extent to which project proponents provide adequate funds to cover resettlement costs and continue to fund social programs after resettlement in order to achieve a development, instead of a loss and decline, outcome is difficult to determine. In the Guidelines, this issue is covered in three ways.

1. In the financial analysis an effort is made to budget for the normal costs of environmental and social mitigation costs.
2. In the economic analysis an effort is made to value the consequences of making the decision to build the dam, i.e., the loss of land and infrastructure due to inundation, as well as any expected loss in livelihoods that occurs after due to displacement and resettlement. The economic analysis proceeds on the basis that the resettlement program as costed takes place, but the actual resettlement costs are not included, as they are effectively a transfer from the project proponent to displaced peoples. Instead, the economic loss of land, infrastructure and livelihoods with the project (as opposed to before the project) is valued.
3. Due to the difficulty of capturing the full range and extent of the economic impacts, certain non-monetised aspects of displacement and dislocation are included as a social indicator in the multi-criteria analysis.

4.3.1 LMB Dams Literature Review

Methods

None of the LMB studies reviewed attempted to provide a replicable method for estimating resettlement costs. Laplante (2005) did provide an interesting method for estimating potential resettlement numbers, but the method was based on extensive GIS analysis and therefore not simple enough for including in the HPST. Laplante (2005) also included estimates of project investment and income compensation for the Nam Theun 2 project, which are included below.

The adequacy of budgeted resettlement costs can be questioned. According to BDP Technical Note 13, "social and environmental mitigation measures are also included in the proposed investments but, it should be noted that these funds are not even sufficient to meet the resettlement costs required for households displaced by the infrastructure and reservoirs" (MRC-BDP 2010b, 8).

Data

- Laplante (2005) estimated that approximately 5,700 individuals would need to be relocated for the Nam Theun 2 project.
- Several studies included specific estimates of displaced individuals by dam—primarily for mainstream dams (see Table 6); sometimes the figures are similar, sometimes not, and the source of the data is often unclear.

Table 6. Estimates of Displaced Individuals by Dam

	Number of individuals		
Dam	Yermoli (2009)	ICEM (2010)	MRC (2010)
Pak Beng	6,700	6,700	—
Luang Prabang	12,966	12,966	—
Xayabouly	2,130	2,130	—
Pak Lay	6,129	6,129–18,000	—
Sanakham	4,000	4,000	—
Pak Chom	—	535	400
Ban Koum	1,122	935	300
Lat Sua	0	0	—
Don Sahong	66	66	—
Stung Treng	10, 617	10,000+	10, 617
Sambor	19,034	19,000+	5,120

With regard to the unit cost of resettlement, the following information and data were found:

- The Draft Technical Guidelines for Resettlement and Compensation Government of Lao PDR indicated that "the compensation should be determined based on the average productive values of land based on the past three to four years of production, and should be equivalent to at least six to seven years of harvest value" (in Laplante 2005). Similar provisions apply in Cambodia according to figures provided in (McKenney 2001).
- In the case of Nam Theun 2, Laplante (2005) estimated that approximately 5,700 individuals would need to be relocated, with project plans pledging a NPV of USD 21 million to facilitate resettlement, for an implicit per person one-time expenditure of USD 3,700.

4.3.2 Additional Literature Consulted

Additional review of the literature provided the following information:

- ICEM included a table summary by key topic of "National legislation on land acquisition and compensation compared to best international practice" (2010d, 49–50).
- BDP Technical Note 12 included a table compiled by International Rivers that included estimates of individuals displaced by existing hydropower developments in Lao PDR (MRC-BDP 2010h).
- A case study of compensation and resettlement associated with hydropower development in Viet Nam assessed resettlement frameworks used, summarised problems encountered (as

voiced by resettled individuals), and determined the root cause of these (Ty, Van Westen, and Zoomers 2013).

4.3.3 HPST Valuation

In the HPST the resettlement costs are merged with environmental mitigation costs as explained further in Section 4.5.

4.3.4 Direction for Future Work and Additional Research

Resettlement costs are typically the product of the number of resettled people and the per person cost of resettlement. Generally, it is not expected that the number of resettled people can be predicted with any degree of reliability. While it is true that reservoir size is an indicator of potential displacement, the location of the reservoir in terms of being in an inhabited area or a remote uninhabited area will also be a determining factor. The cost of resettlement also will vary from project to project. However, some replicable method may be feasible if estimates exist of the numbers of people to be resettled, which often occurs as part of the feasibility stage. In the absence of project-specific information on costs, i.e., for the purposes of the Guidelines, it may be sufficient to establish a per person expected cost of resettlement for each country, or the region generally. A synthesis review and analysis of existing or proposed dams in the Mekong could assess if there are any generalizable and replicable approaches that could be brought to bear on this problem. Some efforts were taken in this direction using the MRC database. The source of the displacement numbers and costs in the database is not clear making any such analysis inconclusive. Gathering project-by-project data from existing dams might be a useful approach to the problem.

Additional work on this topic may therefore include:

- Identifying the number of individuals resettled for projects where no information is currently available.
- Updating the estimates of the number of individuals resettled for projects where estimates are five or more years old.
- Testing existing LMB data for existing and proposed dams to ascertain if a predictive equation can be developed for numbers resettled.
- Collection and analysis of actual resettlement numbers and costs for existing projects in order to derive/validate costs per person resettled for each of the LMB countries.
- Collection and analysis of actual versus expected (planned) resettlement numbers for existing projects in order to assess any bias in planned resettlement numbers for proposed dams.

A further issue is additional on-going costs of economic and social assistance afforded to local and affected people. No systematic dataset on such programs has yet been found. Additional work on this topic may therefore include:

- Collection and analysis of information about such programs from existing dams in the LMB in order to establish a method for estimating the additional cost of such programs.

4.4 Environmental Mitigation Costs

It is widely recognized that hydropower development in the LMB will have adverse impacts on the environment, the degree to which will vary by project. Some of these impacts will end with the environmental impact, but typically the environmental impact will ultimately affect people’s livelihoods or consumption. In the context of hydropower, the primary goal of environmental mitigation would be to avoid or minimize negative environmental impacts of project construction and operation. In most cases, mitigation would involve costs, presumably born by the project proponent and internalized as part of their project budget. Effective mitigation strategies likely will not exist for all impacts; however, for those that do, the cost of such a strategy could be estimated and included in a cost-benefit analysis.

In theory, environmental mitigation costs would be equal to the value necessary to completely offset project-related environmental losses and impacts; but in reality, estimating the value of environmental impacts and determining appropriate mitigation measures/actions can be a costly and time consuming process, the results of which may or may not equal the true value of the impacts given the complexity of attempting to value the myriad of environmental goods and services (both market and non-market) that are potentially impacted. More likely, mitigation costs will assist in "reducing the intensity or coverage of an impact" (ICEM 2010).

Generally speaking, both the types and level of environmental impacts will vary from project to project, and, furthermore, the most effective mitigation strategies likely will vary as well.

4.4.1 LMB Dams Literature Review

Methods

Detailed methods for including environmental mitigation costs were only included in one study reviewed. Maunsell & Lahmeyer (2004:233-34) used the following assumptions for including environmental impacts and mitigation in their model:

- "All negative consequences of a project are either effectively mitigated to meet the appropriate regulatory standards, or borne as a loss by GOL if not mitigated.
- The costs of mitigations or losses are treated as a project cost regardless of which stakeholder bears the cost.
- In cases of negative impact consequences, the costs of mitigations (by more than one mechanisms, if appropriate) are compared with the costs of sustaining the damage to choose the least cost that should be applied to the consequence."

They also note, however, that "many negative environmental consequences cannot be mitigated because of the limited capacity of official environmental agencies to execute appropriate mitigation [and in] these circumstances the negative consequence becomes classed as "unavoidable damage", and is assigned the value of the loss" (Maunsell and Lahmeyer 2004: 137). In addition, note that this approach relies on the accuracy and completeness of the effort to actually value the damages. In this regard, it is worth noting that in none of the studies reviewed was there any attempt to value the downstream impacts of large dams on the Tonle Sap or Mekong Delta ecosystems. As these are the most commonly cited impacts that are expected to be of large magnitude, efforts to date to cost out environmental mitigation measures must be regarded as incomplete.

Data

In their study, Maunsell and Lahmeyer (2004) broke out environmental impacts (and any associated mitigation costs) by construction site (CS), access roads (AR), power transmission lines (PTLs) and reservoir (R) (Table 7). In some cases, mitigation costs are only estimated for a subset of these categories.

Table 7. Environmental Impacts and Mitigation Strategies

Environmental impact	Mitigation (if listed)
Loss/degradation of terrestrial habitat	
Loss/degradation of aquatic habitat	
Impact to rare, threatened or endemic species	Capture and relocation of breeding population (USD 50,000-500,000)
Impairment of fish passage/ migration from stream crossings	(USD 500/crossing)
Habitat fragmentation	
Impairment of terrestrial species movement/ migration routes	PTLs: USD 200-20,000/km
Change in sediment deposition	
Change in nutrient flow	NPK fertiliser (USD 400)
Riverbank erosion	
Construction sites	Site rehabilitation (USD 500/ha) and restoration (USD 50/ha)
Barrier creation	AR: USD 50,000/km PTLs: USD 2,000-6,000/km
Reservoir impacts – Destratification, thermocline distortion, etc.	

Source: Maunsell and Lahmeyer (2004)

ICEM (2010) included a qualitative assessment of the potential for environmental mitigation on a three-point scale (i.e. no potential, potential, high potential) for identified environmental impacts associated with hydropower project development. Those impacts with high potential for mitigation are listed here:

- Increased coastal erosion/accretion
- Decreased floodplain fertilisation
- Large hourly water surface level changes
- Impacts on terrestrial biodiversity and protected areas

The study also made several additional points regarding mitigation. First, ICEM (2010) noted that mitigation opportunities exist for many environmental impacts associated with changes in hydrology, geomorphology, habitat, and sediment dynamics; however, they would all likely result in reduced generation capacity for the project.

Second, while a potential mitigation strategy for tributary dams, ICEM (2010) did not find that fish passages would be a viable mitigation option for mainstream dams due to their height and the intensity and diversity of migrations that occur in the mainstream.

4.4.2 HPST Valuation

In the HPST the resettlement costs are merged with environmental mitigation costs as explained further in Section 4.5.

4.5 Environmental and Social Mitigation Costs

Given the inherent natural variation in resettlement and environmental mitigation costs, the HPST should ideally rely on project specific estimates. So, as with capital costs, the approach taken in the HPST is to allow for the direct input of these costs from the best source available. Should such costs not be available, the environmental and social costs would need to be projected in some fashion. Based on the preceding two sections there is no predictive formula for these costs based on a hydropower project engineering design parameter on which to base a generalized estimate of each of these costs.

Looking at past projects in Lao PDR, Maunsell and Lahmeyer (2004) found that environmental and social mitigation costs were projected to be 0.5–12.0% of total project costs for projects as proposed but 3.0–6.0% of total project costs for as built. A brief assessment was undertaken to assess if it was possible to assign these costs as a percentage of project capital cost based on the MRC project database. Data gathered from the database was analysed and the results suggested a result of 3.7% on average. This figure is used in the HPST to project these mitigation costs when the figures are not provided directly through data collection.

4.6 Power Revenues

Power revenues reflect the sale of electricity generated by the project. Normally, these are simply the amount of projected hydropower production multiplied by the expected price that the project proponent will receive from the buyer. Power revenues are the principal inflow of hydropower and multi-purpose projects and thus drive financial profitability of the project. It is therefore important for the Guidelines to carefully assess both the power generation figure and the price of power.

With respect to power generation, it is important to recognize that most feasibility and design documents produce a figure for expected annual power generation based on the reservoir/plant/turbine design and the available hydrologic flow data. Although the number is typically put forward as a yearly average, this average reflects the expected annual hydrologic variability in the system. However, the resulting figure may not so much represent the actual demand for the power as the potential supply. Even if the number emerges from a full model of demand and supply, the demand is driven by a projection of the future. These projections are often exaggerated. To some extent this is rational, as planners want to ensure that capacity exists for a high demand forecast. Unfortunately, this also means there is a systematic bias to over-estimate power generation at the feasibility and design stages. Previous analyses have found that indeed the actual power generated and sold is typically less than the amounts expected in project documents (World Commission on Dams 2000).

While the overstatement may seem rational, the systemic bias can lead to a misallocation of resources. Put simply, if a project has a 10% rate of return based on a figure for quantity of power sold that is overestimated by, say, 10% the actual financial returns will be less than expected and perhaps low enough that, had the proponent known this in advance, the project would not have received approval and financing. So the HPST should correct for this overstatement in power generation figures, particularly in the initial years of a project, when the shortfall in demand is most likely and where project revenues are discounted to a lesser degree in the financial analysis.

In the LMB quite a number of the hydropower projects in Lao and Cambodia, and increasingly in Viet Nam, are privately financed. This means that power sales agreements are negotiated and prices are fixed or set by formulae over the life of the concession. At the same time, various elements of the project including tax holidays, concession life, and other fees and charges are also negotiated. In other words, the price received by a given proponent is not really the “net” price received for power. For the financier who has in mind a target rate of return it is not just price, but all the other prices, quantities and concession parameters that determine profitability. As a result it should not be surprising that in each country there is not a single set power price that is consistently paid to project proponents.

This creates a difficulty for the Guidelines and creating a “practical and replicable” planning level financial analysis. Every project will have a different price of power, that price may not be determined until the power sales agreement is signed, which happens well beyond the planning phase, and that price represents the result of a particular negotiation for a project of a particular size in a particular location, etc. This problem is solved by acknowledging that the Guidelines' objective is a standardized approach that enables an "apples to apples" comparison of projects. This means that the HPST should use a single price for power. However, the power systems in each country are at different stages of development and are not at all fully integrated, and thus the HPST should use a single price for power for each country.

4.6.1 HPST Valuation: Power Generation

In order to assess power revenues the HPST requires data on expected power generation and price, as well as an adjustment factor to apply to the expected power generation figure to account for the system bias in these numbers. No effort to compare actual with expected power production in the LMB was found in the literature. As a result, as part of the case study, the Guidelines team collected actual power generation from facilities visited in Viet Nam and compared these to the official projections that were provided to participants as part of the site visit. In addition, the figures from the MRC Hydropower Database and the MRC Basin Development Plan were compiled for reference. Not surprisingly, the projects' actual performances were below projected performance across the board. The simple average for the six facilities was 84% for the site visit values. One of the facilities, Srepok 4A, only had one full year of data and performed poorly during that year. Also, the Dray Hlinh project is a very small project and is unrepresentative of the larger dams in a number of ways – i.e., it shares flows with newer private projects that use the same dam. The World Commission on Dams (2000) assessment shows that performance generally improves with age. For this reason, we select 90% as an indicative adjustment factor to eliminate the systemic bias towards over-estimating power quantities and hence revenues. As describe in the HPST User Manual this default figure can be deployed, the default adjustment figure may be changed based on available or new information, or existing production figures may be input directly.

Table 8. Actual versus Projected Mean Annual Energy (GWh/yr)

DATA SOURCE	Projected Figures Yermoli (2009)	 MRC-BDP (2011)	 Site Visit Handout (Varies)	Actual Figures Site Visit from Operator (2014)	Actual as % of Projected Yermoli (2009) vs Actual	 MRC-BDP (2011) vs Actual	 Site Visit Handout vs Actual
Buon Tua Srah	359	450	359	298	83%	66%	83%
Buon Kuop	1,459	974	1,459	1,300	89%	133%	89%
Dray Hlinh 1	100	21	94	78	78%	378%	82%
Srepok 3	1,060	689	1,060	950	90%	138%	90%
Srepok 4	329	220	336	300	91%	136%	89%
Srepok 4A			301	221			73%
Average					86%	170%	84%

4.6.2 HPST Valuation: Power Purchase Price

As indicated above, power prices will vary from project to project. Power prices will also tend to vary from country-to-country depending on the state of supply and demand within each country. The aim of this section then is to arrive at a rough figure that represents the average that is paid to hydropower projects in each of the countries. Power from hydropower projects is destined for all four countries in the LMB and information gathered and the default price used in the HPST is reviewed below for each country. Most of the projects in the region are now being developed by independent power producer (IPPs) and thus the information sought is estimates of the price in IPP power purchase agreements.

Cambodia. Power purchase prices obtained from available sources are presented in Table 9. Existing IPP agreements show a diverse range of values with central values around USD 0.09/kWh. The oldest agreement has the highest price, which is reasonable assuming that the price paid is reduced as the power sector develops. The lower prices used in the financial analysis for Lower Se San 2 can be explained as a weighted average between higher purchase prices in Cambodia and lower prices in Viet Nam (see below). The power purchase price for Cambodia is therefore set at the same USD 0.095 used in the recent country master plan (Nippon Koei 2009).

Table 9. Cambodia: Power Purchase Prices from Hydropower Projects

Source	Project/Basis	Value Year	Value Type	Study Value (USD/kWh)	Adjustment Factor	2014 Value (USD/kWh)
Country Master Plan (2009)	Kiriom I	2002	IPP	$ 0.070	1.56674	$ 0.110
Country Master Plan (2009)	Kiriom II	2010	IPP	$ 0.081	1.11207	$ 0.090
Country Master Plan (2009)	Kamchay	2010	IPP	$ 0.081	1.11207	$ 0.090
Country Master Plan (2009)	Stung Atay	2012	IPP	$ 0.058	1.01583	$ 0.059
Country Master Plan (2009)	Country Forecast	2009	IPP	$ 0.080	1.18797	$ 0.095
EIA (2008)	Lower Sesan 2	2008	IPP-domestic & export	$ 0.068	1.08333	$ 0.074
Feasibility Study (2009)	Lower Sesan 2	2009	IPP-domestic & export	$ 0.061	1.18797	$ 0.072

Lao PDR. Due to the lack of a case study in Lao PDR, few references were obtained (see Table 10). The reported domestic purchase price for the larger, internationally financed projects, like Nam Theun 2, are low and are disregarded here as the projects financial return rest largely with export markets (ECA 2009). A recent review of the Lao PDR hydropower sector by AF-Mercados EMI (2013) suggested the following prices:

- Export average tariff (commissioning in 2016): greater than USD 0.07/kWh
- Average internal tariffs: USD 0.065/kWh (but as low as USD 0.04/kWh)

Consultation with the MRC National Consultant yielded the same USD 0.065/kWh figure so that is the figure used in the HPST for domestic IPP purchases.

Table 10. Lao PDR: Prices paid for Power from Hydropower Projects

Source	Project/Basis	Value Year	Value Type	Study Value (USD/kWh)	Adjustment Factor	2014 Value (USD/kWh)
ECA (2009)	Nam Theun 2	2009	IPP Export primary	$ 0.021	1.07199	$ 0.023
ECA (2009)	Nam Theun 2	2009	IPP Export secondary	$ 0.010	1.07199	$ 0.010
ECA (2009)	Nam Theun 2	2009	IPP Domestic	$ 0.018	1.07199	$ 0.019
MRC National Consultant (2015)	Nam Ngum	2011	Export primary	$ 0.049	1.02189	$ 0.050
MRC National Consultant (2015)	Nam Ngum	2011	Export secondary	$ 0.032	1.02189	$ 0.033
MRC National Consultant (2015)	Nam Ngum	2011	Domestic	$ 0.052	1.02189	$ 0.053
AF-Mercados (2013)	Country	2013	IPP Export average	$ 0.070	1.00983	$ 0.071
AF-Mercados (2013)	Country	2013	IPP Domestic average	$ 0.065	1.00983	$ 0.066
AF-Mercados (2013)	Country	2013	IPP Domestic low end	$ 0.040	1.00983	$ 0.040

Thailand. No studies were obtained directly with respect to Thailand. The relevant Thai price for the HPST is what Thailand in effect pays IPPs in other countries for power imports. With Lao PDR being the principal exporter of power to Thailand, the Lao PDR figures for IPP export prices are relevant here and range from USD 0.023 to USD 0.71 in 2014 dollars. The IPP purchase price supplied by the MRC National Consultant suggested USD 0.04/kWh. Given the variety in prices here, the consultant's figure is used to represent the average expected purchase price.

Viet Nam. For Viet Nam quite a number of studies and figures for particular plants were obtained both from the case study and elsewhere in the country. These vary over quite a number of years, so the conversion to USD 2014 is important to assist in their comparison (Table 11). The median and average prices are roughly USD 0.045/kWh and this is the value deployed in the HPST.

Table 11. Viet Nam: Prices paid for Power from Hydropower Projects

Source	Project/Basis	Value Year	Value Type	Study Value (USD/kWh)	Study Value (VND/kWh)	Adjustment Factor	2014 Value (USD/kWh)
ISH02 Site Visit Interview	Hoa Phu	2014	IPP highest rate		2,400	0.00005	$ 0.115
ISH02 Site Visit Interview	Hoa Phu	2014	IPP normal rate		580	0.00005	$ 0.028
EIA in ISH02 Site Visit Handout	Buon Kuop	2009	EVN stock company	$ 0.045		1.18797	$ 0.053
EIA in ISH02 Site Visit Handout	Srepok 4	2010	IPP	$ 0.045		1.11207	$ 0.050
Design Docs in CDM (2011)	Srepok 4	2007	IPP		685	0.00007	$ 0.051
EIA in ISH02 Site Visit Handout	Buon Tua Srah	2010	EVN stock company		554	0.00006	$ 0.033
EIA in ISH02 Site Visit Handout	Srepok 4A	2008	IPP		753	0.00007	$ 0.050
Feasibility study in CDM (2012)	Srepok 4A	2010	IPP		785	0.00006	$ 0.047
Cited in CDM (2011)	Confidential 28 MW HPP	2005	PPA/MoU price		610	0.00008	$ 0.050
Cited in CDM (2011)	Confidential 6.6 MW HPP	2007	PPA/MoU price		594	0.00007	$ 0.044
Cited in CDM (2011)	Confidential 9 MW HPP	2007	PPA/MoU price		603	0.00007	$ 0.045
Cited in CDM (2011)	Confidential 30 MW HPP	2007	PPA/MoU price		607	0.00007	$ 0.045
Cited in CDM (2011)	Confidential 18 MW HPP	2008	PPA/MoU price		604	0.00007	$ 0.040
ADB (2008)	Song Bun 4	2006	IPP	$ 0.044		1.24712	$ 0.055
Sierra West (2011)	Confidential High end	2011	IPP		750	0.00005	$ 0.037
Sierra West (2011)	Confidential Low end	2009	IPP		550	0.00007	$ 0.038
Sierra West (2011)	Confidential ~260 MWs	2011	IPP		650	0.00005	$ 0.032

4.7 O&M Costs

Hydropower projects are capital-intensive investments. This means that the vast majority of project costs come in the form of up-front capital investments (synonymous here with EPC or engineering procurement and construction). The operations and maintenance (O&M) costs to run the project once it is in operation are typically quite low. Exactly how low is a largely under-researched area. At the planning stages it is typical to see these costs simply projected as a percentage of capital costs or revenue.

A sampling of figures found in the Mekong literature includes:

- The Basin Development Plan projects O&M costs for all LMB hydropower projects at 1% of EPC cost (MRC-BDP 2010g).
- In the case of the Nam Theun 2 hydropower project in Lao PDR, the World Bank uses the estimates from the project proponent's financial model; these figures include on-going environmental and social mitigation and vary to year but are between 1.6% and 2.2% of total capital cost (World Bank 2005).
- The Cambodian Hydropower Master plan assigned O&M cost by type of capital cost with civil and metal works at 0.5% and electro-mechanical and transmission-related facilities at 1.5% (Nippon Koei 2009).
- In the case of the Trung Son hydropower project in Viet Nam, the World Bank included O&M costs at 1.5% of the project's capital costs (World Bank 2011).
- In the case of Buon Kuop hydropower project in Viet Nam, in accordance with guidelines from the Ministry of Industry, O&M costs are set at 0.5% of the project's capital costs (CDM 2009)

Acknowledging the lack of empirical basis for the above estimates, O&M costs are set at 1% of project capital costs in the HPST.

4.8 Taxes and Fees

In the LMB countries, hydropower projects are subject to a variety of taxes and fees that vary from country to country. Generally, however, there will be at least one of two types of taxes applied to such projects. The first is a tax on income and the second is a royalty or natural resource tax. The first is a somewhat standard business net income tax that relies typically on the annual computation of gross sales, and then the deduction of operating costs, depreciation and interest to arrive at net income. This net income is then taxed at the prevailing rate for the type of business, in this case hydropower production. A further feature of this type of tax is that tax holidays may be awarded for projects that are deemed in the national interest. In addition, there are often provisions for the carryover of losses from a previous year to the current year. The latter effectively enables the business to avoid paying taxes until there is net profit in the business on a cumulative basis.

Taxes are potentially important in the financial analysis as they represent another cost to the project during its operational life span. They are therefore important to include in the HPST. However, analysis suggests the magnitude of their impact may be limited. Due to the nature of the hydropower investment, with large capital costs up front, business income taxes that allow the deduction of interest and depreciation, as well as the carry forward of net losses, mean that most such projects will not pay taxes until the latter end of the concession period. In some cases the carry forward of losses may be limited as in Lao PDR where there is a three year limit on the use of a carry forward loss. In some countries lengthy tax holidays are provided, although these are typically of little effect as the project are likely to generate net losses and therefore pay no tax until well beyond any tax holiday.

Tax information was sourced from the relevant countries legal documents and reports to government.

Figure 4. Taxes and Tax Rates

PARAMETER	UNIT	General	Cambodia	Lao PDR	Thailand	Viet Nam
Financial Analysis						
Tax						
Power Gen. Tax/Royalties	%		n/a	5%	n/a	2%
Profit/Income Tax	%		20%	24%	20%	25%
Depreciation Years	Yrs		20	25		30
Income Tax Holiday	Yrs		9	7	8	0

4.9 Interest During Construction (IDC)

The HPST is designed to accommodate projects that come with only a total investment cost (including IDC) or projects that come with a total capital cost and IDC. This section presents the method by which the HPST interpolates the IDC in the former case. The Basin Workbook includes a routine to estimate the IDC from a total investment cost. The formula is derived from a relationship between cost before IDC, IDC, and total cost as developed in MRC-BDP (2010g). The MRC-BDP Technical Note on Power Benefits presents an equation that approximates *IDC* with respect to the engineering procurement and construction, *EPC*, cost:

$$IDC = 0.5 * EPC * P * i$$

where:

P = construction period in years; and

i = interest rate.

In the context of the HPST, we reframe *EPC* as the financial capital costs, CC_F, and then express total investment costs, *TC*, as a function of capital costs and IDC:

$$TC = CC_F + IDC$$

These two equations can be used to derive IDC as a function of total investment costs, the construction period in years, and the interest rate. The following equation is obtained if the multiplier of 0.5 is turned into a constant *k*:

$$IDC = \frac{k * TC * P * i}{(1 + k * P * i)}$$

In the Srepok Basin case study, analysis of the one project for which IDC calculations were available yielded a constant, k, of value 0.385 to calibrate to the capital cost and IDC calculations in the project financial projections. This value is used in the HPST in place of the 0.5 value from MRC-BDP (2010g). For projects where only total investment costs were available, the calculated value for IDC can then be deducted from total investment costs to obtain the capital costs.

4.10 Financing

Loan and equity financing is included in the financial analysis in order to obtain the IDC and the interest payments, which are deductible as part of the tax calculations. The parameters included in the HPST, as shown in Table 12, can be entered for each country; however, the default values are the same for each country and are derived from figures provided during the Srepok Basin case study. As these figures do not affect the economic analysis at all and only affect the tax figures in the financial analysis, their precise magnitude is not of great importance. However, the terms can be adjusted by country or by project if so desired (see the HPST User Manual for the latter adjustment).

Table 12. Financing Parameters

PARAMETER	UNIT	General	Cambodia	Lao PDR	Thailand	Viet Nam
Project Finance						
Financing						
Equity Portion	%	30%	30%	30%	30%	30%
Loan Portion	%	70%	70%	70%	70%	70%
Loan						
Foreign Loan Portion	%	60%	60%	60%	60%	60%
Foreign Loan Interest Rate	%	8%	8%	8%	8%	8%
Foreign Loan Term	Yrs	15	15	15	15	15
Local Loan Portion	%	40%	40%	40%	40%	40%
Local Loan Interest Rate	%	13%	13%	13%	13%	13%
Local Loan Term	Yrs	15	15	15	15	15

5 Economic Valuation of Hydropower, Direct Impacts

5.1 Capital Costs

The economic figure for capital costs of a project, CC_E, is derived from the financial capital costs for the project. The only adjustments are to subtract the environmental and social mitigation costs, *E&S*, and adjust for any shadow pricing of the capital cost components (equipment, labour, etc.):

$$CC_E = \frac{(CC_F - E\&S)}{SC}$$

where

SC = is a shadow price factor for hydropower.

Review of hydropower project documents for the Srepok Basin case study did not reveal frequent use of a shadow price for capital costs. This is not surprising. Many of these documents were for privately financed dams and as such these documents are largely engineering studies and not economic cost-benefit analyses conducted to multilateral standards. An example of the latter is the case of the Song Bung 4 hydropower project (outside the LMB). For this project the ADB used a shadow price for foreign exchange in their appraisal (ADB 2008).

NOTE: Further review and investigation is recommended to assess whether it is reasonable to apply shadow price adjustments to hydropower projects in the LMB.

The default value for the shadow price factor in the HPST is 100%, so that no adjustment occurs.

With respect to the removal of the cost of environmental and social mitigation measures, the HPST takes this step in order to prepare for the inclusion of the costs of lost land and infrastructure, and the continued loss of livelihood post project. This is a different approach than the standard multilateral project cost-benefit analysis in which these costs are left in the analysis and it is assumed that "environment and social costs are fully internalized through the inclusion of mitigation costs" (ADB 2008, 16). It is worth pointing out that to do otherwise obviates the need for the Guidelines project. If all environmental and social costs are fully internalized by including the mitigation costs in the cost-benefit analysis then there is no need to value external costs and no need to incorporate environmental and social indicators into the analysis of the planning portfolio. As described earlier in the LMB literature review and as shown below under the assessment of external costs, it is quite clear that feasibility, design, and appraisal studies of hydropower dams in the LMB fail to not only include the full range and amount of these costs, but often fail to correctly conceptualize what these impacts are and how they impact ecosystems, people, and the economy.

5.2 O&M Costs

As discussed in the previous section, the derivation of O&M costs is quite crude and has little empirical basis. There is therefore little need to further adjust this figure in the economic analysis. So the financial figure for O&M costs is also used as the economic O&M figure.

5.3 Power Benefits

The primary purpose of developing hydropower projects in the LMB is for the generation of electrical power, with a two-part goal of transitioning away from imported fossil fuel dependency and improving and expanding access to electricity in the region. For many of the projects, the generated power will not support just domestic consumption, but will also be exported to other countries in the region. Viet Nam and Thailand have large and fast-growing middle-income economies and, thus, a continual need for additional generating capacity. Cambodia and Lao PDR are also growing, but from a less industrialized base. Furthermore, these two countries sit astride the Mekong and, thus, have access to the bulk of the Lower Mekong River's hydropower potential. As power generation is the primary objective of these projects and, therefore, their primary economic benefit the valuation of these benefits is an important topic. Unfortunately, as pointed out by Jenkins et al. (2011a), when it comes to electricity projects "one hardly ever sees attempts to measure the actual benefits that users receive from such projects. Yet paradoxically, we still say we are quantifying the value of such benefits." This section discusses the choice of valuation method, reviews the LMB literature, and then provides the economic prices attributed to power generation in the countries.

