INFLUENCE OF BUILT STRUCTURES ON TONLE SAP FISHERIES

SYNTHESIS REPORT

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- Ministry of Environment
- Ministry of Water Resources And Meteorology

INFLUENCE OF BUILT STRUCTURES ON TONLE SAP FISHERIES

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WorldFish Center is one of the 15 international research centers of the Consultative Group on International Agricultural Research (CGIAR) that has initiated the public awareness campaign, Future Harvest.

This document is a synthesis of eleven scientific studies produced under the project, *Technical Assistance to the Kingdom of Cambodia for the Study of the Influence of Built Structures on the Fisheries of the Tonle Sap* (TA 4669-CAM):

- H. Lauri. *Tonle Sap built structures database - structure statistics*
- J. Koponen, S. Tes, and J. Mykkänen. *Influence of built structures on Tonle Sap hydrology and related parameters*
- M. Kruskopf. *Impacts of built structures on tropical floodplains worldwide*
- S. Nguyen Khoa and P. Chet. *Review of Tonle Sap built structure Environmental Impact Assessments (EIA) with regard to fisheries*
- E. Baran, N. So, S. Leng, R. Arthur, and Y. Kura. *Relationships between bioecology and hydrology among Tonle Sap fish species*
- E. Baran E., N. So, R. Arthur, S.V. Leng, Y. Kura. *Bioecology of 296 fish species of the Tonle Sap Great Lake (Cambodia).*
- E. Baran, T. Jantunen, M. Hakalin, P. Chheng. *"BayFish-Tonle Sap", a model of the Tonle Sap fish resource*
- T. Jantunen. *Integration of databases to the BayFish – Tonle Sap fish production model*
- R. Arthur, E. Baran, N. So, S. Leng, S. Prum, S.H. Pum. *Influence of built structures on Tonle Sap fish resources*
- B.D. Ratner, D.B. Rahut, M. Käkönen, N. Hap, M. Keskinen, S. Yim Sambo, L. Suong, and R. Chuenpagdee. *Influence of built structures on local livelihoods: case studies of roads, irrigation, and fishing lots*
- D.B. Rahut, N. Hap, and B.D. Ratner. *Enabling alternative livelihoods for aquatic resource dependent communities of the Tonle Sap*

Readers interested in further details concerning the research methodology and findings, as well as references, are requested to consult these source documents. These detailed scientific reports are available at:

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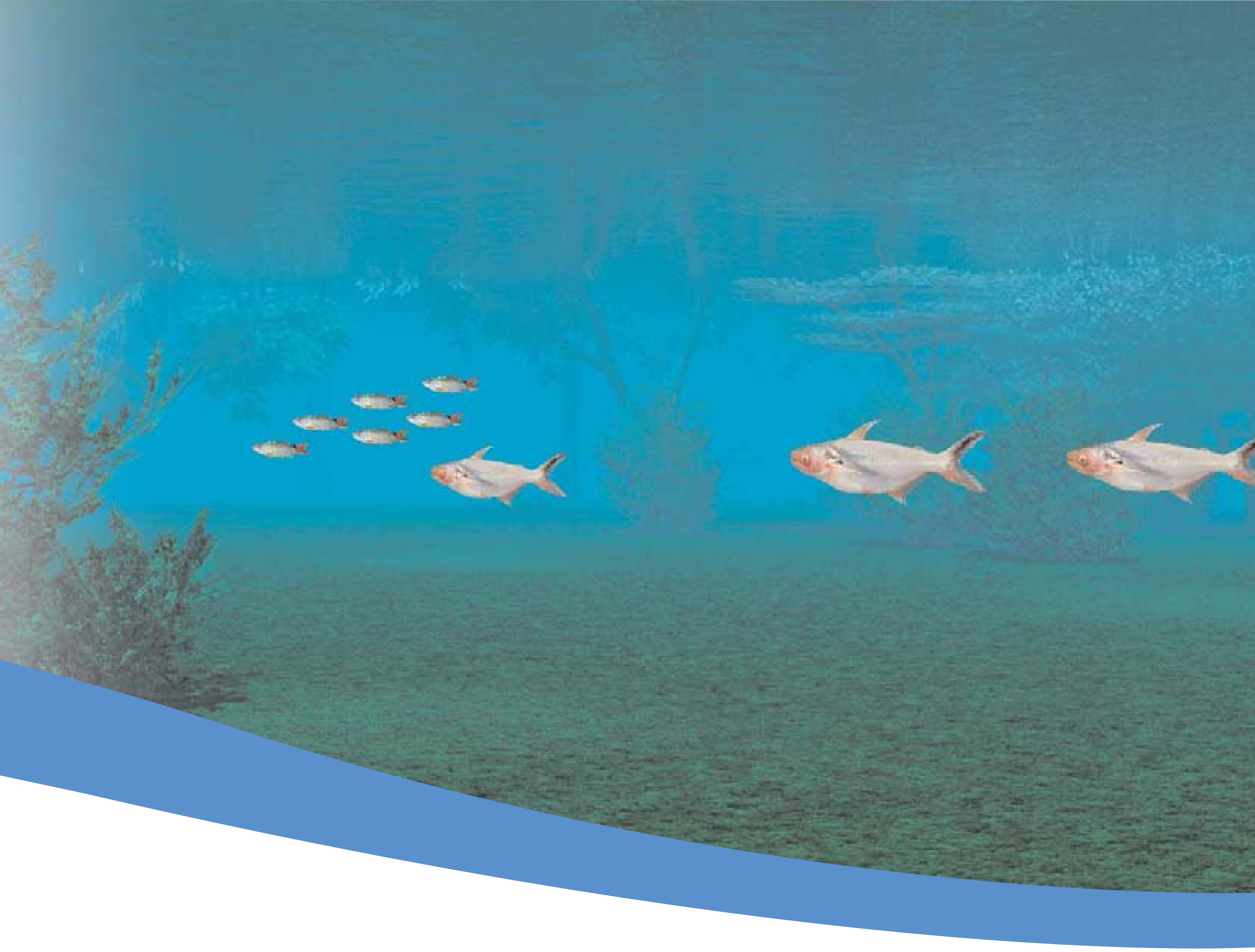
1 INTRODUCTION

1. INTRODUCTION

The inland fishery resources of Cambodia, originating mainly from the Tonle Sap Lake, rank first in the world for their productivity and fourth for their total catch. The floodplains' contribution to income, employment, and food security is higher than in any other country. However, the natural productivity of the Tonle Sap's floodplains will be threatened if the flood pulse, the temporarily submerged habitats, and the fish migration routes of the Tonle Sap Lake are not given attention. In relation to this, the influence of built structures, which modify the hydrology of the system, need to be better assessed in ecological and socioeconomic terms. A review of global research has shown these influences to be complex and very significant (see Table I).

What are built structures?

Built structures consist of a variety of man-made structures that contribute to changing the hydrology of a natural system. They can:
(i) oppose water outflow (e.g. dams, weirs, irrigation schemes, dykes);
(ii) prevent water inflow (e.g. embankments, polders, levees);
(iii) change water inflow or outflow (e.g. roads, canals, large-scale fishing gears);
(iv) degrade water quality (e.g. factories, mines, sewers).



This document is a synthesis of the major findings and recommendations of a study on the influence of built structures on the fisheries of the Tonle Sap Lake. This 13 month study, funded by the Government of Finland through the Asian Development Bank, was carried out between May 2006 and May 2007 by the Cambodian National Mekong Committee (CNMC) and the WorldFish Center. The multidisciplinary study analysed the influence and impact of built structures on hydrology, fish, and ultimately on people. The project established a database of major structures around the Tonle Sap Lake. Hydrologists modeled the influence of infrastructure on the flow and quality of water. Environmental scientists analyzed information about how infrastructure affects the environment. Experts in ecology and fish biology assessed the direct impacts on fisheries. Social scientists and economists evaluated the influence of infrastructure development on people's livelihoods, and studied local people's insights related to the planning, construction, and operation of built structures.

The study assessed the impact of infrastructure on Tonle Sap fisheries on three separate scales. The first covered the entire Mekong Basin including upstream areas which have an impact on the hydrology, ecology and fisheries of the Tonle Sap Lake. The second scale focused on the Tonle Sap tributaries. The third covered the Tonle Sap floodplains and includes the lake itself. The project also undertook three case studies. These included a new road development in Krakor district in Pursat province and the newly-rehabilitated Stung Chinit irrigation scheme in Baray and Santhouk districts in Kompong Thom province. The third case study looked at the impact of large-scale fishing fences in the area of Prek Toal, a floating village in Aek Phnum district of Battambang province.

Table I: Overview of types of built structures and of their consequences

Structure type	Hydrological and environmental changes	Socioeconomic changes	Positive consequences	Negative consequences	Specific impact on fisheries
Hydropower and irrigation dams	Reduction or drying up of floodplains	Changes in income distribution	Power generation	Reduced water storage capacity in wetlands	Reduced species richness and diversity
	Changes in discharge and water level (modified base and peak flows)	Increased regional demand and prices of fish	Increased agricultural production	Reduced flood-plain connectivity, hence loss of natural productivity	Reduction of fish stock
	Modified seasonal flows (in particular dry season flows)		Stabilization of downstream flows	Loss of habitats, foraging and breeding areas for fish	Falling catch rates
	Decreased flooding (frequency, extent, duration and magnitude of floods)		Increased water availability in the dry season	Inhibition of movement and migration of fish	
	Modified water turbidity			Changes in fish migrations and distribution	
	Increased water salinity in deltas				
Dykes, roads	Habitat partitioning	Improved access to markets, education and health	Control of water levels	Reduced water storage capacity in wetlands	Reduction of fish stock
	Changes in the level of the water table	Increased average wealth	Protection from extreme or flash floods	Reduction of floodplain connectivity	Increased catchability of fish
		Increased access to resources	Increased access to resources	Loss of habitats (incl. fish foraging and breeding areas)	
				Restriction of fish migrations	
				Changes in species richness and diversity	
				Changes in species distribution	
Irrigation schemes (aspects not covered by dams)	Increased pollution (pesticides and herbicides)	Changes in income distribution	Increased crop production security	Loss of natural aquatic productivity	Reduction of species richness and diversity
	Vegetation changes	Changes in access rights		Loss of habitats (incl. fish foraging and breeding areas)	
Canals	Changes in water availability	Changes in income distribution	Increased agricultural production	Introduction of alien species (if between watersheds)	
		Changes in access rights	Increased water availability in the dry season		
			Increased area accessible to fish		

Source: Report "*Impacts of built structures on tropical floodplains worldwide*"

