Integrating environmental values into resource allocation
- MRC's approach in the LMB

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Introduction

In 1995 Cambodia, Lao People's Democratic Republic, Thailand and Viet Nam signed the Mekong Agreement, which sets out principles for cooperation in managing the shared resources of the Mekong River. The Agreement explicitly acknowledges that "the Mekong River Basin and the related natural resources and environment are natural assets of immense value to all the riparian countries". This value depends not only on the use of the river's water for domestic supply, irrigation, and hydropower but also on the importance of the river's ecosystems for subsistence livelihoods and as a habitat for fish production, and on its cultural significance to the people of the region.

Under the Agreement, the four countries are working together, through the Mekong River Commission (MRC), to negotiate rules for water utilisation in the LMB, and to formulate a Basin Development Plan (BDP). The rules aim to ensure that water is allocated in a reasonable and equitable manner, and that flows on the mainstream are maintained within acceptable limits to protect the ecological balance of the river and its ecosystems. Within this framework, the BDP will set out a strategy for water resources development, and identify high priority water resources programs and projects with shared benefits.

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

This paper will review on-going programs at MRC relevant to integrating environmental values into water resources planning and management. This work falls into two main areas:

- hydrological simulation models to predict the impacts of different water allocation options
- environmental inventory and analysis to assess the consequences of these impacts.

Hydrological models of the Lower Mekong Basin at MRC

MRC's Water Utilisation Program (WUP) is building a suite of hydrological models for the LMB as part of efforts to better understand the hydrology of the basin and the potential impact of changes. The models are designed to allow analysis of the outcome of possible future scenarios for the development of water resources in the LMB. Scenarios will be formulated to examine the impact on the LMB of external factors such as climate change and construction of dams on the Upper Mekong (Lancang) in Yunnan, as well as the impacts of proposed developments and other changes within the LMB (such as increased irrigation, hydropower development, increased population growth, floodplain protection works).

Hydrological models developed under WUP include:

- hydrological (rainfall-runoff) model (SWAT)
- simulation model for the basin upstream of Kratie (IQQM)
- hydrodynamic model for the floodplain from Kratie to the sea, including the Tonle Sap Lake (ISIS)
- resource allocation and optimization model (RAOM) for the LMB.
- detailed model of Tonle Sap Lake (developed by WUP-FIN 2003)
- detailed model of the Cambodian floodplain (developed by WUP-JICA 2003)

The first four models are being developed for MRC by Halcrow Consulting as part of a Decision Support Framework for the LMB, and are described in MRC (2003a, b).

The hydrological (rainfall-runoff) model provides estimates of flow over time for strategic points within the LMB. The USDA Soil and Water Assessment Tool (SWAT; http://www.brc.tamus.edu/swat/index.html) has been used, providing daily estimates of flow for 138 sub-basins covering all of the LMB except the delta south of Phnom Penh. The SWAT model has been calibrated against available streamflow data for the period 1985-2000. SWAT can also be used to simulate hydrological response due to changes in land use and climate that may occur in the future.

The basin simulation model simulates possible future scenarios for water resource development, to assess their effects on water availability both spatially and temporally. The software used is the Integrated Quantity and Quality Model (IQQM) developed in Australia (NSW DLWC 1999). It is constructed as a complex network of nodes (representing inflows, demands, storages and return flows) and linkages (representing water movement through the river system). The IQQM schematization for the LMB uses a total of 760 nodes for the area upstream of Kratie. Inflow data is provided from the SWAT model, on a daily time-step. The basin simulation model has been calibrated against streamflow data using estimates of demands and information on reservoirs and storages for the period 1985-2000. Separate IQQM models have been constructed to simulate irrigation demands for the Great Lake, and for the Delta, as inputs to the hydrodynamic model.

The hydrodynamic model simulates both flow and water level in the river and on the floodplain, in the area from Kratie to the sea, including Tonle Sap Lake and the distributary channels of the Mekong Delta. The software used is ISIS (Wallingford Software 2003) which has been supplemented and extended by Halcrow (ref WP14). The model has been constructed using over 6,000 nodes and 800 flood cells, with an hourly (rather than daily) time step to deal with tidal effects. The model is currently being calibrated.