5.3.1 Valuation Methods: Choices, Criticisms and Considerations

The economic benefits of power generation are typically calculated using one of two methods:

1. Willingness to pay (WTP). The economic benefits are simply the quantity of power generated multiplied by the market price as measured by the willingness to pay for power. If power can be segmented into different periods of uses then there may be peak and non-peak prices.
2. Cost savings. The economic benefits are derived as the difference in costs between the hydropower project and the next best alternative, typically taken to be the standard thermal power alternative

The cost savings approach is complex to implement and therefore does not lend itself to the Guidelines intent of providing a "practical and replicable" method for evaluating hydropower projects. The willingness to pay approach is more straightforward. This difference in complexity is revealing and leads to a general characterization and criticism of each method.

The cost savings approach relies on a series of intertwined engineering and cost calculations and at the end of the process provides a fairly well defined value for the power generated. The WTP approach relies more on an understanding of the economy but does not in and of itself follow a prescribed path. It is more a matter of mounting an argument in favour of a particular observation about what WTP is in the particular circumstance. Thus the WTP approach is more practical and yet with that practicality comes less certainty about the selected value. The cost savings approach is not quick or easy and may not even be replicable (as power systems are constantly changing and fossil fuel prices are so volatile). While the numbers in any one case appear precise (no error to the calculations is usually assigned), there are many such calculations being carried out in support of many hydropower projects (i.e. in the LMB), all producing different numbers and there is no way to understand which number is the correct, best, or preferred number.

The costs savings approach is subject to the criticism of false precision due to its reliance on a host of engineering and cost factors and assumptions. The WTP approach is subject to the criticism that as with much in economics it is more art than science.

Perhaps as important, is that as with any two competing approaches to economic valuation, these two may result in differing estimates of power benefits. If this is the case then the choice of approach is non-trivial. Unfortunately, no global review of the evidence exists and, thus, there is no answer to the question of how critical the choice of approach may be in correctly understanding hydropower project economics.

The reason that this issue is worth mentioning is the great preponderance of benefit assessments undertaken by power engineers using the cost savings approach. This approach risks the issues associated with the replacement cost approach valuation in the ecosystem services literature (Ellis and Fisher 1987; Freeman 1991). For example, some analysts have used an engineered alternative to natural ecosystem function as the basis for deriving ecosystem benefits. The infrastructural alternative is costed and this figure is used as a proxy for the benefits. However, there is no clarity that the service would be part of the efficient, optimized production/consumption decisions at that price. Similarly, the cost savings approach in effect takes an engineered cost estimate and assumes that this represents the next best alternative or at least a feasible alternative, i.e., one that consumers would be willing to pay for the power at that price. The risk here is that the costed alternative is not really the next best alternative in an optimized least-cost and long-term power generation scenario. Rather it is simply an ad hoc calculation of the cost of an expensive alternative at that point in time.

Jenkins et al. (2011a, 2) allude to the risk inherent in this approach when they characterize the idea of pricing the value of a project in the absence of a standard alternative. In this case, with no other alternatives, the older plants would eventually wear out and generating capacity lessened leading to an ever-increasing price for the power produced by the project. The authors comment:

> One can almost say that cost-benefit analysis carried out under these assumptions would lose virtually all of its power to discriminate between good and bad projects. All would look good in the face of an ever-rising price of energy.

A similar conclusion could be reached if the standard alternative that is selected is an expensive thermal alternative, any other alternative – including any hydropower project – would show economic net benefits under such an approach.

Jenkins et al. (2011a, 3) go on to suggest the need to constrain the benefit estimate by ensuring that not only is the next best alternative selected but that the worth of the project is measured in the context of the future evolution of the power system:

> The image we have tried to conjure up here is that of a motion picture representing the costs and benefits attributable to plant E, not standing alone, but imbedded in a system which is being managed intelligently, with other plants being retired when their staying in the system would entail more cost than benefits, and with new plants being added in a pattern that reflects the continuing use of cost-benefit principles. All of this lies behind the development of our basic tool of analysis, the "moving picture" of how the system would operate in the presence of our project, i.e., "with" the project.

In this caricature of a power system the economic value according to the cost savings approach would be the difference between the "picture" of the system with the project and the system without the project. In strict terms then this net benefit could be contrasted with the net external costs and if the result were positive the project would be worthwhile in economic terms.

So for power systems with elaborate power system planning models that can conduct this type of engineering-economic analysis, the costs savings approach reduces to determining the least cost approach. The only question is how to incorporate the external costs. This leads to questions of whether or not the environmental and social costs can be reduced to monetary terms, whether or not they can be fully valued, and how this is correctly done (through costing "mitigation" or by estimating economic loses). The Guidelines approach implicitly accepts the recommendations of the World Commission on Dams (2000) that these external impacts are not reducible to just monetary estimates and that it is worth pulling these projects out of the power system model and subjecting them to a cost-benefit and a multi-criteria test.

Note that this is almost the same approach taken by the World Bank in its economic appraisal of Nam Theun 2 (World Bank 2005). The World Bank first examined whether or not the hydropower project fit into the least cost power scenario and then it undertook a separate cost-benefit analysis of the project. For the latter though they used the WTP approach to value the benefits of the power produced.

The WTP approach suffers from its own difficulties, including how to arrive at price of power. In theory the figure would be the market price for wholesale power. However, there is often no such market, rather there is a single buyer, or monopsony, at the wholesale level. It is not until power is distributed that consumer demand drives market conditions. Yet even this demand may be affected by the natural monopoly that is power distribution. So the retail price may be subsidized as government attempts to keep prices to consumers for basic needs low. In addition, tiered rate structures may make estimation of a single willingness to pay figure difficult.

For the purposes of the Guidelines, implementing the cost savings approach in its full detail is impractical. The willingness to pay approach is a practical and replicable approach but necessitates a number of assumptions to reach a figure for each country. Below, examples from the literature are reviewed before the prices deployed in the HPST are summarized.

5.3.2 LMB Dams Literature Review

Nam Theun 2: World Bank (2005). The World Bank conducted an analysis of the Nam Theun 2 project to assess whether or not the project would be a) the least-cost choice for electricity supply; and b) economically viable. For the least-cost analysis, the Bank compared the cost of power generation for Nam Theun 2 and four other sources (i.e. oil, coal, gas turbines and combined cycle gas turbines).

Two risk analyses (one using economic values and one using commercial values) were conducted to test the assumptions used in the analysis most likely to affect the results: Nam Theun 2 project costs, demand forecast for electricity and the price of natural gas. For each of these, a low-, base- and high-case scenario was created and assessed.

Because Nam Theun 2 was estimated to be the least-cost option (see data section below), the study then estimated the economic rate of return (ERR) for the project. This analysis explicitly included the environmental and social values as assessed by Laplante (2005). Assumptions for estimating the economic rate of return are included in Table 13. For the economic analysis, the Bank relied not on the costs savings but on the willingness to pay for power in the two countries involved. The Bank used USD 0.07/kWh for Thailand and USD 0.06/kWh for Lao PDR.

Table 13.Summary of ERR Assumptions

Assumption	Value
Thai willingness to pay (price component)	USD 0.07/kWh primary energy USD 0.023/kWh secondary energy
Lao willingness to pay (price component)	USD 0.06/kWh
Thai and Lao system losses	7.1% and 16.9%, respectively
Real economic Nam Theun 2 project cost	USD 1,005.4 million
Present value of E&S costs paid by project	USD 63.8 million
Present value of estimated economic E&S impacts	USD 54.7 million
THB value loss	275 GWh at USD 0.023/kWh
Sub-transmission and distribution costs	Thailand USD 0.0104/kWh; Lao PDR USD 0.044/kWh

As with the least-cost analysis, the sensitivity of the analysis to key assumptions was tested to evaluate how the ERR would fare under more negative assumptions than the base scenarios assumes. For example, project delays, increased project costs, low demand for electricity and atypical hydrological conditions were all tested alone and in various combinations.

Mainstream Dams: Hall and Leebouapao (2005). The authors pursued the potential economic benefits of hydropower for the mainstream dams by first estimating WTP for electricity and then subtracting the marginal cost of generating, transmitting and distributing hydropower to relevant markets. In order to derive estimates using these methods, the following (hydropower project specific) information would be needed:

- Average economic generation costs (USD/kWh)
- Average transmission and distribution costs (USD/kWh)

With regard to the latter they select 45% of the economic generation costs as the marginal cost of transmission and distribution in Lao PDR, based on data from Nam Theun 2.

For WTP estimates, Hall and Leebouapao (2005:34) chose to create a composite WTP 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".

As the study was never finished the WTP

Mainstream Dams: ICEM (2010c). Potential hydropower benefits were estimated at the country level using costs savings approach. For countries where hydropower projects are located (e.g. Lao PDR), net annual benefits were estimated as the total of benefits from domestic power supply and exports minus the annual project costs. Benefits to countries importing power (e.g. Thailand) were estimated as the difference between replacement value and the cost of importing hydropower.

The results suggested:

- Annual benefits from mainstream dams were estimated to be USD 3–4 billion.
- Lao PDR would receive ~70% of these benefits, with Thailand, Cambodia and Viet Nam receiving ~11%, 11%, and 5%, respectively.

Basin Development Plan: (MRC-BDP 2010g). In the Technical Note on Power Benefits, the cost savings methods is proposed to value hydropower benefits. More specifically, in order to capture the value associated with both energy and capacity components of supply, a monomic function was used. In order to capture the potential for changes in fuel prices over the study time frame, prices were updated to account for both inflation and the expected rate of price increase. Investment costs, annual variable costs and annual fixed costs were all included in the calculations (MRC-BDP 2010g, 6–8).

The least cost alternative determined in this report was a thermal plant using fossil fuel, ideally using combined cycle technology; however, this technology a) may not be available in all LMB countries; and b) even if it is available, may not be able to generate power to match demand. Table 14 details the likely breakdown of power replacement by country if hydropower were not available. The financial analysis assessed the differences in rate of return on equity between a) committed projects and proposed projects; and b) mainstream and tributary projects.

Table 14.Summary of Power Replacement Options: MRC Basin Development Plan

Generation Technology	Cost USD/ kWh	Use of generation technology (%) Lao PDR	Thailand	Cambodia	Viet Nam
High or medium speed diesel units using diesel oil	0.3523	30%		50%	
Low speed diesel units using bunker oil	0.160	20%			
Combined cycle units using natural gas	0.0964		60%		
Steam turbine units using coal	0.073	50%	40%	50%	100%
Monomic replacement cost of power (USD/MWh) at 70% system load factor		0.1742	0.0871	0.2126	0.0730

Source: MRC-BDP (2010g)

It is of note that the average rate of return was 49.5% and 7.0% for committed and proposed projects, respectively. Furthermore, only 46% of new projects were estimated to have a rate of return above 10%, as compared to 67% of committed projects. Furthermore, a comparison of rates of return for mainstream and tributary projects showed that the average financial performance was 13% and 5.7% for mainstream and tributary projects, respectively (2010g).

In the final Basin Development Plan, net present value estimates for the benefits of hydropower generation were included by scenario. For the Definite Future scenario, the NPV of hydropower was estimated to be USD 11.5 billion or 98% of total estimated benefits for this scenario (MRC-BDP 2011). Similarly, the NPV of hydropower under the 20-Year and Long Term Very High Development scenarios were estimated at USD 32.8 billion and USD 38.8 billion respectively. Under the latter scenario, hydropower generation benefits only represent 71% of total benefits.

5.3.3 Additional Literature

In the financial analysis we found that the price paid to producers or power was lowest in Thailand, and then increased, largely in line with country GDP per capita in the following order, Viet Nam, Lao PDR and Cambodia. Other things equal the expectation is that the same order will prevail in terms of economic prices and WTP. In a regional study of the Greater Mekong System ICEM (2013) provided an interesting table of data from the Asian Development Bank. The table shows that as expected Thailand has the lowest import tariff and Cambodia the highest import tariff. On the export side, Cambodia has no exports and Lao PDR has the lowest export tariff followed by Vietnam and Thailand. Economists often use international prices as indicative of economic values. In this case there is no regional power grid so these prices are not reflective of competitive market prices. Rather, the data may be useful as ad hoc commentary on the balance of supply and demand in each country.

Table 15. Average Import and Export Tariffs

(USD/kWh)	Average Import Tariff	Average Export Tariff
Thailand	0.048	0.073
Viet Nam	0.051	0.061
Lao PDR	0.063	0.048
Cambodia	0.077	n/a

A more specific data point of interest comes from a 2011 presentation by a member of Thailand's Energy Regulatory Commission. In this presentation the cost structure of Thailand's power sector is presented. Based on the tariffs at the time the cost of transmission and distribution as a percentage of the total average tariff is 22% (Ruangrong 2012). In other words the cost of transmission and distribution as a percentage of generation costs is 28% (22% divided by 78%). This can be compared with the 45% that Hall and Leebouapao (2005) found for Lao PDR. Again there is economic logic in this ordering as one reason that power costs more in Lao PDR than Thailand is the efficiency of transmission and distribution facilities

5.4 HPST Valuation

The approach taken here is that recommended by Hall and Leebouapao (2005), that is to take the WTP and adjust it for transmission and distribution in order to find a net WTP for power generation. The WTP is taken as the current retail price or customer tariff, net of any taxes such as VAT. These figures are presented in Table 16. The WTP prices come from ISH02 national consultants and Suryadi (2014).

Table 16. Average Tariffs Net of VAT

	WTP (USD/kWh)	VAT	WTP ex-VAT (USD/kWh)
Thailand	0.090	7%	0.084
Viet Nam	0.092	10%	0.084
Lao PDR	0.081	10%	0.074
Cambodia	0.177	10%	0.161

The next step is to adjust the ex-VAT prices for the transmission and distribution costs. Using the relationship for the two data points available, 22% for Thailand and 45% for Lao, and using electric power consumption per capita in each country as a proxy for the likely efficiency of the power sector we derive the transmission and distribution costs for Viet Nam and Cambodia. These figures are then applied to derive the WTP net of transmission and distribution.

Table 17. Net WTP for Power

	WTP ex-VAT (USD/kWh)	Consumption (kWh/capita)	T&D Costs	Net WTP (USD/kWh)
Thailand	0.084	2500	22%	0.066
Viet Nam	0.084	1113	37%	0.053
Lao PDR	0.074	353	45%	0.041
Cambodia	0.161	166	47%	0.085

Note that as expected Cambodia, with a high un-served population, limited power generation capability, and no national grid comes out with the highest net WTP for power. Thailand with large, growing demand but a well-developed power sector has a lower net WTP. Viet Nam has a lower net WTP than Thailand. This is due to the rather high transmission and distribution cost factor. Another reason why the Viet Nam number may be low is that the sector is still moving through a process of deregulation and retail prices may still be subsidized. Note however, that the net WTP does lie within the range of the import and export prices. So the figure for Viet Nam is probably low but is not unsupported. The net WTP for Lao PDR is the lowest of all. Note that the retail price was also low. This may be due to government subsidies in an underdeveloped sector, but it may also be due to an abundance of hydropower due to rapid development of the sector. While most of this is for export a portion of each project is destined for the local market.

There is a risk that the procedure above may overstate the transmission and distribution costs. The figure for Thailand is robust as it comes from a set of comprehensive figures from the Energy Regulatory Commission (Ruangrong 2012). The figure for Lao PDR, which comes from the incomplete study by Hall and Leebouapao (2005), appears more of a rough estimate rather than the result of a comprehensive analysis of system-wide data. For this reason the final step in arriving at an economic price for power is to compare the net WTP figures with the HPST financial price developed earlier. There seems little rationale for the economic price of power to be less than the financial price. So, if the net WTP is more than the financial price the net WTP figure is used. If the net WTP is less than the net WTP figure then the financial price is used. This results in a much higher economic price for Lao PDR and a slightly higher price for Cambodia. It seems that the estimate for Lao PDR of transmission and distribution share in the total system costs is probably over-estimated.

Table 18. HPST Values for Economic Price of Power

	Net WTP (USD/kWh)	HPST Financial Price (USD/kWh)	HPST Economic Price (USD/kWh)
Thailand	0.066	0.040	0.066
Viet Nam	0.053	0.045	0.053
Lao PDR	0.041	0.065	0.065
Cambodia	0.085	0.095	0.095

5.5 Power: Transfer of Storage Benefits

For the economic analysis an effort is also made to address the issue of interdependent hydropower facilities. Whether designed in cascade or merely incidentally in cascade, an upstream annual storage facility in the seasonally dry LMB will generate benefits from storage for that facility and those downstream. In the HPST, dry season power generation at a downstream facility that is due to wet season storage in an upstream facility may be deducted from the generating facility and transferred to the upstream facility. The benefit transfer of generation, G_t, in GWh/yr from a downstream facility to an upstream facility is calculated as:

$$G_t = \frac{S_{live} * P_{installed}}{Q_{max}}$$

where:

S_{live} = Live storage of the upstream storage reservoir in million m^3

$P_{installed}$ = Installed capacity of the downstream hydropower project in MW

Q_{max} = Maximum turbine discharge of the downstream hydropower project in m^3/s

NOTE: Further review and investigation is recommended to assess whether the approach to transferring power benefits is applicable in a given situation and whether it should be deployed or not in the HPST.

6 Economic Valuation of Direct Impacts: Multi-Purpose Components

6.1 Irrigated Agriculture

Agriculture is a key sector of the LMB economy. It is estimated that over 40% of LMB land area is devoted to agriculture and that a majority of the region's population depends on agriculture for their livelihood (MRC 2011). Irrigated agriculture, primarily rice production, is the largest user of water in the LMB and diverts approximately 10% of mean annual flow for the entire basin (Hall and Leebouapao (Hall and Leebouapao 2005). In addition to rice, other irrigated crops include vegetables, maize, and soybeans.

Even so, lack of availability of water is still considered a limitation of improving crop yields (Hall and Leebouapao 2005). Increased regulation and storage of water associated with hydropower development, as well as the development of irrigation projects to transfer additional water supply, likely could lead to both increased productivity of some existing lands (e.g. in the form of a second crop per year) as well as the opportunity to develop new areas for agriculture.

6.1.1 LMB Dams Literature Review

Methods

The methods used to assess the value of irrigated agriculture were similar across the studies reviewed. They can be described as follows:

- Obtain total area used for irrigated agriculture (ha) by crop type.
- Determine number of crops per year by crop type.
- Estimate yield by crop type (t/ha/crop).
- Estimate price (USD/kg).
- Estimate gross value by multiplying yield by price by crop type.
- Estimate production costs per crop or per hectare.
- Estimate net value by subtracting production costs from gross value.

Data

- Maunsell and Lahmeyer (2004) used the following assumptions in their study:
    - Rice yield: cultivated paddy - 2.5t/ha/crop/year; hill rice land – 1.5t/ha/crop/year
    - Local value of rice: USD 160/t
- Laplante (2005) used the following assumptions for estimating the value of irrigated agriculture (both baseline and additional increases):
    - Rice yield: 3.5t/ha/crop/year
    - Price: USD 0.10/kg
    - Production costs: USD 130/crop (fertiliser: USD 70; ploughing: USD 30; electricity: USD 30)
- Hall and Leebouapao (2005) assumed production costs were 85% of farm gate price for irrigated crops and 75% for fruits and vegetables.
- The ICEM Baseline Assessment provided detailed estimates of agricultural production in the LMB (see Table 19); however, it is not clear whether or not the paddy area estimates are for irrigated agriculture only (ICEM 2010a). Furthermore, the area considered is only a 100 m corridor centred on the Mekong River. Finally, note that the study assumed a rice price of USD 0.2/kg.

Table 19. Summary of LMB Riparian Agricultural Production

	Chine to Chiang Saen	Chiang Saen to Vientiane	Vientiane to Pakse	Pakse to Kratie	Kratie to Phnom Penh and Tonle Sap	Phnom Penh to the sea
Paddy area (km$^{2)}$	500	3,655	22,916	1,625	13,910	19,810
Yield (t/ha/yr)	1.0	2.0	3.5	2.6	2.6	5.0
Production (t/yr)	50,022	731,019	8,020,710	422,666	3,616,666	9,905,024
Value (USD million)	10.0	146.2	1,604.1	84.5	723.3	1,981.0

Results

- ICEM (2010a) estimated a gain of 17,866 ha of irrigated paddy in the 100 m corridor if all mainstream dams are developed. This equated to 77,701 tonnes of rice/year with an estimated value of USD 15.54 million. Using these estimates, we can derive that the study assumed a yield of 4.3 tonnes/ha/year.
- BDP Technical Note 7 included detailed estimates of irrigated areas by scenario. We include estimates for the Definite Future Scenario (DFS) and the 20-Year scenario in Table 20 (MRC-BDP 2010a). Note that from these estimates, one can derive the incremental increase in irrigated area.

Table 20. Estimated Rice and On-rice Irrigation Areas (hectares)

	Country	Irrigable area	1st season area	2nd season area	3rd season area	Non-rice crop area	Annual irrigated area
DFS	Lao PDR	166,476	166,476	97,224	—	6,977	270,677
	Thailand	1,411,807	1,354,804	148,255	—	252,704	1,755,763
	Cambodia	504,245	273,337	260,815	16,713	12,172	563,037
	Viet Nam	1,919,623	1,669,909	739,594	1,478,740	329,740	4,217,983
	Total	4,002,151	3,464,526	1,245,888	1,495,453	601,593	6,807,460
20-year	Lao PDR	451,296	449,595	329,952	—	40,046	819,593
	Thailand	2,718,480	2,635,477	427,741	—	560,784	3,624,002
	Cambodia	778,488	456,828	378,917	21,594	19,897	877,218
	Viet Nam	2,044,780	1,794,801	739,594	1,487,740	391,311	4,404,445
	Total	5,993,044	5,336,701	1,876,204	1,500,334	1,012,020	9,725,258

- The estimates in Table 20 are based on a number of assumptions including changes in crop gross margin and yield that occur between the DFS and the 20-year plan (Table 21).

Table 21. Rice Crop Tolerance and Yield Potential as Influence by Salinity

Country	Current yield (t/ha)		Simulated yield for 2030 (t/ha)	
	Rainfed	Rainfed w/ irrigation (1st crop)	Rainfed	Rainfed w/ irrigation (1st crop)
Lao PDR	2.3	2.8	3.6	4.4
Thailand	2.3	2.8	3.6	4.4
Cambodia	2.3	2.7	3.4	4.2
Viet Nam	—	2.8	—	5.3
	Dry season (2nd crop)	3rd season	Dry season (2nd crop)	3rd season
Lao PDR	3.8	—	5.9	—
Thailand	3.9	3.6	6.1	5.4
Cambodia	3.1	—	4.9	—
Viet Nam	5.3	5.2	7.5	7.0

- BDP Technical Note 7 included value estimates (see Table 22), which were used to calculate the value of irrigated land based on output (MRC-BDP 2010a).

Table 22. Value of Agricultural Outputs (USD/kg)

Country	Rice (high quality)	Rice (normal)	Maize
Lao PDR	0.25	0.19	0.18
Thailand	0.25	0.19	0.19
Cambodia	0.25	0.19	0.19
Viet Nam	0.22	0.19	0.19

- BDP Technical Note 12 estimated the country-specific benefits of increases to irrigated agriculture under all scenarios. We include the 20-year estimates in Table 23 as an example (MRC-BDP 2010h).

Table 23. Estimated NPV of Increased to Irrigated Agriculture – 20-year Scenario

Country	NPV (USD millions)
Lao PDR	322
Thailand	885
Cambodia	344
Viet Nam	108
Total	1,659

6.1.2 HPST Valuation

The approach taken in the HPST for estimating direct irrigation benefits is as follows:

- Estimate the capital costs and time (i.e. years of construction) required to develop irrigation component of hydropower project.
- Estimate the annual O&M costs of irrigation project.
- Estimate the number of hectares that will benefit from the project.
- Estimate the annual net benefit per hectare (i.e. units produced per hectare multiplied by price per unit minus costs of production). Multiply by total number of hectares in the irrigation project.
- Subtract estimated annual costs (capital and O&M) from benefits.
- Calculate NPV.

Unfortunately, the Srepok Basin case study did not involve any irrigation facilities so the HPST is set up for these calculations, along with a default general parameter for the economic value from agriculture for all countries of USD 1,000/ha.

6.1.3 Direction for Future Work and Additional Research

Valuing the direct benefits of irrigation schemes associated with hydropower projects requires understanding the costs and benefits of crop production, both in terms of new, year round production and the potential addition of a second crop during the dry season on existing cropland. The information currently in hand does not clearly distinguish these two sets of costs and benefits, or between farm economics in each LMB country but additional research should provide such information.

Such estimates could then be used alongside projections of the irrigable area to be developed under those hydropower projects with irrigation potential. At present, this potential remains somewhat unclear as a defined set of irrigation opportunities associated with each proposed hydropower dam has not been found.

A further difficulty with respect to all irrigation development projects is how to understand the cost of developing the infrastructure for conveying, storing and managing the delivery of water to irrigators. These costs can vary substantially with the size, distance and relative elevation of irrigation projects.

With this in mind, additional work on this topic may include:

- Literature review and consultations with agricultural economists in each country to establish the capital costs and operational costs and benefits of developing new paddy production.
- Literature review and consultations to establish the operational costs and benefits of adding a second crop per year.
- Development of a simple engineering model to project irrigation development costs.
- Further research to establish likely irrigation potential of proposed hydropower projects.

6.2 Water Supply

This section covers water supply for domestic and industrial purposes.

6.2.1 LMB Dams Literature Review

Hall and Leebouapao (2005) calculated the net benefits of water supply as quantity of water demanded/supplied times the net benefit per unit (price minus cost). The authors note that the price could be derived in a variety of ways: minimal WTP could be estimated from tariff paid to access municipal water system; or considered the opportunity cost of carrying water from the river. For the purposes of their study, they assumed a price of USD 0.14/m^3 and a cost of provisioning water of USD 0.05/m^3. This cost was based on estimates for municipal systems.

Hall and Leebouapao (2005) also estimated basic water requirements by country (litres per capita per day): Cambodia at 100, Lao PDR and Viet Nam at 150 and Thailand at 200. They also estimated the current net value of Mekong River water for domestic and industrial use to be approximately USD 175 million/year.

Other studies provided the following figures:

- Maunsell and Lahmeyer (2004) used a "local water value" of USD 4/m^3.
- MRC-BDP (2005) cites a 2004 ADB study that provides M&I tariff and cost data as follows:
    - Cambodia (Phnom Penh): tariff of USD 0.244/m^3 and cost of USD 0.082/m^3
    - Lao PDR (Vientiane): tariff of USD 0.042/m^3 and cost of USD 0.033/m^3
    - Viet Nam (Ho Chi Minh City): tariff of USD 0183/m^3 and cost of USD 0.128/m^3

6.2.2 HPST Valuation

The approach taken in the HPST for estimating water supply is as follows:

- Estimate the capital costs and time (i.e. years of construction) required to develop water supply component of hydropower project.
- Estimate the annual O&M costs.
- Estimate the increase in water supply resulting from the project.

- Estimate the value per unit (i.e. price or willingness-to-pay. Multiply this value by the number of units supplied by the project.
- Subtract estimated annual costs (capital and O&M) from benefits.
- Calculate NPV.

Unfortunately, the Srepok Basin case study did not involve any water supply facilities so the HPST is set up for these calculations but requires the project data listed above to be implemented. Placeholder values for the value of water supply are entered as USD/m^3 for each country based on information supplied by ISH02 national consultants. Additional values can be added, or existing values updated, as needed on the Parameter Tab of the HPST (see Table 24).

Table 24. HPST Water Supply Values

PARAMETER	UNIT	General	Cambodia	Lao PDR	Thailand	Viet Nam
Economic Analysis						
Value-Water Supply	USD/m^3			0.18	0.30	

6.2.3 Direction for Future Work and Additional Research

Valuing the direct benefits of water supply associated with multi-purpose projects requires a clear understanding at the country level of current and likely future water demand as well a per unit operational costs and benefits (i.e. sale price or willingness-to-pay).

With this in mind, additional work on this topic may include:

- Literature review and consultations in each country to establish the capital costs and operational costs and benefits of existing water supply facilities.
- Literature review to establish differences between current demand/supply and likely future demand/supply for each country.
- Further research to establish likely water supply potential of proposed hydropower projects.

6.3 Reservoir Fisheries

The reservoirs created by the hydropower projects may provide potential for additional capture and culture fishery opportunities. Among the studies reviewed, the potential for reservoir fisheries are collectively viewed as a benefit of hydropower development. It is important to note that while both production and capture are likely to “increase” due to the reservoir area made available for fish habitat, this is a gross gain in value. The net change in value emerges only when the impacts on the upstream and downstream fishery are included, that is the loss of existing habitat due to inundation, and the potential obstruction of fish passage and change in other related factors in fish production due to dam construction. These latter impacts are discussed further under the external impacts section.

6.3.1 LMB Dams Literature Review

Methods

While multiple documents included quantitative estimates and/or values, only one of the documents reviewed contained specific methods for estimating the value of potential reservoir fisheries. In Technical Note 2 for the BDP scenarios (MRC-BDP 2009), methods were outlined that were presumably the basis for the estimates included in the BDP Main Report (MRC-BDP 2011). First, a fisheries specialist estimated annual production of reservoir fish. This was combined with estimates of fisheries’ development in the reservoirs over a 20-year period. To estimate the economic value of potential reservoir fisheries, current market prices were adjusted using an economic conversion factor. In order to estimate net benefits, production and marketing costs were also estimated and subtracted from the gross value estimates. The NPV of potential reservoir fisheries were then estimated over a 50-year time frame for various development scenarios.

Data

Useful data and estimates compiled from the literature include:

- BDP Technical Note 11 estimated harvest of 200 kg/ha/year as the best-case scenario for large reservoirs and 300 kg/ha/year for small irrigation reservoirs. Similarly, it estimated worst-case scenarios of 50 kg/ha/year and 100 kg/ha/year for large and small reservoirs, respectively. For all dams, it estimated a range of 16-64 t/year in additional harvest from reservoirs (MRC-BDP 2010e).
- The BDP Main Report estimated current fisheries harvest from permanent surface water to be 226,000 tonnes/year (MRC-BDP 2011). The study stated that 'permanent surface water' is primarily reservoirs, but that the exact proportion is not known; however, new estimates other than the baseline were for reservoirs only (see below).

Results

- BDP Technical Note 13 estimated a total LMB annual harvest from reservoir fisheries of 15,141 tonnes, with an associated NPV of USD 91 million, in the Definite Future Scenario. Lao PDR was estimated to have 81% of these harvests. As a point of comparison, under the 20-year plan, annual LMB reservoir fisheries harvest was estimated to be 64,431 tonnes, with a NPV of USD 215 million (MRC-BDP 2010b).
- The ICEM study estimated that with all 12 mainstream dams in place, annual reservoir production from just the mainstream reservoirs would range from 10,000 – 30,000 tonnes and have a value of USD 14 – 42 million/year. In addition, it estimated that 25,000 – 25,0000 tonnes (with a most likely gain of 63,000 tonnes) could be harvested from the rest of the LMB reservoirs (ICEM 2010c)
- The ICEM study used an estimate of USD 0.68/kg (2002 value) for the value of reservoir fisheries – the same as they used for river capture fisheries (ICEM 2010a).