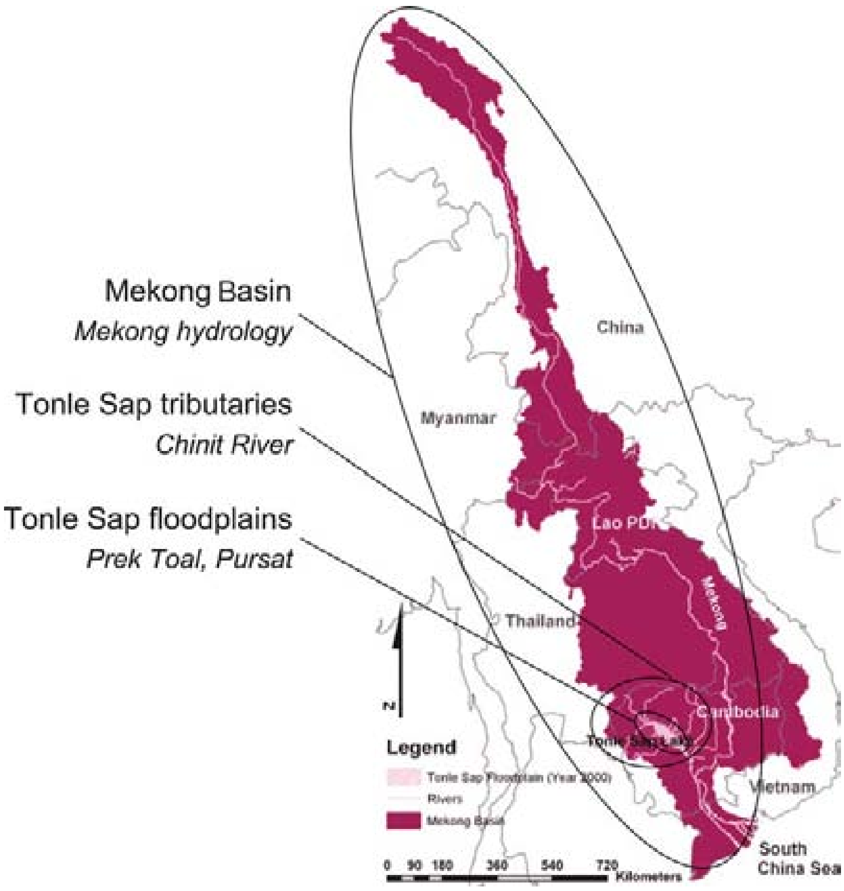


Figure 1: Geographic scales covered by this study

Hydrological Scenarios

To assess the potential hydrological impact of new water development infrastructure in the future, the study examined three scenarios based on different levels of future development on the Mekong River mainstream, and one scenario for the Tonle Sap watershed:

- **Baseline scenario**---represents the existing level of water storage based on the actual situation in 2000 when there was only one hydro-electric dam in the Upper Mekong Basin with a relatively small water-storage capacity of less than one cubic kilometer.
- **Intensive Basin Development scenario**---represents a combined water-storage capacity of 55 cubic kilometers, assuming that seven more hydro-electric dams are built across the mainstream by 2025 in the Upper Mekong Basin. This assumes that China and Lao PDR will each have a water-storage capacity of about 23 cubic kilometers, including almost five cubic kilometers for the Nam Ngum 1 reservoir alone. Thailand and Viet Nam would account for the remaining nine cubic kilometers.
- **Extreme Basin Development scenario**---adds to the second scenario seven more dams on the Mekong mainstream in Lao PDR, Cambodia and Thailand, boosting the total storage capacity to 140 cubic kilometers. The additional 85 cubic kilometers would come from mainstream dams in Lao PDR (Luang Prabang, Pa Mong, Sayabouri), Lao PDR/Thailand (Thakhek, Ban Koum) and Cambodia (Stung Treng and Sambor).
- **Limited Development scenario for the Tonle Sap watershed**---assumes a combined storage capacity of 5.5 cubic kilometers. This adds to the Baseline scenario the hydro-electric and irrigation dams on seven tributaries that flow into the lake, notably the Stung Sen.

2 BACKGROUND

2. BACKGROUND

2.1. THE TONLE SAP LAKE AND CAMBODIAN FISHERIES

Inland fisheries are vital to the Lower Mekong Basin with the combined catches of Cambodia, Lao PDR, Thailand and Viet Nam worth about two billion dollars a year. In terms of volume, annual production by the four countries exceeds 2.5 million tonnes, providing food and income for many of the Lower Basin's 60 million inhabitants, especially the rural poor. Almost 80 percent of the annual catch is from rivers and other natural water bodies. The rest mainly comes from reservoirs and aquaculture. In the Upper Mekong Basin in China and Myanmar, fish production is estimated to be relatively small.

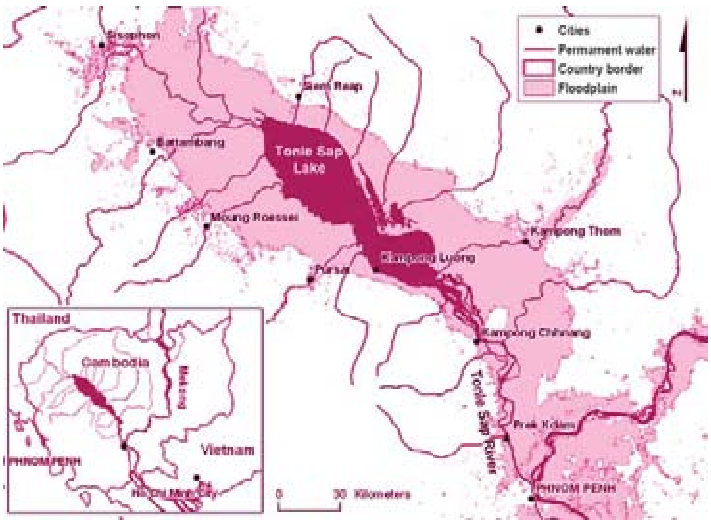


Figure 2: Tonle Sap Lake and its floodplains.
(Map by M. Kummu/WUP-FIN)

Cambodia alone has the world's most productive inland fishery. A single hectare of floodplain can produce up to 230 kilograms of fish a year. In terms of value, the overall fishing sector accounts for 10 to 12 percent of gross domestic product (GDP) and contributes more to income, jobs and food security than in any other country. By volume, Cambodia has the

world's fourth-richest inland fisheries after China, India, and Bangladesh, with the annual catch conservatively estimated at about 400,000 tonnes. Tonle Sap fisheries account for almost two-thirds of the total catch in Cambodia.

If the Tonle Sap Great Lake is the heart of Cambodia, the annual "flood pulse" is what keeps it alive. The flood pulse is a scientific concept referring to the cyclical changes between high and low water levels. It emerged as a new way of describing river ecology two decades ago, gaining broad acceptance worldwide. The Tonle Sap ecosystem has adapted to the exceptionally high natural variability of the lake. Thus, between the dry and the wet season the volume of the lake increases from about 1.3 km3 up to 75 km3, its surface area varies from 2,500 km2 up to about 15,000 km2, and its water level increases from 1.4 m to 10.3 m above sea level.

Fifty seven percent of the water in the Tonle Sap Lake comes from the Mekong River. During an average wet season, about 52 percent comes in directly through the Tonle Sap River, and 5 percent flows overland through the floodplain from the Mekong. Another 30 percent comes from rivers that flow directly into the lake and about 13 percent comes from rainfall over the lake itself. This means that upstream developments and structures potentially influence almost two thirds of the water flowing into the Tonle Sap Lake. Among upstream countries, Lao PDR contributes 19 percent of Tonle Sap water, while China and Thailand contribute 9 and 10 percent respectively.

The Tonle Sap Lake accounts for about 60 per-cent of Cambodia's inland fisheries production. In 2006, the Inland Fisheries Research and Development Institute of the Fisheries Administration estimated the value of fisheries and other aquatic resources of the Tonle Sap Lake conservatively at $233 million a year. The report based its figures on incomes for an estimated 209,000 house-holds dependent on aquatic resources in Kampong Chhnang, Siem Reap, Battambang, Pursat and Kampong Thom. About 150,000 households had annual incomes of $1,000 or less, averaging $470 a year or about $78 per person.

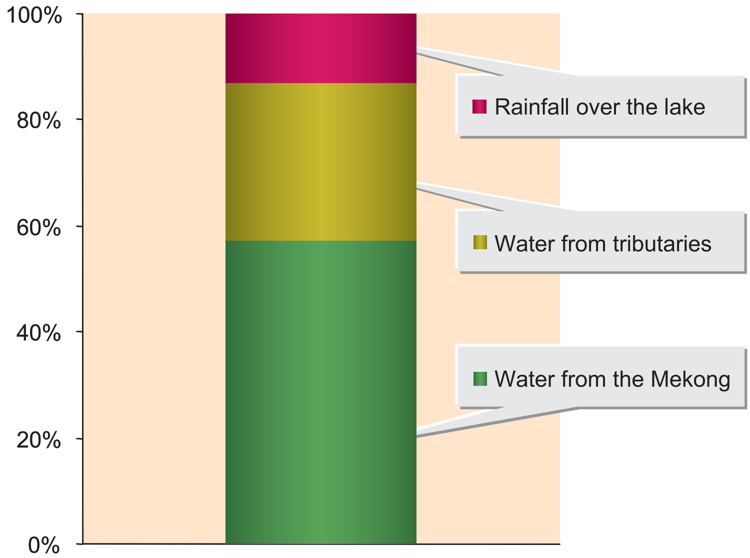


Figure 3: Origin of the Tonle Sap Lake's water

The productivity of Tonle Sap fisheries is affected by infrastructure development. Construction, earthworks and related activities all affect hydrology including seasonally-submerged habitats and fish-migration routes. Dams, irrigation schemes and dikes, for example, oppose outflows of water, whereas embankments, polders and levees prevent inflows. Roads, railways and canals can affect both inflows and outflows. Other developments like factories and sewers may degrade water quality.

With Cambodia's growing population, fishing pressure is also intensifying. Production is now more than three times higher than in 1940 when it was estimated at 120,000 tonnes. Since then, Cambodia's population has also tripled. In 2003, the Department of Fisheries warned that individual catch rates had plunged to less than 200 kilograms a head, down from almost 350 kilograms a head in 1940. With fewer big species caught, the average value of catches is also declining. Moreover, catches are increasingly dominated by smaller, short-lived and rapidly-reproducing fish species which tend to be worth less.