The basin models and DSF are supplemented by additional models for Tonle Sap (WUP-FIN 2003a) and the Cambodian floodplain (WUP-JICA 2003a,b).

A Decision Support Framework (DSF) has also been developed, to provide an interface to access results from the basin models, including flow time-series, statistical analyses of flow characteristics (such as probability exceedance analysis) and spatial analysis of impacts of flow (for example, on flood extent and duration, and salinity intrusion). The DSF provides capability for overlay of hydrological information with spatial data (such as land use, location of villages and towns, location of infrastructure, etc).

Resource allocation and optimization model

A simple resource allocation and optimization model (RAOM) is being developed under the MRC's Basin Development Plan program (BDP). Conceptually, it is similar to the optimisation model developed by Ringler (2001), but draws on hydrological information now available from the WUP models, and uses What'sBest! software (Lindo Systems 2003). Water availability and use is modelled for each of 10 catchments (sub-areas) within the Lower Mekong Basin (Figure 1) such that the outflows from one sub-area are the inflows to the next. The model runs on a monthly time step, using hydrological data imported from the SWAT model. Inflows from the Upper Basin are not modelled, but taken from gauged streamflow data at Chiang Saen.

The RAOM combines hydrological and water-use data to examine how water resources in the LMB can be allocated among various water-consuming activities and functions, under constraints set by the modeller. The constraints can include minimum flow requirements for irrigation, domestic and industrial supply, or for instream uses (wetland functions, fisheries production, navigation, prevention of salinisation, etc). An objective function is defined, and the model optimizes allocation for that function. The objective function must be related to flow. For example, the objective function may be set to maximise the sum of values for water in different uses (where value is defined as a function of volume used in each sector in order to obtain an *economically* optimal allocation of water). Alternatively, the objective function may be set to maximize flow in the dry season at a given point or points; or to minimize area flooded (where area flooded is a function of flow volume).

Thus environmental values can be incorporated into the model in two ways. Pre-determined limits for minimum or maximum flows at specific points can be defined and included as constraints. Alternatively, or additionally, economic values can be defined for environmental benefits as a function of flow, and included as part of an overall valuation of water uses.

While the BDP RAOM is to be used principally to conduct research on the environmental impacts of different water allocation scenarios, it may also be refined and expanded to provide a means of examining the economic implications and quantifying the environmental impacts of various water-use trade offs.

At present, the values being used to run the model are simply unit estimates (not necessarily monetary or economic) that seek to demonstrate the relative worth of water in each of its uses. In order to make the model more suitable for economic analysis these values need to be refined so that they more accurately reflect the true value of water in each of its alternative uses. Expressing the values in monetary economic terms allows for a more realistic assessment and comparison of the impacts of hydrological scenarios and development options and also enables the model to determine economically optimal allocations of water.

McKinney et al (1999) identified the following characteristics as fundamental to an integrated hydrologic-economic model at the basin scale:

- Depiction of the entire river basin;
- Integration of hydrologic and economic relationships in an endogenous system
- Representation of the spatial and temporal distribution of water flow and pollutant transport and mass balance through the river basin;
- Incorporation of water demands from all water-using sectors, including instream or environmental uses;
- Possibility to evaluate economic benefits and costs of each of these demands; and
- Incorporation of economic incentives and institutional roles for policy analysis based on the model

Thus, as far as possible, the economic values will:

- incorporate positive and negative externalities;
- account for different levels of demand between sub-basins and for international trade of water-dependent goods and services, especially hydropower; and
- account for seasonal fluctuations in water demand and hence prices of water-dependent activities and outputs.

