Chapter 6
Mekong at the Crossroads: Alternative Paths of Water Development and Impact Assessment

Marko Keskinen, Matti Kummu, Mira Käkönen, and Olli Varis

Abstract The Mekong Region in Southeast Asia is undergoing rapid transitions socially, economically, and environmentally. Water is related to these changes in a very profound manner, and the Mekong River and its tributaries are seeing increasing number of plans for water development, most notably in the form of large-scale hydropower. The impacts of this development vary among regional, national, and local levels and across different timescales, influencing societies, politics, and the environment in a variety of ways. While different impact assessment and water management frameworks – including Integrated Water Resources Management (IWRM) – have been used by actors at different levels in the basin, they have not been too successful in analyzing and communicating the various development paths and their differing impacts in all their complexity. This chapter discusses the water development pathways in the Mekong Basin, including their potential impacts and the different possibilities to assess them, as of early 2010. It is concluded that the water development and related management practices in the Mekong are at the crossroads methodologically and, even more importantly, politically.

M. Keskinen (✉) • M. Kummu • O. Varis
Water & Development Research Group, Aalto University, P.O. Box 15200, FIN-00076 Aalto, Finland
e-mail: marko.keskinen@aalto.fi; matti.kummu@aalto.fi; olli.varis@aalto.fi

M. Käkönen
Water & Development Research Group , Aalto University , P.O. Box 15200, FIN-00076 Aalto , Finland
Finland Futures Research Centre, University of Turku, Korkeavuorenkatu 25 A 2, FIN-00130 Helsinki, Finland
e-mail: mira.kakonen@utu.fi

J. Öjendal et al. (eds.), *Politics and Development in a Transboundary Watershed: The Case of the Lower Mekong Basin*, DOI 10.1007/978-94-007-0476-3_6,

6.1 Introduction: The Changing Mekong

The Mekong Region is undergoing rapid transitions socially, economically, and environmentally. Economies of the Mekong countries are stabilizing after the political turbulence of several decades, and development pressures towards the region's natural resources are vast. Water is related to these changes in a very profound manner, and the Mekong River and its tributaries are seeing an increasing number of plans for water development. The most remarkable, and most fervently debated, element of such plans is the development of large-scale hydropower. They are therefore also the main focus of this chapter. However, also several other changes, including intensification of agriculture, construction of new infrastructure, and changes in the land use, are likely to have notable impacts to the Mekong's waters. The impacts of these developments vary among regional, national, and local levels and across different timescales, influencing societies, politics, and the environment in a variety of ways. At the same time, new driving forces, most importantly climate change, are entering the discussion, affecting the ways the water resources are being used and developed. Decisions about the forms of water development will therefore have profound and far-reaching implications – not only physical and ecological but also social and political – throughout the basin.[1]

While various impact assessment and water management frameworks, such as Integrated Water Resources Management (IWRM), have been used and adapted by the actors at different levels in the Mekong River Basin, they have not (yet) been too successful in analyzing and communicating the various development paths and their differing impacts in all their complexity. Indeed, while the drive for increased utilization of the river's waters is intensive in all riparian countries, the understanding of the actual impacts of these developments is in many aspects vague, and discussion about the most sustainable development options remains weak. The situation is, however, improving, and there exist an increasing number of initiatives that study and discuss the potential impacts – and general feasibility – of current water development plans. Such initiatives range from water dialogues carried out by actors, such as the M-POWER network (IUCN et al. 2007a), to the "IWRM-Based Basin Development Strategy" and related assessments implemented by the regional Mekong River Commission (MRC 2009a, b).

This chapter discusses the water resources development pathways in the Mekong Basin and considers the different possibilities to assess their impacts. By presenting examples of potential impacts on water quantity, quality, and ecosystem productivity, we seek to highlight the diversity of impacts that water development is likely to induce at different scales. Such examples illustrate the first dimension of the crossroads related to possible development paths and their impacts. The chapter also discusses the challenges related to current practices of impact assessment and water resources management, addressing therefore the second, methodological dimension of the crossroads: the choice between different approaches used for management and impact assessment.

[1] The first full version of this chapter was submitted for review in February 2009 and the updated version in February 2010. Consequently, some of the discussion presented may be partly out-of-date due to rapid progress of Mekong's hydropower plans and related assessments.

The diverse set of impacts presented in this chapter emphasizes the fundamental threats to water resources in the basin, underlining the often neglected importance of fisheries, floodplains, and other common pool resources. Based on this, we argue for management and planning processes that build on existing livelihoods and resource uses, rather than on projects seeking to replace them (see, e.g., Öjendal 2000; Hirsch et al. 2006; MRCS/WUP-FIN 2007; Varis et al. 2008). We emphasize the need for parallel processes and methods for management and impact assessments. Indeed, due to complexities and uncertainties involved, there is a need to use a set of different models and impact assessment methods when assessing the diverse impacts to the water-related ecosystems and livelihoods. This can also be seen to pose a challenge to the concept of IWRM that – despite its calls for context-specificity – tends often to highlight a common, relatively predefined management approach for different scales and contexts.

Finally, while drawing on the analogy of crossroads, we acknowledge the limitations of such a view. In reality, the crossroads does not necessarily exist, at least not as one simple concrete and desirable choice to be made at a particular point in time. For the decisions about the water development – and the methods used in related planning and assessment – are usually done continually through a political process involving actors with varying agendas and interests. Consequently, the decision making about certain types of development has often at least as much to do with power structures and specific ideals than with balanced assessment of different alternatives. We do hope, however, that by highlighting the alternative paths that such decisions could take, we contribute for the broader discussion about the possible ways to use and develop the Mekong's waters.

6.2 Water Development in the Mekong

The human impact on water resources has increased dramatically during the last decades all over the world (Vörösmarty and Sahagian 2000). The Mekong River is one of the few large river basins in the world that has not been irreversibly modified by large-scale infrastructure. While the first dams in the Mekong mainstream (upstream in China; see Chap. 9 of this volume) and several dams in the tributaries have already been built, flow regimes in the lower reaches of the mainstream are still, essentially, natural (MRC 2005).[2] These conditions may not last much longer, as the Mekong River Basin is facing the prospects of a major boom in water infrastructure projects. Huge hydropower dams as well as water diversions for irrigation are planned in different parts of the basin, some on tributaries and others on the mainstream (King et al. 2007; MRC 2008a, 2010). As hydropower dams are expected to have the most radical impacts for the river flows and related ecosystems, they are next discussed in more detail.

There are currently various plans for hydropower development in the Mekong Basin. It is thereby challenging to just keep track of all of them, and even more

[2] Strongly modified waterscapes are also found within the basin: the Mekong Delta of Vietnam is a particularly interesting example of water regime intensively regulated by human interventions (see, e.g., Biggs 2004; Miller 2006; Käkönen 2008).

Table 6.1 Estimates for existing, ongoing, and proposed hydropower dams projects in six Mekong countries (Modified from King et al. 2007)

	Existing dams		Under construction		Proposed/ potential	
	Total	Mekong	Total	Mekong	Total	Mekong
Cambodia	3	1	1	0	33	26
Yunnan, China	2	2	3	2	34	10
Laos	8	8	3	3	32	32
Myanmar	13	0	8	0	15	1
Thailand	10	10	1	0	0	0
Vietnam	18	9	12	9	65	9
Total	54	30	28	14	179	78

Figures for all dams plus those within the Mekong Basin

challenging to estimate the cumulative impacts that such plans are likely to have. Two prominent sources, however, provide some general estimates about the scale of current hydropower plans (King et al. 2007; MRC 2008a). A recent inventory of existing and potential hydropower projects in the six Mekong countries came up with a total of 261 hydropower projects in the region, including 122 projects within the Mekong River Basin (King et al. 2007). Out of this total, an estimated 14 projects were under construction and a further 78 large projects were identified as potential sites within the basin (Table 6.1).

In autumn 2008, the Mekong River Commission (MRC) published a map indicating the location of dams planned in the Lower Mekong Basin (Fig. 6.1). When combined with available information from China, this data includes 28 existing hydropower dams as well as an estimated 14 dams that are under construction, and additional 101 dams that are at the planning stage, most of them in Laos (MRC 2008a). Notable is that this MRC data indicates plans for mainstream dams also outside China, including eight dams in Laos, two in Cambodia, and one in the border area between Laos and Thailand (MRC 2008b). These would be the first dams to be located in the Lower Mekong mainstream and also first mainstream dams to be constructed by an MRC member country. Such plans have thus put also the Mekong River Commission into a new position. Indeed, to respond to these new plans, the MRC has already strengthened its impact assessment practices, including Strategic Environmental Assessment (SEA) of the proposed mainstream dams as well as detailed assessments looking at hydrological, environmental, social, economic, and fish-related impacts of various different water development scenarios under MRC's Basin Development Plan (MRC 2009b, c, 2010).