2.2. BUILT STRUCTURES IN THE TONLE SAP BASIN AND BEYOND

More than fourteen thousand built structures have been identified in the study sites of the Tonle Sap Basin. An overview of these main structures is given in Table II and Table III.

Table II: Number of structures identified in the Tonle Sap Basin

Structure	Number
WATER STORAGE (reservoirs)	55
WATER ROUTING (canals)	3992
FLOW CONTROL (dams, embankments, dikes, gates, weirs, pumping and other stations)	3294
FISHING (bagnets, barrages, fences)	473
AGRICULTURE (rice fields, crop fields, plantations, irrigated areas)	5267
TRANSPORT (bridges, docks, harbors, ferries)	1315
POLLUTION SOURCES (mines)	62
TOTAL	**14,458**

Source: Report "*Tonle Sap built structures database - built structures statistics*"

Built structures found in the Tonle Sap Basin vary in their type, design, and size, making it difficult to assess their influence on the hydrology of the lake. Counting all existing structures in the Tonle Sap Basin (i.e. over 44 percent of the whole country) is a titanic undertaking; during this project only 3 study areas could be covered in detail. Roads cannot be easily counted (their length, width or design might be more important than their number). Counting structures also relies on automatic mapping (e.g. to identify rice fields), with subsequent uncertainties. Categorizing them into simple, distinct groups is often tricky (e.g. difference between weirs, dykes and embankments). Fishing fences can be identified as long as they are not under vegetation cover or underwater (which is often the case with extensive nylon barriers). Canals are many but include a large majority of canals from the Khmer Rouge period that are not actually operational. Major pollution sources (mines, factories, etc.) can be counted, but not diffuse pollution sources due to agriculture or human settlements. Last, the influence of many structures depends on how they are designed and operated. For instance a sluice gate in an irrigation scheme counts as one structure, but its role depends whether it is open or closed, and when; similarly a floodplain road that counts as one structure will have a different influence depending upon the number and size of its culverts.

Table III: Basic statistics on built structures included in the study areas covered

		Land structures		Hydrological structures				Fishing structures
Province	Area (km2) flooded by medium floods	Length of roads (km)	Number of bridges	Length of embankments and dykes (km)	Area of reservoirs (km2)	Number of dams	Area (km2) of irrigation schemes	Length of fish fences (km)
Stung Treng	0	42	17	0	0	0	0	
Oddar Meancheay	31	800	106	7	9	2	32	
Preah Vihear	0	603	138	25	1	10	0	
Banteay Meanchey	1348	970	118	245	16	23	236	
Siem Reap	2825	1161	158	587	28	0	615	45
Battambang	3332	1144	187	300	13	0	1507	77
Kampong Thom	3626	1102	99	163	43	2	462	
Kratie	269	401	36	8	0	1	0	
Pailin	0	148	14	0	0	0	0	
Pursat	1612	996	242	81	0	0	334	
Kampong Chhnang	1964	543	87	255	0	0	64	
Kampong Cham	1642	478	53	265	2	0	193	
Kampong Speu	0	109	6	14	0	0	24	
Kandal	506	272	50	108	0	0	60	
TOTAL	**17156**	**8932**	**1311**	**2064**	**111**	**38**	**3526**	**124**

Source: Report "*Tonle Sap built structures database - built structures statistics*"

Hydropower development has recently become a priority in Cambodia and continues to be a high priority in the region. Table IV below details a number of sites (in Cambodia or on rivers flowing into Cambodia) that have been considered for hydropower development.

Table IV: Sites with existing hydropower capacity or proposed for development

River/Site	Multi-site
Sre Pok	3 sites in Cambodia: 787 MW. 7 sites in Viet Nam: 841 MW
Se San	2 sites in Cambodia: 582 MW / 3042 GW; 5 sites in Viet Nam: 1516 MW
Se Kong	2 sites in Lao PDR: 390 MW / 1269 GW
O Phlai	4 sites; 21 MW / 147 GW
Stung Pursat I	4 sites: 96 MW / 485 GW
Prek Liang	3 sites: 121 MW / 581 GW
Prek Por	3 sites: 34 MW / 204 GW
Prek Ter	3 sites: 50 MW / 269 GW
Stung Battambang	3 sites: 73 MW / 384 GW
Prek Chhlong	2 sites: 31 MW / 203 GW
Prek Kam	2 sites: 8 MW / 53 GW
Prek Kreing	2 sites: 14 MW / 85 GW
Prek Rwei	2 sites: 12 MW / 128 GW
Stung Mongkol Borey	2 sites: 14 MW / 97 GW
Mekong Sambor 2	3300 MW / 14870 GW
O Chum II	1 MW / 4.4 GW
Kamchay	180 MW / 550 GW
Prek Chbar	5 MW / 32 GW
Stung Atay	110 MW / 588 GW
Stung Cheay Areng	260 MW / 1350 GW
Stung Chikreng	2 MW / 8 GW
Stung Chinit	5 MW / 23 GW
Stung Sreng	7 MW / 69 GW
Stung Staung	4 MW / 23 GW
Stung Sva Slapp	4 MW / 20 GW
Stung Tanat	4 MW / 27 GW
Stung Tatay	80 MW / 250 GW
Stung Treng	980 MW / 4870 GW
Upper Prek Ter	15 MW / 77 GW
Upper Stung Siem Reap	1.7 MW / 7 GW

Capacity installation (MW) / Energy production (GW)
Source: Report "*Influence of built structures on Tonle Sap fish resources*"

The development of water resources in the Mekong River Basin is not just for hydropower but also for irrigation and flood mitigation, especially in the Lower Basin. For example, the Mekong River Commission's Basin Development Plan estimated in 2003 that Viet Nam had 580 irrigation projects within the watersheds of the Se San and Sre Pok rivers, two major Mekong tributaries flowing into Cambodia. The schemes irrigate more than 46,000 hectares of rice paddies and coffee plantations. The irrigation water demand there is forecast to reach 3.8 billion cubic meters a year by 2010, up more than a third from 2.8 billion cubic meters in 2001. That represents 63 percent of the dry-season runoff, which can only be withdrawn by adding extensive infrastructure. Further irrigation development and rehabilitation is therefore planned, with 658 works expected in the central highlands by 2010. In Cambodia many irrigation schemes were built under the Khmer Rouge regime and their rehabilitation is a priority under the Basin Development Plan.

2.3. POLICY CONTEXT

Infrastructure development is one of the four priority areas of the government's Rectangular Strategy, focusing on growth, employment, equity and efficiency. With gross domestic product expanding by more than 13 percent, Cambodia had one of the world's fastest-growing economies in 2005. The economy expanded by an estimated 10.4 percent in 2006 and is forecast to grow by around 9 percent in 2007. Under its National Strategic Development Plan for 2006 to 2010, the government is placing greater emphasis on enhancing physical infrastructure, especially in rural areas (Figure 4). Priorities include roads and irrigation facilities, with a major focus on attracting private-sector investment. Under the five-year plan, priorities include enacting a road law, rehabilitating 2,000 kilometers of primary and secondary roads and rehabilitating or rebuilding existing irrigation and drainage systems. Other priorities include expanding the storage capacity of surface water, promoting water-harvesting technologies, developing groundwater resources and flood-mitigation measures, and strengthening water-use groups. The strategic development plan emphasizes the importance of keeping water resources free of contaminants to support the ecological system, especially fisheries. Public investment allocations are estimated at $3.5 billion per year, with transport alone accounting for 15 percent of projected outlays. In its assessment of the five-year plan, the International Monetary Fund has said that infrastructure development, especially in rural areas, will be "critical" to broadening Cambodia's economic base for sustained growth.

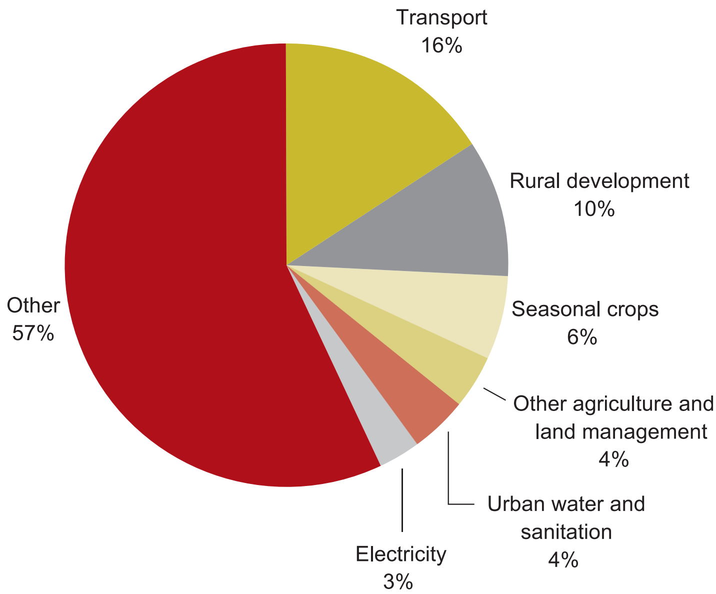


Figure 4: Public investment

Source: *Ministry of Planning, National Strategic Development Plan (2006-2010)*

Enhancing the agricultural sector, including sustainable access to fisheries for the poor, is another main priority of the Rectangular Strategy. Priorities for fisheries include community-based development and improving the livelihoods of poor people with better processing, handling, storage, transport and trade facilities. Other priorities include sustaining water bodies and promoting aquaculture. Under the plan for 2006 to 2010, support is being provided to Commune Councils to undertake rural infrastructure projects such as rehabilitating roads and building small bridges and culverts, wells, sanitation structures, schools, water gates and small irrigation systems.

Strategies to develop, manage and preserve the Mekong River's water and related resources are the responsibility of the Cambodian National Mekong Committee. The committee is comprised of 10 ministries (Land Management, Urban Planning and Construction; Planning; Foreign Affairs and International Cooperation; Environment; Water Resources and Meteorology; Agriculture, Forestry and Fisheries; Industry, Mines and Energy; Public Works and Transport; Tourism; and Rural Development). One of the committee's aims is to contribute to sustainable economic and infrastructure development. Parliamentary oversight for this area primarily rests with National Assembly Commission No. 3 (Economy, Planning, Investment, Agriculture, Rural Development, Environment and Water Resources) and National Assembly Commission No. 9 (Public Works, Transport, Post and Telecommunications, Industry, Mines and Energy, and Commerce).