The objective function can be set to seek to maximise the sum of the values for water in significant water-dependent economic activities such as irrigation; hydropower; municipal & industrial consumption; tourism; fisheries production and shrimp farming; and navigation. Economic benefits of consumptive water demands (for example, irrigation and municipal and industrial uses) are generally straightforward to quantify, as their values are expressed in the market place. Values for hydropower, which is internationally traded, will need to be estimated using shadow prices. Further thought will need to be given to the valuation of navigation and tourism.

The model will also include factors to demonstrate the value of water in environmental services and biodiversity preservation where these cannot be measured by looking at direct consumptive uses of environmental products. Using the basin hydrological models, functions will be developed relating flow volume to environmentally significant parameters such as extent and duration of flooding, and salinity intrusion. In turn, relationships will be sought between these parameters and the economic value of their environmental benefits or costs – for example, flooding and fisheries productivity; or saline intrusion and decreased agricultural production. Economic benefits of environmental water demands are difficult to quantify, as their values are generally not expressed fully (or at all) through market processes. In light of BDP time constraints, the extent to which environmental valuation for instream uses is possible will depend on the progress that is made with current valuation initiatives by MRC-EP, IUCN, WorldFish Centre and WWF among others.

Once the values have been refined and other significant water-dependent activities integrated into the model, then it is envisaged that the model can be used for:

- Determining an economically optimal allocation of water;
- Quantifying the trade-offs between water uses under different objective functions and constraints; and
- Quantifying the impacts of hydrological scenarios and development options

Environmental Inventory and Analysis

Environmental Flows

The MRC Environmental Flow Assessment program or Integrated Basin Flow Management (IBFM) is a three phase program to establish rules for maintenance of acceptable flows in the Mekong mainstream. Under the 1995 Mekong Agreement, the countries agreed to "protect the ecological balance of the river system ", and to establish rules for water utilization that prevent:

- an unacceptable reduction in dry season flows (below the average minimum monthly discharge);
- an unacceptable increase in wet season flood flow; and
- maintenance of mainstream flows at Kratie adequate to support the Tonle Sap reversal and acceptable inundation of the Tonle Sap Great Lake.

The first phase of the program is focused on establishing interim 'flow rules' which effectively maintain the current status of the basin water balance. These initial hydrological requirements, negotiated by representatives from all four LMB countries based on current flow patterns as defined by existing hydrological data, will form a set of interim rules which will be reviewed and supplemented in the second and third phases of the program.

The second and third phases of the IBFM program are focused on identifying and valuing the environmental and socioeconomic impacts of a change from the current 'natural' flow regime. The “Mekong method” being developed is based on the DRIFT program developed in South Africa (King et al 2003). DRIFT (Downstream Response to Imposed Flow Transition) is a holistic approach to advising on environmental flows, drawing on a wide range of bio-physical and socio-economic expertise.

DRIFT is based on the assumption that any change to the natural pattern of river flow will result in changes to river ecology, with impacts for both environment and subsistence use. If the relationship between flows, ecology and subsistence and other uses of river resources are understood, a decision can be made as to how much change is acceptable and the pattern of flows needed to maintain that level of change can be described. These then constitute the environmental flow requirements. The main steps in the DRIFT methodology are:

- Description of the river, and developing predictive capacity on how it would respond to flow changes
- Description of subsistence users of the river and the resources they use, and developing predictive capacity of how river changes would impact on riparian people
- Building scenarios of potential future flows and their impacts on the river and its users
- Macro-economic assessment of the wider implications of each scenario
- Public participation process whereby users of the river can indicate the level of acceptability of each scenario.

Phase 2, beginning early 2004, will be a desk study, using an expert panel approach, with specialists from the LMB countries and international specialists. It will be based on short field visits and information currently available distributed amongst a wide range of agencies. Phase 3, beginning early in 2005, will add field study at the selected river reaches to the initial review. These phases involve collaboration with IUCN in the GEF funded 'Mekong Wetlands Biodiversity and Sustainable Utilization Program', in particular with respect to economic evaluation of components of river and riparian ecology.