6.3.2 HPST Valuation

The approach taken in the HPST for estimating reservoir fisheries benefits is as follows:

- Estimate the capital costs and time (i.e. years of construction) required to develop a producing fishery in the reservoir associated with a specific hydropower project.
- Estimate the annual O&M costs of maintaining the fishery.
- Estimate the number of hectares in the reservoir as well as the expected annual yield per hectare.
- Establish likely species to be harvested from reservoirs and their market value.
- Estimate annual costs of fishing (i.e. boat maintenance, fishing gear, etc.)
- Estimate the annual net benefit per hectare (i.e. units produced per hectare multiplied by price minus the annual costs of fishing)
- Subtract estimated annual costs (capital and O&M) from benefits.
- Calculate NPV.

Unfortunately, the Srepok Basin case study did not involve any reported reservoir fisheries projects. So the HPST is set up for these calculations but requires the project data listed above to be implemented. The value per ton of fish that is deployed in the reservoir fisheries is the same average price as deployed for downstream fisheries impacts, as described further in Section 9. A value of 50 t/ha is entered as a placeholder as a general parameter for the productivity of reservoir fisheries in the LMB. This is the low end of estimates from MRC-BDP (2010e). However, in the case of the Srepok Basin case study a figure of 10 t/ha is used based on the almost total lack of fishing activity in the five reservoirs visited on the case study visit and the absence of any cost information on fishery management.

6.3.3 Direction for Future Work and Additional Research

The value of reservoir fisheries associated with proposed hydropower dams can be derived using a modified version of the methodology described above.

- Obtain estimates of potential reservoir yield per annum (t/ha/year).
- Obtain estimates of the estimated increase in reservoir area likely to have conditions favourable for fishery development (ha).
- Estimate potential per annum harvest for reservoir fisheries (t/year).
- Obtain current market value estimates for relevant species (USD/t). Consider substitute good availability in the future (e.g. decrease in capture fishery harvest) and potential for inflation.
- Adjust market price accordingly using an economic conversion factor.

In order to carry out such calculations the following research and information would be needed:

- Additional literature review and consultations with fisheries specialists in each country to determine yield estimates by reservoir type and current market prices. If possible, the latter would be assessed relative to historical trends to determine if adjustments are needed for the purpose of analysing future scenarios.
- Literature review and consultations to determine what initial capital investment and ongoing operational costs may be required to establish reservoir fisheries and/or harvest operations as well as the likelihood that such investments would occur.
- Development of a simple model based on the methods above to project net and gross revenue

6.4 Flood Control

Greater regulation of river flows, as a result of hydropower dams, likely will help mitigate flooding during the wet season. Likely benefits associated with improved flood control are both direct (e.g. decreases in property & infrastructure damage, lower crop losses) and indirect (e.g. decreased risk of wage loss and relocation) (MRC-BDP 2009). It should be noted that there are a series of positive and negative impacts with changes in the hydrologic regime due to tributary and mainstream dams in the LMB. These indirect costs and benefits are discussed later in the section on hydrologic impacts; this particular section focuses only on the potential multi-purpose benefits of hydropower projects designed to also provide flood control benefits.

6.4.1 LMB Dams Literature Review

Methods

Hall and Leebouapao (2005) present a partial model for estimating flood control benefits to households associated with a particular development scenario; however, it appears the model may not have been completed in the draft available for review. Furthermore, the authors noted that data limitations prevented them from including damages to commercial, industrial and public infrastructure and future income losses associated with long-term damages from flooding (Hall and Leebouapao 2005).

BDP Technical Note 2 also included general methods for estimating the value of improved flood control and the reduction in losses and damage associated with it (MRC-BDP 2009, Annex 4:11). A simplified summary of their approach is presented here:

- Estimate baseline data: total flooded area during an average, a dry and a wet year; flood duration during an average, a dry and a wet year; flood depth during an average, a dry and a wet year.
- Identify and estimate total area of land (ha) benefitting from flood risk reduction. The study notes that the "The key indicators for the decrease in damage by floods are the average area flooded annually to maximum of 0.5-0.9m depth and the average area flooded annually to greater than 0.9m." BDP Technical Note 2 (MRC 2010: Annex 4:11) Changes are then assessed relative to the baseline values for each category. It should be noted that the key indicators used in the BDC main report differed, with the two categories considered being max 1.0 m depth and max greater than 1.0m depth.
- For relevant areas, gather information on households, villages, infrastructure and land use.
- Apply annual economic value data for direct and indirect benefits of flood risk reduction to population and land use data for each relevant area. The economic value data was obtained from the FMMP-C2, Stage 1 Evaluation Report (2008). As an alternative, the study also suggested that historic damage and loss data from flood events could also be used.

Data/Results

- The BDP main report estimated both flood damages and flood damage mitigation by country for each scenario considered (MRC-BDP 2011). The baseline data as well as the data for the Definite Future Scenario are included here in Table 25 as examples.

Table 25. Estimated Benefits of Flood Control

	Lao PDR	Thailand	Cambodia	Viet Nam	Total
Baseline					
Flood damages (USD m/yr)	70	67	26	56	219
DFS					
Flood damages (USD m/yr)	28	27	8	9	72
Flood damage mitigation (USD m)	179	172	51	60	462

6.4.2 HPST Valuation

Flood control was not an explicit objective of the facilities investigated in the Srepok Basin case study and thus flood control is not included in the HPST. Future applications may wish to explore this function and incorporate it explicitly in the future.

6.5 Navigation

Water transport was historically and continues to be an important form of transport in the LMB. At least four key categories of users can be identified: subsistence users, passenger transport, cruises and freight transport. According to ICEM (2010c), the Mekong Delta likely has the highest use of water transport with approximately 70% of goods being transported by water.

Across these categories of users, the potential navigational changes associated with hydropower development are generally positive; however, it should be noted that potential losses could occur for small boat/subsistence users.

6.5.1 LMB Dams Literature Review

Methods

Multiple studies put forward methods for estimating the value of improved navigation; however, the authors noted several methodological concerns.

A general concern noted is that the relationship between flow levels and water transport – or more specifically, total volume and unit cost – is not clearly defined (Hall and Leebouapao 2005; MRC-BDP 2010b). The installation of hydropower dams is projected to increase the river system's number of navigable days during the dry season due to increased flow and depth however, the availability of additional transport days for larger vessels does not necessarily result in their use. A second, related, concern is the lack of data for all major transport modes (water and alternative land-based transport options) at the intra-country level.

Hall and Leebouapao (2005) suggested several options for estimating the value of water trade and transport in the Mekong: a) estimating cost savings over the next best alternative mode of transport; b) willingness-to-pay for water transport; and c) the method they ultimately use in their model, a yes/no decision when flow levels critical to current navigation are reached.

MRC-BDP Technical Note 13, which was completed later than the Hall and Leebouapao study, had access to new information from a study completed by the Navigation Programme (NP) in 2008. Using that data, BDP Technical Note 13 chose to focus on the most active transport reach of the Mekong, namely between Thailand (Chiang Saen) and Yunnan (Guanlei) (MRC-BDP 2010b).

For that reach, first-cut estimates were calculated based on the following methods:

> Based on the minimum safe draft requirements for different types of vessel, as well as data from the hydrological assessment, estimates were made of the number of days per annum the river systems is likely to be navigable for both the present situation and in the future when the UMB and LMB dams are operational. The increase in the number of days of navigation was then converted into an economic benefit by estimating the annual value of inland water transport (IWT) cargo trade in both the "future with" and "future without" dams situations over 50 years. The incremental net benefit stream was then be used to estimate the NPV of navigation benefits (MRC-BDP 2010b, 17).

Data

Useful data and estimates compiled from the literature include:

- ICEM (2010a) included baseline estimated of direct and indirect values associated with navigation and river transport, USD 4.6 million and USD 11.2 million, respectively. Potential impacts were only discussed qualitatively, with mixed findings of potential benefits to larger vessels and potential costs to subsistence/smaller boat users.

Results

- The BDP Main Report estimated the NPV of improved navigation to be USD 64 million for all scenarios considered (MRC-BDP 2011). It should be noted that from a distributional perspective, all of these benefits accrue to Thailand.
- As the finding above suggests, BDP Technical Note 13 found that no scenario with greater development than the Definite Future Scenario resulted in a significant increase in the number of navigable days (MRC-BDP 2010b)

6.5.2 HPST Valuation

Due to a) the general lack of detailed data on the subject, b) the lack of data on substitute transport options within each country; c) the uncertainty around whether an increase in the availability of additional transport days for larger vessels would result in their use; and d) the potentially disparate impacts on large versus small boat users, potential impacts to navigations are not currently included in the HPST. In addition, navigation did not feature in the Srepok Basin case study. However, all of the existing and proposed dams reviewed in the study had not fish or boat passage of any kind and therefore would likely have only external costs associated with the loss of river navigation.

7 Economic Valuation of "Local" External Impacts: Human Populations

So-called "local" impacts in the Guidelines are disaggregated into impacts on human populations and on inundated lands. Due to questions of feasibility and appropriateness the HPST does not attempt to value impacts on culture and health in monetary terms. These are accounted for through the social indicators. The approach taken in the economic valuation is to assess the economic costs of dam construction, the resulting inundation of formerly productive lands and the associated displacement and dislocation of populations. Absent the immediate health impacts the HPST attempts to break down these impacts into the immediate damage caused by displacement into the costs of lost infrastructure and lost lands. Beyond the loss of these productive assets local communities displaced by hydropower projects face the further risk of future dislocation and continued impairment of earning potential.

Actual resettlement costs are not included here as these are financial transfers made by the project. The real economic external costs of displacement are the lost, productive assets that were generating community income and were a store of community wealth, plus the potential on-going dislocation, i.e., the loss of livelihoods (and health outcomes, though these are not included here) into the future. It may be that social mitigation expenditures may address these external costs. However, as a planning model, the HPST does not expect that such detailed work has been undertaken at this stage. Further, the actual ability of mitigation expenditures to fully offset the losses experienced by displaced persons is not well established. The HPST, therefore, estimates only the first round losses that would result from the hydropower or multi-purpose facility. The HPST therefore does not include the benefits that such mitigation expenditures would create for local communities.

Note that at present the HPST does not account for external impacts on other non-displaced but affected peoples. The costs portrayed here thus will understate the local costs. The impacts on other project affected peoples are included in the HPST through the social indicators.

7.1 Culture

Individuals, communities and regions of great ethnic and cultural diversity populate the LMB region, including a strong indigenous presence. For many of these groups, the Mekong River, its tributaries, and its resources play not only an important role in their sustenance and livelihoods, but also have historical, religious, mythical and cultural values. On a more global level, the area is of significant archaeological value, due to the number of historical sites still in existence.

Hydropower development has the potential to affect culture in a variety of ways: loss of culturally important sites, loss of historically important sites, and decreased access to traditional foods, among others.

7.1.1 LMB Dams Literature Review

Data

We provide a brief summary that describes very broadly some of the ways in which the Mekong River and its tributaries are important to the culture.

- The Mekong River and its tributaries are the location for many annual festivals by local populations, siting of temples and sacred trees. For some riparian communities, consumption of fish and other aquatic animals is more than just sustenance; it is part of their cultural identity (ICEM 2010c)
- BDP Technical Note 9 noted that it is not just the river, but also the associated wetland that are often of "religious, historical, archaeological or other cultural significance at the local or national level" (MRC-BDP 2010f, 26)

Results

- ICEM (2010c, 134) concluded that development of the mainstream dams would have "significant negative effects on riparian communities by disrupting their… cultures – i.e., patterns of behaviour, shared beliefs, customs and values."
- BDP Technical Note 12 concluded, "The negative impact of water resources development on these cultural meanings and the values assigned to them could be severe" (MRC-BDP 2010h, 25).

7.1.2 HPST Valuation

As with the studies reviewed from the region, so in the HPST there is no attempt to place an economic value on the potential impacts on culture of hydropower development. This decision does not mean that (a) cultural values do not have economic values or that (b) such values should be ignored or discounted in a decision-making process. The decision is made as estimating the economic value of cultural is (a) practically impossible and (b) pretending to input economic information of this type into decision-making would be inappropriate and of little practical utility. Rather, these values are incorporated into the HPST through the use of social indicators.

7.2 Health

The health and well being of the LMB population have the potential to be affected by hydropower development in a variety of ways – some positive and some negative. Health related impacts are primarily associated with changes in infrastructure (e.g. installation of health clinics) or the environment (e.g. decreases in fish for consumption, which leads to poorer nutrition). Methods exist, and are applied in some regulatory settings in developed countries, to estimate the economic value of changes in health outcomes.

7.2.1 LMB Dams Literature Review

Methods

While Laplante (2005) did not attempt to attach economic values to changes in health, he did include a methodology for estimating the value of health impacts (Pagiola, von Ritter, and Bishop 2004), which is summarized briefly here. The general approach is to identify the change and associated quantity of its impact on health, which then could be valued either as the cost of the illness, the cost of treatment, or the value of statistical life.

Data

No study reviewed included baseline data or estimates of the potential quantity or value of health related impacts potentially associated with hydropower development; however, we summarize here the likely types of impacts that may need to be considered if such an analysis were to occur. Note, however, that the potentially positive impacts would primarily be associated with mitigation efforts, which may or may not occur at a level adequate to result in benefits. Furthermore, lack of appropriate mitigation efforts could result in additional negative impacts.

Positive

- Improved health care
- Improved sanitation
- Improved water supply
- Improved education

Negative

- Decreased food security
- Decline in nutrition
  Decline in protein intake
- Decreased surface water quality
- Increased risk of disease

BDP Technical Note 12 also included a list of common food security indicators (MRC-BDP 2010h, 24).

7.2.2 HPST Valuation

Given the lack of precedent in the LMB with regard to valuing health impacts, it was not feasible to develop a practical and replicable method to value these impacts in economic terms. Impacts on health of hydropower development are incorporated in the HPST through social indicators.

7.3 Infrastructure

Fixed infrastructure in areas that would be permanently inundated or at increased risk of a natural disaster (e.g. erosion, flooding, etc.) due to changes in river hydrology associated with hydropower development could require protection or relocation, or could be lost permanently (potentially requiring the construction of replacement infrastructure).

7.3.1 LMB Dams Literature Review

Methods

No study reviewed included methods for estimating the value associated with infrastructure loss as a result of hydropower development.

Data

No study reviewed included baseline data or estimates of the potential quantity or value of infrastructure that would be impacted under each hydropower development scenario being considered; however, Maunsell and Lahmeyer (2004b) and Laplante (2005) did provide a list of infrastructure types that would need to be considered if such an analysis were to occur:

- Dwellings
- Roads
- Bridges
- Transmission lines
- Schools
- Hospitals/clinics
- Temples
- Administrative buildings
- Pavilions
- Mines
- Markets/shops
- Ferry crossings
- Jetties
- Farm/plantation buildings
- Factories
- Resorts
- Irrigation lines/pump stations

7.3.2 Additional Literature Consulted

During the development of the Srepok Basin case study, we were able to locate and review a number of Resettlement Action Plans (RAPs) for both hydropower development and “other” infrastructure projects in the study region.

In reviewing the RAPs, it became obvious that aggregated values derived from these studies could potentially be used as a first-cut estimate of economic impact, but in the case of these plans, highly specific information (e.g. value of a wooden fencepost versus a metal fencepost and the number of each type within an affected village) had been gathered. Furthermore, these studies primarily focused on residences/homes and secondary structures of households (i.e. toilets, fences, barns, etc.). While not stated directly, it appears that public structures such as schools and medical facilities were more likely to simply be rebuilt in the resettled location.

To that end, we consulted numerous RAPs in order to compare and contrast the estimates used for various residential and secondary infrastructure types. We subsequently selected and/or calculated aggregated values for use in the HPST. In addition, we gathered more general data on the “typical” types and sizes of residential structures in the geographic areas likely to be impacted by hydropower development.

7.3.3 HPST Valuation

The approach taken in the HPST for primary residences is as follows:

- Obtain estimates of the likely number of displaced and/or impacted individuals as well as estimates of average number of residents per household and average size of residence by type. (Note: If more specific estimates are available, either on the type of infrastructure to be lost or the value of that infrastructure, such estimates should be substituted for the more general values described here).
- Obtain mean or median value for each infrastructure type.
- Calculate the estimated annual value of lost infrastructure by type
  - Divide the number of displaced individuals by the average household size to estimate the number of displaced households.
  - Create a weighted average value of the "average" residence using the estimated average value of residence by type and the distribution of households by residence type (e.g. (% of total homes that are concrete x average value of concrete residence) + (% of total homes that are wooden x average value of wooden residence) + (% of total homes that are temporary x average value of temporary residence).
- Multiply the number of displaced households by this weighted average value per residence to calculate the annual estimated value of lost residential structures.
- Use a fixed value per displaced individual/household for loss of secondary infrastructure – multiply this value by the number of displaced individuals/households to calculate the annual estimated value of lost secondary structures.
- Sum estimated annual values by type to estimate total annual value lost.
- Calculate NPV.

A summary of the parameter values included in the HPST is shown in Table 26. Again, if more detailed information is available for a specific project, the parameters section of the HPST should be modified to include it.

Table 26. HPST Parameters for Infrastructure

Economic Valuation						
Property (Structures)	**UNIT**	**General**	**Cambodia**	**LaoPDR**	**Thailand**	**Viet Nam**
Household Size	#		4.7	6.1	3.5	3.9
Concrete/Brick Portion	% of total		5%	9%	30%	15%
Temporary Portion	% of total		50%	40%	0%	13%
Wooden Portion	% of total		44%	47%	69%	72%
Value-Average Residence	USD/HH		1,620			2,960
Value-Concrete Residence	USD/unit		3,000			3,500
Value-Secondary Structure	USD/person		500			500
Value-Temporary Residence	USD/unit		1,000			1,000
Value-Wooden Residence	USD/unit		2,200			3,200

There are a number of ways that the estimated economic impact of infrastructure impacts may be values in economic terms. Table 27 below shows a selection of estimates from RAPs reviewed and their adjustment to 2014 USD figures. The parameter values for residential structures currently included in the HPST are an average value by type for each country.

Table 27. Resource Values for Infrastructure

Source/Citation	Project/Study	Country	Study Year	Structure Type	Study Value (USD/m^2)	Study Value (NC/m^2)	Adjustment Factor	2014 Value (USD/m^2)
Resettlement plan	National Rd 3&6	Cambodia	2004	Concrete residence	$ 20.85		1.400136	$ 29.19
EIA	Lower Sesan II HPP	Cambodia	2011	Metal/cement residence - single story	$ 29.27		1.021891	$ 29.91
EIA	Lower Sesan II HPP	Cambodia	2011	Brick residence - single story	$ 54.02		1.021891	$ 55.20
EIA	Lower Sesan II HPP	Cambodia	2011	Brick/wooden residence - two story	$ 85.69		1.021891	$ 87.57
EIA	Lower Sesan II HPP	Cambodia	2011	Brick residence - two story	$ 156.54		1.021891	$ 159.97
EIA	Lower Sesan II HPP	Cambodia	2011	Temporary residence - single story	$ 24.51		1.021891	$ 25.05
Resettlement plan	National Rd 3&6	Cambodia	2004	Wooden residence	$ 38.19		1.400136	$ 53.47
EIA	Lower Sesan II HPP	Cambodia	2011	Wooden residence - single story	$ 53.49		1.021891	$ 54.66
Resettlement plan	Cua Ong - Mong Duong Road	Viet Nam	2008	Residence class 4		$ 640,000	0.000066	$ 42.53
EIA	Srepok 4A HPP	Viet Nam	2008	Brick residence - average		$ 1,113,359	0.000066	$ 73.99
Resettlement plan	Cua Ong - Mong Duong Road	Viet Nam	2008	Temporary residence		$ 330,000	0.000066	$ 21.93
Resettlement plan	Cua Ong - Mong Duong Road	Viet Nam	2008	Residence class 1 & 2		$ 1,800,000	0.000066	$ 119.62
EIA	Srepok 4A HPP	Viet Nam	2008	Temporary residence		$ 480,000	0.000066	$ 31.90
Resettlement plan	Ha Tay HPP	Viet Nam	2008	Wooden residence		$ 658,000	0.000066	$ 43.73
Resettlement plan	Ha Tay HPP	Viet Nam	2008	Wooden residence		$ 1,028,000	0.000066	$ 68.31
Resettlement plan	Cua Ong - Mong Duong Road	Viet Nam	2008	Residence class 3		$ 800,000	0.000066	$ 53.16
EIA	Srepok 4A HPP	Viet Nam	2008	Wooden residence - average		$ 676,196	0.000066	$ 44.94

Source/Citation	Project/Study	Country	Study Year	Structure Type	Study Value (NC/displaced person)	Adjustment Factor	2014 Value (USD/displaced person)
Resettlement plan	Cua Ong - Mong Duong Road	Viet Nam	2008	Secondary structures	$ 7,246,377	0.000066	$ 478.00

7.4 Displacement and Livelihoods

The creation of hydropower reservoirs will likely displace households and villages. As the issues of resettlement and infrastructure loss for displaced individuals has been discussed previously, this section will focus solely on displacement.

The difference between the impacts of displacement and resettlement should be noted, as the costs of displacement are real, whether or not mitigation efforts for resettlement occur. Furthermore, the benefits of resettlement compensation may or may not offset the actual costs of displacement.

As noted by the World Bank (2001, 1):

> "Involuntary resettlement under development projects, if unmitigated, often gives rise to severe economic, social, and environmental risks: production systems are dismantled; people face impoverishment when their productive assets or income sources are lost; people are re- located to environments where their productive skills may be less applicable and the competition for resources greater; community institutions and social networks are weakened; kin groups are dispersed; and cultural identity, traditional authority, and the potential for mutual help are diminished or lost."

7.4.1 LMB Dams Literature Review

Methods

None of the studies attempted to estimate the total economic impact of displacement, although, as previously discussed, Laplante (2005) did include estimates of project investment and income compensation for the Nam Theun 2 project. Similarly, when discussed in other studies qualitatively, the focus was primarily on costs of resettlement rather than the cost of displacement.

Data

- ICEM (2010d) estimated that 106,964 and ~2 million individuals would be directly and indirectly impacted by LMB mainstream dams, respectively. For the former, this would mean relocation. In addition, it should be noted that a subset of these individuals have already been relocated in recent years, particularly in the Stung Treng and Kratie regions.
- Several studies included specific estimates of displaced individuals by dam– primarily for mainstream dams (see Table 28).

Table 28. Estimates of Displaced Individuals by Dam

	# of individuals		
Dam	Yermoli (2009)	ICEM (2010)	MRC (2010)
Pak Beng	6,700	6,700	—
Luang Prabang	12,966	12,966	—
Xayabouly	2,130	2,130	—
Pak Lay	6,129	6,129–18,000	—
Sanakham	4,000	4,000	—
Pak Chom	—	535	400
Ban Koum	1,122	935	300
Lat Sua	0	0	—
Don Sahong	66	66	—
Stung Treng	10, 617	10,000+	10, 617
Sambor	19,034	19,000+	5,120

7.4.2 Additional Literature Consulted

Impacts. A post-development study of the Yali Falls Dam in Cambodia conducted by McKenny (2001) focused on the impacts to livelihood income. The study found a 57% decrease in income across all livelihood types (see Table 29). The HPST parameter value of 50% is based on this study's findings.

Table 29. Estimated Average Impacts to Household Income

Livelihood income type	Upstream districts (USD)	Lowland districts (USD)
Before the dam	201	92
After the dam (1999)	42.09	60
Income loss (1999)	159	32
Percentage loss	79.1%	34.8%

Income. The World Bank database includes GDP per capita estimates by country (see Table 30). As noted in the "value type" column in Table 30, these estimates are at the country-level (as opposed to a regional or rural-only value).

Table 30. GDP per Capita

Source/Citation	Country	Year	Value Type	Study Value (USD/person)	Adjustment Factor	2014 Value (USD/person)
World Bank	Cambodia	2013	All	$1,006	1.00983	$1,016
World Bank	Lao PDR	2013	All	$1,661	1.00983	$1,677
World Bank	Thailand	2013	All	$5,779	1.00983	$5,836
World Bank	Viet Nam	2013	All	$1,911	1.00983	$1,929

Growth rate. The HPST currently includes country-level Asian Development Bank growth rates (averaged from 2007-2012). (Accessed June 16 at http://www.adb.org/publications/framework-inclusive-growth-indicators-2014-key-indicators-asia-and-pacific).

7.4.3 HPST Valuation

The approach taken in the HPST for estimating lost livelihoods is as follows:

- Select the assumed percentage of annual income lost (in the HPST this value is currently set at 50% for all countries).
- Select the assumed annual growth rate of income (currently set at 2% for all countries).

- Estimate the per individual/household annual income lost—at present, these are country level per capita values, but could be easily modified to a region/village/household value if data are available. Similarly, if annual income and/or expected loss of income data were available for different types of livelihoods (e.g. agriculture, fishing, etc.), these values could also be substituted into the HPST.
- Multiply the number of displaced individuals per project by projected income loss, growth rate of income and per capita income to calculate the total annual lost livelihood value.
- Calculate NPV.

A summary of the parameter values included in the HPST is shown in Table 31.

Table 31. HPST Parameters for Livelihoods

Livelihoods	UNIT	General	Cambodia	LaoPDR	Thailand	Viet Nam
Income Loss	%	50%	50%	50%	50%	50%
Growth Rate of Income	%	2%	4.6%	5.3%	3.2%	4.9%
Per Capita Income	USD/person/yr		1,016	1,677	5,836	1,929

8 Economic Valuation of "Local" External Impacts: Land Uses

The reservoirs created for hydropower projects will inundate large areas of land, some seasonally and some permanently. Additional areas of land will be needed on which to build transmission lines, access roads and other project infrastructure. Loss of these areas will affect not only human populations, but also the flora and fauna that live and/or migrate through these areas.

Three land categories that likely will incur loss of area from hydropower development are discussed here: developed land, forestland and wetlands.

While it does not specify land type, the MRC Hydropower Project Database does include estimates of the reservoir size (km^2) for each hydropower project, which could be used to create a low-bound estimate of impacted land area if no additional information is available.

8.1.1 Additional Literature Consulted

As mentioned previously in the section on infrastructure, during the course of the case study application of the HPST, we were able to locate and review a number of Resettlement Action Plans (RAPs) for both hydropower development and "other" infrastructure projects in the study region.

Many of these RAPs included values associated with lost land; however, in most cases, the categories were limited to residential, agricultural and forest. No additional literature consulted included information associated with the loss of wetlands; if wetlands used for riverbank gardens were included, under agriculture for example, such a designation was not specified.

As all parameters in the HPST related to lost land are included in one category, we present them here (see Table 32) — which are discussed in detail in the subsequent sections.

Table 32. HPST Parameters for Land

Land	UNIT	General	Cambodia	LaoPDR	Thailand	Viet Nam
Agricultural Portion	% of Total		32.6%	10.6%	60.0%	35.0%
Forest Portion	% of Total		55.7%	67.6%	16.0%	45.4%
Residential Portion	% of Total	2%	2%	—	—	2%
Value-Agricultural	USD/ha		1,000			3,500
Value-Forest	USD/ha		820			1,660
Value-Residential	USD/ha		16,000			19,800
Value-Unclassifed Land	USD/ha		1,103			2,375

8.2 Developed Land

Developed land is defined as land currently used by human populations for purposes such as agriculture, aquaculture, gathering & harvesting, and dwelling, among others. Hydropower development will result in both temporary and permanent loss of some developed lands.

8.2.1 LMB Dams Literature Review

In the studies reviewed, agricultural land was the only developed land type for which impact assessment methods were discussed. Other developed land types likely to be impacted were not discussed other than qualitatively. It should be noted that this section focuses only on the economic impacts of lost developed land, and not any infrastructure located on this land, as infrastructure impacts are discussed separately in another section.

Methods

Laplante (2005) noted that without actual market transactions, assessing the actual value of developed land impacted by or lost to hydropower development would be difficult. Given that market transactions for the land in question did not appear to be readily available, or even exist, Laplante turned to The Draft Technical Guidelines for Resettlement and Compensation written by the Government of Lao PDR, which stated that “the compensation should be determined based on the average productive values of land based on the past 3 to 4 years of production, and should be equivalent to at least 6 to 7 years of harvest value” (LaPlante 2005, 83).

Data

- Laplante (2005) estimated the average annual value per hectare by land type as follows: irrigated paddy fields – USD 887/ha; rain-fed paddy fields – USD 350/ha; and shifting cultivation – USD 225/ha.
- Maunsell and Lahmeyer (2004b) included the following estimates for developed land types in their study: non-irrigated cropland – USD 5/ha (global) and USD 200/ha (local); however, it is not clear if these were annual or total estimates.

Results

- The ICEM (2010c) study estimated the mainstream dams would inundate 7,962 ha of paddy, which was estimated to produce 22,475 tonnes/year of rice. The associated value of the rice was USD 4.1 million/year.

8.2.2 Additional Literature Consulted

We reviewed and gather data from a number of RAPs in order to compare and contrast the estimates used for lost land. In addition, we gathered more general data on general land usage (e.g. percentage of total land in agricultural) in the geographic areas likely to be impacted by hydropower development.

8.2.3 HPST Valuation

Due to data access/availability constraints, developed land types were limited to residential and agricultural. If additional levels of specificity are available in the future (e.g. agricultural land can further be broken out by permanent crop, temporary crop, riverbank garden, permanent tree crops, etc.) such information (and associated values) can be added to the HPST.

The current approach taken in the HPST for developed land is as follows:

- Obtain project-level estimates of lost developed land (including inundated land and land used for other project-related activities) — if possible obtain estimates by land type (e.g. agricultural, residential, etc.).
- Obtain mean or median value per hectare values for each land type.
- Calculate the estimated annual value of lost developed land by type
    - For projects where land is broken out by type: multiply the per hectare value by the number of hectares lost for each land type.
    - For projects where land type is not defined: Create a weighted value of the “average” hectare of land using the estimated average value of land by type and the distribution of land by type (e.g. (% of total land that is forest x per hectare value of forestland) + (% of land that is residential x per hectare value of residential land) + (% of total land that is agricultural x per hectare value of agricultural land). Multiply the total hectares of lost land by this weighted average value to calculate the annual estimated value of lost land.
- Sum estimated annual values by land type to estimate total annual value lost.

- Calculate NPV.

A summary of the parameter values included in the HPST for developed land is included at the beginning of this section in Table 32.

There are a number of ways that the estimated economic impact of lost developed land could be valued. Table 33 shows values for agricultural, paddy and residential lands from a variety of studies (all adjusted to USD 2014). Not surprisingly, there is a range of values for each land type; as we were not privy to all details factored into the choice of these values, it was necessary for us identify outliers, consider the study /valuation type and attempt to make a reasonable value selection for each land type.

To that end, we chose to select values for Cambodia from the most recent Cambodian study (i.e. Lower Se San 2) for the HPST. For Viet Nam, an average of paddy and agricultural values was used for agricultural land and an average of residential values (with the exception of one outlier value) was used for residential land.