In his foreword to the five-year plan, Samdech Prime Minister Hun Sen highlighted the importance of ensuring that all resources from both the government and external development partners are directed to priorities and sectors chosen by the government. "It is time now that resources begin to be properly directed and effectively used to maximize the benefits for the disadvantaged and deprived to lift them into the mainstream," he said. The prime minister also said that social and economic growth should be equitable with opportunities and benefits affordable and accessible to all, both geographically and between the rich and the poor.

The prime minister has also highlighted the Tonle Sap Lake's crucial role as an important fish habitat. "We must try our best to preserve and sustain the national fishery resources for our younger generations to come" he said at the National Fish Day ceremony in 2006.

Cambodia's policy priorities for growth and infrastructure development are clear, as are priorities for protection of the aquatic environment and sustainable rural livelihoods. Balancing these priorities involves conscious trade-offs that need to be more clearly understood and debated. The purpose of this study is to sharpen awareness among decision-makers and other stakeholders about the trade-offs associated with infrastructure development, in particular by better appreciating the influence on fisheries.

3 FINDINGS & RECOMMENDATIONS

3. FINDINGS AND RECOMMENDATIONS

Findings detailed below result from a synthesis and integration of studies at different scales and in various disciplines. The recommendations point to key principles and actions needed, based on the findings that are detailed just after each recommendation. These recommendations are meant to help decision-makers in maximizing the economic and social returns from investments in infrastructure while minimizing adverse impacts on the environmental sustainability of the Tonle Sap Lake and on the people who live around the lake.

3.1. NATIONAL-LEVEL DECISION MAKING

This section focuses on water development infrastructure in the Mekong River Basin that may affect water resources, fisheries and livelihoods around the Tonle Sap Lake. The recommendations of this section are for national decision-makers; these include policymakers in the 10 ministries that are members of the Cambodian National Mekong Committee as well as lawmakers in the National Assembly and Senate commissions that oversee infrastructure development. The recommendations are also targeted at domestic and foreign investors in the private sector as well as international donors.

3.1.1. INFLUENCE OF BUILT STRUCTURES IN THE MEKONG RIVER BASIN

☞ RECOMMENDATION 1

When planning infrastructure development, avoid irreversible changes to water flows, especially those affecting seasonal flooding or breaking the natural "connectivity" between various water bodies around the Tonle Sap.
(See also Recommendations 2, 6)

Modifying water flows and flood patterns are the biggest threats to the ecology of floodplains. Once lost, the costs of rehabilitating the ecological functions of floodplains are very high. Any structure affecting water within a floodplain or in rivers upstream is assumed to have some influence on the floodplain environment and should be treated with caution. Most declines in fisheries production in tropical floodplains are either directly or indirectly related to changes in water flows. Seasonal flooding and connectivity are essential for maintaining the ecology of floodplains. Experts generally agree with this conclusion, which is supported by numerous experiences in tropical floodplains in Asia, Africa and South America. These are reported in more than 300 journal articles, reports and books that were reviewed for the study.

Figure 5: Complex network of channels as illustrated by Boeung Tonle Chhmar (upper central part of the Tonle Sap Lake).
Blocking these channels would irreversibly change the hydrological, hydrodynamic and ecological functioning of the area.
Source: Report "*Influence of built structures of Tonle Sap hydrology and related parameters*"

☞ **RECOMMENDATION 2**

In assessing plans for dams and other water developments upstream on the Mekong mainstream, highlight the significant impacts on flooding in the Tonle Sap Lake.

The biggest impact of upstream development on the inflows of Mekong River water into the Tonle Sap Lake will be felt in dry years when the upstream reservoirs withhold the most water in relation to the Mekong's total flow. Hydrological modeling shows that inflows into the lake would decline by between 4.5 cubic kilometers under the Intensive Development scenario and by 11 cubic kilometers under the Extreme Development scenario . Under the Intensive scenario, that represents 4 percent in a wet year and 10 percent in a dry year. Under the Extreme scenario, inflows would fall by about 10 percent in a wet year and 25 percent in a dry year. The strength of these findings is supported by hydrological modeling by the Mekong River Commission since 2001.

Upstream developments will delay the onset of the annual flood in the Tonle Sap Lake and shorten its duration. Under the Intensive scenario in a dry year, the flood would be delayed by up to 12 days depending upon the location and altitude, and its duration would be a week shorter (see Figure 6 and Figure 7). Under the Extreme scenario, the flood would be delayed by one month and its duration would be two weeks shorter.

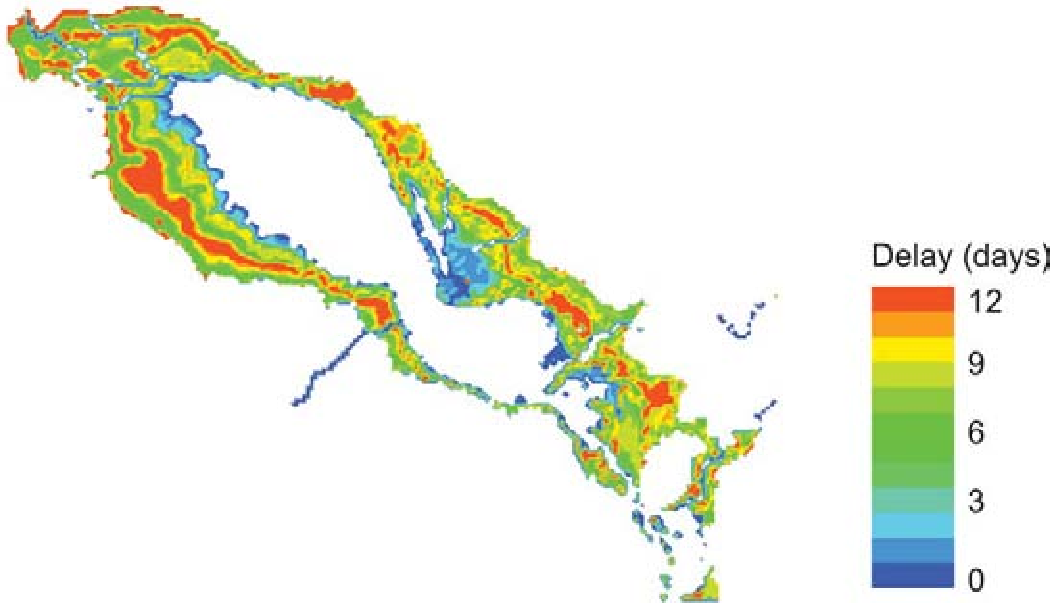


Figure 6: Upstream developments result in flood arriving later.
The simulation, based on 1998 actual hydrological data (very dry year), highlights the difference in flood arrival time between the Baseline and Intensive Development scenarios. The legend shows the number of days delayed.
Source: Report "*Influence of built structures of Tonle Sap hydrology and related parameters*"

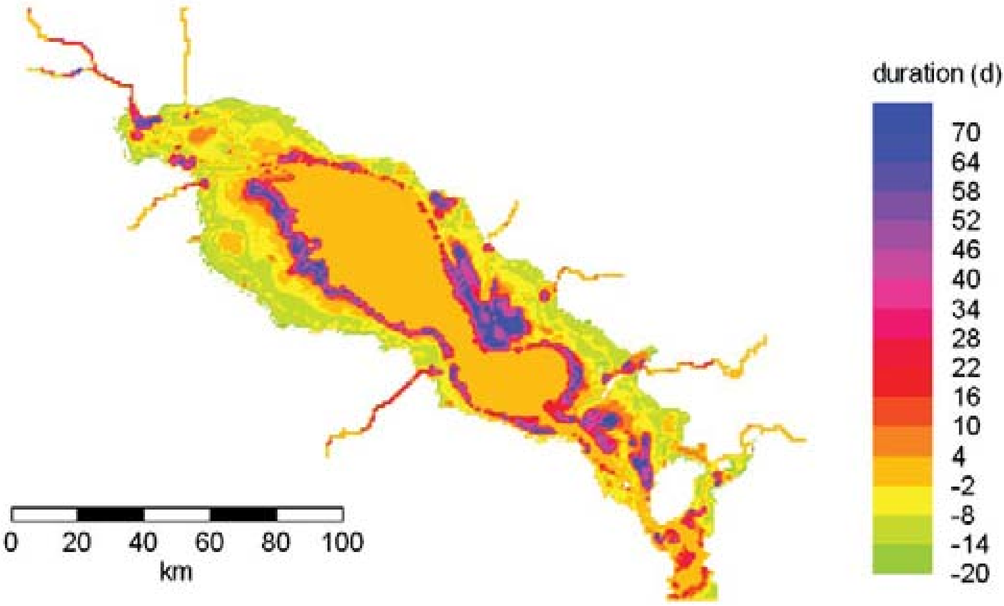


Figure 7: Upstream developments result in floods ending sooner.
The simulation, based on 1998 actual hydrological data (very dry year), highlights the change in the duration of the flood between the Baseline and Intensive Development scenarios. Longer period of inundation near the lake edge (highlighted in gradation from red to blue) is caused by increased water levels during the dry season.
Source:Report "*Influence of built structures of Tonle Sap hydrology and related parameters*"

Upstream developments will also decrease the height and surface area of the flood. Under the Intensive Development scenario in a dry year, the maximum height would be about half a meter lower and the surface area about 10 percent smaller. The main losses would occur in very high areas that are flooded for short periods.

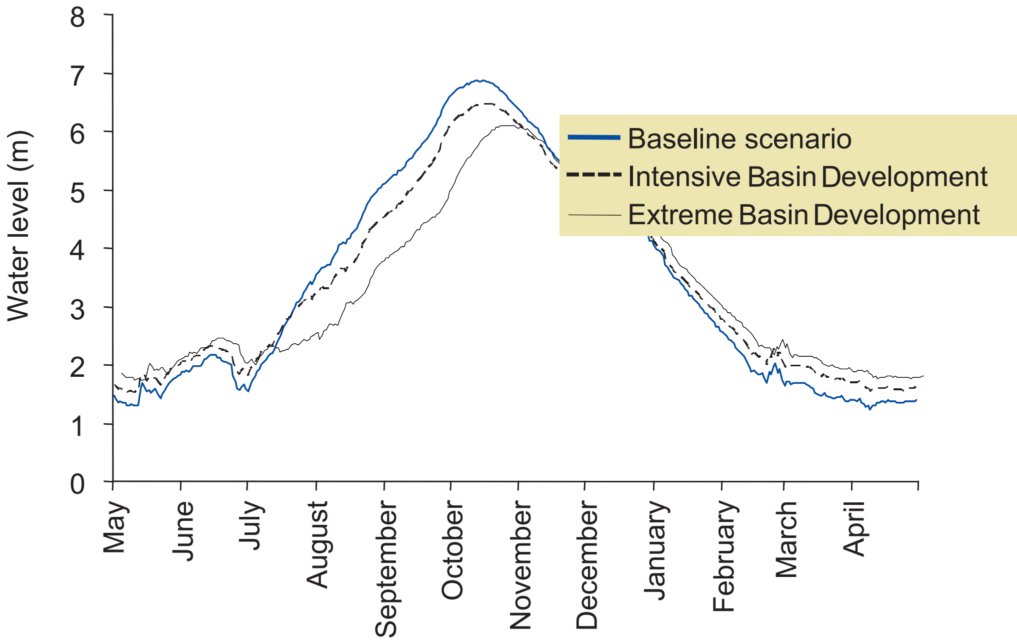


Figure 8: Tonle Sap water levels under Baseline, Intensive Development, and Extreme Development scenarios. Simulation based on 1998 data.
Source:Report "*Influence of built structures of Tonle Sap hydrology and related parameters*"

☞ **RECOMMENDATION 3**

In addition to considering the seasonal impact on water flows, planning of upstream water developments should specifically take into account possible ecological consequences of the changes in flooding, including loss of flooded forests, reduced inflows of sediments, lower oxygen levels, and changes in the drift of fish larvae and juvenile fish.