Phases 2 & 3 will compare simulated flow regimes under different scenarios to existing flow at different locations on the mainstream. Likely development scenarios for the Lower Mekong Basin will be defined under MRC’s Basin Development Plan, and the flows resulting from each scenario will be simulated using the WUP hydrological models. The Environmental Flow Assessment

Program will attempt to assess the impact on different components of the river at each selected sample reach, including water quality, stream morphology, instream and riparian ecology, and instream and riparian livelihood factors.

The initial hydrological rules determined in phase 1 will be subject to continuous review in light of new environmental and socioeconomic assessment resulting from phases 2 and 3. This also applies to assessment of the BDP scenarios driving the simulated hydrological regimes, 'tested' throughout the environmental flow program. Initial advice on the impacts of different development scenarios will be reviewed and expended as more knowledge about the river system is incorporated.

Wetlands inventory and valuation

MRC's Environment Program includes a component entitled "People and Aquatic Ecosystems" which aims to provide information on the values of, dependence on and threats to the basin's aquatic ecosystems. This work relies on collaborative partnerships with IUCN, WWF and UNDP.

In addition to environmental flow assessment, MRC's joint program with IUCN in the 'Mekong Wetlands Biodiversity and Sustainable Utilization Program', involves a component concerned primarily with the inventory and mapping of the wetlands of the LMB. MRC is expanding its wetland mapping program to incorporate environmental valuation and economic values of different wetland types. This will include the application of remote sensing at a coarse resolution across the entire basin, with high resolution images created where ground truthed data are available; incorporation of existing GIS with satellite imagery, existing land use, topographic, inundation, and soil maps, and the creation of 'biodiversity overlays'; and the addition of economic or livelihood values to specific wetland classes. This involves the expansion of the existing wetland classification to incorporate environmental (biodiversity/physical processes) and socioeconomic values (local utilization of wetland products).

In March 2002, MRC and World Wildlife Fund (WWF) held a joint workshop to establish a base of information concerning the economic value of natural seasonal flooding in the Mekong Basin, in the context of preserving the ecological functions reliant on the natural flood regime of the region. The outputs were a summary of available information from experts in the region, and suggestions to guide WWF's further analyses of the natural flood regime (MRC 2002).

Valuation of Mekong Fisheries

The Mekong River Basin hosts one of the most diverse freshwater fisheries in the world, with over 1,200 recorded fish species and a diverse fauna of other aquatic animals (OAAs) such as shrimps, crabs, molluscs, reptiles and insects (Sverdrup-Jensen 2002). Many Mekong fish species are migratory, crossing national boundaries during their life cycle. The floodplain is an important habitat for most species at some stage in their life cycle, and the fishery is crucially dependent on the flood pulse of the annual monsoon. Thus management of the fishery is of regional concern both in terms of the migratory stocks, and maintaining the pattern of flooding to maintain fish habitats. Changes to the patterns of water flow in the basin could have profound impacts on the ecology of the river, and on fish production.

The Mekong fishery is enormously important both commercially and for subsistence livelihoods throughout the LMB. Catches and consumption are highest during the flood recession, when fish and OAAs becoming concentrated in diminishing bodies of water, or migrate or are forced to move from floodplain areas back to main river channels. During such movements they can be caught by various kinds of filtering gears (such as stationary trawls or fences and traps) or netting devices. Catches are also high at the start of the flood when aquatic animals migrate upstream to breed and are caught in trapping devices, or as is more common nowadays, by gillnets. The seasonal excess of fish is fermented, dried, salted or smoked and stored and eaten over the low-catch months, or it is used to feed fish held in cages or ponds. Although aquaculture is growing in importance, the vast majority of inland fish in the LMB is derived from the wild fishery, and much aquaculture is simply a conversion of wild-caught fish.

To value inland fisheries we need to be able to quantify the yield (or production) of the fishery and its value. One way to determine yield is to study catches. Unlike marine fisheries, catches in the LMB are spread among millions of people operating many kinds of gears in a wide range of habitats and over different time scales. So large errors accrue if we attempt to estimate total catches by multiplying the number of gears (or fishers) by their catch rates (as both terms are subject to high errors). Official statistics are usually based on catches recorded (or guessed) for larger gears, so are much lower than actual figures (Coates 2002).