Total theoretical potential for hydropower production in the entire Mekong Basin has been estimated to be around 43,000 MW, with some 30,000 MW technically available[3] in the four Lower Mekong Basin countries either in the

[3] According to WEC (2007), technically exploitable hydropower capability (namely potential) is the amount of the gross theoretical capability that can be exploited within the limits of current technology. Economically exploitable capability, on the other hand, is the amount of the gross theoretical capability that can be exploited within the limits of current technology under present and expected local economic conditions.

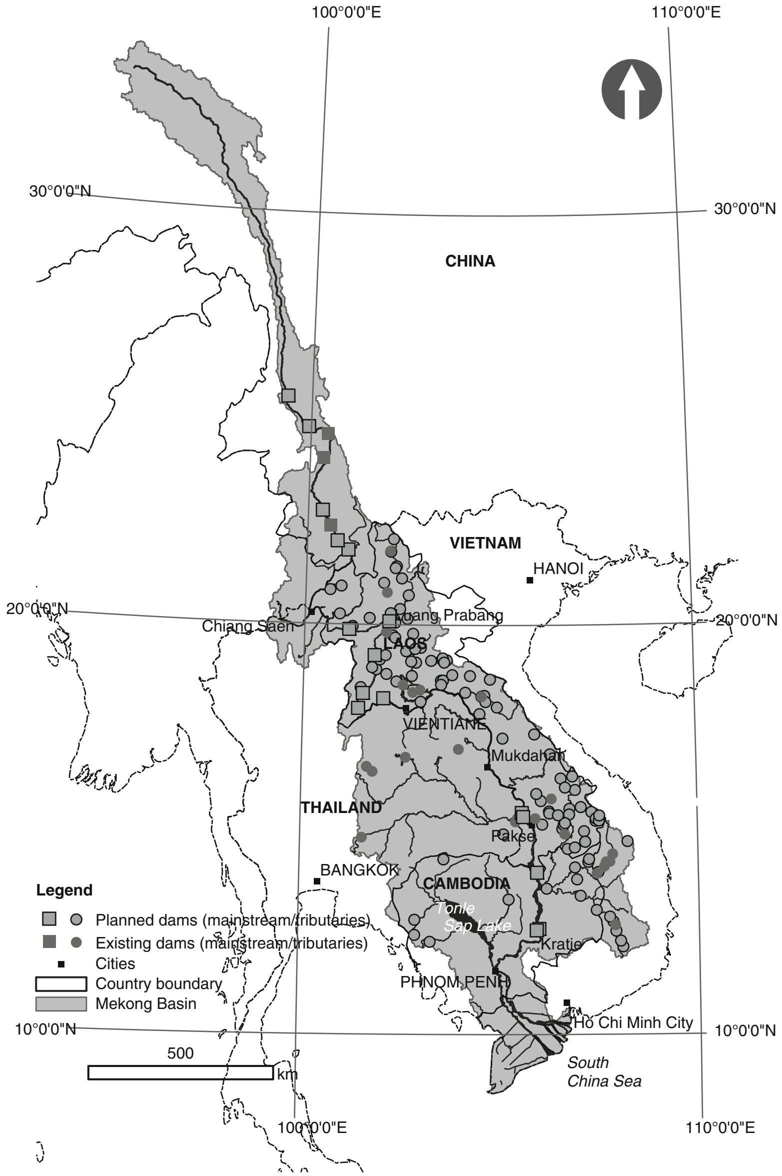

Fig. 6.1 The map on existing and planned hydropower dams in the Mekong Basin, showing existing (*darker*) and planned (*lighter*) projects (Modified from MRC 2008a)

mainstream (13,000 MW) or tributaries (17,000 MW) (King et al. 2007). Considerable amount of both the production capacity and active storage capacity is located in the Chinese part of Lancang-Mekong River, with plans including construction of projected 15,600 MW in the Mekong mainstream with a combined active storage of 23,200 million cubic meters by year 2025 (King et al. 2007). It is therefore relatively clear that next decade is likely to see an increasing amount of large-scale hydropower development both in the upper and lower parts of the basin. The actual cumulative impacts of these dams will depend on their amount, location, and storage capacity, as well as operational procedures, but the impacts are in any case most likely to be major. Consequently, looking at the current development plans and the overall political economy of the basin, we are likely to see a paradigmatic change in the water development in the entire region. Such developments – and consequent impacts – will also place new expectations for the water management practices at both national and regional level.

6.3 Estimating the Impacts

One of the central aspects of any decision-making process related to water development is to estimate the potential impacts that such development is likely to have. Consequently, different impact assessment methods are being increasingly used to inform water development planning. Indeed, decision making is relying nowadays so much on technical expertise and assessments that Rayner (2003: 163) has characterized the present era as the "age of assessment."

The impacts of water development can be both positive and negative, and they can also be felt very differently in different areas and times as well as by different social groups. In terms of hydropower development, more secure electricity production, increased water availability and predictability for agriculture, and income gained from the export of hydroelectricity represent obvious and often-stated examples of positive impacts, and ultimate reasons, for such projects. At the same time, however, there are also a variety of environmental, social, and economic impacts that the water development causes to water-related ecosystems, and consequently on livelihoods and industries dependent on them.

Numerous impact assessment processes have been undertaken also in the Mekong River Basin by actors at various levels. A great majority of these assessments indicate that the planned water developments in the basin are likely to cause remarkable changes for the availability of water-related resources – most importantly fish – and, consequently, for the livelihoods and food security of millions of people (see, e.g., MRC 2006a, 2009c, 2010; IUCN and IWMI 2007a; MRCS/WUP-FIN 2007; Dugan 2008). Yet, the estimates about the actual magnitude of such impacts remains varied, with different assessments providing widely differing estimates on the potential environmental, social, and economic impacts. Particularly basin-wide assessments have several challenges related to their comprehensiveness and overall reliability (see, e.g., Mirumachi and Nakayama 2007; MRCS/WUP-FIN 2007; Wyatt and Baird 2007; Keskinen 2008, 2010; Kummu and Sarkkula 2008).

6.4 Hydrological Models as a Tool for Impact Assessment

Various kinds of computational models provide one way to simulate the potential changes in the river system due to different kinds of developments.[4] Models are generally used to improve understanding of cumulative and aggregate effects, to provide forecasts, and to help to quantify different scenarios. These in turn are helpful for long-term planning of water resources development as well as for the assessment of water-related impacts. There has, however, also been active discussion about the challenges linked with the models and their results, related for instance to their transparency, reliability, and the possibilities for misuse (see e.g., Sarkkula et al. 2007; Käkönen and Hirsch 2009).

This chapter draws on the findings from the hydrological modeling and impact assessment work carried out in the Lower Mekong Modelling Project (WUP-FIN) under the Mekong River Commission (MRCS/WUP-FIN 2007). The hydrological models of the WUP-FIN Project used the basin-wide scenarios developed within the Decision Support Framework (DSF) of the MRC as their starting point to simulate the changes in flow regime with foreseen hydropower developments in subbasin scale. In addition, environmental and socioeconomic analyses were carried out to understand better the consequent environmental, social, and economic impacts that such flow changes are likely to have (see MRCS/WUP-FIN 2007; Sarkkula et al. 2007). However, as the scenarios used in the impact assessment of the WUP-FIN Project were developed already several years ago, even the most radical scenario, i.e., so-called High Development Scenario,[5] included only Chinese mainstream dams and some Lower Mekong Basin tributaries dams. Consequently, the estimates presented in this chapter can be considered to be relatively moderate, and the actual cumulative impacts of the current hydropower development plans – including several dams for the Lower Mekong mainstream – are likely to be much bigger in terms of changes in both water quantity and water quality.

[4] For more information on models and their use in environmental planning and decision making in the Mekong, see, e.g., Jakeman et al. (2006) and Sarkkula et al. (2007).

[5] The MRC used up to 2005 five development scenarios to assess the potential impacts of different development paths: Chinese Dams, Low Development, Embankments, Agriculture, and High Development (World Bank 2004). While such an approach was very useful in highlighting the differences between the estimates for different scenarios, the MRC later on gave up using them and replaced them with less controversial – and less illustrative – Flow Regimes (see also Käkönen and Hirsch 2009). More recently, however, the different development scenarios have been brought back to the discussion, and current MRC publications include several development scenarios for the Mekong, even with different timescales (MRC 2009a, b, 2010).