Table 33. Resource Values for Agricultural and Residential Land

Project/Study	Country	Study Year	Land Type	Study Value (USD/ha)	Study Value (NC/ha)	Adjustment Factor	2014 Value (USD/ha)	Value Type
Lower Sesan II HPP	Cambodia	2011	Slash & burn agricultural	$ 800		1.02189	$ 807	Proposed compensation value
Lower Sesan II HPP	Cambodia	2011	Agricultural	$ 900		1.02189	$ 920	Proposed compensation value
Railway Rehabilitation	Cambodia	2009	Agricultural sharecropping	$ 6,000		1.18797	$ 7,128	Replacement-cost value
Railway Rehabilitation	Cambodia	2009	Agricultural	$ 27,500		1.18797	$ 32,669	Replacement-cost value
Railway Rehabilitation	Cambodia	2009	Agricultural	$ 27,500		1.18797	$ 32,669	Compensation value
BDP Technical Note 13	Cambodia	2010	Paddy recession	$ 1,291		1.11207	$ 1,435	NPV
National Rd 3&6	Cambodia	2004	Paddy	$ 44,427		1.40014	$ 62,205	Proposed compensation value
National Rd 3&6	Cambodia	2004	Paddy Village 2	$ 45,000		1.40014	$ 63,006	Proposed compensation value
National Rd 3&6	Cambodia	2004	Paddy Village 3	$ 45,000		1.40014	$ 63,006	Proposed compensation value
Cua Ong Mong Duong Road	Viet Nam	2008	Agricultural		250,000	0.00007	$ 17	Replacement-cost value
Nam Tan HPP	Viet Nam	2008	Agricultural		120,000	0.00007	$ 8	Proposed compensation value
Song Bung HPP	Viet Nam	2011	Agricultural		53,660,636	0.00005	$ 2,676	Compensation value
SEI Study Viet Nam HPP	Viet Nam	2008	Agricultural	$ 2,800		1.08333	$ 3,033	Regulatory value
Ha Tay HPP	Viet Nam	2008	Agricultural perennial plant		35,000,000	0.00007	$ 2,326	Compensation value
Ha Tay HPP	Viet Nam	2008	Agricultural rubber tree		35,000,000	0.00007	$ 2,326	Compensation value
Ha Tay HPP	Viet Nam	2008	Agricultural rubber tree		35,000,000	0.00007	$ 2,326	Replacement-cost value
Ha Tay HPP	Viet Nam	2008	Agricultural perennial plant		45,000,000	0.00007	$ 2,990	Replacement-cost value
Srepok 4A HPP	Viet Nam	2008	Agricultural annual tree		70,000,000	0.00007	$ 4,652	Compensation value
Srepok 4A HPP	Viet Nam	2008	Permanent industrial tree land		70,000,000	0.00007	$ 4,652	Compensation value
Ha Tay HPP	Viet Nam	2008	Agricultural		95,000,000	0.00007	$ 6,313	Compensation value
Ha Tay HPP	Viet Nam	2008	Agricultural		115,000,000	0.00007	$ 7,642	Replacement-cost value
SEI Study Viet Nam HPP	Viet Nam	2008	Agricultural	$ 5,600		1.08333	$ 6,067	Proposed compensation value
Trung Son HPP	Viet Nam	2013	Agricultural		712,384,050	0.00005	$ 34,366	Replacement-cost value
BDP Technical Note 13	Viet Nam	2010	Paddy recession	$ 1,109		1.11207	$ 1,233	NPV
Ha Tay HPP	Viet Nam	2008	Paddy		37,500,000	0.00007	$ 2,492	Compensation value
Ha Tay HPP	Viet Nam	2008	Paddy		55,000,000	0.00007	$ 3,655	Replacement-cost value
Srepok 4A HPP	Viet Nam	2008	Paddy other		60,000,000	0.00007	$ 3,987	Compensation value
Srepok 4A HPP	Viet Nam	2008	Paddy wet		70,000,000	0.00007	$ 4,652	Compensation value
Sung Vui HPP	Viet Nam	2008	Paddy		200,000,000	0.00007	$ 13,291	Compensation value
Nam Tan HPP	Viet Nam	2008	Paddy		200,000,000	0.00007	$ 13,291	Proposed compensation value

Project/Study	Country	Study Year	Land Type	Study Value	Study Value (NC/ha)	Adjustment Factor	2014 Value (USD/ha)	Value Type
National Rd 3&6	Cambodia	2004	Residential	$ 6,820		1.40014	$ 9,549	Proposed compensation value
Lower Sesan II HPP	Cambodia	2011	Residential/village	$ 15,700		1.02189	$ 16,044	Avg suggested price
National Rd 3&6	Cambodia	2004	Residential Village 2	$ 65,000		1.40014	$ 91,009	Proposed compensation value
National Rd 3&6	Cambodia	2004	Residential Village 3	$ 65,000		1.40014	$ 91,009	Proposed compensation value
National Rd 3&6	Cambodia	2004	Residential near district office Village	$ 80,000		1.40014	$ 112,011	Proposed compensation value
National Rd 3&6	Cambodia	2004	Residential along road Village 1	$ 100,000		1.40014	$ 140,014	Proposed compensation value
Cua Ong Mong Duong Road	Viet Nam	2008	Residential road & rural		10,000,000	0.00007	$ 665	Replacement-cost value
Ha Tay HPP	Viet Nam	2008	Residential		150,000,000	0.00007	$ 9,968	Compensation value
Ha Tay HPP	Viet Nam	2008	Residential		205,000,000	0.00007	$ 13,623	Replacement-cost value
Srepok 4A HPP	Viet Nam	2008	Residential		600,000,000	0.00007	$ 39,872	Compensation value
Cua Ong Mong Duong Road	Viet Nam	2008	Residential central area		240,000,000	0.00007	$ 15,949	Replacement-cost value

8.3 Forestland

Forestland is a general term for a variety of systems, defined by their primary cover – trees, and each with its own functions and unique range of goods and services.

Hydropower development would result in permanent loss of upland and flooded forestland. In addition to being a home for important flora and fauna, forestland is used by the regional population for gathering and harvesting.

8.3.1 LMB Dams Literature Review

Methods

BDP Technical Note 13 (MRC-BDP 2010b) estimated total area of forestland lost b using estimates of reservoir size (from the hydropower database) and land use data for each proposed development location.

Unit values were then applied to the area estimates to calculate annual economic value. These annual estimates were then used to calculate NPV over a 50-year period. Laplante (2005) used a similar method to estimate the value of forestland lost to the Nam Theun 2 project.

Data

- Laplante (2005) estimated the average annual value per unit to be USD200/ha and USD400/ha for bamboo groves and forest areas, respectively.
- BDP Technical Note 13 used a unit value for forestland (all types) of USD 700/ha (MRC-BDP 2010b).
- It appears that Maunsell and Lahmeyer (2004b) estimated the amount of forestland lost by project, but these estimates were not readily available in their final report. The categories used were bamboo and giant grassland, old secondary woodland and young secondary woodland. The associated economic values for these categories are included in Table 34.

Table 34. Forestland Values

	Value (USD/ha)		
Forestland type	Global	Local – un-degraded	Local - degraded
Bamboo and giant grassland	10	0.5	0.5
Old secondary woodland	200	200	100
Young secondary woodland	100	50	25

Results

- BPD Technical Note 13 (MRC-BDP 2010b) included estimates of the economic value associated with forestland loss at the country-level for all scenarios considered. Table 35 includes estimates for three of the scenarios.

Table 35. Estimated NPV of Impacts to Forestland

(USD m)	Definite future	20-year plan	Long-term very high dev.
Lao PDR	-130	-236	-354
Thailand	0	0	0
Cambodia	-6	-122	-454
Viet Nam	-17	-14	-14
Total	-153	-172	-822

- ICEM (2010c) estimated that development of mainstream dams would result in the inundation of 25,000 ha of forestland.

8.3.2 HPST Valuation

The approach taken in the HPST valuation is as follows:

- Gather project level data on lost forestland (ha). In cases were only the total lost land (not by land type) is available, use a country-level estimate of forestland as a percentage of total land multiplied by total lost land to estimate lost forestland.

- Calculate the annual estimated value of lost forestland by multiplying units inundated (ha) by per unit value for each type.
- Sum estimated annual value by type to estimate total annual value lost for each project.
- Calculate NPV.

There are a number of ways that the expected impact of lost forestland may be valued in economic terms. Table 36 shows the studies values were ultimately selected from for the HPST and their adjustment to 2014 USD figures. The estimates are the 2011 Lower Se San 2 hydropower project value for Cambodia (USD 820/ha) and the Srepok 4A hydropower project value for Viet Nam (USD 1660/ha). Values from these two studies were chosen as they represented compensation values as opposed to other possible types of values (e.g. ecosystem values, comparable timber value, etc.). These estimates can easily be updated on the HPST parameters page in the future as needed.

Table 36. Resource Values for Forestland

Source/Citation	Project/Study	Country	Study Year	Land Type	Value (USD/ha)	Study Value (NC/ha)	Adjustment Factor	Value (USD/ha)
Resettlement plan	Lower Sesan II HPP	Cambodia	2011	Forest	$800		1.02189	$818
EIA	Srepok 4A HPP	Viet Nam	2008	Productive forest		25,000,000	0.00007	$1,661

8.4 Wetlands

Wetland is a general term for a class of complex systems, defined by the level of water saturation in the soil, but each with its own functions and unique range of goods and services. According to Hall and Leebouapao (2005), coastal, estuarine and freshwater wetlands cover an estimated 6–12 million hectares in the LMB.

Due to the diversity of goods and services found in wetlands, and the varied combinations of these goods and services across wetland types, each type would ideally be valued based on the combined value of each function, good and service it provides. Unfortunately, as Hall and Leebouapao (2005) noted, this might be realistic when valuing an individual wetland, but would be extremely difficult (and likely time and cost prohibitive) when estimating values for a variety of wetland types over a large area, such as the LMB.

Hydropower development will result in impacts to both the distribution and area of LMB wetlands primarily because of changes in flow and flooding. These impacts will affect, in turn, the quantity and quality of ecosystem services provided by those wetlands. (MRC-BDP 2010f)

8.4.1 LMB Dams Literature Review

Methods

For the reasons briefly described above, per unit benefit transfer was the valuation method used in the studies reviewed. Two of these studies (Hall & Leebouapao 2005; (ICEM 2010c) explicitly stated they used values from a meta-analysis of wetland values conducted by Schuyt and Brander (2004).

What is of note, however, is that each of the three studies categorized the types of wetlands included in their analysis differently (see Table 37).

Table 37. Summary of Wetland Type by Study

Hall & Leebouapao (2005)	ICEM (2010)	BDP Technical Note 13 (MRC 2010)
– Mangrove	– Unvegetated sediment	– Seasonally inundated forests
– Unvegetated sediment	– Freshwater marsh	– Inundated grasslands
– Salt/brackish marsh	– Freshwater woodland	– River gardens
– Freshwater marsh		– Marshes, small pools and seasonal wetlands
– Freshwater woodland		

Data

- Drawing on data from Schuyt and Brander (2004), Table 38 presents relevant wetland estimates included in Hall and Leebouapao (2005) and ICEM (2010c). Note that these values are in 2000 USD.

Table 38. Summary of Wetland Value by Type

Wetland type	Value (USD/ha/year)
Mangrove	19
Unvegetated sediment	202
Salt/brackish marsh	23
Freshwater marsh	15
Freshwater woodland	228

- BDP Technical Report 13 used the following values for wetlands: USD 2,000/ha for seasonally flooded forest; USD 1,000 for marshes, lakes and ponds; and USD 600 for inundated grassland (MRC-BDP 2010b).
- Maunsell and Lahmeyer (2004b) used the following values for wetlands/floodplain: USD 200/ha (international), USD 1,000 (local – un-degraded and degraded).

Results

ICEM (2010c) estimated that development of the mainstream dams would result in a 17% loss of in-channel wetland on the Mekong River, with the associated economic value of this loss estimated to be USD 3–13.8 million/year (2000 prices).

The BPD Main Report estimated the NPV of wetland loss under the Definite Future Scenario to be USD 228 million (MRC-BDP 2011). The net present economic value of wetland changes estimated under other development scenarios considered ranged from a positive USD 36 million under the long term development plus climate change scenario to a USD 310 million loss under the long term very high development scenario (see Table 39).

Table 39. Estimated Impacts to Wetlands (including River Gardens) – Area and NPV

	Definite future		20-year plan		Long-term very high dev.	
	ha	USD mil	ha	USD mil	ha	USD mil
Lao PDR	-4,867	-27	-5,910	-18	-5,870	-18
Thailand	-9,317	-47	-11,364	-34	-11,299	-34
Cambodia	-20,979	-153	-34,902	-169	-51,763	-249
Viet Nam	-41	-1	-440	-4	-1,013	-9
Total	-35,204	-228	-52,616	-225	-69,945	-310

8.4.2 HPST Valuation

Projects assessed during the case study did not include information on wetland losses. Presumably, if there were losses, they were included in the total area lost estimates, but no additional information was provided. As such, impacts on wetlands of hydropower development are indirectly incorporated in the HPST through the environmental indicators—more specifically the impact on the environmentally sensitive areas indicator.

9 Economic Valuation of External Impacts: Fisheries

The Mekong River fisheries are not only of great economic value to the LMB, but also provide a substantial contribution to the diet of LMB residents. In this section we review regional data on the Mekong fishery, followed by sections on riverine fisheries, aquaculture and marine in so far as they are related to dams and hydropower project. The emphasis in this section is simply to examine what impacts are identified in the literature and to summarize the data that are deployed in Section 11.

9.1 LMB Overview

While much is known about the fish of the Mekong, It is important to acknowledge that a comprehensive data set regarding fish production (i.e. harvest) and consumption is lacking (Hortle 2007; Hortle 2009; Baran, Jantunen, and Kieok 2007; Anonymous 1992). Official and reported statistics can be lacking or inaccurate for a variety of reasons (Hortle 2009; MRC-BDP 2010e). Figures will also be quite different depending on whether they come from regional surveys or FAO statistics, as reported directly from official statistics by government (ICEM 2010b). For example ICEM (2010b) used FAO data and estimated average regional consumption of freshwater (capture and culture) fish to be 13.8 kg/person/year, compared to estimates by MRC-BDP (2011) of 45.5 kg/person/year. Generally, harvest data are underreported and therefore consumption estimates may be more accurate. Hortle (2009) is the latest attempt to provide a comprehensive set of figures for the fishery. As this effort attempts to reconcile consumption data and ecological productivity data and as such the figures represent the best estimates available.

According to Hortle (2009), consumption of Inland fish and other aquatic animals in the LMB totals about 2.6 MT/yr. The distribution by country is provided in Table 40. With estimated aquaculture exports from the Mekong Delta the total annual yield of the LMB is estimated at 3.6 MT/yr. Updated to 2009, Hortle (2009) suggests first sale prices on average of USD 1.00/kg to USD 1.80/kg and retail market prices of USD 2.00/kg to USD 3.60/kg. At first sale then the value of the LMB fishery is worth USD 3.6 to 6.5 billion and double that at market. Perhaps as important as the economic value is the importance of fish and other aquatic animals in the diet of inhabitants of the LMB (FAO country-wide estimates are provided in Table 41 from ICEM (2010b). It is generally agreed that the development of hydropower dams will have negative impacts (to varying degrees) on river and delta fisheries and positive impacts for aquaculture fisheries.

Table 40. Consumption and Value of LMB Fisheries by Country

	Consumption estimate (1000 t/yr)	Consumption Per Capita	Value range (USD millions)
Lao PDR	209	43.0	124–576
Thailand	911	40.5	540–2,509
Cambodia	587	51.4	348–1,617
Viet Nam	853	48.7	468–2,173
Total	2,560	—	1,400–6,500

Table 41. Freshwater Fish Protein as a Percentage of Total Animal Protein Consumed

	% of total (Avg. 2002-03)
Lao PDR	38%
Thailand	16%
Cambodia	50%
Viet Nam	13%
Global	6%

9.2 Inland Capture Fishery

In addition to having one of the highest levels of aquatic biodiversity found anywhere in the world, the fisheries of the Mekong River also support the 12 million households of the LMB – both through income and sustenance. In Cambodia, the 1.2 million people living near the Tonle Sap depend on capture fisheries almost entirely for their livelihood (Hall and Leebouapao 2005).

It is generally agreed that hydropower development on the Mekong River will have a negative impact on riverine fish species; hydrological conditions will change, migration routes will no longer be accessible, and the annual pattern of floodplain inundation and recession will be altered, among others. It should be noted that not all impacts to riverine fisheries associated with hydropower development were assessed quantitatively by the studies reviewed. For example, the BDP Main Report estimated riverine fishery losses associated with barrier impacts and changes in flood control, while potential impacts associated with changes in hydrological conditions, water quality and sediment transport were only discussed qualitatively (MRC-BDP 2011). In other words the value estimates do not accurately represent the full potential cost of hydropower development scenarios.

This section focuses on the likely impacts to inland capture fisheries, while potential impacts to biodiversity will be discussed in a later section.

9.2.1 LMB Dams Literature Review

Methods

The BDP Main Report does not explain the valuation approach for capture fisheries; however, working backwards from the data requirements listed, it appears that the steps taken to estimate the value of changes to riverine fisheries under various development scenarios included the following:

- a Fisheries Specialist estimated changes in riverine fishery harvest under each scenario considered; and
- this volume was multiplied by current output prices, while at the same time labour, marketing and other input costs were subtracted (MRC-BDP 2011).

How the changes in riverine fishery harvest were estimated and which changes were incorporated is not described in detail in the BDP Main Report or associated Technical Note, so it is difficult to evaluate this approach.

ICEM (2010c) did include estimates of changes in river fisheries quantity and value associated with hydropower development; however, details on the methods used were not included.

Data

ICEM (2010) estimated the first-sale value of river fisheries was USD 3.0 billion/yr and the retail value was USD 6.0 billion/yr.

Results

For development of the mainstream hydropower dams ICEM (2010) estimated a decrease in riverine fisheries harvest of 340,000 t/yr, with an associated value of USD 476 million/yr. From these estimates, it can be inferred that an average price of USD 1.40/kg; however, it is not clear why this price was chosen.

Table 42 presents estimated impacts to riverine fisheries under the Definite Future and 20-year Scenarios for the Basin Development Plan (MRC-BDP 2011). Similar estimates are available for each scenario considered. Total losses range from USD 950 million to USD 1.95 billion for the two scenarios.

Table 42. Estimated Impacts to River Fisheries under two BPD Scenarios

	DFS		20-year	
	Quantity (t/yr)	NPV (USD million)	Quantity (t/yr)	NPV (USD million)
Lao PDR	-37,931	-228	-52,075	-174
Thailand	-31,258	-188	-48,371	-162
Cambodia	-53,917	-324	-340,804	-1,139
Viet Nam	-34,459	-207	-137,734	-461
Total	-157,565	-946	-578,984	-1,936

9.2.2 Valuation of Fishery Losses: HPST Approach

Hall and Leebouapao (2005) assumed that the benefit of capture fisheries to LMB countries was the net value of the resource, calculated as the gross value minus the opportunity cost of the resources used to capture or produce the fish. This cost varies considerably among the different fisheries and among different gear types used in the same fishery. The key question is what is this value and how would it be affected by hydropower development.

There is considerable agreement by economists that a capture fishery that lacks explicit management or organization, either local or from external sources is a perfect example of an “open access” common pool resource. Such a fishery is likely to be subject to unfettered competition, or a “race to the bottom,” that competes away any rent or profit that could be earned from sustainable management of the fishery. To the extent that LMB capture fisheries exist in this condition, economists would suggest that there is likely to be no net revenue (or profit) to these fisheries, and over time they are likely to be subject to overfishing leading to further decreases in stocks, species, and gross revenue.

Does the loss or diminution of such a fishery due to hydropower development then affect gross national product and affect national economic development, or not? The answer is that it probably does not affect these as much as if the fishery were sustainably managed (and was of higher and sustained long-term value), but there is an important impact nonetheless, and that it is best represented by the change in value of the fishery, as explained below.

An important input in fishing effort is labour. Small-scale artisanal fisheries and subsistence fishing, such as those in the LMB rely on time invested by the fisher. Income earned by fishers from their “own” production comes either from meeting household nutritional needs (which represent a cash cost savings) or from sales of fish at landing (or the market). Out of this “income,” the cash costs of fishing are met leaving some surplus. This surplus (or cost savings) is the net income earned by the fisher. While this figure may be low, and therefore suggest no real “profit” to labour in the fishery in actuality the fisher faces the choice of fishing or engaging in other activities or engaging in employment (formal or informal). That fishing is such an important occupation in the LMB most likely reflects the lack of other more profitable employment opportunities. So, a decline in the fishery due to hydropower development would impose costs on these fishers, being the loss of the net return to labour that they gain or the loss of own production of fish for their family. The latter then imposes an additional cost to the household. Such a change would also then “strand” the fishers’ existing investment in capital equipment such as boats and gear.

For small, marginal changes in a fishery, and in the presence of a well-developed market for employment the assumption might be made that the fisher simply takes up another occupation that yields almost equal return to labour. In the case of large scale development of hydropower in the LMB, and particularly in countries like Cambodia and Lao PDR, with large numbers of artisanal or subsistence fishers and limited alternative employment opportunities, these assumptions do not hold. It is therefore appropriate to suggest that the loss of fish production is best represented by the loss of the value of the fish catch (i.e. the change in production valued at the market price).

To estimates the economic impacts on fishery harvests would include the following steps:

- Estimate change in fishery production (t) due to hydropower development.
- Assign a per unit weighted average value to fish production at landing (USD/t).
- Estimate change in economic value (USD millions).

9.2.3 Direction for Future Work and Additional Research

Further work on the external impacts to river fisheries of hydropower development requires that this effort be comprehensive geographically, but also in terms of aggregating the impacts of changes in various physical, chemical, biological and ecological conditions on the fishery. This is a large undertaking. Formative efforts in this direction included in the HPST for the Srepok River Basin are expanded on in Section 11. The on-going Delta Study or the planned MRC Council Study may produce more comprehensive and rigorous estimates of likely productivity changes and economic impacts than are found in the literature to date.

Various complicating factors will impinge on this type of analysis including:

- Distinguishing between the individual vs. cumulative impacts of hydropower development, depending on the focus of the valuation effort.
- Changes in fish production may lead to a shift from marketable to less marketable species and, thus, the weighted average value may, other things equal, decline.
- The change in price over time is hard to predict given that it depends on trends in supply and demand, as well as the availability of substitute goods.
- Demand over time for fish will reflect changes in population (positive), incomes (negative, as consumers switch to meat from fish), the price of substituted (like meat) and, thus, could grow or decline over the long-term.
- Supply over time of fish from capture fisheries may be expected to decline, however, as reviewed above the total supply of fish may still grow due to increases in reservoir fisheries and production from aquaculture.

Each of these factors needs to be considered in the valuation exercise. Ultimately, there will be a range of estimates possible over the long-term. The primary question will be the order of magnitude of this range and not so much the exact figure for the loss in economic value.

9.3 Aquaculture

LMB aquaculture occurs in inland freshwater, brackish water and the Mekong Delta, with the delta being the dominant producer and exporter in the region. The potential for growth of this industry in the region, independent of hydropower development, was noted in several studies. More specifically, 20-year growth potential was forecasted to double from 2Mt to 4Mt (MRC-BDP 2011). The dominant species for inland aquaculture are catfish and tilapia (ICEM 2010b).

According to BDP Technical Note 11, hydropower development has the potential to have both benefits and consequences for aquaculture (MRC-BDP 2010e). Potential benefits include: new reservoirs; increased water availability and distribution in the dry season; and increased availability and reliability of electricity, among others. Potential negative impacts include: variable pulsing flows and unplanned/ irregular release of water from hydropower plants.

What was not clear in the studies reviewed is whether gains in aquaculture were considered a direct result of hydropower development and/or increased investment in aquaculture.

9.3.1 LMB Dams Literature Review

Methods

Data requirements outlined in BDP Technical Note 2 (MRC-BDP 2009) provide a general idea of how the economic value of aquaculture (and other fisheries) was calculated in the BDP Main Report . More specifically, the following were listed as data requirements: estimated increase in total area available for aquaculture production (ha), average yield (t/ha), input and labour costs, marketing costs, and output prices.

Data

While a number of studies reviewed included baseline data, the ICEM (2010) study appeared to have the most recent information and is included here for that reason.

Using FAO data, ICEM (2010b) estimated the average 2005–07 value of aquaculture for the four LMB countries to be approximately USD 2.4 billion (Cambodia – USD 60 million, Lao PDR – USD 100 million, Thailand – USD 400 million, and Viet Nam USD 1.8 billion). In total, the average production of aquaculture fisheries for all four countries across this same timeframe was 2.7 Mt/year. Similar data on the volume of fish produced by species by country are also available from the FAO. From these estimates, we can infer a value of USD 0.88/kg.

Results

Estimates of the NPV of aquaculture in the BDP Main Report range from USD 1.1 billion under the Definite Future Scenario to UDS 2.5 billion under the long-tern very high development scenario (MRC-BDP 2011). The associated volume of production is estimated to be 3-8 t/year. It should be noted that in this study, aquaculture estimates do not include additional reservoir fishery production.

9.3.2 HPST Valuation

While hydropower development may result in reservoirs where aquaculture may be possible, the findings of our literature review were not clear on whether potential gains to aquaculture would be direct result of hydropower development or simply an increased investment in aquaculture. Given that no clear relationship between these two were seen during the case study field visits, nor were any additional studies on the topic located, potential benefits to aquaculture are not currently included in the HPST.

9.3.3 Direction for Future Work and Additional Research

Additional research should be undertaken to determine likely aquaculture development with or without hydropower development – and the potential differences in fixed and on-going operational costs between the two.

Additional research also should be done on a) other factors affecting aquaculture development in the LMB; and b) the potential impact of hydropower development on these factors (e.g. feed developed from fish caught in capture fisheries).

Should it be determined that hydropower dams do affect aquaculture the following methodology for valuation is suggested:

- Obtain estimates of the increase in area likely to have conditions favourable for aquaculture (minus reservoirs, which are valued above).
- Obtain estimates of potential yield per annum (t/ha/year)
- Estimate potential per annum harvest for aquaculture fisheries (t/year)

- Obtain current market value estimates for relevant species (USD/t). Consider substitute good availability in the future (e.g. decrease in capture fishery harvest) and potential for inflation.
- Adjust market price accordingly using an economic conversion factor.
- Obtain estimates for labour, other input costs and marketing costs.
- Adjust input costs using an economic conversion factor to account for distortions, including subsidies.
- Subtract costs from gross economic value to estimate net economic value.

9.4 Marine

Marine fisheries, defined as those in the marine waters of the Mekong River Delta (MRD) and nearby sea, are considered in just one of the studies reviewed. The information below comes entirely from ICEM (2010c). While these fisheries will not be directly impacted by hydropower development, there may exist potential for indirect impacts associated with reduced flow of sediment and nutrients from the Mekong River into the MRD.

9.4.1 LMB Dams Literature Review

While it is generally recognized that the productivity of marine fisheries in the MRD are linked to the sediment plume and associated nutrients, the exact relationship is not known. For that reason, the ICEM study used the replacement cost of nutrient loss associated with hydropower development (of the mainstream dams) as a basic indicator of the value of marine fisheries.

Data

In 2008, marine fisheries harvest in the Mekong Delta was estimated to be 563,000 tones, with a value of USD 1.1 to 2.0 billion.

Results

According to the ICEM report, there would be an estimated reduction of 4,535 tonnes of phosphate per year entering the Mekong Delta if all 12 mainstream dams were built. This would be approximately a 50% reduction from the baseline and has an estimated replacement value of USD 40 million per year. The inferred price per kg of phosphates is USD 8.80.

9.4.2 Next Steps

The use of the replacement cost approach, as described in the results section above, for this purpose is very crude and provides limited confidence. Much depends on the extent to which the delivered nutrients affect biological production in the marine ecosystem. The USD 40 million could be an overstatement or an understatement, it simply is not clear. That said the inferred price for phosphates is substantial, and quite a bit higher than that deployed in the HPST (see Section11.3). A preferred method would be to use the productivity approach, which would, however, require deriving the relationship between the nutrients and the productivity of the fishery. This could be undertaken in either of two ways. First, it could be derived through an empirical analysis of observed changes in nutrients and production levels; however, this is difficult to do if past natural perturbations in the desired variables are not evident or are not observed in the likely ranges that are being forecast. Man-made changes in sediment delivery are already occurring due to the UMB dams, but the resulting data is only of short duration at this point in time. Given these limitations, the second option, a process-based model that quantifies the response functions involved, may be a more practical method for estimating these changes in productivity.

The ICEM report has identified a potential external impact that other studies have not included. However, the value estimate is not reliable. A focused valuation study with a multidisciplinary team is required to assess these impacts and develop a valuation study that would yield order of magnitude value estimates that could be associated with hydropower and dam development scenarios.

9.4.3 HPST Valuation

Due to the likely indirect relationship between hydropower development and MRD fisheries, as well as the limited information available on the nature of that relationship, potential impacts to MRD fisheries are not currently included in the HPST. They are, however, indirectly addressed through the analysis of nutrient and sediment loss included in Section 11.

10 Economic Valuation of External Impacts: Agriculture

Agricultural production, particularly paddy, is of great caloric and economic importance to the residents of the LMB. In this section we review efforts to date to assess impacts of hydropower development on agriculture in the Mekong. Sub-sections on riverbank gardens, recession/rain-fed paddy, the effects of saline intrusion on agriculture in the Mekong River Delta, and riparian and aquatic vegetation. The emphasis in this section is simply to examine what impacts are identified in the literature and to summarize the data that are deployed in Section 11.

10.1 Riverbank Gardens

Riverbank gardens are planted in land exposed by receding river waters, and are used by a large percentage of the population living along the Mekong River both for sustenance and livelihood. Riverbank gardens are used to grow fresh vegetables, maize and tobacco, among other crops. Depending on their location, riverbank gardens could be affected by hydropower development in different ways: permanent inundation, changes in sediment/nutrient deposition, and/or changes in water depth/quality.

10.1.1 LMB Dams Literature Review

Methods

The methods used to assess the value of riverbank gardens were similar across the studies reviewed. They generally can be described as follows:

- Estimate baseline total area of riverbank gardens (ha).
- Estimate annual yield riverbank garden produce (kg/ha).
- Assign a per unit value to the agricultural production (USD/kg).
- Estimate net economic value (USD m) under current conditions.
- Estimate change in total area of riverbank gardens due to hydropower development as well as any associated change in annual yield and price, and then calculate the change in annual net economic value of production.
- Calculate NPV.

The high nutrient content of the land exposed by receding waters and the ease of access suggest that input costs associated with riverbank gardening are minimal (ICEM 2010c). Based on the studies reviewed, it appears that riverbank gardens are typically operated by households as opposed to commercial enterprises and, as mentioned previously, contribute to both household income and consumption.

Data

Laplante (2005) estimated the potential impacts of Nam Theun 2 on riverbank gardens. In his study, he assumed that riverbank gardens contributed USD 200-500/ha/year. He also noted that project developers anticipated mitigation costs of USD 2,000-2,500/ha to develop alternative gardens.

ICEM (2010c; 2010a) estimated the size and value of riverbank gardens for the LMB as seen in Table 43. In per hectare terms the low and high range of yield value is USD 1,500/ha to US 4,800/ha (ICEM 2010a).

Table 43. Estimates of Size and Value of Riverbank Gardens in each Riparian Zone

Zone	River dependent rural pop. (2005)	% HH using RBGs	Total area of RBG (ha)	Yield of vegetables (t)	Total value per year (USD mil.)
Chiang Saen to Vientiane	313,939	14	2,166	12,997	3.2 - 10.4
Vientiane to	1,343,182	13	8,395	50,369	12.6 - 40.3
Pakse to Kratie	232,397	11	1,278	7,669	1.9 - 6.14
Kratie to Phnom	3,581,952	7	12,358	74,146	18.5 - 59.32
Phnom Penh to	6,482,368	29	95,291	571,745	142.9 - 457.4
Total	11,953,838	—	119,488	716,926	179 - 574

Note: Yield of vegetables was assumed to be 0.6kg/m^2 and worth USD 0.8/kg.

Results

ICEM (2010c) estimated that some 150,000 hectares of riverbank gardens would be affected with over 119,000 hectares lost due to inundation by reservoirs. ICEM also present two estimates for the associated economic loss: USD 21 million/year (p 59) or USD 25.1 million/year (p 13).