Dams upstream will sharply reduce the input of sediments into the Tonle Sap Lake, adversely affecting the recycling of nutrients and possibly threatening dry-season habitats, especially in areas with high fish productivity. The Upper Mekong Basin is the source of more than 50 percent of the suspended sediments in downstream areas of the Lower Basin. The planned cascade of eight dams in the Extreme Development scenario has the potential to trap nearly all of these sediments (see Figure 9). Loss of sediments in flood water would result in a loss of natural soil fertility (hence a loss of rice production or higher production costs due to increased use of fertilizers). It could also lead to increased erosion along the Mekong's banks and possibly to a lower survival rate for fish eggs, their buoyancy being reduced. These findings about sedimentology must be treated with caution, however, as the sediment processes of the Mekong are not very well known. For example, the origin of very fine sediments of most importance to the Tonle Sap Lake has not been studied.

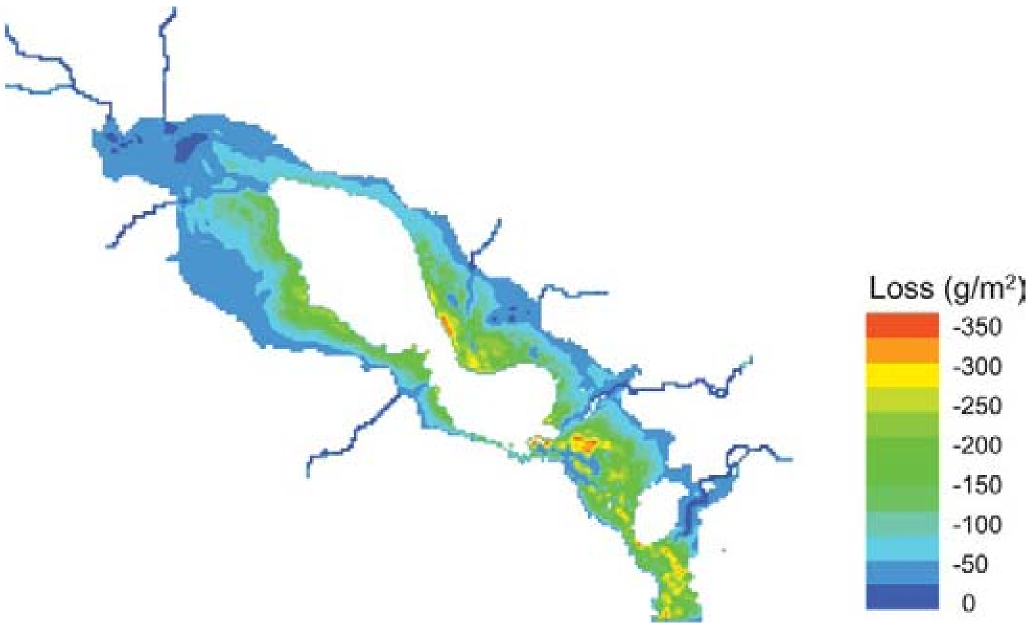


Figure 9: Upstream developments result in decreased sediment input in the lake.
Simulation based on 1997 data. Reduced sedimentation is caused by trapping by dams upstream. The most impacted areas shown in dark overlap with areas with high fisheries productivity.
Source: Report "*Influence of built structures of Tonle Sap hydrology and related parameters*"

Delays in the onset of the flood will result in delays in the arrival of oxygen-rich waters. Dissolved oxygen levels in Tonle Sap water generally decline during dry season, until the inflow of oxygen-rich water at the beginning of flood season. While fish may swim to more oxygenated waters, eggs and larvae unable to move may be adversely affected if the arrival of the flood is delayed. Flow changes may also have an impact on the drift of fish larvae and juveniles, which usually end up on the northern and eastern shores of the lake. Under the Intensive Development scenario, eggs and floating particles tend to drift more towards the western shore, indicating possible negative impacts on highly-productive fishing lots in the northern part of the lake. This finding is, however, based only on computer simulations and needs to be verified by observations in the field.

Upstream developments will expand the edge of the lake during the dry season, destroying some flooded-forest areas if they are permanently submerged. Under the Intensive Development scenario, hydrological modeling shows that the surface area of the lake will expand by between 300 and 900 square kilometers *in the dry season* in an average year (Figure 10). That is equivalent to between a 15 and 45 percent increase in the lake's dry-season size. Permanent flooding of some areas is likely to kill the flooded forests that are located along the lake edge and cannot tolerate permanently flooded conditions, as they requires temporary emersion to complete their lifecycle. This forest acts as a buffer protecting the floodplain against storms and rough water conditions on the lake; this oxygen and nutrient rich habitat is also important to fish as a breeding, feeding and shelter area. The scope of the study did not include assessing the possible impacts of an expanded dry-season lake on the flooded-forest plant species or invasive species such as the water hyacinth (*Eichornia crassipes*) or mimosa (*Mimosa pigra*).

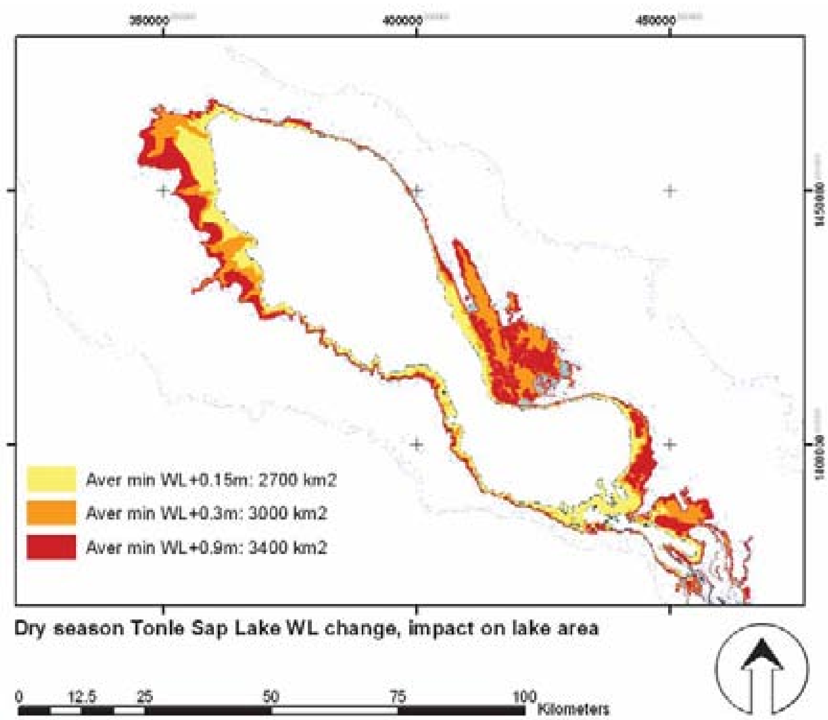


Figure 10: Upstream developments result in higher water levels in the dry season.
Light areas correspond to 15 cm water level rise, medium colour areas to 30 cm and dark colour areas to 0.9 m rise.
Source: Report "*Influence of built structures of Tonle Sap hydrology and related parameters*"

☞ **RECOMMENDATION 4**

The livelihood benefits of floodplains should be properly evaluated and integrated into basin-wide water development planning, with particular focus on the impact of dams on fisheries.

In terms of ecological and social benefits, floodplains are among the most valuable landscapes in the world. A global review of tropical floodplains completed during the study found that fish and other natural resources are the primary benefits, followed by the replenishment of nutrients and fertile soils for farmlands and pastures. However, much is still unknown about the ecological functions of floodplains and how to value them properly. This is a reason why the impact of man-made structures on tropical floodplains is not well documented with the exception of large dams. Most of the available information is qualitative rather than quantitative. Valuations should be conducted in such a way that the results can be integrated into more conventional economic cost-benefit analyses of proposed investments in water development projects, and allow more thorough economic analyses of the predicted returns for different investment options.

Dams are the main type of structure having an impact on fisheries production, through their negative impact on fish migrations. In the Mekong Basin, 87 percent of fish species for which information is available are migratory species. Sixteen percent of these species are known to be sensitive to hydrological migration triggers that will be modified by dam construction. Since the bulk of the catch actually consists of a small number of species groups that are predominantly sensitive to hydrological migration triggers, a very large proportion of the total catch is likely to be affected by river modifications (96 percent of the catch at Khone Falls, Southern Laos). The most important impact of flow modification due to upstream built structures would be experienced during the dry season and at the beginning of the rainy season.

The study found no examples of positive long-term impacts of dams on fisheries, nor any effective mitigation measures in the Mekong Basin. Reservoirs are sometimes presented as a way to create new fisheries upstream, but this usually does not compensate for the loss of downstream fisheries. Similarly, fish passes are often proposed to help fish migrate. However, there are no examples of fish passes that work in the Mekong Basin. This is mainly due to ecological factors and the intensity of migrations which fish passes cannot accommodate. Out of the hundreds of species in the Mekong Basin, only nine are known to breed in reservoirs. The effectiveness of the new fish pass at Stung Chinit completed in 2006 has not yet been assessed.