6.5 An Array of Impacts, Radical Consequences

This section discusses the projected impacts of large-scale hydropower development in the Mekong Basin by presenting examples of the impact estimates on water quantity, water quality, and ecosystem productivity. By doing this, we aim to highlight two important issues. First of all, the existing estimates already in some, relatively simple water-related indicators such as water levels and sediments point toward remarkable potential changes due to hydropower development. Second, the examples illustrate that the actual impacts to systems as complex as floodplains or fisheries are much more difficult to estimate, since the impacts to these systems are felt through a combination of several impacts, both direct and indirect. In addition, due to the critical social and economic importance of the floodplains and the fisheries, the physical and ecological impacts need to be closely connected with broader social and political dimensions – a process that is still at a very early stage in the Mekong. Consequently, we hope that the findings presented in this chapter are useful also when studying and discussing the ongoing impact assessment processes and their results, including those within the MRC (2009b, c, 2010).

Most of the discussion on the potential impacts presented in this chapter focuses on the Tonle Sap Lake system that forms a particularly important economic, social, and environmental resource for the entire Mekong Basin and for Cambodia in particular (Fig. 6.2). Overall, the Tonle Sap Lake and the resources it supports form a central source of livelihoods and food for well over a million people living in the lake and its floodplains (Keskinen 2006; Keskinen et al. 2007). The significance of

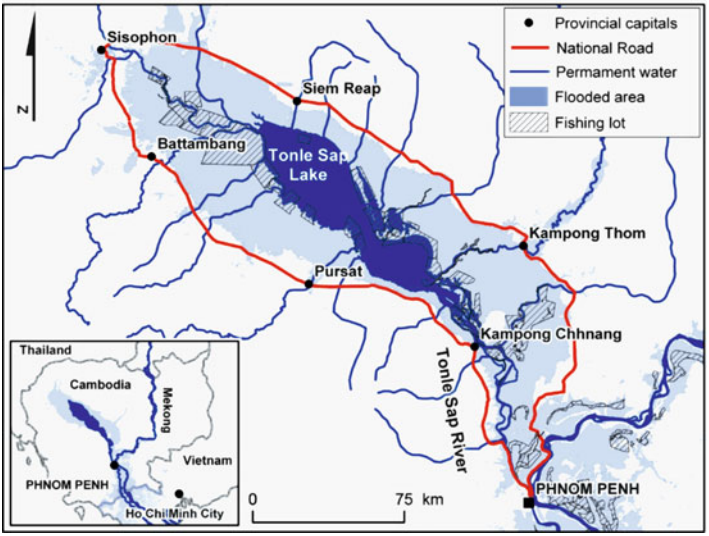

Fig. 6.2 The map of the Tonle Sap Lake area, showing the private fishing lot areas and the flooded area during exceptionally high-flood year of 2000

the Tonle Sap extends, however, much further, as it is estimated that up to half of Cambodia's population benefits from the lake's resources (Bonheur 2001).

The Tonle Sap is known for its extraordinary flood pulse system[6] with a remarkable but nevertheless rather regular seasonal variation in the lake's water volume and level (Lamberts 2006; MRCS/WUP-FIN 2007). The main driver of the flood pulse system is the Mekong River and its floods: during the wet season the water level in the Mekong mainstream rises faster than the water level in the lake. As a result, part of the floodwaters run to the Tonle Sap River, causing the river to reverse its flow back toward the Tonle Sap Lake. The lake thus loses its only outlet, and the floodwaters extend to large floodplain areas surrounding the lake. An exceptional and highly productive floodplain ecosystem has been formed based on this flood pulse system, and the Tonle Sap is considered to be among the world's most productive freshwater ecosystems and fishing grounds (Rainboth 1996; Lamberts 2001, 2006). This productivity is epitomized by the immense fish catches of the Tonle Sap Lake and the Tonle Sap River.

Taken together, the unusual flood pulse system and immense aquatic production of the Tonle Sap make it perhaps the single most vulnerable area to major changes in water quantity and quality of the Mekong River (see, e.g., Lamberts 2008; Kummu and Sarkkula 2008). The Tonle Sap is also exceptional for a lake of its size, as due to its exceptional flood pulse system, the impacts of any environmental change are felt as a combination of changes in its own basin and that of the Mekong River. The actual "impact basin" of the Tonle Sap Lake is thus not merely the lake basin (86,000 km^2), but the entire Mekong River Basin upstream from the Tonle Sap (680,000 km^2). This, naturally, makes the assessment of potential impacts to the area a particular challenge – and at the same time very much a regional issue as well.

6.5.1 Example of Impacts 1: Changing Water Levels

Different Cumulative Impact Assessment (CIA) studies have looked at the impacts of the planned hydropower development to water quantities of the Mekong (Adamson 2001; ADB 2004; DHI 2004; World Bank 2004) – and more such studies are currently being carried out (see, e.g., MRC 2009b, c, 2010). The estimates of these assessments are, however, relatively inconsistent due to the different assumptions used and the differences in the models and assessment tools themselves (Keskinen 2008; Kummu and Sarkkula 2008).

The three earlier CIAs discussed here (Adamson 2001; ADB 2004; World Bank 2004) indicate that planned development in the upper parts of the Mekong Basin

[6] Flood pulse is a term for an ecological paradigm integrating the processes of productivity in river-floodplain ecosystems, with a particular focus on the lateral exchange of water, nutrients, and organisms between a water body and the connected floodplain. For more information, see Junk et al. (1989).

will alter the water levels downstream and, consequently, in the floodplains. The dry season water levels are subject to rise and flood season water levels to decrease. Such changes would mean that the future flood amplitude will be smaller, leading to decreased extent of the floodplains and, consequently, to less potential spawning habitats to fish and other aquatic animals. Further, due to the smaller flood amplitude, less water will also enter to the floodplains from the mainstream.

The floodplain ecosystems need both the dry and the wet periods, and the increased low water levels would therefore permanently change the floodplain ecosystems. In the case of the Tonle Sap, the analysis of the dry season water level rise due to Mekong upstream development has in the different CIA studies been estimated as follows:

- 0.15 m increase: Estimate based on the MRC's basin-wide CIA under the Integrated Basin Flow Management (IBFM) process using the MRC's Decision Support Framework modeling tools (World Bank 2004)
- 0.30 m increase: Estimate based on the analyses of the downstream hydrological impact of the Chinese cascade of dams (DHI 2004; Adamson 2001)
- 0.60 m increase: Estimate based on the basin-wide CIA conducted within the Nam Theun 2 environmental impact assessment study using MIKE Basin model (ADB 2004)

The impact of the estimated water level rises for the dry season area of the Tonle Sap Lake is presented in Fig. 6.3.[7] The estimated rise of 0.60 m in dry season water level, as simulated by ADB (2004), would result in the permanently inundated area of 3,200 km^2. This would lead to the increase of the permanent lake area by nearly 1,000 km^2 (40%) when compared to from the current situation[8] (Kummu and Sarkkula 2008).

This kind of a rise in the lake's dry season water level, and the consequent extension of the permanent lake, would result in varied impacts to the Tonle Sap and its ecosystem. Some of these impacts would be largely positive, including improved navigation possibilities due to higher water levels. The most radical impact is, however, likely to be negative: increased water level would lead to permanent submersion of flooded gallery forest strips situated in the Tonle Sap floodplains, leading to their gradual destruction. These forest strips make an important physical barrier between the lake and the floodplain and create favorable conditions for sedimentation and aquatic production. The reduction of the flooded forest area could therefore have a significant impact on the whole Tonle Sap ecosystem and on floodplain dynamics, including the immense aquatic production of the lake-floodplain system.

[7] The 30-day minimum water level during the analysis period of 1997–2006 for May was 1.44 m above mean sea level (amsl), which was used as a reference level. The bottom of the lake lies at 0.6 m (amsl), and thus during the low water level, the average depth of the lake is only around 0.8 m with a lake area of around 2,300 km^2.

[8] Such a radical increase in the permanent lake area is explained by the fact that the Tonle Sap floodplain is extremely flat, and even small changes in the dry season water level thus permanently inundate large areas of the floodplain.