Loss of riverbank gardens are estimated in (MRC-BDP 2010f) based on draft information from the ICEM study at 4,317 hectares (of a total 118,738 hectares of gardens). The BDP Main Report estimated that hydropower development would negatively affect river gardens and approximately 12,600 people and 3,700 people between Chiang Sean to Nakhon Pnom and Nakhon Pnom to Ubol Rachathani, respectively (MRC-BDP 2011). No explicit economic loss is attributed to riverbank gardens in the report, although it may be included with agricultural lands lost due to inundation.

Obviously there are inconsistencies in the ICEM analysis. Either the acres affected, as reported, are exaggerated by a factor of 10 or the original value estimates were significantly reduced.

10.1.2 HPST Valuation

Projects assessed during the Srepok Basin case study did not include information on existing riverbank gardens or projected losses. Along the Srepok River in Cambodia, there was concern by communities regarding the increased daily variation in flows with hydropower development upstream in Viet Nam but it was not evident that this would impact any “river gardens.” Also, the studies reviewed above estimated impacts on river garden for the mainstream Mekong River only. It is unclear where the Guidelines, which are designed for tributary sub-basins and mainstream, should include this impact of hydropower development. Outside of impacts to these gardens by permanent inundation it is not clear how increasing variability of flow would necessarily eliminate these gardens. In the Srepok Basin pump irrigation of these gardens was observed early in the dry season.

HPST does not include the valuation of these aspects. As these appear important in a particular context these values would need to be added into the HPST through either the local costs economic valuation component or included as social indicators.

10.2 Recession/Rain-fed Rice

Recession agriculture, primarily rice, is planted along the edges of water bodies (e.g. Tonle Sap) as floodwaters recede. According to one source, changes in annual flooding as a result of hydropower development likely could result in reduced area available for recession rice production, particularly in the Tonle Sap region of Cambodia (MRC-BDP 2010h).

It should be noted that it is not clear whether estimates for changes in recession rice production were included with the riverbank gardens estimates calculated in the ICEM (2010c) study, as reviewed above. This issue would need to be resolved in order to avoid any double counting of losses.

10.2.1 LMB Dams Literature Review

Methods

Both Laplante (2005) and BDP Technical Note 12 (MRC-BDP 2010h) used similar methods to estimate potential impacts to recession rice. They are described generally here:

- Estimate baseline total of available area for recession rice (ha).
- Estimate annual yield for rain-fed rice (kg/ha).
- Assign a per unit value to rice production (USD/kg).
- Estimate net economic value of production (USD m).
- Estimate change in total area available for recession rice due to hydropower production as well as associated change in annual yield and annual net economic value using the same process.
- Calculate NPV.

Data

- Laplante (2005) estimated rain-fed paddy yield to be 2.8 t/ha, with an associated value of USD 150/t.
- BDP Technical Note 7 included detailed estimates associated with rain-fed rice production. Assuming this is correct, the study assumed a yield of 2.3 t/ha for all estimates as shown in Table 44 (MRC-BDP 2010a). Also note that gross margin (or net revenue) is around USD 100/ha in Lao PDR and Cambodia.

Table 44. Summary of Rain-fed Rice Production (per Hectare)

Country	Material costs (USD)	Labour costs (USD)	Mechanization costs (USD)	Net income (USD)	Gross margin (%)	Days of labour	Return on labour day (USD)
LAO PDR	112	331	30	102	21	104	4.2
Cambodia	108	294	43	130	29	112	3.8
NE Thailand	140	196	202	37	7	49	4.8

Results

The BDP Main Report estimated the NPV of impacts on recession rice for all scenarios considered (MRC-BDP 2011). These loss estimates ranged from USD 144 million under the Definite Future Scenario to USD 278 million under the 20-year plus climate change scenario. Technical Note 13 (MRC 2010) further broke out the estimates by country, as seen in Table 45 (MRC-BDP 2010b).

Table 45. Estimated Losses for Recession Rice

	LAO PDR	Thailand	Cambodia	Viet Nam	Total
DFS					
Recession rice area lost (ha)	-20,806	-36,911	-82,129	-8,118	-174,964
NPV loss (USD million)	-19	-10	-106	-9	-144
20-year					
Recession rice area lost (ha)	-24,083	-43,257	-105,081	-12,211	-184,632
NPV loss (USD million)	-21	-22	-122	-13	-178

10.2.2 HPST Valuation

Projects assessed during the Srepok Basin case study did not include information on existing recession/rain-fed rice production or projected losses. As with riverbank gardens, if there were losses, presumably, they would be included in the total area lost estimates, but no additional information was provided. As such, impacts on recession/rain-fed rice production are indirectly incorporated in the HPST through three economic indicators: loss of total land (which includes "unspecified" land); loss of livelihood; and downstream impacts (including nutrient and sediment loss), all of which are discussed further in other sections.

10.2.3 Direction for Future Work and Additional Research

Prior studies provide useful guidance on valuing changes to recession/rain-fed rice production due to hydropower development. The approach recommended is as follows:

- Obtain estimates of baseline area available for recession/rain-fed rice
- Obtain estimates of number of crops planted per year and average annual yield (kg/ha) for dry, wet, and average years.
- Obtain current market value estimates (USD/kg).
- Obtain current estimates of input costs – e.g., labour, fertilizer, machinery (USD/ha or USD/kg).
- Estimate per unit net value (USD/kg).
- Estimate the change in area available for recession/rain-red rice due to hydropower development (ha).
- Assign a per unit value to the loss in production (USD/kg).
- Calculate the change in annual net economic value of production.
- Calculate NPV.

10.3 Paddy (Delta)

The Mekong River Delta (MRD) is the most productive rice-producing region of Vietnam. In 2007, the MRD produced 20 million tonnes of rice, accounting for 55% of total production (37 million tonnes) that year. Of this, 4.65 million tonnes were exported, with an estimated 90% coming from the MRD. The estimated value of these exports was USD 2.9 billion. (USDA FAS 2009)

Changes to downstream hydrology in terms of water quantity and water quality due to upstream mainstream and tributary hydropower projects may affect downstream paddy production in the Mekong Delta. Reduced nutrient loading and decreased sediments may negatively impact production, while reduced saline intrusion may have positive benefits for paddy production by increasing the number of hectares on which to farm.

10.3.1 LMB Dams Literature Review

Methods

No study reviewed included specific methods for addressing potential impacts of changes in nutrient loading and sediment deposition association with hydropower development on MRD agriculture production. ICEM (2010c) stated, however, that much of the MRD agricultural land adjacent to the river is dependent on overbank siltation and estimated that mainstream dams would decrease nutrient loadings from 4,000 tonnes/yr to 1,000 tonnes/yr for the MRD floodplain.

BDP Technical Note 8 estimated potential impacts to MRD agriculture production associated with decreased saline intrusion (MRC-BDP 2010d). The methods used are described generally here:

- Estimate baseline total of available area affected by saline intrusion by class (ha).
- Estimate annual yield in saline intrusion affected areas by class (kg/ha).
- Assign a per unit value to rice production (USD/kg).
- Estimate net economic value of production (USD millions).

- Estimate change in total area of available for production due to decreases in saline intrusion associated with hydropower production as well as the associated change in annual yield and annual net economic value using the same process.

The study also noted that yields from wet season (summer-autumn) crops are most likely to be affected by saline intrusion, as March-April is when MRD waters currently have the highest salinity (MRC 2010).

Data/Results

- BDP Technical Note 7 used a yield of 3.4 tonnes/ha for MRD rice paddies (MRC-BDP 2010a).
- BDP Technical Note 8 conducted a detailed study of the potential change in saline affected areas in the MRD. We present estimates for the baseline, DFS and 20-year scenario in Table 46 (MRC-BDP 2010d).

Table 46. Comparison of Change in Area and Production for Salinity-affected Land in the MRD

	Salinity affected area (000 ha)	Avg. wet season production (000 t/yr)	Impact NPV (USD millions)
Baseline	1,851	4,548	—
DFS	1,579	5,014 (+10.3%)	+20
20-year	1,543	5,042 (+10.9%)	+27

10.3.2 HPST Valuation

Salinity intrusion was not included in the HPST. The effects of live storage on the Mekong River flow reversal, Tonle Sap and the MRD is described in Section 11. There is the potential for higher dry season flows due to live storage in the basin to "push out" the salinity front in the MRD. More to the point it is not possible for the HPST to simulate this given just information about project storage amounts. The MRC-BDP Technical Note 8 work on this topic does not provide any causal linkage or equation for doing this (MRC-BDP 2010d). Furthermore, the MRC-BDP work is not clear as to whether there is an increase in salinity under the future scenarios – it appears that in a number of the scenarios salinity falls from baseline levels. Nor is there any attempt to address the multiplicity of causal factors that are affecting salinity in the MRD.

10.4 Riparian & Aquatic Vegetation

Local populations use a variety of riparian and aquatic plant species, both for personal use and for income (Hall and Leebouapao 2005). It appears, however, that there have only been localized studies to date on the importance and value of these resources to households and communities in the region.

A field study in one village in the Chian Rai Province concluded that at least 65 riverine plants were used by the community for medicinal herbs, animal feed, fishing bait and gear, household tools and rituals (Hall 2005). The most commonly recognized of these plants were freshwater algae (gai) and river weed, both of which could be sold for income.

Changes in flow, flooding and general river hydrology associated with hydropower development may have an impact on this type of vegetation and/or the regional population's ability to access and harvest it.

10.4.1 LMB Dams Literature Review

Methods

Hall and Leebouapao (2005) proposed two options for valuing riparian and aquatic plant species:

- Estimating the net revenue generated by their sale.
- Estimating the replacement cost of species used in the community for reasons other than sale.

Data/Results

No broad-scale analysis of the importance, frequency of use or value of riparian and aquatic species was located in our review of literature. Furthermore, there was no attempt to estimate the potential economic impact of hydropower development to riparian and aquatic species used by human populations.

10.4.2 HPST Valuation

Case study projects did not include information on current use of riparian/aquatic vegetation by households in the study area, nor did they consider potential impacts. As previously reviewed studies appeared highly localized, it was not possible to determine the reliability of those values to the case study areas. Further field assessment would be needed to understand if the loss of these ecosystem goods is sufficient to merit the incorporation of it into the impact analysis. In the meantime, it is recommended that the loss of these resources be considered as part of the un-quantified social and environmental impacts in the ISH02 process. To the extent that riparian/aquatic plants are sold for income, impacts are indirectly incorporated into the HPST through the “loss of livelihood” indicator.

11 Economic Valuation of "Downstream" External Impacts: Hydrologic Function

Development of hydropower projects will cause changes to hydrologic function and river morphology, both on the tributaries and the mainstream, with some effects accumulating as they move downstream. When considering the economic value of these impacts, it is not the direct change in hydrologic function or river morphology that is necessarily valued. Rather it is how this change affects downstream physical and chemical fluxes, how these affect ecological systems, and how these interact with established patterns of human behaviour to affect economic production (livelihoods) or consumption (lifestyle).

As noted in earlier sections, downstream external impacts may occur immediately below a reservoir or hundreds to thousands of kilometres downstream depending on the volume of the storage. The river in effect carries the physical and chemical changes from hydropower development as far downstream as they can reach before they are attenuated or decay to insignificance. As part of the Srepok Basin case study, an effort was made to examine what appeared to be some of the major channels and impacts on the principal large ecosystems downstream on the mainstream Mekong River, the Tonle Sap Lake and the Mekong Delta.

NOTE: While these efforts are formative and may need adaptation or additional data in order to be applied to other tributaries of the Mekong, the idea was to develop valuation routines that could be applied to dams and reservoirs in other areas of the Mekong. In doing this there is necessarily a heavy reliance on the existence of underlying science and modelling that is needed, for example, to link a dam a thousand miles upstream to a change in habitat of a hectare of the Tonle Sap Lake. This effort seeks to build on recent efforts and models to develop valuation approaches that can assess the economic losses in a practical and replicable fashion, as per the objectives of the ISH02 Guidelines.

The selection of impacts for valuation, therefore, proceeded according to both the received perception of the large-scale impacts of hydropower development and the supply of likely scientific information that could underpin such analyses. Three external impacts of hydropower development are addressed here through economic valuation.

1. Impact of change in ***flow regime*** on downstream flow and water storage regime on Tonle Sap and resulting change in habitat and fish/agricultural/forest productivity.
2. Impact of dams as ***barriers to fish migration*** and fish productivity as felt in the tributaries, in the mainstream, in the Tonle Sap, and in the Mekong Delta.
3. Impact of reservoirs and dams in changing the ***downstream sediment regime***:
    a. Increase in sediment and bedload trapped in reservoirs; and
    b. Decrease in sediment and bedload in the mainstream, Tonle Sap and Mekong Delta.

While the modelling effort links dams and reservoirs to downstream physics, chemistry and ecology, the economic values derived stem from productivity changes in fisheries, agriculture, and sand and gravel mining, which are separately described in other sections in this paper, i.e., in Sections 9, 10, and 12.5 respectively. Information in these sections is not repeated here; only the parameters actually deployed in the valuation are reiterated here.

11.1 Flow Regime Change and Fish Production in Tonle Sap Lake

Following a brief background section, the causal chain that links reservoir storage to fish production in Tonle Sap is described. Results from an application to the Srepok Basin then are presented

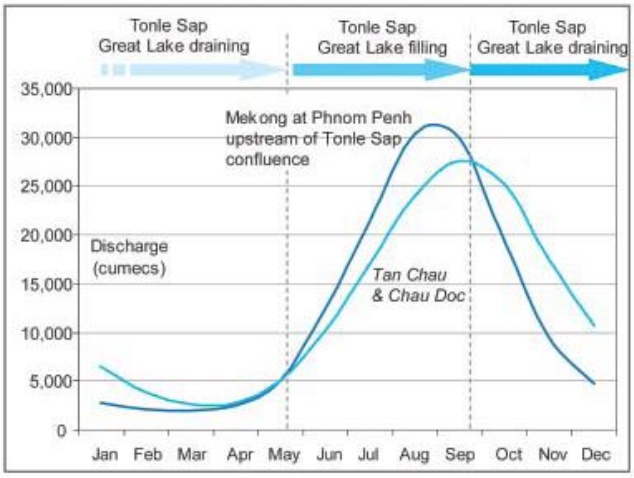
11.1.1 Background: Unregulated Hydrologic Function

The natural, unregulated function of the Mekong River floodplain, the Tonle Sap, and the Mekong Delta is well understood and documented (MRC 2005). During the wet season as the Mekong River rises, it reverses course, backing water upriver into the Tonle Sap. The consequences are as follows:

> This means that the huge upstream seasonal floodplain storage and the natural modification effects from drainage into and then out of the Tonle Sap reduces the intensity of the flood hydrograph and distributes the volume over a much longer period of time. (MRC 2005, 55)
>
> As stored water flows out of the lake back to the mainstream during the dry season, the low flows in the Mekong are increased and are therefore higher downstream of Phnom Penh than they would be otherwise. The benefit is more water for irrigation and a reduction in the amount of saltwater intrusion in the delta. (MRC 2005, 10)

The annual cycle is best understood from the Figure 5. The lake fills from the flow reversal during June through September. Outflows occur from October onwards. In simple, engineering terms the Tonle Sap functions as an off-stream re-regulating reservoir, though one that operates naturally (and with out the cost of human engineering). The end result is one of the great floodplain/lake ecosystems of the world. The Tonle Sap benefits from the floodplain inundation and over time species, habitat and humans have adjusted to the seasonal flooding. The question is how does this all change when the river is regulated by dams and storage.

Figure 5. Annual Draining and Filling Cycle of the Tonle Sap



Source: MRC (MRC 2005, 53)

11.1.2 Hydroecological Change due to Alteration of the Flow Regime

The development of reservoir storage above the Tonle Sap, whether mainstream or tributary, inevitably results in the alteration of the flow regime in the Mekong River. This is well described by many authors, and is fundamental to the MRC's Basin Development planning efforts (MRC-BDP 2010c; MRC-BDP 2011).

However, the change in flow is just the first step in arriving at a change in productivity analysis. The full causal chain that must be analysed includes:

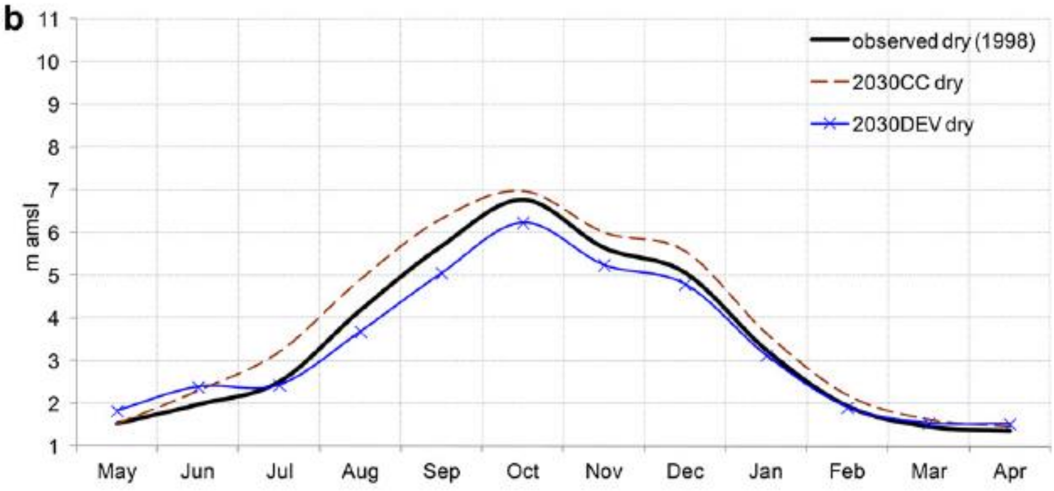
- Active storage in the Mekong River Basin upstream causes
    - Lower wet season flow
    - More dry season flow
- Change in Tonle Sap flow reversal, changes Tonle Sap water levels
- Change in Tonle Sap water levels change habitat

- Change in Tonle Sap habitat changes primary productivity and fish production
- Change in fish production causes change in economic output

For the purposes of the Srepok Basin case study, the hydroecological analysis and modelling in Arias et al. (2012) is combined with information on the Tonle Sap fishery from Hortle (2009) in order to develop a valuation routine that is driven by the amount of upstream storage associated with individual hydropower reservoirs.

Dry season energy is highly valuable in the Mekong Basin given both the lower flows and the increases in basin temperature that occur during this time. In general, reducing wet season production and increasing dry season production represents increased firm power, which can be more profitable than maximizing annual energy production (Wild and Loucks 2014). The net effect below the hydropower projects is more dry season flow, less wet season flow. For the Tonle Sap there is a lower reversal into the lake and a lower drainage amount out in dry season. Arias et al. (2012) have modelled the effect of hydropower storage development on the Tonle Sap flow reversal and found that this development affects the reversal most during dry years, less so during average water years and has only a small impact during wet years. Figure 6 shows an example of this flow difference. The 2030DEV scenario used by the authors is a 20 year impact scenario that includes development of the Upper Mekong Dams and LMB developments through 2008 plus 11 mainstream dams and other developments planned up to 2030 based on MRC-BDP (2011).

Figure 6. Comparison of Mean Monthly Water Level for Dry Year at Kampong Loung



Source: Arias (2012: 59)

Notes: historical observed records for 1998 and model predictions for 2030CC-climate change scenario for 2030's; 2030DEV-water resources infrastructure development scenario for the 2030's.

The change in regime downstream may be expected to affect flood recession agriculture (through lower Tonle Sap levels in winter) and fish production (through lower Tonle Sap levels in winter).

Note that irrigation development that uses active storage in multi-purpose projects represents a withdrawal of rainy season flow from the system without the compensation of additional flow during the dry season. So active storage used for irrigation has the same impact on the Tonle Sap as described above but also represents less water to the Mekong Delta during the dry season. So it is a complete loss to the downstream system.

In addition, there generally is no impact expected on dry season flows to the Mekong River Delta. Instead of the rainy season water being stored in Tonle Sap, it is now stored in the hydropower reservoir.

Arias et al. (2012) track through the impacts of these changes in water levels on five different types of habitat present in the Tonle Sap. The results are shown in Table 47, grouping the open water and gallery forest areas together (it is assumed that gallery forest and open water have approximately the same fish yield).

Table 47. Habitat Area: Baseline and Scenarios (Hectares)

	Rainfed	Transitional	Seasonally Flooded	Open Water & Gallery Forest	Total
Baseline (modeled)	838,600	474,400	478,700	820,700	2,112,400
Change due to Future Scenarios (modeled)					
UMD	81,300	(18,900)	(61,200)	(1,200)	
2030DEV	106,100	(28,100)	(81,000)	3,100	
2060DEV	**121,500**	**(13,300)**	**(104,100)**	**(3,100)**	

Source: Arias et al. (2012)

Each habitat type has its own natural productivity in terms of fish production. Gathering figures from Hortle (2009) allows the compilation of rough ranges for each habitat type. Midpoint estimates are then derived for use in developing the change in productivity valuation relationship shown in Table 49.

Table 48. Fish Yield by Habitat Type

Yield Estimates	Yield per Area		
	Low kg/ha	High kg/ha	Midpoint kg/ha
Seasonally flooded land and water within the major flodd zone, including some rice fields	100	200	150
Tonle Sap Seasonally Flooded	300	400	350
Rain-fed rice fields and associated habitats not within the major flood zone	50	100	75
Large water bodies, including reservoirs	100	300	200

Source: Hortle (2009)

The information on baseline habitat areal extent and the change under each water resource development scenario can then be combined with the fish yield figures to estimate the total fish production for each habitat type under the baseline and the development scenarios. Note that the total estimated fish yield in the baseline is 365,000 tons/yr. This compares with the estimate of just under 600,000 tons/year of consumption in Cambodia (from Table 40 above). The total change in fish production can then be derived by comparing scenarios to the baseline. Results suggest 5% to 8% changes in fish production for the three scenarios (see Table 49).

Table 49. Baseline and Scenario Changes in Fish Production by Habitat Type

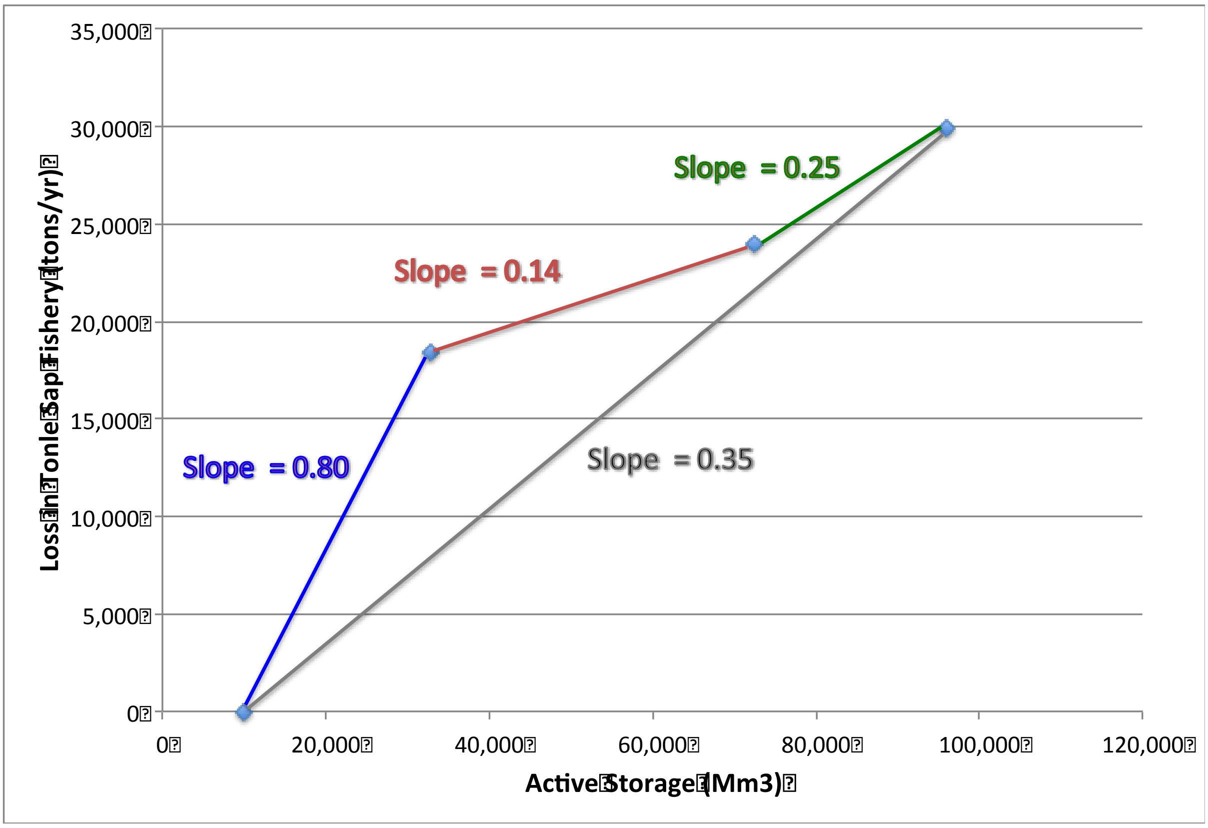
	Total Habitat by Type (hectares)				Fishery Production		
Scenarios	Rainfed	Transitional	Seasonally Flooded	Open Water & Gallery Forest	Fish Yield (tons/yr)	Change in Fish Production (tons/yr)	% of Baseline
Baseline (modeled)	838,600	474,400	478,700	820,700	365,740		
Future Scenarios (modeled)							
UMD	919,900	455,500	417,500	819,500	347,343	(18,398)	-5%
2030DEV	944,700	446,300	397,700	823,800	341,753	(23,988)	-7%
2060DEV	960,100	461,100	374,600	817,600	335,803	(29,938)	-8%
Fish yields (kgs/ha/yr)	75	150	350	200			

The active storage associated with the baseline and three scenarios is as follows, according to Arias et al. (2012):

- Baseline: 9,906
- UMD: 32,842
- 2030Dev: 72,492
- 2060Dev: 95,903

The plot of these figures and the resulting change in fish production is provided in Figure 7. The change from the baseline run through to full development suggests that for every 1 Mm^3 increase in live storage there is a 0.35 t/yr loss in the Tonle Sap fishery. If the baseline is taken as the UMD or 2030DEV scenarios and the impact examined through to the 2060DEV scenario the response is lower at 0.14 t/yr to 0.25 t/yr, respectively.

Figure 7. Functional Relationship between Basin Live Storage and Tonle Sap Fishery Production



11.1.3 Application to the Srepok Basin

To demonstrate the application of this approach we use the hydropower projects in the Srepok Basin. The live storage of each hydropower project, whether existing, under construction or planned is provided in Table 50, along with the expected change in fish production under the different scenarios. It is difficult to be precise about which scenario applies to which hydropower project, but overall the changes in production expected amount to from 1,700 tons/yr to 5,000 tons/yr depending on how responsibility is assessed. The estimated project-by-project lost value of fish production is provided in Table 51. The per unit value of fish production is set at USD 2.80/kg as the midpoint of the market value of catch from Hortle (2009) as previously referenced in the section on fisheries. The annual loss in the Tonle Sap fishery ranges due to full build out of the Srepok projects listed is from USD 5 million to USD 14 million per year. Note that the approach taken in the tables is to measure the loss from the baseline to each scenario and average the costs across all the storage in each scenario. The alternative approach, deployed in the HPST is to assess only the marginal changes between scenarios. Since the UMD scenario is already in place, this reduces the impact of additional live storage significantly given how steep the response is for the UMD scenario.

Table 50. Srepok Basin Hydropower Projects: Change in Fish Production

Srepok Basin Hydropower Projects	Live Storage (mm3)	Fish Production Change by Scenario (tons/yr)		
Buon Tua Srah	523	(419)	(200)	(182)
Buon Kuop	26	(21)	(10)	(9)
Dray Hlinh 1	1	(1)	(1)	(0)
Srepok 3	63	(50)	(24)	(22)
Srepok 4	8	(7)	(3)	(3)
Srepok 4A	0	(0)	(0)	(0)
Lower Srepok 4	44	(35)	(17)	(15)
Lower Srepok 3B	66	(53)	(25)	(23)
Lower Srepok 3A	3,931	(3,153)	(1,507)	(1,368)
Lower Srepok 3	5,253	(4,214)	(2,013)	(1,829)
Lower Sesan 2	333	(267)	(128)	(116)
Total Option 1 (LS 3A & 3B)	4,995	(4,007)	(1,915)	(1,739)
Total Option 2 (LS 3)	6,251	(5,014)	(2,396)	(2,176)

Table 51. Srepok Basin Hydropower Projects: Value of Lost Fish Production

Srepok Basin Hydropower Projects	Value of Fish Production Lost by Scenario (USD)		
	UMD	2030DEV	2060DEV
Buon Tua Srah	1,173,731	560,835	509,401
Buon Kuop	57,564	27,505	24,983
Dray Hlinh 1	3,144	1,502	1,365
Srepok 3	141,158	67,448	61,263
Srepok 4	18,956	9,057	8,227
Srepok 4A	225	107	97
Lower Srepok 4	98,822	47,219	42,889
Lower Srepok 3B	148,232	70,829	64,333
Lower Srepok 3A	8,828,811	4,218,605	3,831,716
Lower Srepok 3	11,797,950	5,637,327	5,120,327
Lower Sesan 2	748,349	357,578	324,784
Total Option 1 (LS 3A & 3B)	11,218,991	5,360,687	4,869,057
Total Option 2 (LS 3)	14,039,898	6,708,580	6,093,335

11.1.4 HPST Valuation

In the HPST, the productivity change in the fishery due to the change in flow regime, FP_Q, in t/yr, is the product of the dose response parameter, s, and the change in the live storage, STO, in million cubic meters:

$$\Delta FP_Q = s * \Delta STO$$

The value of s is set at 0.18, which represents the marginal change in going from the UMD scenario to the 2060 scenario.

The annual change in the value of production, VFP_Q, is simply the change in fish production multiplied by the market price of fish, PF, as more fully explained in Section 9.2.2.

$$\Delta VFP_Q = P_F * \Delta FP_Q$$

The default market value of fish set in the HPST is USD 2.8/kg or USD 2,800/t.

11.2 Dams as Barriers to Fish Migration

The adverse impact of dams on populations of migratory fish is well established (World Commission on Dams 2000). It is also well-known that the Mekong River Basin is home to quite a large number of migratory fish (Hortle 2009). Nevertheless, hydropower development has made little effort to accommodate fish passage. For example, each dam that has been built on the Srepok River has further fragmented the river, increasing the distance that upstream/downstream migration runs are 100% blocked. Here we use the latest scientific modelling to attempt to value this blockage in economic terms. The simulation model prepared by Ziv et al. (2012) models the potential impact of the six dam-development scenarios in the 2011 Basin Development plan on the biomass of migratory species in the floodplains, as well as the species at risk due to habitat loss. The model aggregates a vast quantity of data on the fishery, including migration routes, monitoring data, habitat, productivity of fish, and distances to hydropower facilities. The output of the model is a prediction of the loss in biomass that will occur with the construction of hydropower projects, assuming no fish passage is provided.