Even a small percentage lost in fisheries will amount to tens of thousands of tonnes and millions of dollars when considering the total production of 2.6 million tonnes each year. The loss would also affect millions of people with fisheries-associated livelihoods. For instance, the fish groups that are extremely sensitive to hydrological triggers include shark catfishes (Pangasiidae), which are commercially important to both capture fisheries and aquaculture. Among the 10 fish groups that dominate the Tonle Sap catch, four are sensitive to such triggers. They account for 18 percent of the volume of the Tonle Sap catch and 14 percent of its value. On the other hand, several environmental impact assessments (EIAs) conclude that negative impacts on fisheries would be minor because of biases or flaws in their approach such as a limited scope, or because of a focus on percentages lost rather than on tonnage and livelihood values lost. In general, most dam projects in the Mekong Basin lack undisputable EIAs and detailed baseline studies that would allow the full range of cost-benefit analyses.

☞ **RECOMMENDATION 5**

Adopt regional guidelines such as the Strategic Environmental Framework for the Greater Mekong Sub-region (GMS), which promote strategic environmental assessments addressing the cumulative impacts of multiple development projects.

Large infrastructure projects increasingly require cumulative-impact and strategic-environmental assessments. Most structures are not isolated from the surrounding environment. The cumulative impact of many structures can be assessed, although this is complicated as it is more than simply adding up the individual impacts of each structure. In general, impact assessments rarely quantify benefits that might be lost. Existing guidelines and recommendations on how to implement EIAs typically do not include instructions on how to consider specific environmental characteristics of floodplains, how to assess the impacts of projects on floodplain ecosystems, or how to include economic valuation of the lost benefits of floodplains.

3.1.2. INFLUENCE OF BUILT STRUCTURES IN THE TONLE SAP WATERSHED

☞ **RECOMMENDATION 6**

Give special attention to infrastructure developments within the Tonle Sap Basin, because these have direct impacts on fisheries, and because they can magnify the influence of upstream changes in water flows.

The influence of hydropower and irrigation projects within the Tonle Sap Lake's catchment basin would significantly add to the impact of developments upstream in the Mekong Basin. Even smaller dams within the Tonle Sap catchment would have an impact similar to upstream dams in reducing inflows of water in the wet season and increasing dry-season flows. Figure 11 shows the influence on water level of Tonle Sap developments in the case of the Tonle Sap scenario that adds hydro-electric and irrigation dams across seven tributaries that flow into the lake. Impacts of Tonle Sap projects are felt earlier than those of upstream projects. The combined impact of Tonle Sap projects and Mekong upstream projects is significantly higher than the impacts assessed separately.

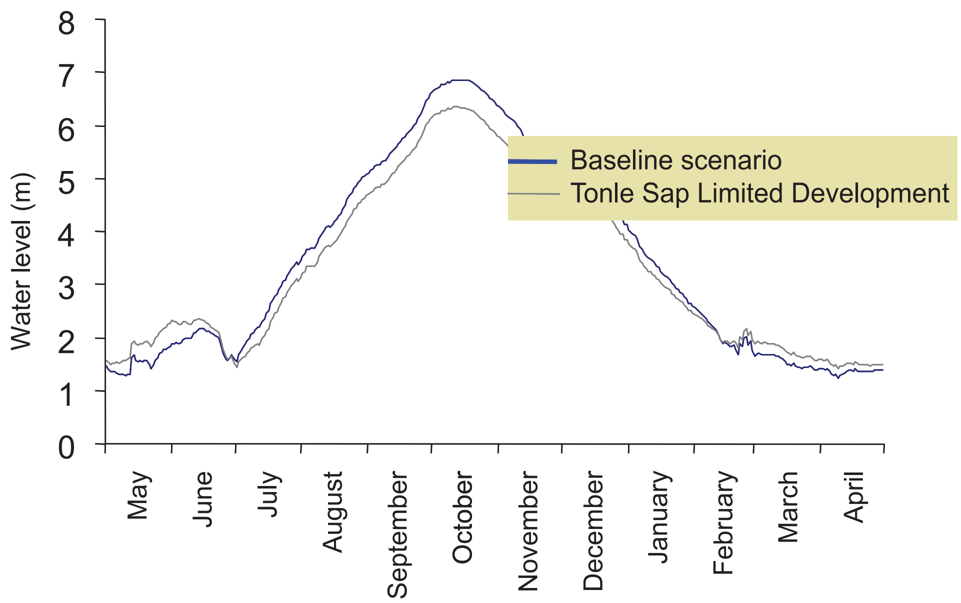


Figure 11: Impact of the potential Tonle Sap dam developments on the lake water levels.
Source: Report "*Influence of built structures of Tonle Sap hydrology and related parameters*"

Table V: Water storage potential of existing and planned hydropower and irrigation reservoirs in the sub-basins of the Tonle Sap watershed.

Sub-basin	net storage capacity million m3
Sen	2900
Staung	550
Chikreng	160
Mongkol Borey	115
Sreng	610
Chinit	390
Pursat	860
TOTAL	**5585**

Source: Report "*Influence of built structures of Tonle Sap hydrology and related parameters*"

☞ RECOMMENDATION 7

Improve the Environmental Impact Assessment process, particularly the coverage of fisheries, coupled with capacity-building for EIA practitioners.

Environmental Impact Assessments (EIAs) should be improved for Tonle Sap infrastructure projects that may have a significant impact on water and aquatic resources. Access to Environmental Impact Assessments for Tonle Sap development projects is difficult, reports being scattered across various ministries and provincial and district government offices or with project developers. Very few are available at the Ministry of Environment or other relevant ministries. Assessments are not systematically recorded or classified. The study evaluated in detail only 10 reports, mostly involving projects funded by external donors. Reports for other projects were unavailable because they were either inaccessible or did not exist.

Tonle Sap EIAs tend to be narrowly focused, covering a fraction of the area, the resources, the time period, and the people possibly impacted. These EIAs are often geographically limited to the project area, which provides at best a partial estimate of the impact on fisheries. They tend to be narrowly focused on short-term biological and physical changes to water flows and fish (Table VI); few assessments mention other aquatic resources like crabs, shrimps and snails - important sources of food for many people, especially the poor. They neglect longer-term impacts on the ecological system and livelihoods. Moreover, they do not systematically address socioeconomic consequences of impacts on fisheries and there are wide variations in coverage. Last, participation of stakeholders is generally very limited due to lack of a systematic mechanism for the consultation of local communities, provincial authorities, and local or international NGOs in the EIA process.

Table VI: Fish-related aspects of Tonle Sap Environmental Impact Assessments.

Fisheries aspect and scale of assessment	Coverage	Note
• Physical habitat (e.g. water bodies, vegetation)	High	Covered in most EIA reports
• Fish ecology (e.g. migration)	High	Covered in most EIA reports
• Biodiversity	Medium	Focus on fish species diversity
• Ecological integrity	Very Low	Only a few components of the ecosystem considered
• Fisheries production	Medium	Focus on fishing effort
• Livelihood of fishers and fishing communities	Low	Focus on a few livelihood assets and functions
• Institutional arrangements	Low	Not much considered
• Management of fisheries	Low	Not much considered
• Consideration of other key relevant sectors	Low	Most EIAs are sectoral
• Spatial scales	Very Low	Focus on project boundaries
• Temporal scales	Very Low	Focus on short-term impacts

Source: Report "*Review of Tonle sap built structures Environmental Impact Assessments (EIA) with regard to fisheries*"

The quality of the Environmental Impact Assessments (EIAs) of Tonle Sap projects that might have a significant impact on water resources and fish is insufficient. The EIA process refers to the overall mechanism in place to request, submit, accept and monitor project EIAs. Increased awareness of the importance of EIA practice should be supported. There is need for improving the capacity of EIA practitioners in: i) defining the scope with a holistic approach; ii) increasing the use of available knowledge through systematic consultations of local stakeholders and of scientists; iii) making use of methods that deal with scarce data and uncertainty; iv) using methods for valuation of trade-offs between the various costs (esp. social and environmental) and benefits of built structure projects, and by v) improving stakeholder participation and the transparency of the process.

☞ RECOMMENDATION 8

Impact assessments and regional negotiations over water allocation should take into account the unique importance of the Tonle Sap Lake for fisheries productivity and fish diversity not only in Cambodia but throughout the Mekong system.

One of the major findings of the study is that the Tonle Sap Lake has almost 300 species, making it the third-richest lake in the world in terms of fish diversity. A review of scientific literature identified 296 species, more than twice the number recorded before. That makes the lake the richest in the world only after Lake Malawi (433 species) and Lake Tanganyika (309 species), both in Africa (Figure 12). The dominant families in the Tonle Sap Lake are carps and minnows (*Cyprinidae*) with 108 species, sheatfishes (*Siluridae*) with 20 species, bagrid catfishes (*Bagridae*) and loaches (*Cobitidae*) with 17 species and shark catfishes (*Pangasiidae*) with 14 species (Figure 13).

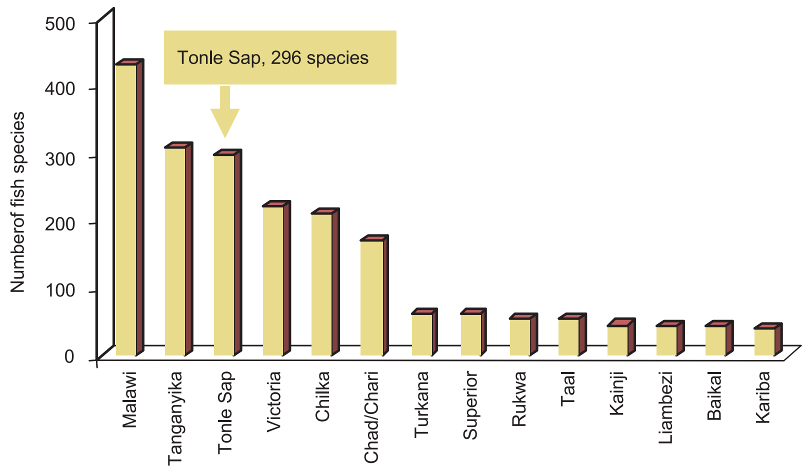


Figure 12: Fish diversity in major lakes of the world.
Source: Report "*Relationships between bioecology and hydrology among Tonle Sap fish species*"

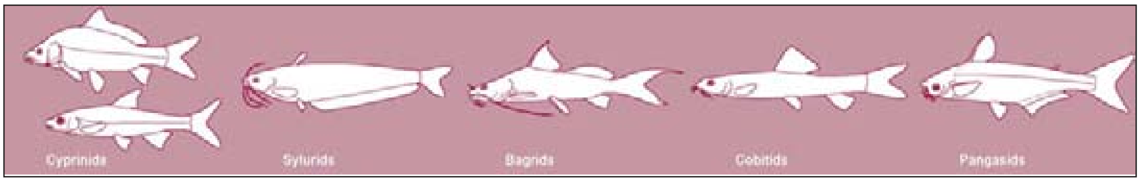


Figure 13: Dominant fishes of the Tonle Sap Lake.
Source: Report "*Relationships between bioecology and hydrology among Tonle Sap fish species*"

The Tonle Sap Lake's importance in sustaining the health of Mekong fisheries is reaffirmed by the fact that it is home to a large proportion of fish species found in the Mekong River system. Although it accounts for only 11 percent of the Mekong Basin in terms of surface area, the Tonle Sap watershed has almost a third of all species recorded in the river and almost half of all the families. This qualifies the lake as an exceptional hotspot for biological diversity and calls for special attention by national and international institutions.