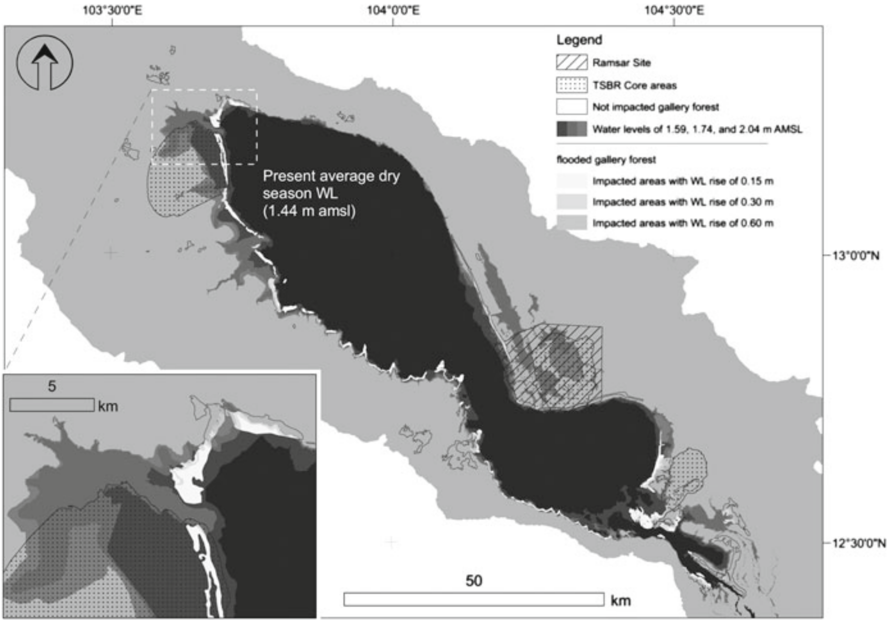

Fig. 6.3 Estimated changes in the inundated area of the Tonle Sap due to the increased dry season water level (Modified from Kummu and Sarkkula 2008)

The evolution of the biological functioning of the Tonle Sap floodplain to its present state has taken several thousands of years (Tsukawaki 1997), indicating that what is lost in the structure and productivity of the floodplain can have far-reaching and long-lasting consequences.

The CIAs also suggest that the peak water level during the rainy season would decrease, reducing the inundated area of the Tonle Sap Lake (Fig. 6.4). The total area of the Tonle Sap floodplain would therefore decrease by 7–16%, depending on the assessment used. In the case of CIA carried out by ADB (2004), the average floodplain area would decrease from present 10,750 to 9,060 km^2 by year 2025, resulting in around 15% decrease in both cumulative flooded area and flood volume. The hydropower development in the Mekong upstream would also cause changes in the flood duration in the Tonle Sap floodplain. The results from the WUP-FIN hydrological models, using input from the MRC Flow Regimes, indicate that the period of inundation would be decreasing in most parts of the floodplain by 1–2 weeks (MRCS/WUP-FIN 2007).

6.5.2 Example of Impacts 2: Changing Sediment Load

Sedimentation can be a curse or a blessing, depending on the viewpoint. For the natural environment, sedimentation is crucial, providing nutrients and other materials

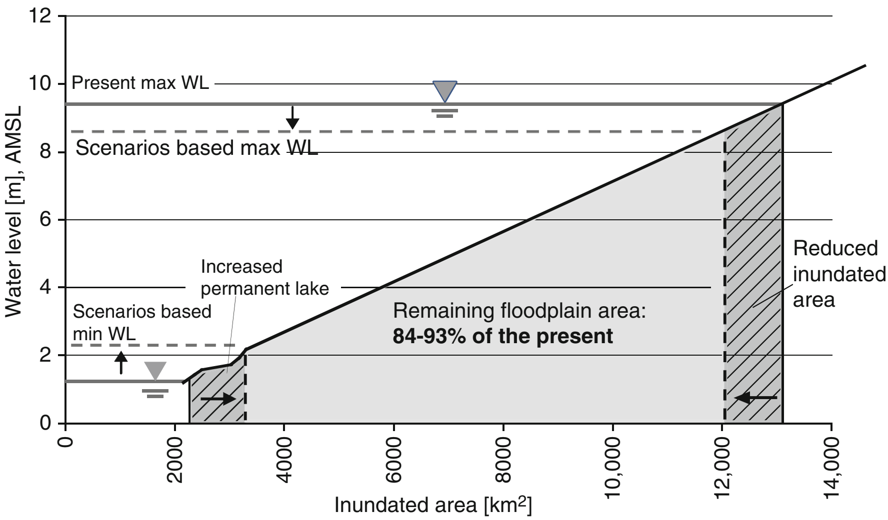

Fig. 6.4 Reduction in the area of the Tonle Sap floodplain due to the increased dry season water level (WL) and reduced wet season water level (Modified from Kummu and Sarkkula 2008)

that fuel biological productivity of the ecosystem and feed natural geomorphological processes. For humans, however, sedimentation can be problematic, causing, for example, problems for transportation and maintenance of aquatic infrastructure (Kummu et al. 2008).

The Mekong Basin yields approximately 475 km^3 of water each year from a catchment area of 816,000 km^2 (Kummu 2008), and transports annually around $140–150 \times 10^9$ kg of total suspended sediments to the South China Sea (Milliman and Syvitski 1992). Modeled estimates for the potential sedimentation trapping for the planned cascade of eight dams in the Chinese part of the Mekong mainstream provided a result of over 90% theoretical trapping efficiency (TE) of the suspended sediment[9] (Fig. 6.5) (Kummu and Varis 2007; Kummu et al. 2010). Already this is likely to have significant impact on the whole Mekong sediment budget, as more than half of the total sediment flux originates from China (Kummu and Varis 2007; Walling 2008). The basin-wide trapping efficiency is estimated to be over 60%, if the currently planned reservoirs will be constructed (Kummu et al. 2010).

The planned construction of large-scale hydropower dams and related reservoirs will thus affect the sedimentation and erosion processes in the downstream river channels and the connected floodplains, the delta, and the coastal areas. Overall, the geomorphological impacts of the dams include bed scour, armoring of the channel,

[9] Theoretical trapping efficiency (TE) stands for the ratio of sediment deposition in the reservoir and synchronous total sediment input to the reservoir.

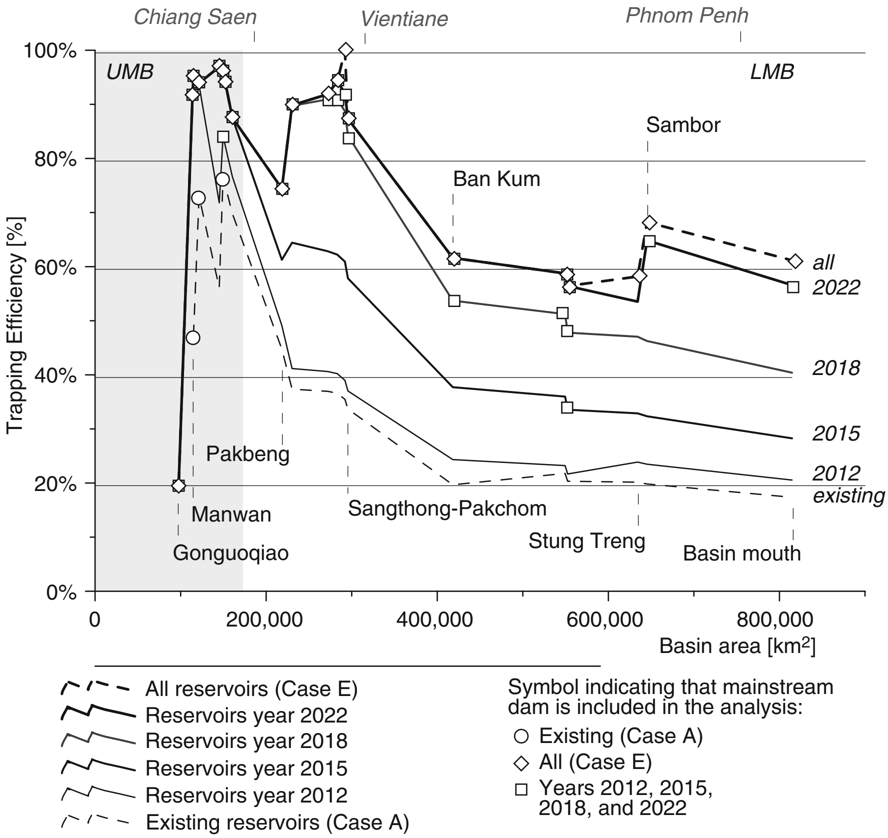

Fig. 6.5 The temporal development of the basin-wide trapping efficiency (TE) for each of the existing and planned mainstream dam locations and at the basin mouth (area = 816,000 km^2) (Modified from Kummu et al. 2010)

bar and island erosion, and channel degradation and narrowing. Impacts on floodplain ecosystems are more difficult to predict, but riffles and pools are likely to be eroded. In addition, the reduced suspended sediment concentration in the floodwaters is likely to have impact on both aquatic and agricultural production as the amount of nutrients flowing to the floodplains system gets reduced (Kummu and Varis 2007).

In the case of the Tonle Sap system, the nutrients bound to suspended sediments are considered important for the system to maintain its long-term sustainability and high productivity (Kummu et al. 2008). Consequently, changes in the sediment load of the Mekong River will have a direct impact on the sediment load from the Mekong River to Tonle Sap Lake, and therefore most probably also on the high aquatic production of the lake.