Another way to quantify catches is to study markets, but in the LMB a large portion of fishery products are either eaten by the fishers' families or are traded via diffuse networks or through many very small markets. Where markets are surveyed, traders are often reluctant to provide accurate data on prices and quantities (as they are afraid of incurring taxation). For these reasons accurate market information for most of the fishery cannot be obtained.

The third way to quantify the fishery is to study consumption of fish and OAAs, because consumption can be related to yield. Yield is the sum of consumption+ exports + fish for animal feed + wastage minus imports (note that some adjustments need to be made for aquaculture conversions). In the LMB, exports of inland products would exceed imports, so consumption alone provides a conservative estimate of yield. To estimate total consumption we need to multiply population by per capita consumption. Population data are available from censuses and are quite precise, and per capita consumption is within a relatively narrow range, so the resulting total estimate is much more precise than any based on catches or markets.

It has been estimated based on surveys throughout the LMB that average consumption of fish and other aquatic animals (OAAs) from inland waters is about 36 kg/person/year as fresh whole weight equivalent (Sverdrup-Jensen 2002), or about 2 Mt/year. Recent estimates are that annual consumption is around 3 Mt/year or about 55 kg/person/year; earlier estimates did not account for some components (such as portions of the preserved fish or other aquatic animals) (Hortle and Bush 2003). This figure is quite reasonable, as accurate figures from developed countries range between 15-90 kg/person/year. The estimated direct value of the fishery is about US$0.70 per kg, or over $2b per year, and the indirect value is several times higher, as the fishery requires many inputs (e.g. fishing gear, fuel, ice, preservatives, such as salt,, boats and boating equipment), and trading the fish requires transportation and infrastructure.

Based on detailed MRC survey data, up to two-thirds of the LMB's population are involved in fishing at least part-time or seasonally. Again these statistics do not appear officially, because government agencies classify people by primary occupation. So for example, all people in a district could be classified as working on farms, as labourers, or in handicrafts, but if all were engaged in fishing as a secondary occupation, fishing may be the most important occupation overall, but be entirely missed by the survey. And most trading of fishery products does not appear in official "cash economy" statistics as it is outside conventional market systems.

Assessments of the size and value of the fishery have been carried out by the MRC in several provinces throughout the LMB, and the data provide a snapshot at the time of the survey. The fishery is rapidly changing so the emphasis now is to detail techniques for continuous monitoring selected indicators of the fishery, with basinwide assessments only possible at longer intervals (5-10 years).

The MRC's current programs which relate to valuing the fishery include:

- long-term monitoring of catches, to establish accurate figures for catch-rates of different gears,
- long-term monitoring of selected markets, to study trends in species, sizes and prices, which can be used to place a monetary value on yield, and
- assessment of methods for consumption studies, as most previous work relied on interviews, which may not accurately reflect actual consumption.

Monitoring the size and value of the inland fishery of the LMB will be a very large challenge. The actual value of the fishery is becoming more widely known, and all riparian fisheries agencies are aware of the problems inherent in collecting accurate statistics (see papers in (Clayton *et al.* 2003). The MRC, for its part, is carrying out selected work as noted above, which can assist in developing monitoring systems for basinwide estimates or yield and value, but to establish and maintain such systems, and to carry out periodic basin-wide assessments would require some major commitments by all riparian governments.

Conclusions

Under the 1995 Mekong Agreement, two important aspects of MRC's work are establishing rules for maintenance of flows; and formulation of a regional Basin Development Plan to optimise joint benefits from Mekong resources. In both, environmental valuation is crucial. Determining an acceptable levels of flow must take into account the enormous dependence in the region on fisheries and other resources from the river and their links to river flows, as well as the river's important biodiversity, cultural and existence values. The environmental flow assessment methodology requires that these values, and their potential loss under changed flow regimes, are explicitly stated so that informed decisions about future river condition can be made.