11.2.1 Application to the Srepok Basin

In the Srepok Basin case study, the hydropower project at the confluence of the Srepok River with the Se San River is the Lower Se San 2 project. This facility, once completed, will effectively block these two rivers (two of the so-called “Triple S” rivers) to migration upstream or downstream. The Triple S Basin is the lowest major subbasin on the Mekong River and lies below the natural barrier at Khong Falls upstream of Stung Treng. As a result, this basin is a major contributor to the fisheries migration in the lower third of the Mekong River. Not surprisingly the biomass loss that Ziv et al. (2012) derive is the highest for any proposed hydropower project. At an estimated 9.2% loss for the lower Mekong, this figure represents a loss of 92,000 tons/yr, based on Hortle (2009) estimates that the Mekong River Delta and the Tonle Sap fishery accounts for about 1 million tons/yr of fish production. Valued at the same market price deployed for the flow regime analysis, USD 2,800/ton, this is USD 257 million per year for the Lower Se San 2. It is noteworthy that the annual revenues from power production are expected to be only one-half of this per year (under full production).

11.2.2 HPST Valuation

In the case of the impact of dams as barriers to fish migration the change in fish production due to barrier effect, FP_B needs to be derived from the Ziv et al. (2012) model or other estimates. The change in value of production, VFP_B, is simply the change in fish production multiplied by the market price of fish, P_F, as more fully explained in Section 9.2.2.

$$\Delta VFP_B = P_F * \Delta FP_B$$

The market price of fish is the same price set in the HPST as described in the description of the valuation routine for the change in flow routine due to reservoir storage.

The Srepok Basin case study incorporates this relatively simple valuation routine. Note, however, that there are three difficulties associated with making this approach replicable in the HPST.

The first issue can be best discussed in the context of the Srepok Basin case study. Ultimately, the intent of the Guidelines is to assist in the evaluation of hydropower and multi-purpose projects at the planning level. This raises the issue of how to accommodate the fact that in the Srepok Basin the only biomass loss figure provided by Ziv et al. (2012) is for the Lower Se San 2. As this project is currently under construction this figure is relevant. However, if all the loss were attributed to the Lower Se San 2 project, then other existing and potential projects would not bear any of the external costs.

In general, in an economic planning exercise the full cost might be applied to the dam lowest down in the catchment, like the Lower Se San 2. If the cost makes that project un-economic, as happens with Lower Se San 2, then the assumption would be that the project should not be built. At that point then the analysis would move upstream to find the next hydropower project. The impact on biomass would need to be re-evaluated as the distance to the dam has increased and the model would likely produce a lower impact on fish production and so a lower monetary damage estimate. If the dam were likewise judged un-economic, then the sequence would be repeated over again with the next hydropower project upstream in the system. The interesting feature is that as the analysis moves upstream the costs will decrease; however, so will the flow passing through each project and also the potential hydropower production and gross economic benefits. It is therefore hard to predict a priori how this planning sequence would play out in any one instance. In the Srepok Basin it seems likely that moving a short distance upstream to the Lower Srepok 3 or 3A projects would significantly reduce the impacts, as probably one-half or so of the impact would be experienced on the Se San River and not the Srepok River. However, the power production from these facilities is also greatly reduced. Furthermore, should these facilities be deemed unattractive, the next possible facilities, Lower Srepok 3B and 4, are actually located upstream of the confluence between the Srepok and two major tributaries to the Srepok. At this point, or as the analysis moves upstream and into Viet Nam, it may be that the costs diminish to the point where the other economic factors outweigh the lost fish production. Another possibility, which exists in the Srepok, is that there may be a natural barrier to migratory fish (typically high falls). At that point the cost may simply drop to zero.

The obvious second difficulty pointed out by the discussion above is the problem of having access to model results for all, or the most pertinent, hydropower facilities in a subbasin.

The third and final difficulty is how to assess the impact in a sequence of dams, as discussed above, when one or more dams are already built. At that stage is the loss of fish occasioned by the dam or dams a bygone conclusion, representing a sunk cost? If so, then the loss due to upstream dams does not enter into the decision, as the loss is a cost that is already in effect. From an economic planning perspective that might be the theoretically correct approach, but it may not be very satisfactory to stakeholders engaged in the planning exercise.

These topics should be the subject of further development of the HPST and the Guidelines.

NOTE: Further review and investigation is recommended to assess whether and how to deploy the Ziv et al (2012) modelling results to additional basins and projects in further applications of the HPST.

11.3 Dams and Reservoirs as Sediment Traps

The role of dams and reservoirs in altering sediment transport is also well known. The Mekong River is thought to generate 160 M tons of suspended sediment per year of which 80 M tons is thought to originate in the LMB (Wild and Loucks 2014). In the Mekong River concerns over the impact of Chinese hydropower projects on the Upper Mekong largely revolve around the consequences of these dams for sediment transport and deposition along the mainstream, in the Tonle Sap, and the Mekong River Delta (M. Kummu and Varis 2007; Walling 2008; Matti Kummu et al. 2008). The role of hydropower development in LMB tributaries has been less well studied, in part due to data gaps in sediment monitoring on the mainstream, i.e., lack of comprehensive monitoring below each tributary makes it difficult to confirm tributary inputs. Progress has been made in modelling and calculating the sediment trapping by tributary dams (M. Kummu et al. 2010; Wild and Loucks 2014; Kondolf, Rubin, and Minear 2014). With these models it may be possible to estimate the impact that this change in hydrologic function has on downstream ecosystems and economies.

11.3.1 Application to the Srepok Basin

Wild and Loucks (2014) provide data on sediment generation and sediment trapping in the Triple S Basin, which is expected to produce 6% to 16% of the total Mekong Basin sediment load (10-25 M t/yr). With the information contained in this paper in the Srepok Basin case study it was possible to assess the:

- Increase in sediment and bedload trapped in reservoirs.
- Decrease in sediment and bedload in the mainstream, Tonle Sap and Mekong Delta.
- Economic value of the lost sediment and bedload, in terms of its nutrient and physical value

The method is replicable if the data inputs in terms of expected sediment trapping can be derived for other tributary basins, using one or more of the Wild and Loucks (2014) approaches. We use the Srepok Basin case study to demonstrate the valuation method.

Wild and Loucks (2014) use the MRC-calibrated SWAT model to generate daily inflows and SedSim to generate sediment concentrations and simulate daily sediment trapping. The authors assume a uniform generation rate for suspended sediment of 290 t/km^2/yr based on best available data. This produces 22.7 M t/yr in suspended sediment for the Triple S basin, within the range expected. A rating curve is used to partition annual sediment flow into daily sediment loads. Trapping efficiency is determined using the Brune curve method. For reporting settled sediment mass the bulk density of sediment is assumed to be 1,200 Kg/m^3 based on reported density from the Mekong Delta. The trapped sediment figures come from 100-year modelling of the 21 years of flow data available. Wild and Loucks (2014) state that from 10 to 20% of sediment will consist of bedload. Bedload is the sand, gravel and larger material that travels along the river bottom. As 100% of bedload is trapped behind a dam, the focus of the analysis is on the remaining portion, the suspended sediment.

Wild and Loucks (2014) report that the midpoint figure for the entire Triple S Basin is 17.7 M t/yr of trapped sediment or 11% of the Mekong basin estimated total of 160M t/yr. The results provided by the authors for the Srepok Basin are presented in Table 52. The midpoint of the mean trapped sediments as reported by Wild and Loucks (2014) is used in the analysis.

Table 52. Sediment Rate and Trapping for Hydropower Dams in the Srepok Basin Case Study

Project Name	Drainage Area	Unregulated Suspended Sediment	Wild and Loucks (2014) Trapped Sediments Mean	Case Study Trapped Sediments Midpoint
	Km^2	M t/yr	M t/yr	M T/yr
Buon Tua Srah	2,930	0.85	0.45 – 0.51	0.48
Buon Kuop	7,980	2.31	0.06 – 0.28	0.17
Dray Hlinh 1	8,880	2.58	-	-
Srepok 3	9,410	2.73	0.65 – 1.01	0.83
Srepok 4	9,568	2.77	0.20 – 0.28	0.24
Srepok 4A	9,560	2.77	-	-
Lower Srepok 4	13,727	3.98	1.58 – 2.14	1.86
Lower Srepok 3B	14,341	4.16	-	0.04
Lower Srepok 3A	25,311	7.34	-	2.47
Lower Srepok 3	25,174	7.30	3.16 – 3.44	3.30
Lower Se San 2	49,200	14.27	1.50 – 6.50	4.00

Source: Drainage area from the Srepok Basin case study project data, Unregulated suspended sediment calculated based on drainage area and annual rate of sediment generation. Trapped sediments from Wild and Loucks (2014) are mean ranges, those used in the case study are the midpoints

11.3.2 HPST Valuation

11.3.2.1 Determination of quantity of material trapped

In order to value the economic losses due to the change in sediment the approach is first to derive the **quantities** of each element of suspended sediment and the amount of bedload as follows:

- The trapped sediment is divided into suspended sediment and bedload portions.
- The suspended sediment is divided into its component parts consisting of:
  - Nutrients: nitrogen, phosphorous and potassium, and
  - Physical material: clay, silt, and sand.
- The bedload factor is calculated as 15% of the unregulated sediment load.
- As 100% of bedload is captured at every reservoir, only the incremental additional bedload due to the increase in drainage area is multiplied by the bedload factor for each project to estimate total bedload.

For any of the **nutrients**, *N*, the derivation in kg/yr is as follows:

$$N = SSY_T\ M\ ton * \frac{10^9 kg}{M\ ton} * NP\ \frac{mg}{kg} * \frac{kg}{10^6\ mg}$$

Where:

- SSY_T is the total suspended sediment yield that is trapped at the reservoir.
- *NP* is the nutrient portion of the total suspended sediment that is trapped in mg/kg.

For the **physical materials**, *M*, the derivation in m^3/yr is as follows:

$$M = SSY_T\ M\ ton * \frac{10^9 kg}{M\ ton} * MP\ /\ SDB\frac{kg}{m^3}$$

where:

- *MP* is the material portion in percent of the total suspended sediment that is trapped in Mt/yr.
- SDB is the sediment bulk density (kg/m^3).

The incremental **bedload** for the *n*th reservoir, BL_n, where *n* is ordered from upstream to downstream in M t/yr is:

$$BL_n = BP\left[SSY(DA_n) - \sum_{i=1}^{n-1} SSY(DA_i)\right]$$

where:

- *BP* is the bedload factor representing the bedload as a portion of the total suspended sediment in percent.
- DA_i is the drainage area for the ith reservoir
- *SSY(DA)* is the suspended sediment yield for the drainage area

The unit conversions to arrive at bedload in m3/yr is:

- $BL = BL_n\ M\ ton * \frac{10^9 kg}{M\ ton}\ /\ SDB\frac{kg}{m^3}$

The physical and chemical parameters deployed in the case study are shown in Table 53 and come from Wild and Loucks (2014) and Arias (2013).

Table 53. Parameter Values for Sediment Valuation

Parameter		
Bedload	%	15%
Clay Portion	% of total	45%
Sand Portion	% of total	40%
Silt Portion	% of total	15%
Sediment - K	mg/kg	12.5
Sediment - N	mg/kg	7.5
Sediment - P	mg/lg	5.5
Sediment Bulk Density	kg/m3	1,200
Value-Physical Sediment	USD/m3	1.50
Value-Sand & Gravel	USD/m3	3.00
Nutrient Value	USD/kg	0.75

11.3.2.2 Value of Materials Trapped

The next step is to take the quantities of nutrient, physical material and bedload and value these at their apparent market price. In the case of nutrient values we do not make an effort to quantify their productive value. Rather we make the simplifying assumption that the nutrients contribute to ecosystem productivity downstream, whether in the mainstream Mekong River, the Tonle Sap, the Mekong Delta, or the estuary/near-shore area of the Delta. We do this using the replacement cost approach, that is valuing each mg of nutrient according to the cost of acquiring a similar amount in the market. While not an ideal approach, this approach is appealing as the productivity of agriculture and fisheries are underpinned by the nutrients brought in to the Tonle Sap and onto Delta fields by the hydrologic regime of the Mekong River. Both Vietnam and Cambodia have active and growing markets for fertilizer for agricultural use (Vuthy, Pirom, and Dary 2014; Thang 2014). Indemundi.com provides market reports of current prices for various fertilizers, with the principal fertilizers ranging between USD 350/t to over USD 500/t. Thang (2014) reports a steadily rising price for NPK mixes in Vietnam, with a price of approximately VND 15,000/kg in 2013 or approximately USD 0.75/kg.

For physical sediment (i.e. sand, gravel, silt, clay) it is assumed that this sediment has a market value. Sand and gravel mining is a well-known occurrence in the Mekong Basin as reported further in Section 12.5. A price of USD 3/m^3 is used for sand and gravel based on updating figures in the LMB literature review to 2104 USD (Hall and Leebouapao 2005; ICEM 2010a). For silt and clay there are no market values to deploy. However, much of the sediment that is used to irrigate paddy fields ultimately will settle onto the field. Over time this raises the level of the fields. In the Mekong Delta in order to keep fields low enough to allow the inflow of irrigation water, and to generate income, farmers will allow intermediaries to “harvest” the top layers from their fields. This material is then used by brickmakers to fashion the bricks that are seen along the roadside in the Delta. It does appear then that there is some value to this residual physical mater, so we attribute USD 1.50/m3 to the clay and silt material.

11.3.3 Results for the Srepok Basin

The physical and chemical results for trapped sediment, nutrients and bedload in the Srepok Basin are shown in the next three tables. Annual and present values are shown. The present values vary from just under USD 1 million for Lower Srepok 3B up to USD 53 m for Lower Se San 2 (see summary in Table 57. All told the losses from the Cambodian dams come to over USD 100 m (including only one of Lower Srepok 3 or 3A). For Viet Nam they approach USD 25 m.

Table 54. Nutrient Loss Valuation for Hydropower Dams in the Srepok Basin Case Study

Project Name	Nitrogen	Phosphorus	Potassium	Annual Loss in Value	Present Value of Loss
	kgs/yr	kgs/yr	kgs/yr	USD m/yr	USD m
Buon Tua Srah	3,600	2,640	6,000	0.01	0.06
Buon Kuop	1,275	935	2,125	0.00	0.02
Dray Hlinh 1	-	-	-	-	-
Srepok 3	6,225	4,565	10,375	0.02	0.10
Srepok 4	1,800	1,320	3,000	0.00	0.04
Srepok 4A	-	-	-	-	-
Lower Srepok 4	13,950	10,230	23,250	0.04	0.20
Lower Srepok 3B	311	228	518	0.00	0.00
Lower Srepok 3A	18,521	13,582	30,869	0.05	0.26
Lower Srepok 3	24,750	18,150	41,250	0.06	0.35
Lower Se San 2	30,000	22,000	50,000	0.08	0.42

Table 55. Physical Material Loss Valuation for Hydropower Dams in the Srepok Basin Case Study

	Sediment Loss (m^3/yr)			Annual Loss in Value (USD m/yr)				PV Loss
Project Name	Clay	Silt	Sand	Clay	Silt	Sand	Total	USD m
Buon Tua Srah	180,000	60,000	160,000	0.3	0.1	0.5	0.8	5.1
Buon Kuop	63,750	21,250	56,667	0.1	0.0	0.2	0.3	1.6
Dray Hlinh 1	-	-	-	-	-	-	-	-
Srepok 3	311,250	103,750	276,667	0.5	0.2	0.8	1.5	8.8
Srepok 4	90,000	30,000	80,000	0.1	0.0	0.2	0.4	3.2
Srepok 4A	-	-	-	-	-	-	-	-
Lower Srepok 4	697,500	232,500	620,000	1.0	0.3	1.9	3.3	18.0
Lower Srepok 3B	15,548	5,183	13,821	0.0	0.0	0.0	0.1	0.4
Lower Srepok 3A	926,064	308,688	823,168	1.4	0.5	2.5	4.3	23.9
Lower Srepok 3	1,237,500	412,500	1,100,000	1.9	0.6	3.3	5.8	31.9
Lower Se San 2	1,500,000	500,000	1,333,333	2.3	0.8	4.0	7.0	38.6

Table 56. Bedload Loss Valuation for Hydropower Dams in the Srepok Basin Case Study

	Unregulated Bedload for Drainage Area	Bedload Trapped by Each Reservoir		Annual Loss in Value	Present Value Loss
Project Name	M t/yr	M t/yr	M^3/yr	USD m/yr	USD m
Buon Tua Srah	0.13	0.13	106,213	0.3	1.9
Buon Kuop	0.35	0.22	183,063	0.5	3.0
Dray Hlinh 1	0.39	0.04	32,625	0.1	0.7
Srepok 3	0.41	0.02	19,213	0.1	0.3
Srepok 4	0.42	0.01	5,728	0.0	0.1
Srepok 4A	0.42		-	-	-
Lower Srepok 4	0.60	0.18	150,764	0.5	2.5
Lower Srepok 3B	0.62	0.03	22,258	0.1	0.4
Lower Srepok 3A	1.10	0.48	397,663	1.2	6.6
Lower Srepok 3	1.10	0.50	414,954	1.2	6.9
Lower Se San 2	2.14	1.04	865,976	2.6	14.3

Table 57. Summary of Sediment Loss Valuation for Hydropower Dams in the Srepok Basin Case Study

	Drainage Area	Active Storage	Nutrient Loss	Physical Material Loss	Bedload Loss	Total
Project Name	Km^2	M m^3	USD m	USD m	USD m	USD m
Buon Tua Srah	2,930	523	0.06	5.1	1.9	7.1
Buon Kuop	7,980	26	0.02	1.6	3.0	4.7
Dray Hlinh 1	8,880	1	-	-	0.7	0.7
Srepok 3	9,410	63	0.10	8.8	0.3	9.3
Srepok 4	9,568	8	0.04	3.2	0.1	3.4
Srepok 4A	9,560	0	-	-	-	-
Lower Srepok 4	13,727	44	0.20	18.0	2.5	20.7
Lower Srepok 3B	14,341	66	0.00	0.4	0.4	0.8
Lower Srepok 3A	25,311	3,931	0.26	23.9	6.6	30.7
Lower Srepok 3	25,174	5,253	0.35	31.9	6.9	39.1
Lower Se San 2	49,200	333	0.42	38.6	14.3	53.4

11.4 Downstream Valuation Summary

The effort to value downstream external impacts examined the

- Impact of storage reservoirs on the flow regime and its impact on the Tonle Sap fishery.
- Impact of dams as barriers to fish migration and fish productivity as felt in the tributaries, in the mainstream, in the Tonle Sap, and in the Mekong Delta.
- Impact of reservoirs and dams in trapping suspended sediment (including nutrient and physical material) and bedload

The results suggest a number of preliminary findings:

- Fish migration may be the primary economic impact from hydropower dams, with the potential to create losses that outweigh hydropower revenues

- Sediment loss impacts are more moderate in nature and occur at a significant scale relative to hydropower revenues.
- Active storage and the change in flow regime appears of a lesser extent here, but the valuation effort for this impact is not comprehensive at all, focussing only on fisheries impacts in the Tonle Sap.

Increasing availability of relevant and detailed spatially explicit ecohydrological models suggest the need to pair these studies with more detailed socio-economic studies of rural and subsistence production to arrive at better valuation through the changes in productivity approach.

Table 58. Summary of Sediment and Bedload Valuation for Hydropower Dams in the Srepok Basin Case Study

	Drainage Area	Active Storage	Storage and Flow Regime Loss	Fish Migration Loss	Sediment Loss	Total
Project Name	Km^2	M m^3	USD m	USD m	USD m	USD m
Buon Tua Srah	2,930	523	1.6	-	7.1	8.7
Buon Kuop	7,980	26	0.1	-	4.7	4.8
Dray Hlinh 1	8,880	1	0.0	-	0.7	0.7
Srepok 3	9,410	63	0.2	-	9.3	9.5
Srepok 4	9,568	8	0.0	-	3.4	3.4
Srepok 4A	9,560	0	0.0	-	-	0.0
Lower Srepok 4	13,727	44	0.1	-	20.7	20.8
Lower Srepok 3B	14,341	66	0.2	-	0.8	1.0
Lower Srepok 3A	25,311	3,931	10.9	-	30.7	41.6
Lower Srepok 3	25,174	5,253	14.6	-	39.1	53.7
Lower Se San 2	49,200	333	0.9	1,422.0	53.4	1,476.3

12 Economic Valuation of External Impacts: Other Ecosystem Services

Ecosystem services are defined by the Millennium Ecosystem Assessment to include provisioning, supporting, regulating and cultural services (Millennium Ecosystem Assessment 2005). Many of the provisioning services are considered in the preceding sections. In this section a number of supporting, regulating and cultural services in the LMB that may be affected by hydropower development are examined. In addition to their consideration (and valuation) on a service-by-service basis, ecosystem services produced by particular land uses may be considered jointly through deriving values for specific land uses. These are discussed later in this document. Of these impacts only carbon is directly included in the HPST. Sand and gravel mining is included through the valuation of changes in the sediment regime under the "downstream" valuation section.

12.1 Biodiversity

The Mekong River has some of the highest levels of biodiversity found in any river system in the world. At present, 850 species have been identified in the mainstream and its tributaries – with an estimated 250+ of them endemic (ICEM 2010c; MRC 2011). At present, there are a number of endangered species, as identified by the IUCN Red-list process, which live in the Mekong River. These include a number of fish, crocodiles, turtles and river-dependent mammals. In addition, the LMB wetlands support almost 100 globally threatened species (MRC-BDP 2010f).

The terrestrial area surrounding the river is also rich in biodiversity. A recent study estimated the greater Mekong region includes 20,000 plant, 430 mammal, 1,200 bird, and 800 reptile and amphibian species (MRC 2011).

Hydropower development is generally expected to have a negative impact on biodiversity, which could manifest itself in a variety of ways:

- Blocked or impaired fish migration routes
- Reduction in wetlands, forestland and other terrestrial areas
- Reduction in wetland seasonal variability
- Reduction in freshwater habitat in the MRD
- Changes in habitat quality or availability
- Changes in water quality, flow and depth
- Changes in ecosystem processes
- Increased habitat fragmentation
- Increased risk for invasive species

As MRC-BDP (2010f, 40) noted, "[The] above changes may be classified as direct or indirect, permanent or temporary, having an impact on the long term or on the short term and as stand alone or cumulative."

12.1.1 LMB Dams Literature Review

Methods

Several of the studies reviewed provided detailed estimates of baseline and impact quantities. In addition, the MRC-BDP (2011) assessment contained NPV estimates of these impacts; however, methods for how these economic values were estimated could not be found. Maunsell and Lahmeyer (2004) also attempted to value biodiversity impacts in monetary terms using a simple approach of species impact and an estimate of the lost local or global value.

It should be noted that it is difficult to identify the exact impacts associated with hydropower development only, as compared to other potential changes (e.g. changes in land use, agriculture intensification, etc.) as well as the cumulative effects of multiple changes.

Data

ICEM (2010) (2010b)included a breakdown of fish species by zone for the mainstream (See Table 59).

Table 59. Number of Fish Species in Each Zone of the Mainstream Mekong River

	China	Chiang Saen to Vientiane	Vientiane to Pakse	Pakse to Kratie	Kratie to Phnom Penh and Tonle Sap	Phnom Penh to the sea
Number of families	13	12	—	36	40	56
Number of species	151	140	—	252	284	486
Endemic species	19	26	—	40	31	28
Introduced species	7	4	—	5	4	3
Native species	125	110	—	207	249	455
% of endemics	12.6	18.6	—	15.9	10.9	5.8
% of total (781)	19.3	17.9	—	32.3	36.4	62.2

In addition to providing per hectare estimates of the value of habitat, Maunsell and Lahmeyer (2004) included, among others, the following value estimates related to biodiversity:

- International biodiversity value of fish per specimen: USD 200–2,500.
- Local market value of fish per specimen: USD 0.15–20.
- Number of fish in each species population at start of Project: 1,000.
- Number of fish per species to be relocated: 30.
- Cutting of Phayes Langur and Gibbon animal movement routes: USD 200–20,000.
- International biodiversity value of Phayes Langur per animal: USD 12,000.
- International biodiversity value of Gibbon per animal: USD 5,000.
- Local market value of Phayes Langur per animal: USD 80.
- Local market value of Gibbon per animal: USD 60.
- Capture and relocation of species breeding population: USD 50,000–500,000.

There is no substantiation of these values and they must be regarded merely as guesswork.

Results

- ICEM (2010c) noted that approximately half the distance of the Lower Mekong is currently categorized as a “Key Biodiversity Area.” The study then estimated that 80% of these areas would be affected by hydropower development with 58 and 26 migratory species at high risk and medium risk, respectively, from hydropower development.
- ICEM (2010c, 98) estimated that the development of all of the LMB mainstream dams would result in over 50% of the river between Chiang Saen and Kratie becoming a reservoir – effectively flooding a variety of habitats and resulting in the loss of “76% of all rapids; 48% of all deep pools; and 16% of all sand bars in the section between the Chinese border and Sambor.”
- The MRC-BDP (2011) assessment identified 32 ‘environmental hotspots’ within the LMB and estimated the number of impacted hotspots on a 3-point scale for each development scenario considered. Table 60 shows the estimates for three of the scenarios, in addition to the baseline.

Table 60. Number of Hotspots Impacted by Scenarios

	Low	Medium	High
Baseline	29	3	0
DFS	23	7	2
20-year	11	7	14
VHDS	0	0	32

- The MRC-BDP (2011) assessment estimated the NPV of impacts to environmental hotspots/biodiversity for all development scenarios considered. Under the Definite Future Scenario, the estimated NPV of losses was USD 85 million, while under the 20-year and very high development scenarios, the losses were USD 330 million and USD 700 million, respectively.

12.1.2 HPST Valuation

The economic valuation of biodiversity is a controversial subject, and not just among environmentalists, but also economists. There are no generally agreed upon estimates of the economic value of a lost or endangered species. Indeed, many economists would agree that attempting to do so is neither appropriate nor useful. The impact on biodiversity from hydropower development in the LMB is likely to be substantial, based on global experience with dams (World Commission on Dams 2000). Exactly what the economic consequences are of such impacts goes beyond the remit of the ISH02 project. Furthermore, in the opinion of the MRC consulting team attempting to value this external impact – as attempted by those cited above – is not an appropriate use of economics. Rather the value of a unique portion of each of the LMB countries natural heritage is a matter for non-monetary assessment, as part of the social and environmental indicators process being developed as part of the ISH02 project.

12.2 Greenhouse Gas Emissions and CO2 Emission Reductions due to Hydropower

Middle East oil currently provides 78% of energy for the Greater Mekong Sub-region (MRC 2012); so there is the potential for reduced greenhouse gas (GHG) emissions associated with a displacement of fossil fuel power sources with hydropower in the LMB.

Studies have shown that hydropower as a source of energy generally emits fewer greenhouse gas emissions than fossil fuel dependent sources; however, there have been recent studies that suggest there are differences between GHG emissions from tropical versus non-tropical hydropower (Fearnside and Pueyo 2012). In the Mekong context, Laplante (2005) noted that reduced emissions associated with a switch from fossil fuels to hydropower may be offset by GHG emissions from dam reservoirs – as organic carbon in the recently inundated lands begin to decompose.

12.2.1 LMB Dams Literature Review

Methods

In the energy sector generally, and in particular with hydropower, there is an emphasis on increases and decreases in carbon dioxide emissions. Note that reservoir emissions may be from greenhouse gases more generally, but these are often converted to carbon dioxide for simplicity sake. While basic methods were presented for estimating the net change in GHG emissions and calculating an associated value, little in depth efforts were made in the studies reviewed for estimating the economic value associated with this change.

Results

Laplante (2005) estimated that the Nam Theun 2 project would reduce CO_2 emissions by 20 million tonnes over the life of the analysis, with an estimated NPV of USD 34 million. In addition, the study placed a negative cost of USD 18–30 million on reservoir GHG emissions, suggesting a net benefit of USD 4–16 million. The author did note that the timing of the release of emissions (e.g. a bulk of emissions at one point in time versus a sustained rate of emissions over a period of years) could substantially alter the impact (and associated value).

ICEM (2010c) estimated the LMB mainstream dams would have net GHG emissions reductions of 40–50 million tonnes CO_2/year.

Nippon Koei (2009) deploy methods based on those of the Clean Development Mechanism (CDM) to calculate the change in CO_2 emissions for a full portfolio of proposed Cambodian hydropower projects. The study suggests emission reductions for the Cambodian power grid of 755 t-CO_2/GWH (0.755 kg CO_2/kWh) when hydropower is deployed in place of diesel power. For the loss of forest sequestration due to submergence of forestlands in hydropower reservoirs the study provides emissions reductions due to hydropower emissions due to loss of forest sequestration of 5.19 t-CO_2/ha/yr based on IPPC 2006 guidelines for calculating national greenhouse gas inventories. The CDM parameters (reported below) are also used for calculating reservoir emissions. It is worth noting however that Nippon Koei (2009) misconstrues the CDM guidance on the use of the power density requirements. In the study the reservoir emissions are simply left out for power densities of less than 4 W/m^2. These projects are still credited with net emissions reductions. For example Lower Se San 2 is credited with 937,000 t-CO_2/yr of emissions reductions even though the power density is 0.52 W/m^2. As a shallow, large surface area reservoir that will flood a large area of tropical forest this project would not qualify for any greenhouse gas credit under the CDM. The project may even lead to an increase in greenhouse gas emissions.

The Buon Kuop hydropower project submitted project design documents to the Clean Development Mechanism for approval (No Author 2006). This project has a power density of over 50 W/m^2 and thus qualifies for the CDM program. Calculations of the emission reductions for the Viet Nam power grid in the proposal suggest a factor of 535 t-CO_2/GWH for hydropower. At full production the facility is expected to yield over 773,000 t-CO_2/yr.

12.2.2 Additional Literature Consulted

Methods. The Clean Development Mechanism provides the current methods for registering new hydropower projects for carbon credits (CDM 2015). The guidelines do not apply to hydropower projects with a power density of less than 4 W/m2. Projects with power density between 4 and 10 W/m^2 must calculate reservoir emissions at 90 t-CO_2/ha/yr. Projects with a power density over 10 W/m^2 are instructed to set reservoir emissions at zero. Clearly the intent of the guidelines is to exclude projects with a large reservoir surface area and a low installed capacity. This is no doubt due to the uncertainty regarding what the reservoir emissions would be and in order to avoid certifying a project under the CDM that might actually increase greenhouse gas emissions overall.

Global Social Costs. The most recent US government interagency effort finds that the global social cost of carbon is USD 11 to 37 per t-CO_2 for 2015 reductions. The range is determined by the shape of the cost curve over time and the discount rates employed (5% and 4% respectively) (IAWG 2013). The discount rates and the resulting costs are derived for regulatory purposes, in particular to ensure internal consistency in government analyses across agencies and sectors. The cost estimates originate from three different global models (PAGE, FUND and DICE) that attempt to pair global climate models with global economic models. Based on the US Government work a recent IMF publication selects a USD 35/t-C02 as representative of the social costs of emissions (Parry et al. 2014) A recent academic study claims that enabling climate change to affect the underlying growth rate of economics may lead these models to project even higher social costs of up to USD 220 per t-CO_2 (Moore and Diaz 2015). In a commentary, a leading economist suggests that the global models have little empirical basis and that the treatment of economic impact in these models is “completely ad hoc and of almost no predictive value” (Pindyck 2013, 44). Further, the author points out that these models completely fail to incorporate the risk of a possible catastrophic climate outcome. As a result the author expects that a range of USD 10 to 40 per t-CO_2 for the most likely scenarios is approximate but the true value might be as high as USD 200 per t-CO_2 if catastrophic risk is included (Pindyck 2013).

Carbon Pricing. Various schemes to internalize potential damages from climate change by pricing carbon exist around the world, primarily consisting of trading in emission reductions or carbon taxes. A recent World Bank report inventories these efforts and documents that they price carbon at anywhere from USD 1 to USD 168 per t-CO_2 (Kossoy et al. 2014).