6.5.3 Example of Impacts 3: Changing Ecosystem Productivity

The Tonle Sap flood pulse is largely (52%) driven by the water that is pushed up into the lake by the reversed flow of the Tonle Sap River during the rise of Mekong River flood (Kummu and Sarkkula 2008). As discussed above, the Mekong floodwaters do not only bring water, but also nutrient-laden sediments which are mostly deposited into the floodplain. The floodwaters integrate the terrestrial vegetation into the aquatic phase of the ecosystem, and this interaction forms the driving force for the high ecosystem productivity of the lake. Very little is known, however, about the exact relation between ecosystem productivity and the flood pulse (MRCS/WUP-FIN 2007).

The scenario work carried out within the WUP-FIN project estimated the cumulative impacts of the changing floodplain conditions in the Tonle Sap. The focus of the assessment was on the changes caused by so-called Flow Regime 3[10] of the MRC that was the most intensive water resources development scenario at the time (MRC 2006a). The simulation results for the Tonle Sap can be summarized as follows:

- The inundated floodplain habitat would be reduced by around 15%.
- The period of inundation would be shortened by 1–2 weeks.
- The increased dry season water level would inundate permanently a major part of the flooded forest around the lake, thus extending the permanent lake area.
- Dissolved oxygen conditions would worsen by extending strongly anoxic period in the floodplain during early flooding due to slowly rising flood.
- Sediment and nutrient input to the lake with the floodwaters would be reduced.

While providing sound estimates on the potential changes in floodplain productivity is particularly challenging due to complex nature of the Tonle Sap system (Lamberts and Koponen 2008), initial estimates of the cumulative impact of the changes in above-mentioned factors were made as well. The cumulative impacts were estimated by introducing a cumulative indicator for floodplain productivity potential by giving an estimate for the minimum and maximum value for each individual factor. These estimates gave a value in the order of 25% reduction in the floodplain productivity potential, even with rather conservative estimates for individual indicator changes.[11] Although the linkages between the primary production,

[10] The Integrated Basin Flow Management process of the MRC assessed the impacts of three different Flow Regimes that were compositions of numerous characteristics of the hydrological system under concern. The Flow Regime 3 included most intensive development of the three regimes, including an approximate 4.5 times increase in hydropower electricity production and a 40% increase in irrigated area (MRC 2006a).

[11] This estimate is consistent with the assessment made by the expert panel within the Phase 2 of the MRC's Integrated Basin Flow Management (IBFM) process in 2006. The panel estimated that the Flow Regime 3 would result at least in an overall 20–30% reduction in the productivity potential of the Tonle Sap Lake and its floodplain (MRC 2006a).

fish production, and the fish catches are very complex, it can be assumed that any loss of primary production will directly result in the loss of secondary production and, consequently, in the reduction of the fish catches[12] (MRCS/WUP-FIN 2007). Due to the remarkable significance of the Tonle Sap's fisheries for Cambodia and even for the entire Mekong system, this kind of reduction would have severe consequences both economically and socially.

6.6 Multiple Crossroads: Water Development in a Transboundary Setting

The examples presented above point out some of the physical and environmental impacts that hydropower development in the Mekong Basin is likely to have, including potentially radical changes in water quantity and quality as well as in the ecosystem productivity. Yet, the examples represent only some of the potential impacts, and the actual overall impact to Mekong ecosystem will naturally be a combination of the different impacts. These combined impacts vary across different spatial and temporal scales (Kummu 2008), and also extend to broader issues than just hydrological and environmental impacts. In the case of Tonle Sap, for example, it remains difficult to provide reliable estimates on what would be the actual cumulative impacts of different basin development scenarios due to the complexity of the Tonle Sap system and weak understanding of the main drivers for the lake's high aquatic productivity.

The studies presented in this chapter provide thus an example of the major challenge related to current impact assessment practices in the Mekong: the problem of assessing comprehensively the cumulative impacts of basin development options. Cumulative assessment is particularly challenging in the case of complex systems such as the fisheries or floodplain dynamics, including the Tonle Sap system (Keskinen 2008; Kummu 2008). A meaningful impact assessment of crosscutting issues such as these would require a holistic approach that utilizes and integrates expertise from several disciplines and makes use of a number of different models and impact assessment frameworks. Yet, many of the existing impact assessment approaches have a relatively narrow focus, and they thus tend to "compartmentalize" the environment and social systems into selected indicators and sectors only[13] (Lamberts 2006; Keskinen 2008).

Consequently, despite enormous resources put into the different water management and impact assessment processes, they have not been that efficient in capturing comprehensively the combined impacts of different development plans at different

[12] For more discussion on primary productivity, please see MRCS/WUP-FIN (2007) and Lamberts and Koponen (2008).

[13] See also MRC (2009b) with its separate – although closely connected – assessments of hydrological, environmental, social, economic, and fish-related impacts.

parts and levels of the Mekong River Basin. As argued by Keskinen (2008), the reasons for this can be found from broader challenges with current basin-wide impact assessments, including:

- Reliability and representativeness of the information used in the assessments
- Challenge in addressing the different spatial and temporal scales
- Problems in assessing the crosscutting impacts
- Lack of true public engagement in the assessment processes

Despite these challenges, the results from the assessments are used to guide development planning in the basin. For example, the World Bank and the Asian Development Bank (ADB) stated in relation to their Mekong Water Resources Assistance Strategy that "the analytical work on [MRC] development scenarios has, for the first time, provided evidence that there remains considerable potential for development of the Mekong water resources" (World Bank and Asian Development Bank 2006). This statement has been criticized by different actors (Middleton 2007; IUCN and IWMI 2007b), and it is also much bolder than the more careful interpretation given by the modelers themselves (Käkönen and Hirsch 2009).[14] For this reason, the statement has also been used as an example of the use of the impact assessment results to justify certain kind of decisions and policies.

Indeed, the discussion about water development and its impacts is closely related to the differing valuations and understandings of the river and the resources it provides. Currently, the concept of "balanced development" (see, e.g., MRC 2006b; World Bank and Asian Development Bank 2006) seems for the key regional players such as the World Bank and the ADB as well as for the MRC and its member countries' governments to be closely connected to centralized, large-scale interventions such as hydropower dams. However, this kind of view tends to neglect the fact that the basin's waters have already for centuries been used and livelihoods developed through a diverse small-scale use of water-dependent resources, most importantly fish and wetlands. "Balanced development" can therefore become a euphemism that is used to hide vested interests promoting certain kinds of development paths and paradigms.

Consequently, to use the analogy applied in this chapter, the crossroads seem to be strong between centralized water development, on the one hand, and alternative approach with emphasis on more local-level development and better consideration of existing livelihood sources, on the other. Most current development plans focus on relatively large-scale, technocratic interventions that support irrigated agriculture, water diversions, and hydropower. Yet, a majority of the population in the basin relies on livelihoods that are smaller-scale and more dependent on natural resources. Worryingly, the planned large-scale developments are in many cases undermining

[14] It is also interesting to note that the World Bank and the ADB were selective on what they consider relevant from the MRC's findings: the strategy builds much more on the MRC's hydrological modeling exercises than on the MRC's fisheries studies that would not allow such a straightforward statement.

these more traditional livelihoods by impacting negatively the availability of and access to common pool resources such as fish (Phillips et al. 2006; MRCS/WUP-FIN 2007; Keskinen 2008).

The differing views and valuations also impact the ways different management and assessment methods are considered. The national and regional organizations focusing on large-scale utilization of the river resources tend to promote general, centralized frameworks and approaches for water management and impact assessment. For example, the World Bank and the ADB relied on the centralized Decision Support Framework (DSF) of the MRC in their Mekong Water Resources Assistance Strategy, while the MRC itself recently adopted an IWRM approach to support the implementation of the DSF (MRC 2006b, 2009a). While the IWRM as a theoretical concept puts together several well-intentioned ideas and objectives, it has also been criticized to easily lead to centralized, predefined management practices that lack proper understanding of local contexts and remain largely technical and even mechanical processes (see, e.g., Biswas 2005; Warner et al. 2008; Keskinen 2010).[15]

Such criticism relates to the general vagueness of the IWRM concept that has been seen to make IWRM prone to misinterpretations and even intentional misuse (Molle 2008). As noted by Svendsen et al. (2005), IWRM has also a strong normative content: it implicitly suggests that social, environmental, and economic aspects are compatible, when they in reality are often – including the current setting in the Mekong – in contrast with each other, making the entire IWRM procedure a highly political process. Overall, the challenges of current management and assessment practices have led to suggestions that impact assessment and management activities should build on different kinds of assessments at different levels, instead of prefixed and too narrowly defined management and assessment frameworks (see, e.g., Cash 2000; Cash and Moser 2000).