A Basin Development Plan must conform to the rules for maintenance of flows, but also seeks to optimise allocations for maximum socio-economic benefit to the riparian countries. Comparison of water allocation options will be facilitated if a realistic economic valuation can be made of environmental uses of water, and of the loss of amenity that may result from diverting water to other uses.

MRC uses scenario analysis as a tool to integrate environmental values into planning and regulation. Hydrological simulation models provide predictions of the consequences of different water allocation options in terms of river flows. Studies of wetlands, fisheries and subsistence use employing a range of valuation methods are building up an understanding of the economic and other benefits derived from the river and how these might change. The resource allocation and optimisation model will examine economically optimal allocation of water, and quantification of the trade-offs between water uses and the environment. Based on this information, the countries of the LMB aim to make informed decisions on water resource use and development, balancing the need for development for economic growth and poverty alleviation with protection of the river and its resource base.

References

Clayton, T., Funge-Smith, S. J., Bartley, D. M., and Barlow, C. (2003). New approaches for the improvement of inland capture fishery statistics in the Mekong Basin. RAP Publication 2003/01. 1-145. FAO and MRC: Thailand.

Coates, D. (2002). Inland capture fishery statistics of Southeast Asia: current status and information needs. RAP Publication 2002/11, 1-114. Bangkok, Thailand, FAO Regional Office for Asia and the Pacific.

Hortle K.G. and Bush, S. (20023) Consumption in the Lower Mekong Basin as a measure of fish yield. pp. 75-81 in Clayton et al. (2003), cited above.

King, J, Brown, C and Sabet, H (2003) A scenario-based holistic approach to environmental flow assessments for rivers. River Research and Applications 19, 619-639.

LINDO Systems (2003) http://www.lindo.com

McKinney, D.C, Xai, C., Rosegrant, M.W., Ringler, C. and Scott, C.A. (1999) *Integrated Basin-Scale Water Resources Management Modeling: Review and Future Directions*, IWMI SWIM Paper No.6, Colombo, Sri Lanka: International Water Management Institute.

MRC (2002) Establishing the Economic Value of the Flood in the Mekong Basin. Summary of Workshop held in Phnom Penh (March 20-21, 2002). Internal report, Mekong River Commission, Phnom Penh, Cambodia.

MRC (2003a) WUP-A Working Paper No. 14 – Model Development and Calibration. Mekong River Commission Water Utilisation Program Component A. MRC, Phnom Penh, Cambodia. 54 pp.

MRC (2003b) Resource allocation and optimisation model developed for MRC Basin Development Plan. Report by Halcrow Consulting to MRC BDP. Internal report, Mekong River Commission, Phnom Penh, Cambodia.

NSW DLWC (1999) Integrated Quantity and Quality Model. New South Wales Department of Land and Water Conservation, Sydney. http://www.dlwc.nsw.gov.au/care/water/iqqm/

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

Sverdrup-Jensen, S. (2002). Fisheries in the Lower Mekong Basin: Status and Perspectives. MRC Technical Paper No. 6, 1-95. Phnom Penh, Cambodia, Mekong River Commission.

Wallingford Software (2003) http://www.wallingfordsoftware.com/products/isis/

WUP-FIN (2003a) WUP-FIN Model Report. Mekong River Commission, Phnom Penh, Cambodia.
http://www.eia.fi/wup-fin/publications.htm

WUP-FIN (2003b) WUP-FIN Final Report. Mekong River Commission, Phnom Penh, Cambodia.
http://www.eia.fi/wup-fin/publications.htm

WUP-JICA (2003a) Consolidation of hydro-meteorological data and multi-functional hydrologic roles of Tonle Sap Lake and its vicinities. Main Report. WUP-JICA Final Report, 2003. Mekong River Commission, Phnom Penh, Cambodia.

WUP-JICA (2003b) The study on hydro-meteorological monitoring for water quantity rules in the Mekong River Basin. WUP-JICA Final Report. Mekong River Commission, Phnom Penh, Cambodia.

Figure 1: sub-areas of LMB modelled using the resource allocation model