Regional Studies. In a study forecasting the Thai power sector and resulting carbon emissions (Promjiraprawat and Limmeechokchai 2012) confirm that the government's target of achieving an average of 440 t-CO_2/GWH is realistic under future scenarios and that abatement costs under a 40% emissions reductions scenario are USD 5.26 to 8.20 per t-CO_2.

12.2.3 HPST Valuation

12.2.3.1 Quantity of CO2 Emissions (reduction)

The approach taken in the HPST is to deploy the CDM methods cited above. The first step is to calculate the power density and evaluate whether any net emission reduction benefit can be credited, so whether the power density is greater than 4 W/m^2. If so the methods are used as follows to calculate each component change in emissions:

- Increase in emissions due to the loss of submerged forest and therefore the loss of future forest carbon sequestration; this is calculated using the 5.19 t-CO_2 per hectare of forestland lost as cited above for Cambodia (more precise country figures can be entered as they are obtained by future study teams).

- Increase in emissions due to emissions from reservoirs; this is calculated using the CDM figure of 90 t-CO_2 per hectare of reservoir surface area per year for projects with a power density between 4 and 20 W/m^2.

- Decrease in emissions due to hydropower generation with zero emissions displacing grid generation with a country specific CO_2 concentration; these factors are as cited above for Cambodia, Thailand and Vietnam, with the Lao factor using the same figure as Cambodia (update country figures can be entered as they are obtained by future study team).

A summary of these parameters as they appear in the HPST parameters is provided below.

Table 61. HPST Parameters for CO_2 Emissions

Carbon						
Forest Sequestration	t CO2/yr/ha	5.19	5.19	5.19	5.19	5.19
Reservoir Emissions	t CO2/GWH	90.0				
Power Density Trigger 1	W/m2	4				
Power Density Trigger 2	W/m2	10				
Fossil Fuel Avoidance	t CO2/GWH		755	755	440	535

In order to carry out these calculations information about each projects installed capacity, reservoir area, annual power generation, submerged forestland area, and country-by-country destination of power generation would be required.

Once each component change in emission reduction is prepared the net total change in reduction emissions is calculated. Given that unsuitable shallow reservoirs with low installed capacity are effectively excluded from these calculations, most facilities will show net emissions reductions.

12.2.3.2 Valuation of Emissions reductions

There are a number of ways that the expected value of these reductions could be valued in economic terms. The table below shows a few of the figures cited above and their adjustment to 2014 USD figures. The social cost of carbon figures cited above could be used or values from global or regional emissions trading systems deployed. However, the study by (Promjiraprawat and Limmeechokchai 2012) shows that the costs of abatement are relatively low in the region with a higher end of USD 8/t-CO_2. This is approximately the lower end of the global social cost of carbon figures and so USD 10 t-CO_2 is taken as a conservative value of the economic value of emissions reductions for the region. This figure appears in the HPST parameters page and can be updated in the future.

Table 62. Resource Values for CO_2 Emission Reductions

Source/Citation	**Project/Study**	**Country**	**Study Year**	**Value Type**	**Study Value (USD/t-CO^2)**	**Adjustment Factor**	**2014 Value (USD/t-CO^2)**
EPA (2013)	US Interagency Study	Global	2007	Social Cost (2015 at 3%)	$ 37.00	1.19003	$ 44.03
EPA (2013)	US Interagency Study	Global	2007	Social Cost (2015 at 5%)	$ 11.00	1.19003	$ 13.09
IMF(2014)		Global	2014	Approximation	$ 35.00	1.00000	$ 35.00
Promjiraprawat (2012)	Thai power sector	Thailand	2012	Abatement Costs-Low	$ 5.26	1.01583	$ 5.34
Promjiraprawat (2012)	Thai power sector	Thailand	2012	Abatement Costs-High	$ 8.20	1.01583	$ 8.33

12.3 Bioprospecting

As considered briefly above under, individuals and communities in the LMB already use local flora and fauna for medical purposes. Bioprospecting refers to the potential that there may be as yet medical or pharmaceutical applications derived from biodiversity. Two routes for this exist, one is simply randomized or purposeful testing of species biochemical potential and the other is through ethnobotany and the testing of long-held medicinal practices by indigenous communities. In economic terms, bioprospecting is typically described as an option value – value for something not being used today, but that may be used in the future. In this sense it reflects a specific future use value attributable to biodiversity.

The LMB is widely recognized for its diversity of flora and fauna both in its waters and terrestrial areas. Loss of wetlands and forestland to inundation and project structures and changes in river hydrology are likely to impact regional species; however, it may be difficult to assess how such impacts might affect the option value for regional species.

12.3.1 LMB Dams Literature Review

Methods

Two methods for estimating option values are contingent valuation and benefit transfer. Contingent valuation would require primary data collection, while benefit transfer would rely on the relevance and transferability of existing studies on the topic. These studies have often taken the form of productivity analyses in which the use of species in developing new drugs is examined in terms of the statistics of the likelihood of finding a "hit" substance that can then lead to a successful and marketable pharmaceutical.

Data

Laplante (2005) cited a study by Simpson (1997), which reviewed WTP to preserve biodiversity hotspots by pharmaceutical companies in 19 different countries/regions. The study found a range of WTP from USD 0.02-2.29/ha across the countries/regions assessed (Simpson 1997). While this study is subject to a number of shortcomings, it reflects the rather low expected values from this approach (Aylward 1993; Barbier and Aylward 1996).

12.3.2 HPST Valuation

Value associated with bioprospecting is a potential value associated with the conservation of biodiversity. Contrary to the popular press it has received, this value is likely to be marginal when brought back to the hectare of natural habitat. As such, it is recommended that bioprospecting be included as a component of biodiversity, and therefore included in the social and environmental indicators being developed as part of the ISH02 project.

12.4 Tourism and Recreation

Southeast Asia is already a popular tourist destination and tourism to the region is expected to continue to grow (ICEM 2010). While tourism data exist for the four LMB countries (see Table 63), it is not always easy to discern what proportion this industry's economic value is directly or indirectly related to the Mekong River and how that proportion of the value would potentially be affected by hydropower development.

Table 63. Recent International Tourism Statistics

	International tourists		
	Quantity (millions)	Value (USD millions)	% of total exports
Lao PDR	1.786	413	17.18%
Thailand	19.230	30,926	11.86%
Cambodia	2.882	1,790	24.08%
Viet Nam	6.014	5,620	5.31%

Source: indexmundi.com

That being said, it is likely that hydropower development would have some impact on both perception and willingness to pay for activities associated with the Mekong River (ICEM 2010).

12.4.1 LMB Dams Literature Review

Methods

While several of the studies reviewed discussed the potential impact of hydropower development in the region on tourism, none of them directly included methods related to valuing potential changes in tourism associated with hydropower development.

Data

ICEM (2010a)reported the following baseline tourism statistics

- In 2005, river dolphins brought 75,000 and 7,612 domestic and foreign tourists, respectively, to the Kratie region.
- From 2005-06, over 30,000 tourists, both domestic and foreign, travelled to Stung Treng, often for ecotourism.
- From 2005-06, an estimated 1.2 million foreign tourists and 8 million domestic tourists visited the Mekong Delta. Can Tho attracted 1.1 million tourists in 2009, which generated an estimated USD 31.6 million.
- Extrapolating from available sources, river-based tourism was estimated to be worth USD 15 million and USD 41.7 million in 2003 and 2007, respectively.

12.4.2 HPST Valuation

It is likely that two separate, but related, analyses need to occur to estimate potential impacts on tourism – those associated with losses or changes to environmental assets or locations and those associated with tourism to hydropower projects themselves. The lack of existing research into this topic may be rectified by initial stocktaking and review of the existing tourism literature. Further work would attempt to identify the potential loss of sites and values associated with them based on benefit transfer from the numerous studies on tourism and recreation in developing countries. In addition, for Lao PDR, as the country most likely to be developing large numbers of hydropower projects, a further question that can be examined using survey approaches is whether large-scale dam development would affect the countries growing reputation as an ecotourism destination and, if so, what could the cost of this be. As tourism is an important and growing element of GDP in the LMB countries, and particularly Lao PDR, such studies would greatly assist the ISH02 project. Initial review and assessment may be undertaken as part of the ISH02 project, as desired; however, primary data collection and analysis to fill this gap would be needed separately.

12.5 Sand and Gravel Extraction

Extraction of sand and gravel from the Mekong islands and shoreline occurs for construction purposes. Changes in sediment flow and deposition associated with hydropower development could affect the amount of sand and gravel available for extraction as examined in Section 11.3.

12.5.1 LMB Dams Literature Review

Methods

Hall and Leebouapao (2005) estimated the value of sand and gravel as the net value of production – calculated by estimating the market value of sand and gravel minus the costs of production.

Data

Some of the studies reviewed included baseline estimates of sand and gravel extraction, but none included quantitative estimates of potential impacts to the industry as a result of hydropower development.

- Hall and Leebouapao (2005) estimated that in Lao PDR the 2002–03 market value of sand and gravel was USD 2.86/m^3 and USD 2.93/m^3, respectively; however, costs of production were USD 2.42/m^3 for sand and USD 2.87/m^3 for gravel.
- Table 64 shows 2002–03 estimates of sand and gravel production and net value (for Lao PDR only) based on data provided by Hall and Leebouapao (2005). It should be noted that there appears to be a typo in the study, in which it was stated that the total value was "$141,500 million annually" Hall and Leebouapao (2005, 38); however, the actual value, upon recalculation is USD 141,500, as shown in Table 64. Furthermore, this typo was carried over into ICEM study, which then used the erroneous estimate to extrapolate a value for the LMB (ICEM Economics Baseline 2010: 46 (ICEM 2010a, 46)

Table 64. LAO PDR Estimates of Sand and Gravel Production for 2003

	Production (m^3/yr)	Market price (USD/ m^3)	Production cost (USD/ m^3)	Net value/unit (USD/ m^3)	Net value (USD millions/yr)
Sand	229,176	2.86	2.42	0.44	0.101
Gravel	219,708	2.93	2.87	0.06	0.013
Total	448,884	—	—	—	0.114

- ICEM (2010) estimated sand and gravel to be worth USD 2.86/m^3 in Lao PDR and Cambodia and USD 1.00/m^3 in Thailand and Viet Nam.

This information on sand and gravel mining is incorporated into the valuation of changes in the sediment regime carried out above in Section 11.3.

13 Appendix 1: Economic Valuation Methods

Regardless of how resources available to society are allocated and managed, under conditions of scarcity their use in one activity for productive or consumptive purposes implies that they are not available to other uses. That is, the use of scarce resources entails an opportunity cost for society. This basic fact applies to all the resources that are invested in hydropower dams and hydropower production, just as it does to irrigation development. It also applies to the impacts created by such activities, including those only indirectly or distantly related to economic activity, such as when a dam alters the hydrologic regime or habitat available to fish that are ultimately reduces harvested for food or commercial use. Economists have long used a variety of valuation approaches to understand and estimate the costs and benefits of resource use. This includes changes to the environment and natural resources such as occur following hydropower development. Freeman (1993) provides a comprehensive overview of these methods. A summary chart of the full range of methods is provided in Table 65 below.

The principal economic valuation methods can be grouped into four different categories based largely on two criteria. The first grouping criteria is based on the whether the behaviour that reveals value is individual behaviour observed within actual market settings or whether the behaviour is elicited as a hypothetical response to constructed market scenarios. The second criteria is determined by whether monetary values derived from the technique are observed directly in the markets for the good or service or merely inferred from behaviour and preferences in other, related markets. These two grouping criteria create four categories: market prices, stated preferences, revealed preferences, and choice modelling.

Table 65. Valuation Methods

	Observed Behaviour	**Hypothetical Behaviour**
Value Directly Derived	*Market Prices* *(Direct Observed)* Competitive market prices Shadow-pricing	*Stated Preferences* *(Direct Hypothetical)* Contingent Valuation (dichotomous choice, willingness-to-pay, bidding games)
Value Indirectly Derived (inferred)	*Revealed Preferences* *(Indirect Observed)* Productivity methods Avertive (defensive) expenditure Travel cost Hedonic pricing Substitute goods	*Choice Modelling* *(Indirect Hypothetical)* Contingent referendum Contingent ranking Contingent behaviour Contingent rating Pairwise comparisons

Source: Aylward et al. (2001)

Approaches relying on direct **observed behaviour** include the use of competitive market prices and accompanying shadow-price adjustments and can be more simply labelled as "market price" methods. When possible the use of such techniques is preferred, as the valuation outcome will be based on actual, not hypothetical, choices, and does not require the analyst to make assumptions and inferences about people's behaviour. Market methods may be useful in particular for valuing the direct impacts of hydropower development, although revealed preference approaches are also often used to value water where direct market prices are not available such as for agriculture, domestic purposes, flood control, and industrial production (Young 1996). For example, the production function approach is often used to determine the value of environmental or natural resource goods or services that are inputs into production processes. A change in flow or sediment transport will have an impact on downstream ecology and productive practices, particularly fisheries and agriculture. By observing behaviour in input and output markets and understanding relevant bio-geophysical processes it is possible to value the marginal productivity of – and hence economic benefits provided by – the natural input and thereby establish the cost or benefit associated with changes in flow or sediment, for example.

Methods involving **hypothetical behaviour** will have limited application to the case of hydropower development. These approaches are more typically used for examining the value consumers' hold for so-called "non-market" goods and services. For example, tourism, recreation, aesthetic, and cultural values associated with nature and biodiversity can be derived through survey work aimed at understanding consumer preferences and willingness to pay for items that are not usually purchased or sold, or for which fees charged are nominal and likely understate the true societal value of the consumer experience or the asset. Such methods also require direct interaction with consumers and thus, while very useful at valuing goods and services that may not be examined using observed behaviour, can also be expensive and time-consuming to carry out.

In sum, the methods for economic valuation are well established. The issue with respect to drafting Guidelines is rather one of whether or not they can be applied in a "practical and replicable" fashion to the variety of impacts associated with hydropower development.

Below, a brief overview of the concepts and assumptions underlying the primary methods that are applicable to dams is provided as well as examples of how these methods can be applied to different categories of dam project impacts. Secondary methods are also briefly treated. The limitations of each of the methods is also discussed.

Finally, it should be noted that the choice of a valuation method depends on a variety of factors, including the specific nature of the impact, the availability of data, expertise, time and resources. In practice, multiple approaches may be possible for valuing a given impact and the ultimate choice of a method will be case specific.

13.1 Market Methods

Most of the emphasis in this chapter is on valuation approaches for non-market impacts of dams. As indicated earlier, many of the social and environmental impacts of dams are conveyed through physical, chemical or biological changes brought on by the construction of the dam. Thus, even where the end result is a change in market values, the valuation effort often goes beyond simple market methods. However, given that many of the products and services that will be affected are traded in markets and can be assessed using productivity methods (as discussed in the next sub-section) which itself relies on market data it is useful to briefly review market methods. The accuracy of market estimates depends on the extent to which the goods or services of concern are regularly traded in a competitive market. That is, the market must be characterised by several buyers and sellers and must not be constrained in undue manner. The correct measure of net benefits using this method is the change in consumer and producer surplus associated with the resource/impact of concern.

The data generally required to calculate consumer and producer surplus changes include the quantity of the resource or service of concern demanded at different prices and the quantity supplied at different price levels. These data are considered both before and after the expected impact. Through modelling of supply and demand curves, economists can estimate changes in consumer and producer surplus and arrive at the benefits or costs of the impact.

A number of the impacts of dam projects that result from the flooding of the reservoir may be valued using market approaches – such as the loss of commercial timber and non-forest resources, and the creation of a reservoir fishery. Where these are bought and sold in markets, supply and demand modelling – or more straightforward assessment of quantities and unit prices – can be employed to develop net benefit estimates. For example, a dam project may result in external benefits such as the creation of a new reservoir fishery. In this case, a simplified market-based approach may be taken whereby net benefits are calculated based on estimates of the commercial harvest levels and prevailing market prices. This approach can be taken when the impact is not expected to significantly affect market prices or the resources devoted to harvesting fish (i.e. production costs, level of effort by fishermen). However, a more sophisticated analysis is required if the new fishery is expected to cause large-scale changes in the regional catch that affect market prices and the commercial fishing effort. This approach estimates the changes in consumer and producer surplus based on modelling of supply and demand interactions in the commercial fishing market.

The data and resource demands associated with developing a supply and demand model can be significant. Demand curve estimation may require a significant amount of data on consumption of a good or service at different price levels (e.g. demand for fish at different market prices). Likewise, supply curve estimation may require detailed information on production costs and supply conditions (e.g. capital cost, labour cost, and catch information for different types of commercial fishing vessels).

13.2 Revealed Preference Approaches

Revealed preference techniques are premised on the economic concepts of “substitute” and “complementary” goods. For instance, similar ecotourism sites may be substitutes for each other; if the environmental quality of one site declines, people may make more visits to the other site. Likewise, environmental amenities and property values are complementary goods; if environmental amenities improve, property values will generally increase. By analysing individual behaviour in substitute and/or complementary markets, economists can infer values for the non-market resource or impact of concern.

13.2.1 Productivity Methods

Productivity methods essentially look to value changes in output using market prices if these are available, or using unit values for the output derived from other methods. The process of quantifying the output changes can, however, be quite involved and typically, in the case of dams, will involve specialists in other disciplines and affected groups working with economists to derive the relevant linkages between the dam and the economic activity that is affected. The productivity method is best suited to valuing changes in outputs such as forestry, fisheries and agriculture but can be applied to a wide range of frequently affected activities.

The productivity approach may also be used to value health impacts. For example, reservoirs created by dams can result in higher incidences of water-borne diseases, such as schistosomiasis and malaria. Estimates of the costs of illness may be developed to value these losses. It should be noted that the cost-of-illness method does not attempt to measure several other significant types of losses associated illnesses, including pain and suffering, lost leisure time, and the cost of any efforts people have made to avoid the illness altogether. Therefore, the cost-of-illness approach is often considered a lower bound on the true cost of higher incidences of disease. To account for the full range of impacts from a higher incidence of illnesses, a willingness-to-pay to avoid illness study can be undertaken. This approach, which is often considered an upper bound estimate on illness, is described in more detail below (see Stated Preference Approaches).

Productivity methods may also be used to value the benefits of avoiding additional increment of pollution in terms of the expected environmental damage. This would apply in particular to the atmospheric externalities, whether positive or negative, of dams. Potential damages include health impacts, materials damage, reduced agriculture production, global warming, and other effects. However, while several studies have been conducted to estimate the monetary damages per ton of various air pollutants, the results of these studies are subject to a high level of uncertainty. Not only are damage estimates based on many estimated parameters, but damage values tend to vary depending on the (proposed) location of the alternative power generation facility. For instance, a facility located near a large population centre will have greater impacts than a facility located in a rural area.

The economic linkages between catchment land use and reservoir operations, and the need for watershed management are also captured by productivity approaches. Models linking land use to hydrological variables that subsequently influence dam operations and economic benefits can be used to assess a variety of upstream-downstream linkages including those transmitted through sedimentation, changes in water yield and timing.

13.2.2 Avertive Expenditure Method

The avertive expenditure method (also known under the guise of avoided costs, defensive expenditures or preventive expenditures) is typically used to value non-market environmental goods or services that enter into the household activities – though it may also apply to commercial production. The technique involves identifying the manner in which an improvement in environmental quality (i.e. reduction in noise pollution) leads to households switching away from the purchase of a conventional market input due to the environmental improvement. In such a case the "defensive" expenditure that is no longer necessary provides a valid measure of the benefits of environmental improvement.

The avertive expenditure method is often used to value the benefits of pollution control. It would be a logical extension then to use this method to examine the benefits of improvements in water quality (i.e. reductions in expenditures on water treatment) or other changes in defensive expenditures related to hydrological outcomes such as investments in flood control measures. The technique is implicitly used to value the benefits of catchment management where dredging (of dams, irrigation canals, etc.) is avoided through a reduction in sediment levels.

The averted cost approach can also be used to estimate the pollution costs avoided by constructing hydropower capacity rather than combustion-based alternatives.

It is important to stress the importance of the direction of change in the relationship between the inputs. The change must be from a pattern of expenditures aimed at avoiding welfare reducing effects of poor levels of environmental quality or service provision. In other words, the environmental damage must already be the status quo and defensive behaviour must be observed. This is different than assessing what expenditure would be necessary were a (new) degradation of environmental function to occur. The latter is essentially the basis for the replacement cost approach (covered below). As a result, this technique may be of limited usefulness for the negative social and environmental costs of dams. It may, however, be of use in the analysis of the benefits of ecosystem restoration following a change in operations or decommissioning.

13.2.3 Travel Cost Method

Travel cost models are analytical tools frequently applied to assess the value of recreational opportunities, as well as value the quality and characteristics of these opportunities. For example, the recreational values of a river or reservoir eco-tourism site can be estimated by analysing the travel and time costs incurred by individuals visiting the site (or a similar alternate site). This approach assumes that individuals' time and travel costs serve as proxies for the value that individuals' place on recreational activity at the site.

A travel cost model typically examines the location from which visitors to a recreational site travelled. The analysis considers the number of trips taken to the site for a given travel distance. This essentially represents the quantity of the resource demanded (i.e. recreational activity at the site) at a given price (i.e. travel cost). Using data on multiple visitors, economists can construct a demand curve for the recreational activity at the site and estimate consumer surplus (i.e. the area under the demand curve).

13.2.4 Additional Methods

Many additional revealed preference methods and models beyond those discussed above are possible. Chief among these are hedonic pricing and substitute goods approach. Hedonic pricing can be used to value water, but only where robust land markets exist. In developing countries, the substitute good approach may often be of value in valuing subsistence goods. Where a non-marketed good has a close substitute which is marketed the value of the non-marketed good can be roughly approximated by the observed market price.

Revealed preference approaches are limited by the quality of the underlying behavioural and bio-physical data and models. For instance, recreational demand models rely on individual perceptions of changes in recreational opportunities and/or quality. Valuing changes in environmental quality is possible where the changes have an obvious effect on popular recreational activities, but using recreational models may not be appropriate for measuring changes in environmental quality that are difficult for the public to observe. Similarly, where the ability to predict or assess the environmental changes – be they physical, chemical or biological – that are effectuated by dams is limited, the reliability of valuation efforts will be similarly circumscribed.

13.3 Stated Preference Approaches

Stated preference approaches attempt to measure willingness-to-pay values directly. Unlike revealed preference approaches, which rely on markets to infer values for environmental and social factors, stated preference methods develop values by conducting surveys to directly elicit information about respondents' preferences for non-market factors, i.e., respondents "state" their values. Contingent valuation (CV) is the most frequently employed stated preference technique and can be used to measure a variety of dam project impacts.

The technical components of a CV study include:

- Creating a hypothetical market that provides survey respondents with a description of the good or service being valued;
- Developing a contingent situation under which the good would be provided;
- Creating a hypothetical payment vehicle; and
- Providing respondents with an opportunity to express a value for the good or affected service.

The analyst then compiles the survey data and applies statistical techniques to estimate average willingness to pay (i.e. consumer surplus) associated with the non-market factor under consideration.

Whether an effective CV study can be designed to value impacts of dams depends on a number of factors, including the specific nature of the impact and the likelihood that respondents can accurately estimate their willingness to pay for (or to avoid) the impact. For example, it may not be possible to design a CV study that elicits peoples' true willingness to pay to avoid socio-cultural losses. The impact is difficult to define adequately and to the satisfaction of all concerned parties and complex to convey through survey questions. Moreover, respondents may not be capable of providing reliable estimates of intangible factors given the public's lack of experience valuing such impacts.

Although the CV method can be used to value many different types of non-market factors, and CV remains the only established method for assessing intrinsic values, the reliability and validity of CV has been the subject of much controversy. For a variety of reasons, respondents' stated intentions may not equal their true willingness to pay. The debate primarily focuses on whether respondents can provide reliable estimates of the value of non-market goods, given that the public has little or no experience with purchasing such goods. While respondents may be able to express values for more tangible dam impacts, they may be unable to express values for more abstract effects (e.g. community fragmentation). Indeed, it may be extremely difficult to develop a survey instrument free of bias that yields meaningful responses for such impacts. For instance, since CV surveys seek only hypothetical willingness-to-pay values, respondents may not carefully consider personal budget constraints when stating willingness to pay. The problem of bias may be especially difficult to avoid for projects where a charged political atmosphere already exists.

The detailed procedures associated with a CV survey and analysis generally require a significant commitment of time and resources. Costs are sensitive to factors such as the survey design, survey sample size, the type of survey instrument (i.e. interview, mail survey), the nature of data analysis, and other factors. In practice, the investment made in CV surveys is usually proportional to the resource values in question, i.e., more complex surveys are done to support larger resource management decisions.

13.4 Choice Modelling

Choice modelling techniques are not discussed in any detail here. These models are typically used in consumer research to examine the attributes of goods and services upon which consumers confer value. In other words they involve asking hypothetical questions of respondents, which only indirectly shed light on the value of a good or service. Application in the case of dams would be in the assessment of changes in recreation or tourism or in the case of subsistence resource use (where other methods are not available).

13.5 Secondary Methods for Valuing Dam Project Externalities

13.5.1 Replacement Cost (or Potential Expenditure) Approaches

The replacement cost method is essentially an accounting procedure provides an estimate of the cost to replace a good, service, or resource affected by a dam project with an alternative. The replacement alternative will be a good, service, or resource (e.g. similar agricultural land) or monetary compensation that provides the same level of benefits. This of course, begs the question of whether it is worthwhile to undertake the replacement. This is an approach receiving considerable coverage in the practitioner literature and essentially no mention in academic texts

Ecological services are often said to be “valued” using the replacement cost approach. For example, ecological services provided by wetlands include flood control by storing runoff, water quality protection and treatment, and water supply to groundwater aquifers. Evaluating the loss of these services due to dam-related impacts can be difficult because wetland services are not traded in markets. One approach to estimating the value of wetlands is to consider the cost of constructing man-made alternatives. For example, to assess wetlands’ water quality protection services, the cost of constructing a wastewater treatment plant that filters wastewater in a manner similar to wetlands can be assessed. Likewise, the value of wetlands might be reflected in the cost of building flood control structures such as levees. Some or all of these costs could be avoided if wetland areas were preserved or restored.

Again, this approach begs the question of whether the replacement cost is worth undertaking as the results have no basis in consumer behaviour, i.e., there is no behaviour that might reveal preferences for such an arrangement. The technique makes the implicit assumption that the replacement cost is worth paying. In other words, the technique involves making an inference regarding choices that would be made by consumers or household. Of course, the weakness of the technique stems from the fact that there is often little basis for making such an inference.

13.5.2 Benefits Transfer

Benefit transfer valuation methods do not require primary data gathering (e.g. surveys) or other primary economic research. Rather, they involve the application of unit value estimates, functions, data and models from existing studies to estimate benefits associated with the resource or impact under consideration. The main advantage of benefits transfer, compared to primary research, is that it can reduce both the time and resources needed to develop net benefit estimates. Benefits transfer involves three basic steps:

1. Identifying and characterising the resource or service to be valued. This step can be challenging because the resource or service may depend upon unique site conditions and complex ecological factors.
2. Reviewing existing valuation literature to identify potentially applicable studies. This step entails identifying primary studies that evaluate similar resources and/or services as those expected to be affected.
3. Conducting the benefits transfer and calculating economic benefits (or losses). This step involves application of the values, functions, data and/or models from appropriate existing studies.

In general, benefits transfer estimates will be more meaningful and defensible if the benefits transfer has the following characteristics:

Reliance on high-quality studies. The benefits transfer analysis should incorporate results from high-quality studies, based on adequate data, sound economic methods, and correct empirical techniques.

Consistency between the resource to be valued and the resource in existing studies. Evaluating the applicability of existing studies to valuing a dam project resource or impact involves comparing the characteristics of the resource or impact with those in the existing studies. If these characteristics differ, it will be necessary to consider whether the differences are likely to have a significant effect on the valuation, and if so, whether adjustments can be made to account for these differences.

Consistency in the characteristics of the affected population. The characteristics of the population holding values for the dam project resource or impact should be comparable with the population included in the existing studies. Relevant characteristics include, but are not limited to age, income, education level, proximity to the site and the level of environmental concern.

Accurate estimate of the size of the population holding values for the dam project resource or impact. Each dam project resource impact will have a geographic area over which its users are drawn. An important component of economic benefits estimation is defining the size of the population that holds values for the dam project resource or impact. This assessment will affect the magnitude of net benefit estimates.

Obviously, within the limitations of what constitutes a credible transfer of benefits this method is applicable to a wide range of external impacts of dams. The preceding discussion makes it clear that a key limitation of benefits transfer lies in the ability of the analyst to locate appropriate results from existing studies and apply them to the dam project resource or impact of concern in a sophisticated manner. Close attention must be paid to the consistency of key factors of the case being studied and existing studies, such as physical and geographic attributes, the availability of substitutes, and socio-economic characteristics.

Likewise, the quality of the benefits transfer will depend on the number of relevant studies; relying on average values from multiple studies is likely to be more reliable than transferring values on the basis of one or a few existing studies. It follows that the ability to develop defensible benefits transfer estimates in the future will depend on investments in primary research on the economic valuation of dam impacts today. By building a "library" of primary studies, future valuation of economic valuation of dam project impacts could be performed via less expensive benefits transfer techniques.

14 Appendix 2: Summary of Existing Literature Valuing the Impacts of Large Dams in the Lower Mekong Basin

The following sections review existing studies that are of direct relevance to the ISH02 project. Directly relevant means studies that have attempted to value the direct and indirect costs and benefits of large dams in the Lower Mekong Basin (LMB). These range from studies of a single dam through to assessments of development scenarios involving many mainstream and tributary dams. Following the brief review, results of a more in depth impact-by-impact review are presented, summarizing the extent to which each study identified, quantified, or valued each of the potential impacts of large dams.

14.1 Lao Tributary Dams (Power System Development Plan or "EVALS" study) – Lao PDR and The World Bank (Maunsell and Lahmeyer International 2004a)

The Lao Power System Development Plan study developed by Maunsell and Lahmayer International is a comprehensive assessment of the Lao power sector, potential power export markets and evaluation of 33 potential generation projects, of which all but two were hydropower projects. The intent was to outline a power development path for the period 2005 to 2020. The goal of the study was to apply the same framework for analysis and methods to analysing the full suite of projects. The study evaluated each project as a standalone project, although some cumulative hydrological and environmental impacts were explored for projects in a cascade. The study was a desktop study using existing data from a number of prior studies of individual projects and the Lao power sector. No fieldwork was undertaken. The work progressed through a screening phase using proprietary hydropower software called "EVALS." The screening ranked projects in terms of their weighted average power generation costs and shortlisted 19 hydropower projects with values over a prescribed threshold.

Of the shortlisted projects only Nam Theun 2 and Nam Ngum 3 exceeded an installed capacity of 500 MWs. The only mainstream project included was Thakho, a small 30MW run of river project. The shortlisted projects were then assessed in terms of their project cash flows. The relevance of this study to ISH02 is the subsequent effort to value the positive and negative social and environmental impacts of the shortlisted projects (using spreadsheet model called "SESAMEE"). Impacts that were valued were those in the immediate vicinity of the project site. No downstream impacts in the mainstream Mekong River were included. These values were then integrated into a single net value of average generation costs, which was used to rank the shortlisted projects. The valuation of these external impacts was based on market data and changes in quantities for various resource and environmental goods in the vicinity of each dam. The authors applied both an international and local (Lao) value in pricing the impacts. The final project rankings are based on the international prices.