This thus brings us to the second emerging crossroads in the Mekong: that of different methods, approaches, and tools. While different "commonly accepted" standard approaches are promoted as means to achieve balanced development, their actual implementation remains only partially successful. One of their main challenges is that their use leads easily to the neglect of local contexts and needs, and that they fail to understand the fundamental differences between different spatial and temporal levels (see, e.g., Keskinen 2008, 2010; Warner et al. 2008; Käkönen and Hirsch 2009). Consequently, complementary approaches and frameworks for management are being discussed and suggested, many of them highlighting the need for more diverse approaches making simultaneous use of various methods.

The good news is that there already exists a variety of impact assessment processes in the Mekong Basin, implemented by governmental agencies, regional

[15] The MRC does acknowledge the challenges related to the IWRM approach, noting that "It is recognized that there is no blueprint for achieving IWRM and that various management instruments, enabling environments and institutional entities are involved. In this respect, the MRC does not expect IWRM to be achieved quickly, and certain aspects of IWRM are likely to remain at the national level and not be fully achieved at the basin scale" (MRC 2006b: 21–22).

organizations, as well as by the academia and the NGOs (see, e.g., MWBP and IUCN 2005; Lazarus et al. 2006; MRC 2006a; Swift 2006; MRCS/WUP-FIN 2007; ADB 2008; Bezuijen et al. 2008; TKK and SEA START RC 2009; Keskinen et al. 2010). These processes provide a remarkable knowledge base about the estimated impacts at different scales, and about the strengths and weaknesses of different assessment methods. The challenge is that they are currently neither properly coordinated nor properly embedded in the decision-making structures. Better coordination between the assessment processes and, in particular, increased interaction between the assessments at different scales would thus be potentially very beneficial for impact assessment in the basin. Particularly important would be to capture better the diverse experiences from the local-level assessments and take these as a basis for broader, regional assessments.

6.7 Conclusions: Way Forward

This chapter has discussed the estimated impacts of planned water development in the Mekong Basin, concluding that such impacts are likely to be significant, impacting both the environment and the societies along the Mekong in remarkable ways. At the same time, however, we highlighted the challenges of current assessment methods, underlined by the problems related to approaches relying on methods with too narrow focus. As a corollary, we argued for the existence and significance of two major crossroads: one related to different development paths and decisions, and the other one to the approaches and methods used to assess the potential impacts of such decisions.

6.7.1 Where to from the Crossroads? [16]

What would then be the possible ways forward from the two crossroads? First of all, we see that the distribution of estimated benefits, costs, and risks from the basin development should form an elementary starting point for any development plan. Practically all current impact assessments estimate that the planned water development in the Mekong Basin will result in remarkable, largely negative impacts to the water-related resources, most importantly fish. Consequently, there is a need for thorough discussion on whether the people in the Mekong countries are really willing to bear the consequences of losing an essential part of their ecosystem services and food security, and, overall, to accept such unequal distribution of the benefits and costs of planned water development.

[16] This section draws on Keskinen (2008) and Sarkkula et al. (2009).

Related to this, it needs to be recognized that most of the current assessment procedures tend to overly "scientize" and depoliticize the knowledge production,[17] and as a result, the moral and political dimensions of water resources development are at risk of being excluded from the discussions (Käkönen and Hirsch 2009). The assessments are never simply objective, technical processes, as already the definition of the issues to be looked at – and thus the relevant group of experts to analyze them – is a value-laden act. Similarly, the selection and use of assessment tools is shaped by certain assumptions, values, and power relations. No assessment tool should therefore be treated as a simple "truth machine."

Instead of hasty decisions about the way forward, few steps aside are therefore needed to properly discuss the conclusions of different impact assessment processes, and – based on this discussion – to assess the plausible development alternatives and their implications for the Mekong. As the planned development is likely to have remarkable impacts to the people in the basin, this pause should be coupled with radical strengthening of development dialogues with stakeholders in different riparian countries. The MRC's current assessments are, together with its increased emphasis on transparency and participation, promising steps forward, and should therefore be both supported and critically discussed.

Overall, we anticipate that the improved consideration of differing opinions and views on water development would bring to the fore the uneven share of benefits and risks between upstream and downstream as well as between social groups. This, in turn, is likely to draw more attention to the potential of alternative, smaller-scale development options as an alternative path complementing – and partly even replacing – the current path that tends to focus on larger-scale, centralized water development.

Following from this, the way forward for current impact assessment approaches seems much clearer: better utilization of and tolerance toward the diversity of different assessment methods and forms of knowledge. Indeed, we believe that water management and related impact assessment in the Mekong River Basin would benefit from a more multiscale approach that combines assessments from lower levels up to the regional level, and makes better use of interdisciplinarity and participatory approaches. Assessments of complex environmental and social issues should also have long-term perspective, building on adaptive, learning-orientated process.

Due to complexities and uncertainties involved in the assessment of development alternatives, there is also a need to use a set of different models and assessment approaches – instead of just a single model or approach – when assessing the

[17] By "scientization" we mean that science is given an instrumental and decisive role in legitimating policy (Bäckstrand 2004). The expectation that political consensus about development plans can simply follow from scientific consensus of the impacts and consequent trade-offs is, however, rather problematic. Scientization can hinder debate about the different development policies, and instead lead to narrower discussions about the scientific validity of the estimated impacts or to the issues of remediation and mitigation (cf. Szerszynski 1996; Wynne 2002; Demeritt 2006).

impacts to the water-related ecosystems and livelihoods.[18] While such a diversity of differing assessment methods causes increased divergence between the estimates, it also enhances the credibility and transparency of the results and decreases the possibility of completely unrealistic estimates. The variation in change estimates can also be beneficial in communicating the inherent uncertainties related to such estimates, facilitating discussion about the ways the impact assessment should actually be used.

6.7.2 The Other Side of the Coin: The Political Aspects of Water Management

These kinds of practical recommendations provide, however, only one side of water resources management. While acknowledging and appreciating such recommendations, it is crucial to recognize the highly political nature of water development, and consequently, of related planning and impact assessment processes. The underlying reasons – and solutions – for the present-day challenges with water resources development are therefore likely to lie beyond merely methodological issues, and can instead be found from broader political processes related to water management both within and between the riparian countries.

The political nature of water management has examples in the Mekong Region as well. The importance of Mekong fisheries, for instance, has been accepted widely by the riparian governments and regional organizations, but the results from the fisheries studies have been used only selectively when arguing for certain development policies (Friend et al. 2009; Käkönen and Hirsch 2009). It is also important to note that the political relations between the Mekong countries are largely building on growing economic cooperation and regional integration, with regional water management decisions being often subjugated to these broader processes.[19] This is vividly exemplified by the meager role that the Mekong River Commission (MRC) has had – despite its theoretically strong mandate – on shaping the development paths in the Mekong[20] (see, e.g., Keskinen 2006; Dore and Lazarus 2009).

---

[18] Global climate models present a good example of the benefits of this kind of multimodel use: The Intergovernmental Panel on Climate Change (IPCC) uses results from over 20 different climate models when producing their change estimates for global climate change, making use of the diversity of differing methods and increasing the credibility of their estimates.

[19] The growing regional cooperation does not, however, necessarily mean that the countries would be giving up their sovereignty on making water-related decisions. In fact, as argued by Fox and Sneddon (2007), the Mekong Agreement can even be seen to promote "environmental securitization" of the riparian states.

[20] It must also be remembered that the MRC members include only four Lower Mekong countries, with China – an increasingly influential regional hegemony – being outside the organization and its decision-making processes. See also discussion about hydro-hegemony by Zeitoun and Warner (2006).

Even if the certainty of the impact estimates increases, it is therefore by no means self-evident that the increased knowledge will have an effect on the actual decision making about water management and development. In order for alternative development options to gain ground, the politics behind seemingly science-based decisions need to be brought into debate as well (Käkönen and Hirsch 2009). Different water management and impact assessment methods are often used in overly consensual ways, resulting in situations where the politics are taken out from the decision making. The objectives of IWRM, for example, are rarely in harmony with each other, but are in fact often antagonistic (Molle 2008). As a result, IWRM can – despite its calls for a balance between economic, social, and environmental issues – be used to give legitimacy to approaches where the priority is given to economic growth, and harmful environmental and social impacts are presented as lamentable but inevitable losses that just need to be compensated.

Within this kind of frames, research findings on the severity of potential impacts do not create a consideration of alternative pathways. Instead, the entire crossroads – that of real choices, competition of ideas, popular participation, and, at the end of the day, democratic decisions – disappears and there appears to be just one possible way forward. The question is thus not anymore which development path to take, but just being how to proceed along the one that somehow already got selected.