☞ **RECOMMENDATION 9**

When assessing the impact of infrastructure development on Tonle Sap fisheries, focus on species that are economically important and that depend on hydrological triggers for migration. In particular, prioritize trey sleuk russey (**Paralaubuca typus*****), trey chhkok and trey sraka kdam (two species from the *****Cyclocheilichthys*** ***genus) and trey pra (species from the*** **Pangasius** ***genus) as indicator species.***

Overall, the Tonle Sap Lake has 23 species whose annual migrations are triggered by changes in water levels, and another 3 species triggered by changes in water flows. These fishes, accounting for about 10 percent of the species documented for the Tonle Sap Lake, are particularly sensitive to the hydrological consequences of infrastructure development such as delays in the arrival of floodwaters, increased water levels in the dry season and changes in the speed of the current. The impact of changing water levels on the remaining 90 percent of Tonle Sap species is still unknown.

Changes in water levels affect the annual migrations of these indicator species which account for 13 percent of the Tonle Sap Lake's catch, or between 38,000 tonnes and 56,000 tonnes a year. It is not clear how sensitive the two species of trey riel (*Henicorhynchus* genus) are to changes in water levels as their migrations may also be triggered by the phases of the moon. But if they are included, the proportion of the catch whose migration is triggered by changing water levels jumps to 38 percent, amounting to between 110,000 tonnes and 164,000 tonnes a year.

For trey sleuk russey (*Paralaubuca typus*), reproductive migrations and their dependence on environmental triggers are clearly documented. As for trey pra (*Pangasius* species), seven are very sensitive to hydrological migration triggers and three are less sensitive. These catfishes are highly valuable to both capture fisheries and aquaculture. Of the seven *Cyclocheilichthys* species, trey chhkok (*Cyclocheilichthys enoplos*), the most abundant by far, is very sensitive to hydrological triggers.

☞ **RECOMMENDATION 10**

In designing fisheries management strategies and conducting impact assessments, consider three ecological groups of fishes rather than the traditional two. This highlights the importance of species which rely on tributaries as dry season refuges.

Fish species are currently classified under two ecological groups known as "white" and "black" fishes, but another category is needed. White fishes migrate between floodplains where they feed and the Mekong mainstream where they breed. Black fishes spend their whole lifecycle in floodplains and can resist harsh environmental conditions. However, this classification into two ecological ''guilds'' is too crude to reflect major responses to changes in water flow or quality. For example, several species spend the dry season in tributaries such as Stung Pursat and Stung Chinit where they may be sensitive to infrastructure development. Management plans should therefore consider "grey" fishes as a third group with intermediate patterns of behavior. The recommendation to consider "grey" fishes as a third group is based on interviews with 102 experienced Tonle Sap fishermen and is supported by studies in the western and central African floodplains as well as Bangladesh.

3.2. SUB-NATIONAL LEVEL DECISION MAKING

This section focuses on infrastructure issues that are of relevance to decision-makers at local levels (province, district, and commune). Local decision-makers include provincial administrators and policymakers in the provincial departments of the 10 ministries that are members of the Cambodian National Mekong Committee. The recommendations also aim to inform district administrators, Commune Councils, community fishery committees, domestic and foreign investors in the private sector, international donors and non-governmental organizations.

3.2.1. LOCAL INFLUENCE OF LAND STRUCTURES

The following findings are from the case study on floodplain roads in Pursat province.

> ☞ **RECOMMENDATION 11**
>
> ***Explicitly take water flows and fish-migration routes into account when planning and building roads on floodplains, using culverts and bridges to avoid blocking complex networks of channels. Also ensure that planning addresses how these structures will be managed and maintained.***

The velocity of water flows on the floodplain is generally very slow compared to the lake so the impact of roads depends on where they are placed. Locals at the Pursat study site expect that roads themselves will not have a significant impact on the abundance of fish or composition of species, compared to other pressures from rising fish demand and destructive fishing practices. They also consider culverts and gates effective as mitigation measures for allowing water flow. The views expressed in interviews with locals were unanimous but contradict the ecological literature highlighting the negative impacts of habitat fragmentation by roads on local fisheries. A possible explanation for this contradiction is that the culverts act as bottlenecks and make fish easier to catch, camouflaging any reduction in the overall fish stocks. (*See Recommendation 13 below for maintenance and management recommendations*)

Road-management committees have an important role to play in fisheries protection by instituting rules that prohibit culverts from being blocked by fishing gears. This is a commendable practice at the Pursat study site that should be encouraged elsewhere in the country. But these rules are not always followed and more intensive fishing gears are being deployed. The committees need to pay more attention to fisheries issues and coordinate their work with other stakeholders.

> ☞ **RECOMMENDATION 12**
>
> ***Coordinate road development among ministries and also with local institutions, particularly Commune Councils, to ensure proper planning and maintenance.***

Management structures and institutions are key to minimizing any negative impacts of roads and ensuring their long-term maintenance. At the planning stage, effective coordination is essential to identify the potential impacts of a new road on the environment, notably fish habitats and migration routes, and to ensure that remote communities have access. At the maintenance stage, inter-ministrial coordination is critical. The Ministry of Rural Development is responsible for maintaining roads, while the Ministry of Water Resources and Meteorology is responsible for culverts and the Fisheries Administration of the Ministry of Agriculture, Forestry and Fisheries is responsible for regulating fisheries.

In both planning and maintaining roads, Commune Councils have a natural coordinating role to play with local bodies, such as community-fishery and road-maintenance committees, and traditional and religious institutions, such as Buddhist and Islamic institutions, which can mobilize collective action. Assuring their participation in the planning and design of the road development can make maintaining and managing the structure more efficient in those cases where local bodies are responsible for these tasks.

☞ **RECOMMENDATION 13**

Ensure that road planning takes into account the poorest groups by clarifying who will benefit and how. Provide alternative livelihood support services targeting poorer families to help them accumulate household assets, such as education, cattle and savings.

Villagers interviewed most frequently cited the main benefits of new roads as access to public services and markets. They noted that market access was especially significant for selling fish, which is difficult or expensive to preserve for long periods. Villagers believed better access to markets allowed them to get better prices for their fish. Roads also increased access to villages by fish wholesalers. With more fish being traded, villagers reported that there was now less fish being kept for local consumption. Better market access has also increased the incentives to produce goods to sell at markets and boosted local trade in fruit, cattle, poultry, and medical supplies.

Following the construction of a new road in Pursat, the contribution of fishing to average household incomes declined in all villages surveyed. Fishing is still the main source of income in some villages but has been eclipsed by rice farming in some cases. This finding is based on quantitative analysis and is consistent with lessons from road projects elsewhere. In Bangladesh, for instance, road projects in rural areas have sharply reduced poverty by boosting farm output and wages and reducing the cost of inputs and transport.

Average incomes rose much more sharply in richer households after the road construction. Quantitative analysis showed that changes in household incomes are strongly correlated with assets such as education, cattle and savings. In other words, richer households are likely to be more capable of taking advantage of the potential benefits of a road.

Social and cultural factors also influence who benefits more from built structures. In Pursat, the study found that an ethnic Cham village seemed to benefit more from the new road than ethnic Khmer villages. The Cham village had more connections to networks with other villages and also had institutions that were better organized, notably a locally-managed Islamic system for redistributing incomes.

Clarifying the benefits of a road project facilitates informed public debate about whether an investment is worthwhile and how it might be modified to benefit the poorest households. Modifications may entail building small feeder roads or using labor-intensive construction methods to develop local skills among the poorest groups. Skills acquired could later be used for maintaining the road.

To increase the household assets of the poorest groups, the study identified the top priorities as credit, agriculture, forestry and fisheries extension services and other skills training. Specific priorities could be based on local participatory assessments with services provided by government extension activities, micro-finance institutions and non-governmental agencies. Credit could focus on productive investments related to extension activities.

3.2.2. LOCAL INFLUENCE OF HYDROLOGICAL STRUCTURES

The following findings are from the case study on the Stung Chinit irrigation scheme and small-scale private reservoirs in Kampong Thom province.

> ☞ **RECOMMENDATION 14**
>
> ***Assess the ecological impacts of dams and reservoirs at the planning stage. Determine the pros and cons in the long run so that informed decisions can be made and mitigation measures taken.***

Small-scale reservoirs on the floodplain so far have had a relatively limited influence on the flow and quality of water around the Tonle Sap Lake. Private irrigation structures are being extensively developed on the floodplain. As an illustration of this trend, Figure 14 shows recent developments in Kompong Thom province over an area of about 30 square kilometers. The overall storage capacity of the floodplain is quite limited as the depth of water trapped is only about one and a half meters. Existing reservoirs in the Tonle Sap floodplain have a surface area of less than 100 square kilometers with a storage capacity of about one-tenth of a cubic kilometer. Even if another 400 square kilometers of reservoirs were built, it would increase storage capacity to barely half a cubic kilometer of water. That compares to annual inflows into the Tonle Sap Lake ranging from 44 to 107 cubic kilometers in recent years. Although irrigation in the upper reaches of the floodplain traps a significant part of the flood, its overall impact on the floodplain's seasonal inundation is limited. Field measurements showed that the irrigation structures also had a limited impact on water quality.