The study reports the generation costs (adjusted for social and economic values) for the projects that range from USD 0.016/kWh (for Nam Theun 2) to USD 0.087. Assuming a return of 17% the study reports financial tariffs for the projects that range from USD 0.04 to USD 0.12, excluding Nam Theun 2. The study states that the social and economic values had little influence on the ranking except where one or two projects had significant environmental issues. The expectation that this would be the case is suggested by comments in the preamble to the SESAMEE section, which asserts that "mitigating the environmental and social consequences of power generation projects are generally a relatively minor part of most projects' overall cost" (Maunsell and Lahmeyer International 2004a, 130). According to the authors' prior mitigation costs in Lao PDR have been in the 3% to 6% for projects actually built (% of total costs, presumably). The study acknowledges the difficulty of valuing project consequences in economic terms and states that this can lead to "costly and time-consuming issues and open-ended processes." The study avoids this issue by carrying out a very detailed desk study of over 2,000 detailed project-specific parameters and over 350 constants applicable to all projects. Not surprisingly the study considers the data quality of the inputs to the SESAMEE model to be low. The net present value of social and environmental costs range from the low USD millions up to USD 100 million. A key element of the approach is to value each impact and then cost mitigation measures, taking the mitigation measure to be the cost if it is less than the potential damage costs and it more or less is expected to fully mitigate the impact. For Nam Thuen 2, as an example, the costs are expected to be in the USD 40 to USD 90 million range at local and international prices, respectively.

14.2 Nam Theun 2 - World Bank (Laplante 2005)

In 2005, Laplante conducted a study for The World Bank entitled "Economic analysis of the environmental and social impacts of the Nam Theun 2 Hydroelectricity Power Project." As the title suggests, the study's overarching goal was to assess the economic value of potential environmental and social impacts associated with the development of Nam Theun 2 project, located on the Nam Theun River, in the Lao's People Democratic Republic (Lao PDR). According to the study, once completed, the hydroelectric project would have a generating capacity of 1,070 megawatts (MW), with an estimated power generation net present value of USD 266 million. Approximately 93% of that capacity would be sold to Thailand, with the remaining MW being used by Lao PDR. In addition, Lao PDR would benefit substantially from financial flows from export revenues, taxes and royalties.

The study considers potential environmental and social impacts across five geographic areas: Nam Theun downstream, Nakai Nam Theun NBCA, Nakai Reservoir, Xe Bang Fai and Mekong River as each of these areas would be affected differently by the proposed project.

The study estimated the net present value of potential impacts across the proposed life of the project (i.e. 2004-2034) and assumed a discount rate of 10%. Due to limited data availability, a number of potential impacts are identified by the author, but were considered qualitatively in the analysis.

Two noteworthy features of the hydropower project that factor substantially into the analysis were a) the trans-basin transfer of water from the Nam Theun River into the Xe Bang Fai River; and b) the inundation of the Nakai Plateau, which would displace approximately 5,600 individuals.

When possible, the study did include valuation estimates of potential impacts. Broadly, the study estimated large potential negative impacts for fisheries, biodiversity and riverbank gardens, among a number of other areas. Many potential positive impacts of the project were associated with mitigation compensation and investment in areas such as poverty alleviation, health and education. Reduction in greenhouse gas emissions and increased potential for irrigated agriculture were also found to be positive impacts of the project. The environmental and social costs were reported as USD 55 miliion, which exceeded the expected environmental and social mitigation costs that were expected to be paid by the project at appraisal (World Bank 2005)

Several limitations of the study should be noted. First, few baseline values (quantity or value) appeared in the report; making it difficult to assess the proportional value of estimated impacts. Furthermore, while impact values were included for many topic areas, the associated quantity of impact (e.g. tonnes of fish) was not. Finally, many topic areas were only described qualitatively, as significant research outside the scope of the analysis would have been required to obtain such values. As the author notes, this does not mean there are not impacts, but rather additional research must be conducted.

14.3 LMB Mainstream Dams – MRC-IBFM (Hall & Leebouapao (2005)

As part of the Integrated Basin Flow Management (IBFM) Phase 2, Hall and Leebouapao conducted a study entitled "Economic valuation of alternative Lower Mekong River flow regimes," which was prepared (but not completed) for and submitted to the Mekong River Commission (MRC). The goal of the study was to analyse the potential economic impacts associated with three alternative flow regimes on the Mekong River in the Lower Mekong Basin (LMB).

In part, this study utilized the Resource Allocation Model (RAM) of Basin Development Plan (BDP) for its analysis. As described in the report, the RAM "relates changes in river flows to estimates of the economic value of key potential development benefits and certain negative impacts resulting from those flow changes" (Hall & Leebouapao 2005). Furthermore, the RAM could then use this information to estimate the associated total annual economic value for water uses and assess trade-offs between competing water uses.

The study relied on existing studies and data for its analysis and estimated the economic value of LMB resources using a variety of techniques including "market productivity, hedonic pricing, factor productivity, opportunity cost, damage costs avoided, substitute costs, and benefit transfer" (Hall & Leebouapao 2005).

While the report provided a detailed discussion of how economic impacts would be measured, the study available for review was not in a completed form. More specifically, two key sections included in the table of contents (i.e. Overview of Resource Goods and Service Links to River Zone Ecological Conditions & Economic Benefits and Costs of Alternative Flow Regimes) were missing from the report. Detailed information is included on the hydropower projects modelled in RAM.

14.4 Ecosystem Services in the LMB – MRC-GTZ (Rowcroft 2005)

In 2005, Rowcroft submitted a study to the MRC-GTZ Cooperation Programme on payments for ecosystems services. The study first discussed the economic theory and principles behind the notion of payment for ecosystem services and specifically highlights the potential for payments for ecosystem services in the context of watershed management. Next, it reviewed existing applications of such payments and discusses notable features, key findings and limitations of said applications. Finally, recommendations were made for how the MRC and others could best evaluate potential opportunities for payment for ecosystem services in the Lower Mekong Basin.

While the study provided a foundational overview of payment for ecosystem services, and also described in detail practical applications and the associated features/ components that are more or less likely to make for a successful project, the study did not include quantitative estimates of payments for ecosystem services, or their economic value, nor did it appear to list which types of ecosystems services in the LMB would be most likely to benefit from such programmes.

14.5 LMB Hydropower Project Database – MRC-BDP (Yermoli 2009)

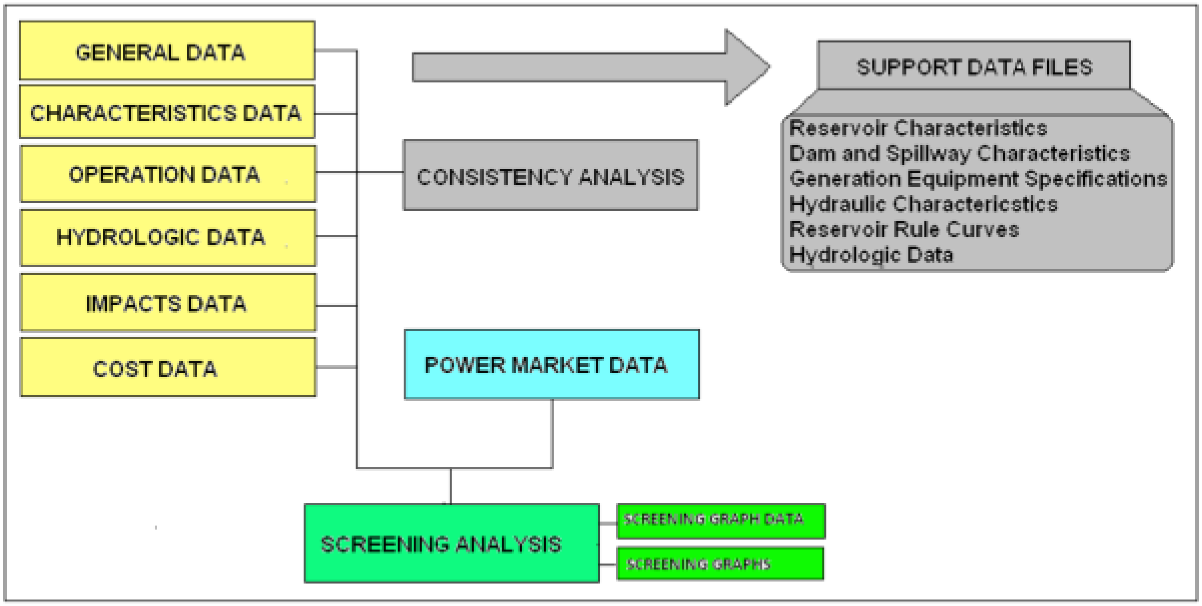
The BDP hydropower database was created with three objectives in mind (Yermoli 2009):

- to formulate and assess basin-wide development scenarios for the IWRM-based Basin Development Plan;
- to further the process of implementing the Procedures for notification, prior consultation and agreement (PNPCA) and the MRC Internal procedures for implementation of the PNPCA (November 2005);
- to support the formulation of the MRC Hydropower Program.

Data on over 100 existing and proposed hydropower projects in the LMB was collected and entered into a in a Microsoft Excel™. The data structures are shown in the figure below. The database includes a range of information regarding each project. Of most relevance to the ISH02 project is the effort to provide standardized information on the following parameters for such a large sample of projects across the LMB:

- construction and other cost data
- hydropower generation
- hydropower values
- a set of social and environmental scores

Figure 8 BDP Hydropower Project Database Structure



14.6 LMB Mainstream Dams – MRC-SEA (ICEM 2010b; ICEM 2010a; ICEM 2010d; ICEM 2010c)

In 2010, the International Centre for Environmental Management (ICEM) completed a study (along with baseline reports) entitled “Strategic Environmental Assessment (SEA) of hydropower on the Mekong mainstream.” This study, conducted for the Mekong River Commission, was a multi-step analysis to examine the broader strategic issues associated with considering and potentially implementing multiple hydropower projects in the LMB. More specifically, the SEA focused on the potential benefits, risks and uncertainties associated with 12 specific proposals for hydropower projects on the mainstream of the lower Mekong River.

The study considered three distinct hydro-ecological zones and five different dam groupings. While the fundamental question the study considered was “To dam or not to dam the Mekong River,” it also provided a wealth of baseline and impact assessment data. More specifically, detailed information was provided on the following stakeholder-prioritized topics:

- Power systems
- Economic systems
- Hydrology & sediment
- Terrestrial systems
- Aquatic systems
- Fisheries
- Social systems
- Navigation
- Climate change

Briefly, the greatest potential benefits described were primarily at the county level, stemming from export revenues, increased power security and decreased power costs. For example, Lao PDR and Cambodia would receive an estimated USD 3-4 billion per year in export revenues.

The most significant risks identified were associated with fisheries (including loss of biodiversity, loss of income from commercial fishing and loss of sustenance from subsistence fishing) and agriculture (including inundation of land, reduced nutrient loading, and loss of riverbank gardens).

As for the distribution of impacts, at the country level, Lao PDR was estimated to receive both 70% of the overall benefits of the projects and approximately 70% of the annual export revenues. At the community level, poor in rural and urban riparian areas, particularly those who rely on fisheries and/or riverbank gardens for income and/or sustenance were estimated to be the most negatively impacted. In addition, the study estimated that over 100,000 individuals would be displaced if all 12 projects were implemented, with another ~2 million estimated to experience direct/indirect effects.

In addition to the detailed quantitative data, the report also includes a table “summary of impact significant and mitigation potential again key issues” where significance is ranked as low, medium or high and potential avoidance/mitigation is ranked on a three-point scale of no potential, potential or high potential.

It should be noted that in addition to assessing potential impacts associated with the 12 identified projects, the SEA also includes baseline reports, submitted as separate documents. These document includes detailed information on past, current and future trends for a variety of topics including; economics, energy and power, hydrology and sediment, terrestrial ecosystems and agriculture, aquatic ecosystems, fisheries, and climate change.

14.7 LMB Dam Scenarios – MRC-BDP (MRC-BDP 2010 and 2011)

As part of the Basin Development Plan Programme, Phase 2, a basin-wide scenario assessment was conducted. Scenarios selected could be categorized as follows”

- Baseline situation: Hydrological status of 1985-2000; socioeconomic status of 2008-2009; economic prices of 2009.
- Definite future situation (DFS)
- Foreseeable future situation (FFS)
- Long-term future situation (LFS)

To conduct the assessment, each scenario was examined against seven assessment areas with a total of 74 parameters (further aggregated to 42 criteria). The assessment areas considered were:

- Hydrological assessment
- Land use and condition assessment
- Water quality and geomorphology
- Production assessment
- Environmental assessment
- Economic assessment
- Social assessment

The main report contains detailed estimates (in most cases both estimated quantity and value) at the country and basin-wide for both the baseline situation and other (future) situations. The majority of these estimates can be found in Appendices B and C.

In support of the main report, Technical Note 13 was written to assess the potential economic benefits and costs associated with various development scenarios for the Lower Mekong Basin (MRC-BDP 2010b).

In addition to estimating benefits and costs, the technical report outlines a) overarching development objectives and key economic indicators; and b) approaches and methods for conducting the economic assessment.

Direct and indirect impacts for a range of topic areas (e.g. hydropower, irrigated agriculture, reservoir fisheries, aquaculture, capture fisheries, wetlands, biodiversity) were considered across a 50-year time frame. All estimates were expressed as net present value (NPV), calculated using a 10% discount rate. In addition to a “definite future” scenario, nine additional development scenarios, and the associated benefits and costs, were presented. The report also discussed the potential distribution of impacts; however, this was only done at the country level.

While it is not always clear how each specific impact estimate was calculated, the technical report did include detailed estimates of both potential impact quantities and values. Furthermore, assuming the definite future scenario can be considered the baseline, relative or proportional impacts could also be calculated using the data in this report.

14.8 LMB Mainstream Dams – USAID (Costanza et al. 2011)

A recently completed report by Costanza et al. (2011), funded by the United States Agency for International Development, aimed to provide additional analysis and guidance to support the Mekong River Commission’s Basin Development Plan (BDP) and Strategic Environmental Assessment (SEA) in the Lower Mekong Basin.

Initial sections of the report a) provided an overview of fundamental issues in decision-making processes including risk, uncertainty and intergenerational issues and b) summarized lessons learned from other countries with large hydropower projects that would be relevant for fisheries and other key LMB ecosystem services.

Perhaps most relevant to the task at hand is the report’s section on valuation methodologies appropriate for assessing changes in ecosystem services --- and the associated analysis, which focused on three categories: fisheries, wetlands and total ecosystem services. Data for the fisheries analysis came from the second MRC-BDP planning studies. The values of wild, reservoir and aquaculture fisheries under baseline and future scenarios (i.e. definite future, w/ 6 hydropower projects and w/ 11 hydropower projects) were estimated using multiple discount rates to conduct a sensitivity analysis.

The wetlands analysis used benefit transfer to apply values for three types of wetlands (i.e. flooded forests, marshes, and inundated grassland) from a study conducted in the Mississippi Delta. Like the fisheries analysis, multiple scenarios are considered at various discount rates. Finally, total ecosystem service values estimated in the BDP2 were revised and tested for sensitivity.

14.9 Dam/Fish Tradeoffs of LMB Dams (Ziv et al. 2012)

In this study, Ziv et al. used a fish migration model to assess trade-offs (and present a strategy for optimization) between hydropower, fish production (for food) and biodiversity (specifically fish species) in the Mekong River and its tributaries.

Hydropower planning scenarios for the modelling effort came from the MRC Basin Development Plan 2 (BDP2) (2010). Fisheries production and migration data was compiled from multiple sources spanning 1936-2010. Using this information, the study initially modelled the potential impact of the six dam-development scenarios in the BDP2 on “biomass of migratory species in the floodplains, as well as the number of species at risk for extinction because of habitat loss” (Ziv at al. 2012).

Of the 78 tributary dams proposed, at the time of this study, only 27 were still in the planning process (and, in theory, could or could not be built). The study authors chose to focus in more detail on these 27 dams and used their model to estimate the “difference in average migratory fish biomass for all scenarios with and without each dam” (Ziv at al. 2012).

The study had two key findings. First, it revealed that the tributary dams were estimated to generate less energy than the mainstem dams and have higher impacts on fish (for food and for biodiversity). Second, study results could be used to help optimize (at least across energy and fish) selection of which hydropower projects to implement (i.e. trading off loss of fish biomass per each additional terawatt hour of hydropower).

15 References

ADB. 2008. 'Proposed Loan to the Socialist Republic of Viet Nam: Song Bung 4 Hydropower Project'. Report and Recommendation of the President to the Board of Directors. Manila: Asian Development Bank.

AF-Mercados EMI. 2013. 'Options Paper on Hydropower Fiscal and Revenue Sharing Issues'. Prepared for the Government of Lao PDR (MOF, MEM, MIP).

Anonymous. 1992. 'Fisheries in the Lower Mekong Basin: Review of the Fishery Sector in the Lower Mekong Basin'. Bangkok: Interim Committee for Coordination of Investigations of the Lower Mekong Basin.

Arias, Mauricio E. 2013. 'Impacts of Hydrological Alterations in the Mekong Basin to the Tonle Sap Ecosystem'. http://ir.canterbury.ac.nz/handle/10092/8913.

Arias, Mauricio E., Thomas A. Cochrane, Thanapon Piman, Matti Kummu, Brian S. Caruso, and Timothy J. Killeen. 2012. 'Quantifying Changes in Flooding and Habitats in the Tonle Sap Lake (Cambodia) Caused by Water Infrastructure Development and Climate Change in the Mekong Basin'. *Journal of Environmental Management* 112 (December): 53–66. doi:10.1016/j.jenvman.2012.07.003.

Aylward, Bruce. 1993. 'The Economic Value of Pharmaceutical Prospecting and Its Role in Biodiversity Conservation'. *LEEC Discussion Paper* 93-05: 74.

Aylward, Bruce, Jeremy Berkhoff, Colin Green, Pablo Gutman, Anneli Lagman, Michelle Manion, Anil Markandya, et al. 2001. 'Financial, Economic and Distributional Analysis'. Cape Town: World Commission on Dams.

Ballofet, Armando, Bruce Aylward, and James Taylor. 2014. 'Guidelines for the Evaluation of Hydropower and Mulit-Purpose Project Portfolios: Initial Draft for Review'. Prepared for the MRC Initiative for Sustainable Hydropower. Vientiane: Mekong River Commission.

Baran, Eric, Teemu Jantunen, and Chong Chiew Kieok. 2007. *Values of Inland Fisheries in the Mekong River Basin*. Phnom Penh: World Fish Center.

Barbier, E.B., and Bruce Aylward. 1996. 'Capturing the Value of Pharmaceutical Prospecting in a Developing Country'. *Environmental and Resource Economics* 8: 157–81.

Brealey, Richard A., and Stewart C. Myers. 1988. *Principles of Corporate Finance*. 5th ed. New York: McGraw-Hill.

CDM. 2009. 'Project Design Document for Buon Kuop Hydropower Project'. Project Design Document for the Clean Development Mechanism. Clean Development Mechanism.

———. 2015. 'CDM: Grid-Connected Electricity Generation from Renewable Sources'. Clean Development Mechanism ACM0002 Version 16.0. United Nations Framework Convention on Climate Change. Accessed June 8. https://cdm.unfccc.int/methodologies/DB/EY2CL7RTEHRC9V6YQHLAR6MJ6VEU83.

Costanza, Robert, Ida Kubiszewski, Peter Paquet, Jeffrey King, Shpresa Halimi, Hansa Sanguanngoi, Nguyen Luong Bach, et al. 2011. 'Planning Apporaches for Water Resources Development in the Lower Mekong Basin'. Report for US Agency for international Development. Portland: Portland State University and Mae Fah Luang University.

ECA. 2009. 'The Potential of Regional Power Sector Integration: Nam Theun 2 Generation Case Study'. Submitted to ESMAP. London: Economic Consulting Associates.

Ellis, Gregory M., and Anthony C. Fisher. 1987. 'Valuing the Environment as Input'. *Journal of Environmental Management* 25: 149–56.

Fearnside, P, and S Pueyo. 2012. 'Greenhouse-Gas Emissions from Tropical Dams'. *Nature Climate Change*, no. 2: 382–84.

Freeman, A. Myrick. 1991. 'Valuing Environmental Resources Under Alternative Management Regimes'. *Ecological Economics* 3: 247–56.

———. 1993. *The Measurement of Environmental and Resource Values*. Washington DC: Resources for the Future.

Hall, B, and L Leebouapao. 2005. 'Economic Valuation of Alternatives Lower Mekong River Flow Regimes [Incomplete Draft]l'. IBFM Report. Vientiane: Mekong River Commission.

Hortle, Kent. 2007. 'Consumption and the Yield of Fish and Other Aquatic Animals from the Lower Mekong Basin.pdf'. MRC Technical Paper 16. Vientiane, Lao PDR: Mekong River Commission.

———. 2009. 'Fisheries of the Mekong River Basin'. In *The Mekong: Biophsyical Environment of an International River Basin*, 197–249. Amsterdam: Elsevier.

IAWG. 2013. 'EPA Technical-Update-Social-Cost-of-Carbon-for-Regulator-Impact-Analysis.pdf'. Washington DC: US Government Interagency Working Group on Social Cost of Carbon.

ICEM. 2010a. 'Economics Baseline Assessment Working Paper'. Prepared for the Mekong River Commission. Hanoi: International Centre for Environmental Management.

———. 2010b. 'Fisheries Baseline Assessment Working Paper'. Prepared for the Mekong River Commission. Hanoi: International Centre for Environmental Management.

———. 2010c. 'MRC Strategic Environmental Assesment of Hydropower on the Mekong Mainstream'. Prepared for the Mekong River Commission Final Report. Hanoi: International Centre for Environmental Management.

———. 2010d. 'Social Systems Baseline Assesment Working Paper'. Prepared for the Mekong River Commission. Hanoi: International Centre for Environmental Management.

———. 2013. 'Ensuring Sustainability of GMS Regional Power Development: Baseline Report'. Prepared for ADB - TA 7764 REG. Hanoi: International Centre for Enviormental Management.

Jenkins, Glenn P., Chun-Yan Kuo, and Arnold C. Harberger. 2011a. 'Chapter 18: The Abcs of Electricity Project Analysis'.

———. 2011b. *Cost-Benefit Analysis for Investment Decisions*. Discussion Papers DDP 2011-01 to 2011-20. Kingston ON: Queen's University. http://jdintl.econ.queensu.ca/discussion-papers/.

Kondolf, G. M., Z. K. Rubin, and J. T. Minear. 2014. 'Dams on the Mekong: Cumulative Sediment Starvation'. *Water Resources Research* 50 (6): 5158–69. doi:10.1002/2013WR014651.

Kossoy, Alexandre, Klaus Oppermann, Alexandrina Platonova-Oquab, Suphachol Suphachalasai, Niklas Höhne, Noémie Klein, Alyssa Gilbert, et al. 2014. 'State and Trends of Carbon Pricing 2014'. https://www.openknowledge.worldbank.org/handle/10986/18415.

Kummu, Matti, Dan Penny, Juha Sarkkula, and Jorma Koponen. 2008. 'Sediment: Curse or Blessing for Tonle Sap Lake?' *AMBIO: A Journal of the Human Environment* 37 (3): 158–63. doi:10.1579/0044-7447(2008)37[158:SCOBFT]2.0.CO;2.

Kummu, M., X.X. Lu, J.J. Wang, and O. Varis. 2010. 'Basin-Wide Sediment Trapping Efficiency of Emerging Reservoirs along the Mekong'. *Geomorphology* 119 (3-4): 181–97. doi:10.1016/j.geomorph.2010.03.018.

Kummu, M., and O. Varis. 2007. 'Sediment-Related Impacts due to Upstream Reservoir Trapping, the Lower Mekong River'. *Geomorphology* 85 (3-4): 275–93. doi:10.1016/j.geomorph.2006.03.024.

LaPlante, Benoit. 2005. 'Economic Analysis of the Environmental and Social Impacts of the Nam Theun 2 Hydroelectricity Power Project'. Report submitted tor the World Bank.

Maunsell, and Lahmeyer International. 2004a. 'Power System Development Plan for Lao PDR'. Prepared for Lao PDR, Ministry of Industry and Handicrafts, Department of Electricity and the World Bank Main Report. Auckland: Maunsell Limited in association with Lahmeyer GmbH.

———. 2004b. 'Power System Development Plan for Lao PDR'. Prepared for Lao PDR, Ministry of Industry and Handicrafts, Department of Electricity and the World Bank Main Report. Auckland: Maunsell Limited in association with Lahmeyer GmbH.

McKenney, Bruce. 2001. 'Economic Valuation of Livelihood Income Losses and Other Tangible Downstream Impacts from the Yali Falls Dam to the Se San River Basin in Ratankiri, Cambodia'. Phnom Penh: Oxfam America, Southeast Asia Regional Office.

Millennium Ecosystem Assessment. 2005. *Ecosystems and Human Well-Being: Synthesis*. Washington DC: Island Press.

Moore, Frances C., and Delavane B. Diaz. 2015. 'Temperature Impacts on Economic Growth Warrant Stringent Mitigation Policy'. *Nature Climate Change* 5 (2): 127–31. doi:10.1038/nclimate2481.

MRC. 2005. *Overview of the Hydrology of the Mekong Basin*. Vientiane: Mekong River Commission.

———. 2011. *State of the Basin Report*. Vientiane: Mekong River Commission.

———. 2012. 'Transboundary River Basin Management: Addressing Water, Energy and Food Security'. Vientiane: Mekong River Commission.

MRC-BDP. 2005. 'Economic Valuation of Water Resources (RAM Applications)'. BDP Library Volume 8. Vientiane: Mekong River Commission.

———. 2009. ‘Assessment Methodology’. Basin Development Plan Programme, Phase 2 Technical Note 2. Vientiane: Mekong River Commission.

———. 2010a. ‘Agricultural Impacts’. Basin Development Plan Programme, Phase 2 Technical Note 7. Vientiane: Mekong River Commission.

———. 2010b. ‘Economic Benefits and Costs’. Basin Development Plan Programme, Phase 2 Technical Note 13. Vientiane: Mekong River Commission.

———. 2010c. ‘Hydrological Assessment’. Basin Development Plan Programme, Phase 2 Technical Note 2. Vientiane: Mekong River Commission.

———. 2010d. ‘Impacts of Changes in Salinity Intrusion’. Basin Development Plan Programme, Phase 2 Technical Note 8. Vientiane: Mekong River Commission.

———. 2010e. ‘Impacts on Fisheries’. Basin Development Plan Programme, Phase 2 Technical Note 11. Vientiane: Mekong River Commission.

———. 2010f. ‘Impacts on Wetland and Biodiversity’. Basin Development Plan Programme, Phase 2 Technical Note 9. Vientiane: Mekong River Commission.

———. 2010g. ‘Power Benefits’. Basin Development Plan Programme, Phase 2 Technical Note 6. Vientiane: Mekong River Commission.

———. 2010h. ‘Social Assessment’. Basin Development Plan Programme, Phase 2 Technical Note 12. Vientiane: Mekong River Commission.

———. 2011. ‘Assessment of Basin-Wide Development Scenarios’. Basin Development Plan Programme, Phase 2. Vientiane: Mekong River Commission.

Nippon Koei. 2009. ‘The Master Plan Study of Hydropower Development in Cambodia’. Final Report. Tokyo: Japanese International Cooperation Agency. libopac.jica.go.jp/images/report/11925774_01.pdf.

No Author. 2006. ‘Buon Kuop Hydropower Project’. Project Design Document Version 03-28 July 2006. Clean Development Mechanism.

Pagiola, S., Konrad von Ritter, and J. Bishop. 2004. *How Much Is an Ecosystem Worth?* Washington DC: The World Bank. http://dx.doi.org/10.1596/0-8213-6378-6.

Parry, W.H., Dirk Heine, Eliza Lis, and Shanjun Li. 2014. *Getting Energy Prices Right: From Principle to Practice*. Washington DC: World Bank.

Pindyck, Robert S. 2013. ‘Pricing Carbon When We Don’t Know the Right Price’. *Regulation*, no. Summer: 43–46.

Promjiraprawat, Kamphol, and Bundit Limmeechokchai. 2012. ‘Assessment of Thailand’s Energy Policies and CO2 Emissions: Analyses of Energy Efficiency Measures and Renewable Power Generation’. *Energies* 5 (12): 3074–93. doi:10.3390/en5083074.

Rowcroft, P. 2005. ‘Payments for Environmental Services: A Review of Global Experiences and Rocommendations for Their Application in the Lower Mekong Basin’. Submitted to the Irrigation and Forestry Programme of the MRC-GTZ Cooperation Programme.

Ruangrong, Pallap. 2012. ‘Power Tariff Structure in Thailand’. Energy Regulatory Commission of Thailand presented at the Singapore EAS.

Schuyt, K, and L Brander. 2004. ‘The Economic Values of the World’s Wetlands’. Gland: World Wildlife Fund.

Simpson, R.D. 1997. ‘Biodiversity Prospecting: Shopping the WIilds Is Not the Key to Conservation’. Mimeo. Washington DC: Resources for the Future.

Suryadi, Beni. 2014. ‘ASEAN Electricity Tariff 2014’. *Talk Energy*. http://asean.bicaraenergi.com/2014/05/asean-electricity-tariff-2014/.

Thang, Tran Toan. 2014. ‘Fertilizers in Vietnam’. Policy Note 11. Washington DC: International Food Policy Research Institute.

Ty, Pham, A. Van Westen, and Annelies Zoomers. 2013. ‘Compensation and Resettlement Policies after Compulsory Land Acquisition for Hydropower Development in Vietnam: Policy and Practice’. *Land* 2 (4): 678–704. doi:10.3390/land2040678.

Vuthy, Theng, Khiev Pirom, and Phon Dary. 2014. ‘The Fertilizer Industry in Cambodia: Market, Challenges and the Way Forward’. Policy Note 06. Washington DC: International Food Policy Research Institute.

Walling, Des E. 2008. ‘The Changing Sediment Load of the Mekong River’. *AMBIO: A Journal of the Human Environment* 37 (3): 150–57. doi:10.1579/0044-7447(2008)37[150:TCSLOT]2.0.CO;2.

Wild, Thomas B., and Daniel P. Loucks. 2014. ‘Managing Flow, Sediment, and Hydropower Regimes in the Sre Pok, Se San, and Se Kong Rivers of the Mekong Basin’. *Water Resources Research* 50 (6): 5141–57. doi:10.1002/2014WR015457.

World Bank. 2001. ‘Operational Policy: Involuntary Resettlement’. In *The World Bank Operational Manual*. Washington DC: The World Bank. http://siteresources.worldbank.org/INTFORESTS/Resources/OP412.pdf.

———. 2005. ‘Nam Theun 2 Project Economic Analysis’. Washington DC: The World Bank.

———. 2011. ‘Trung Son Hydropower Project: Financial Analysis’. Washington DC: World Bank.

World Commission on Dams. 2000. *Dams and Development: A New Framework for Decision-Making*. London: Earthscan.

Yermoli, Carlos. 2009. ‘Hydropower Project Database: User’s Manual’. Basin Development Programme. Vientiane: Mekong River Commission.

Ziv, Guy, Eric Baran, So Nam, Ignacio Rodríguez-Iturbe, and Simon A. Levin. 2012. ‘Trading-off Fish Biodiversity, Food Security, and Hydropower in the Mekong River Basin’. *Proceedings of the National Academy of Sciences* 109 (15): 5609–14. doi:10.1073/pnas.1201423109.