Consequently, what is needed for real crossroads to emerge in the Mekong Region is the fostering of political dialogue at both national and regional levels. The domains of alternative visions and development values should gain more space and louder voice so that stronger articulations of differing pathways would emerge. These alternative development options should be assessed together with the options given by the current developmentalist agenda, and their benefits and costs discussed openly. Only this enables an emergence of real crossroads, where informed, deliberate decisions on different development pathways can be taken.

Acknowledgments This chapter summarizes the findings from the so-called Mekong IWRM research project that was implemented 2005–2007 by the Water & Development Research Group at the Helsinki University of Technology (now part of Aalto University). Many of the research findings have therefore been discussed also elsewhere, most importantly in the Mekong at the Crossroads special issue of Ambio (Vol. 37, No. 3). The Mekong IWRM project was funded by the Finnish Ministry for Foreign Affairs and the Academy of Finland, while the writing process for this chapter was supported by the Academy of Finland project 133748. The authors would like to thank all Mekong IWRM project counterparts and contributors for their encouragement and support. Our research has been closely linked with the Lower Mekong Modelling Project (WUP-FIN) that operated under the Mekong River Commission. Dr. Juha Sarkkula and Jorma Koponen deserve therefore special thanks for their collaboration as well as for their crucial contribution to the findings presented in this chapter. Thank you also to Joakim Öjendal, Stina Hansson, and Sofie Hellberg, as well as for an anonymous reviewer for the constructive comments.

References

Adamson PT (2001) Hydrological perspectives on the lower Mekong basin: the potential impacts of hydropower developments in Yunnan on the downstream flow regime. Int Water Power Dam Constr 53(3):16–21

ADB (2004) Cumulative impact analysis and Nam Theun 2 contributions – final report, NORPLAN and EcoLao, Asian Development Bank, Manila, Philippines

ADB (2008) Lao people's democratic republic: preparing the cumulative impact assessment for the Nam Ngum 3 hydropower project, Final CIA report – Main report, technical assistance consultant's report, Vattenfall power consultant AB in association with Ramboll Natura AB and Earth Systems Lao, Asian Development Bank (ADB), Manila

Bäckstrand K (2004) Civic science for sustainability. Glob Environ Polit 3(4):24–41

Bezuijen MR, Timmins R, Seng T (eds) (2008) Biological surveys of the Mekong river between Kratie and Stung Treng Towns, Northeast Cambodia, 2006–2007. WWF Greater Mekong – Cambodia Country Programme, Cambodia Fisheries Administration and Cambodia Forestry Administration, Phnom Penh

Biggs D (2004) Between rivers and tides: a hydraulic history of the Mekong delta, 1820–1975. PhD thesis, University of Washington, Seattle

Biswas AK (2005) Integrated water resources management: a reassessment – a water forum contribution. In: Biswas AK, Varis O, Tortajada C (eds) Integrated water resources management of south and south-east Asia. Oxford University Press, New Delhi, pp 319–336

Bonheur N (2001) Tonle Sap ecosystem and value. Technical Coordination Unit for Tonle Sap, Ministry of Environment, Phnom Penh

Cash DW (2000) Distributed assessment systems: An emerging paradigm of research, assessment and decision-making for environmental change, viewpoint. Glob Environ Chang 10(4):241–244

Cash DW, Moser SC (2000) Linking global and local scales: Designing dynamic assessment and management processes. Glob Environ Chang 10(2):109–120

Demeritt D (2006) Science studies, climate change and the prospects for constructivist critique. Econ Soc 35(3):453–479

DHI (2004) Study on natural reverse flow in the Tonle Sap river. Danish Hydraulic Institute (DHI) Water & Environment/Mekong River Commission Secretariat, Vientiane

Dore J, Lazarus K (2009) De-marginalizing the Mekong river commission. In: Molle F, Foran T, Käkönen M (eds) Contested waterscapes in the Mekong region – hydropower, livelihoods and governance. Earthscan, London, pp 357–381

Dugan P (2008) Mainstream dams as barriers to fish migration: international learning and implications for the Mekong. Mekong river commission. Catch Cult 14(3):9–15

Fox CA, Sneddon C (2007) Transboundary river basin agreements in the Mekong and Zambezi basins: Enhancing environmental security or securitizing the environment? Int Environ Agreements Polit Law Econ 7(3):237–261

Friend R, Arthur R, Keskinen M (2009) Songs of the doomed: the continuing neglect of capture fisheries in hydropower development in the Mekong. In: Molle F, Foran T, Käkönen M (eds) Contested waterscapes in the Mekong region – hydropower, livelihoods and governance. Earthscan, London, pp 307–331

Hirsch P, Jensen KM, Boer B, Carrard N, FitzGerald S, Lyster R (2006) National interests and transboundary water governance in the Mekong. Australian Mekong Resource Centre at The University of Sydney in collaboration with Danish International Development Assistance, Sydney

IUCN, TEI, IWMI, M-POWER (2007a) Exploring water futures together: Mekong region waters dialogue. Report from regional dialogue. The World Conservation Union (IUCN), Thailand Environment Institute (TEI), International Water Management Institute (IWMI) & M-POWER, Vientiane, Lao PDR

IUCN, TEI, IWMI, M-POWER (2007b) Feedback on WB/ADB joint working paper on future directions for water resources management in the Mekong river basin. Mekong Water Resources Assistance Strategy (MWRAS), the World Conservation Union (IUCN), Thailand Environment Institute (TEI), International Water Management Institute (IWMI) and M-POWER, Vientiane, Lao PDR

Jakeman A, Letcher R, Norton J (2006) Ten iterative steps in development and evaluation of environmental models. Environ Model Softw 21(5):602–614

Junk WJ, Bayley PB, Sparks RE (1989) The flood pulse concept in river-floodplain systems. In: Dodge DP (ed) Proceedings of the international large river symposium (LARS), vol 106. Canadian Special Publication of Fisheries and Aquatic Science, Ottawa, pp 110–127

Käkönen M (2008) Mekong delta at the crossroads: more control or adaptation? Ambio 37(3):205–212. Available online at: http://water.tkk.fi/global/publications

Käkönen M, Hirsch P (2009) The anti-politics of Mekong knowledge production. In: Molle F, Foran T, Käkönen M (eds) Contested waterscapes in the Mekong region – hydropower, livelihoods and governance. Earthscan, London, pp 333–365

Keskinen M (2006) The lake with floating villages: socioeconomic analysis of the Tonle Sap lake. Int J Water Resour Dev 22(3):463–480

Keskinen M (2008) Water resources development and impact assessment in the Mekong basin: which way to go? Ambio 37(3):193–198. Available online at: http://water.tkk.fi/global/publications

Keskinen M (2010) Bringing back the common sense? Integrated approaches in water management: lessons learnt from the Mekong. Dissertation for the degree of doctor of science in technology, Water and development publications, Aalto University, Helsinki, Finland

Keskinen M, Käkönen M, Tola P, Varis O (2007) The Tonle Sap lake, Cambodia; water-related conflicts with abundance of water. Econ Peace Secur J 2(2):49–59

Keskinen M, Chinvanno S, Kummu M, Nuorteva P, Snidvongs A, Varis O, Västilä K (2010) Climate change and water resources in the Lower Mekong River Basin: putting adaptation into the context. J Water Clim 1(2):103–117

King P, Bird J, Haas L (2007) The current status of environmental criteria for hydropower development in the Mekong region: a literature compilation. Consultants Report to Asian Development Bank, Mekong River Commission Secretariat and World Wide Fund for Nature, Vientiane

Kummu M (2008) Spatio-temporal scales of hydrological impact assessment in large river basins: case Mekong. Doctoral thesis, Water and development publications. Helsinki University of Technology, Espoo, Finland. Available online at: http://water.tkk.fi/global/publications

Kummu M, Sarkkula J (2008) The impact of Mekong river flow alteration on the Tonle Sap flood pulse and flooded forest. Ambio 37(3):185–192. Available online at: http://water.tkk.fi/global/publications

Kummu M, Varis O (2007) Sediment-related impacts due to upstream reservoir trapping in the lower Mekong river. Geomorphology 85:275–293

Kummu M, Penny D, Sarkkula J, Koponen J (2008) Sediment: curse or blessing for Tonle Sap lake? Ambio 37(3):158–163. Available online at: http://water.tkk.fi/global/publications

Kummu M, Lu XX, Wang JJ, Varis O (2010) Basin-wide sediment trapping efficiency of emerging reservoirs along the Mekong. Geomorphology 119(3–4):181–197

Lamberts D (2001) Tonle Sap fisheries: a case study on floodplain gillnet fisheries. Asia-Pacific Fishery Commission, Food and Agricultural Organisation (FAO), Bangkok

Lamberts D (2006) The Tonle Sap lake as a productive ecosystem. Int J Water Resour Dev 22(3):481–495

Lamberts D (2008) Little impact, much damage; the consequences of Mekong River flow alterations for the Tonle Sap ecosystem. In: Kummu M, Keskinen M, Varis O (eds) Modern myths of the Mekong – a critical review of water and development concepts, principles and policies. Water & Development Publications, Helsinki University of Technology, Espoo, Finland, pp 3–18. Available online at: http://www.water.tkk.fi/global/publications

Lamberts D, Koponen J (2008) Flood-pulse alterations and productivity of the Tonle Sap ecosystem: a model for impact assessment. Ambio 37(3):178–184

Lazarus K, Dubeau P, Bambaradeniya C, Friend R, Sylavong L (2006) An uncertain future: biodiversity and livelihoods along the Mekong river in northern Lao PDR. IUCN, Bangkok/Gland

Middleton C (2007) The ADB/WB/MRC 'Mekong water resources assistance strategy': justifying large water infrastructure with transboundary impacts. Paper prepared for critical transitions in the Mekong region, Regional Center for Sustainable Development, Chiang Mai, 29–31 Jan 2007

Miller F (2006) Environmental risk in water resources management in the Mekong delta: a multi-scale analysis. In: Tvedt T, Jakobsson E (eds) A history of water: water control and river biographies, vol 1. Tauris, London, pp 172–193

Milliman JD, Syvitski JPM (1992) Geomorphic/tectonic control of sediment discharge to the ocean: the importance of small mountainous rivers. J Geol 100:525–544

Mirumachi N, Nakayama M (2007) Improving methodologies for transboundary impact assessment in transboundary watercourses: navigation channel improvement project of the Lancang-Mekong river from China-Myanmar boundary marker 243 to Ban Houei Sai of Laos. Int J Water Resour Dev 23(3):411–425

Molle F (2008) Nirvana concepts, narratives and policy models: insight from the water sector. Water Altern 1(1):131–156

MRC (Mekong River Commission) (2005) Overview of the hydrology of the Mekong basin. Mekong River Commission, Vientiane

MRC (Mekong River Commission) (2006a) Flow regime assessment. Integrated basin flow management report no 8: flow-regime assessment. Water utilization program/environment program. Mekong River Commission, Vientiane, Lao PDR

MRC (Mekong River Commission) (2006b) Strategic plan 2006–2010: meeting the needs, keeping the balance. Mekong River Commission, Vientiane

MRC (Mekong River Commission) (2008a) Existing, under construction and planned/proposed hydropower projects in the lower Mekong basin, Sept 2008. Map produced by the Mekong River Commission. Available online at: http://www.mrcmekong.org/programmes/hydropower.htm. Accessed 07 July 2009

MRC (Mekong River Commission) (2008b) Fish migration emerges as key issue at regional hydropower conference. Mekong river commission. Catch Cult 14(3):4–8

MRC (Mekong River Commission) (2009a) IWRM-based basin development strategy for the lower Mekong basin. Incomplete consultation draft no 1 – Oct 2009. Mekong River Commission, Vientiane

MRC (Mekong River Commission) (2009b) Assessment methodology – economic, environmental and social impact assessment of basin-wide water resources development scenarios. Technical note, draft – Oct 2009. Basin Development Plan Programme, phase 2, Mekong River Commission, Vientiane

MRC (Mekong River Commission) (2009c) Inception report. MRC SEA for hydropower on the Mekong mainstream. Mekong River Commission (MRC) and International Center for Environmental Management (ICEM), Vientiane

MRC (Mekong River Commission) (2010) Synthesis of initial findings from assessments – assessment of basin-wide development scenarios. Technical note 1, draft – Feb 2010. Basin Development Plan Programme, phase 2, Mekong River Commission, Vientiane

MRCS/WUP-FIN (2007) Final report – part 2: research findings and recommendations. WUP-FIN phase 2 – hydrological, environmental and socio-economic modelling tools for the lower Mekong basin impact assessment. Mekong River Commission and Finnish Environment Institute Consultancy Consortium, Vientiane, Lao PDR. Available on-line at: http://www.eia.fi/wup-fin/wup-fin2/publications.htm

MWBP, IUCN (2005) Thai Baan research on the ecology and local history of the seasonally-flooded forest in the lower Songkhram river basin. The Mekong Wetlands Biodiversity

Conservation and Sustainable Use Programme (MWBP) and the World Conservation Union (IUCN)
Öjendal J (2000) Sharing the good: modes of managing water resources in the lower Mekong river basin. PhD dissertation, Department of Peace and Development Research, Göteborg University, Gothenburg, Sweden
Phillips D, Daoudy M, McCaffrey S, Öjendal J, Turton A (2006) Trans-boundary water cooperation as a tool for conflict prevention and for broader benefit-sharing. Phillips Robinson and Associates, Windhoek
Rainboth WJ (1996) Fishes of the Cambodian Mekong. FAO Species Identification Field Guide for Fishery Purposes/Food and Agriculture Organisation of the United Nations (FAO), Rome
Rayner S (2003) Democracy in the age of assessment: reflections on the roles of expertise and democracy in public-sector decision making. Sci Public Policy 30(3):163–170
Sarkkula J, Keskinen M, Koponen J, Kummu M, Nikula J, Varis O, Virtanen M (2007) Mathematical modelling in integrated management of water resources – magical tool, mathematical toy or something in between. In: Lebel L, Dore J, Daniel R, Koma YS (eds) Democratizing water governance in the Mekong region. Mekong Press, Chiang Mai, pp 127–156
Sarkkula J, Keskinen M, Koponen J, Kummu M, Richey J, Varis O (2009) Mekong hydropower and fisheries – what are the impacts? In: Molle F, Foran T, Käkönen M (eds) Contested waterscapes in the Mekong region – hydropower, livelihoods and governance. Earthscan, London, pp 227–249
Svendsen M, Wester P, Molle F (2005) Managing river basins: an institutional perspective. In: Svendsen M (ed) Irrigation and river basin management: options for governance and institutions. CABI Publishing, Wallingford, pp 1–18
Swift P (2006) Livelihoods in the Srepok river basin in Cambodia: a baseline survey. The NGO Forum on Cambodia, Phnom Penh
Szerszynski B (1996) On knowing what to do: environmentalism and the modern problematic. In: Szerszynski B, Lash S, Wynne B (eds) Risk, environment & modernity: towards a new ecology. Sage, London
TKK, SEA START RC (2009) Water and climate change in the lower Mekong basin: diagnosis and recommendations for adaptation. Water and Development Research Group, Helsinki University of Technology (TKK), Finland and Southeast Asia Regional Center (SEA START RC), Chulalongkorn University, Thailand. Water & Development Publications, Helsinki University of Technology, Espoo, Finland
Tsukawaki S (1997) Lithological features of cored sediments from the northern part of the Tonle Sap lake, Cambodia. The international conference on stratigraphy and tectonic evolution of southeast Asia and the South Pacific, Bangkok, Thailand, 19–24 Aug 1997, pp 232–239
Varis O, Kummu M, Keskinen M (2008) Mekong at the crossroads. Ambio 37(3):146–149. Available online at: http://water.tkk.fi/global/publications
Vörösmarty CJ, Sahagian D (2000) Anthropogenic disturbance of the terrestrial water cycle. Bioscience 50(9):753–765
Walling D (2008) The changing sediment load of the Mekong river. Ambio 37(3):150–157
Warner J, Wester P, Bolding A (2008) Going with the flow: river basins as the natural units for water management? Water Policy 10(Suppl 2):121–138
WEC (2007) 2007 Survey of energy resources. World Energy Council (WEC), London
World Bank (2004) Modelled observations on development scenarios in the lower Mekong basin. Mekong regional water resources assistance strategy (MWRAS), Prepared for the World Bank with MRC cooperation, Technical assessment by Geoff Podger and Richard Beecham and review, observations and conclusions by Don Blackmore, Chris Perry and Robyn Stein. World Bank, Vientiane, Lao PDR
World Bank, Asian Development Bank (2006) WB/ADB Joint working paper on future directions for water resources management in the Mekong river basin. Mekong water resources

assistance strategy (MWRAS), June 2006. The World Bank and Asian Development Bank, Washington, DC
Wyatt AB, Baird IG (2007) Transboundary impact assessment in the Sesan river basin: the case of the Yali falls Dam. Int J Water Resour Dev 23(3):427–442
Wynne B (2002) Risk and environment as legitimatory discourses of technology: reflexivity inside Out? Curr Sociol 50(3):459–477
Zeitoun M, Warner J (2006) Hydro-hegemony – a framework for analysis of trans-boundary water conflicts. Water Policy 8(5):435–460