Figure 14: Recent private irrigation schemes in Kampong Thom
Source: Report "*Influence of built structures of Tonle Sap hydrology and related parameters*"

Although the impact of existing reservoirs on Tonle Sap tributaries is relatively small individually, the cumulative impact of many new ones may significantly affect water flows into the lake. The study modeled the newly-rehabilitated irrigation scheme at Stung Chinit and also included field sampling. The reservoir takes less than a week to fill in June when water flows are not particularly high. Field measurements showed that its impact on water flows was insignificant (see Figure 15). Simulations indicated the concentration of suspended sediments in the reservoir at slightly less than 20 milligrams a liter, down from 25 milligrams in naturally-flowing waters upstream. Measurements didn't show any clear impact from trapping sediments (see Figure 16). The measurements did not show any clear impact on nutrients in the reservoir either. The spillway efficiently aerated the water flowing out of the reservoir, boosting oxygen levels. Simulations showed that the concentration of oxygen in the reservoir is not as high as the natural stream but nevertheless still high, even at the bottom. (*See also Recommendation 6, Figure 11*)

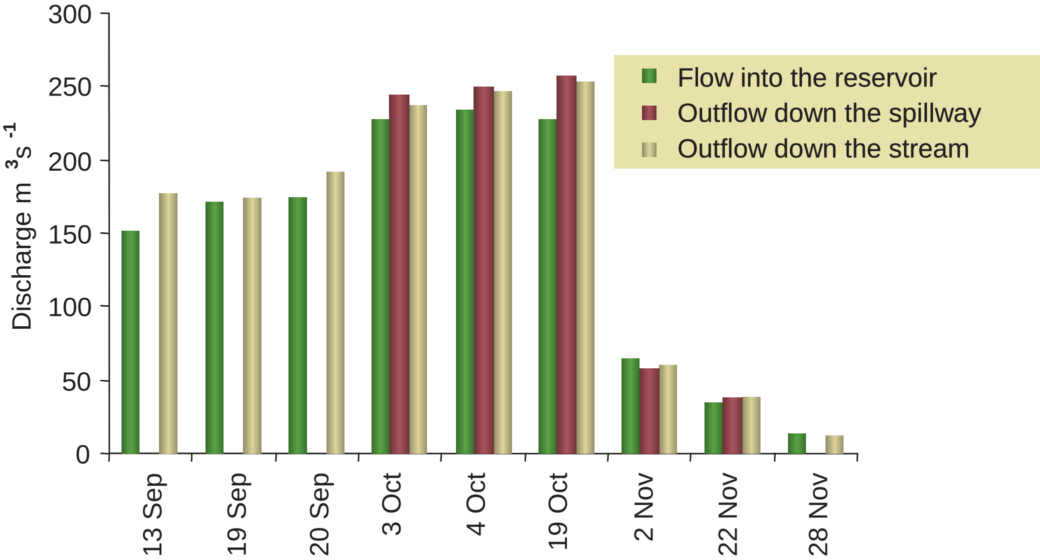


Figure 15: Stung Chinit reservoir's impacts on flows. Measurements between September and November 2006. Green bars represent the inflow, while brown and sand bars show the outflow.
Source: Report "*Influence of built structures of Tonle Sap hydrology and related parameters*"

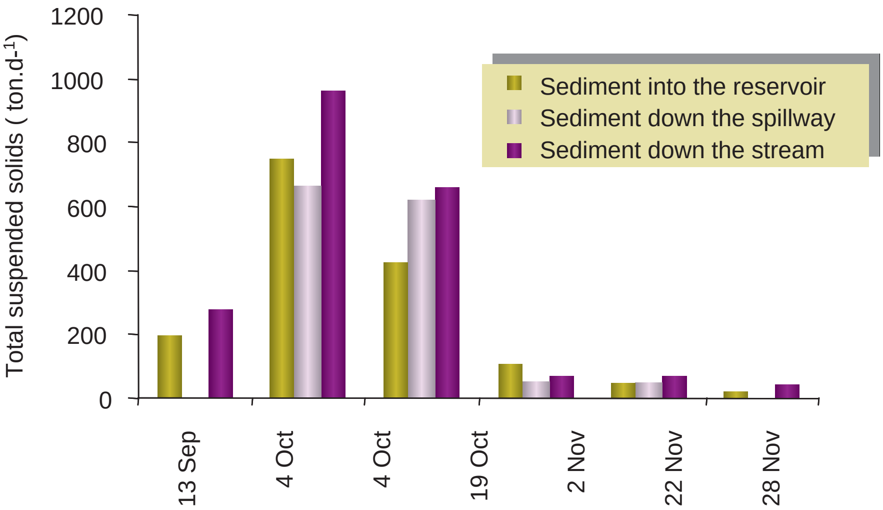


Figure 16: Limited impact of Stung Chinit reservoir on sedimentation. Sediment outflow measured between September and November 2006. Brown bars represent the sediment input, while purple bars show the sediment output.
Source: Report "*Influence of built structures of Tonle Sap hydrology and related parameters*"

Although the Stung Chinit reservoir adversely affects fish migration between upstream areas and floodplains, conditions in the reservoir itself are favorable for fish, creating a new fishing ground. The Stung Chinit reservoir provides an important new fishing ground close to some villages but has also flooded some rice fields. Fishermen interviewed in upstream and central areas believed the reservoir could become a productive fishing ground. But they were concerned that any immediate gains might simply reflect the retention of fish in the reservoir and that the positive impact could be short-lived. In the longer term, they were concerned that the reduced connection to downstream areas would erode the reservoir's production eventually. Although it is too early to determine the final impact of the reservoir, this is a very real possibility. Fishermen also highlighted the need to assess the fish pass as they were not convinced that it was working as planned.

Maintaining downstream flows and upstream migration is important to the sustainability of fish catches. Villages downstream seem to have borne several costs and received fewer benefits from the irrigation scheme. All people interviewed downstream blamed flow changes for reduced fish abundance and smaller catches from the river. Rice-field fisheries also seem to have suffered. Respondents mentioned that local fish abundance was closely linked to the seasonal flooding of the lake with bigger floods leading to more fish. Downstream groups were also concerned about controls over releasing reservoir water and the risk of floods from upstream.

Figure 17: The fish pass of Stung Chinit reservoir (Photo E. Baran)

Effective fish passes should be considered for any irrigation scheme in Cambodia to maintain the natural connectivity between upstream and downstream areas. Features to be taken into account before construction include the biological and physiological characteristics of migrating species as well as the position, width and height of the fish pass. However, the efficiency of the fish pass in Stung Chinit could not be assessed given the timing of the project vs. that of migrations, and because of the existence of an alternative waterway for fish to swim past the reservoir.

Since the scheme started operating only in May 2006, the study could not assess the full nature of its impact and instead focused on short-term impacts during the start-up phase that might highlight some of the possible longer term effects. The study highlighted the need for follow-up studies to assess the agricultural gains from irrigation and changes to fisheries. For managing the release of water, researchers should consider using tools such as Environmental Flow Assessment (EFA) and Downstream Response to Imposed Flow Transformation (DRIFT) methodologies, and incorporating lessons from sluice-gate management in Bangladesh.

☞ **RECOMMENDATION 15**

Analyze the social and economic costs and benefits of irrigation projects for different social groups at the planning stage. Make complementary investments to make sure poorer households can take advantage of new opportunities.

Irrigation schemes offer opportunities for a large range of economic activities. In Stung Chinit, livelihoods were found to be diversifying in all income groups. Among households close to the reservoir, the proportion engaged in fishing has risen markedly. The proportion of households raising livestock has also increased. Livelihoods in downstream areas are also diversifying, albeit due to declining incomes from fishing. The study found that households with more education and livestock holdings were better placed to take advantage of more profitable opportunities.

Securing land rights is essential as agricultural land values typically increase with improvements in irrigation. Poorer households may face pressure to vacate or sell land if their tenure is insecure. Villagers in the study identified credit, agricultural and fishery extension services and market access as key constraints that need to be addressed. Complementary investments to improve household assets should be based on participatory assessments in project areas.

☞ **RECOMMENDATION 16**

Provide training to Commune Councils to build effective communication channels between local officials, engineers and villagers. Support the establishment of water-user committees to promote equitable distribution of water and avoid conflicts over operating and maintaining the system.

Getting villagers to take part in infrastructure planning is a key factor in shaping their perceptions of a scheme's suitability and their willingness to invest in its long-term maintenance. Villagers in the Stung Chinit case study felt they did not really take part in the planning phase but were just briefed about upcoming activities without adequate two-way communication taking place. They complained that their own knowledge of irrigation was not appreciated and that engineers ignored their insights into perceived mistakes in establishing tertiary canals. Project staff wanted farmers to help maintain the irrigation scheme. Having not been encouraged to take part in the planning and construction phases, villagers seemed to be hesitant.

Table VII: Brief summary of generic upstream and downstream influences of irrigation schemes

	Upstream	Downstream
Significant hydrological changes	Creation of reservoir; reduced connection to rice fields; reduced connection between upstream and downstream sections	Reduced flow
Water quality	Much poorer	Poorer
Fish size	Increased size of some fish	Stable or decreased fish sizes
Fishing effort	Fishing in reservoir Distance to fishing grounds reduced	Increased use of efficient gears Distance to fishing grounds increased
Fish price	Decreased	Increased
Fishing lease price	n/a	Decreased
Fish abundance	Increased for some species	Overall decline
Direct livelihood opportunities	May increase with reservoir fishing	May increase for direct beneficiaries of irrigation but decrease for others who lose out from decline in fish abundance
Indirect livelihood opportunities	Depends on other household assets to take advantage of new opportunities for processing, petty trade, etc.	Depends on household assets
Resource access	Some households typically lose land to the reservoir, but may increase access to fishing areas created	May not be directly affected, but the benefits from access may decline if the river is less productive

Source: Report "*Influence of built structures on Tonle Sap fish resources*"

3.2.3. LOCAL INFLUENCE OF FISHING STRUCTURES

The following findings are primarily from the case study on large-scale fishing fences and associated management practices in Battambang province.

☞ RECOMMENDATION 17

Promote future studies on how large-scale fishing fences affect the movement of fish and longer-term fish recruitment, and appropriate mitigation measures.

Laboratory experiments demonstrated that bamboo or nylon fishing fences cause only minimal resistance to water flows and do not slow down water recession, whereas it is clear that the fences and the nets obstruct fish movements. A water retention effect becomes significant at current speeds that are much higher than those usually measured on the floodplain (Figure 18). Nylon nets attached to bamboo fences have an even smaller impact on water flows. On the other hand, the fences have a clear impact on fish movement - even more so when nylon nets are attached. The mesh size of the nets is typically five millimeters whereas the space between the bamboo slats is between 10 and 15 millimeters. In both cases, most fish are trapped.

Figure 18: The influence of fishing fences on Tonle Sap flood recession is minimal. Experiment conducted in a laboratory fixed bed flume in Bangkok. (Photo J. Mykkanen)
Source: Report "*Influence of built structures of Tonle Sap hydrology and related parameters*"

Over the whole lake, the length of bamboo fences within fishing lots currently in operation after the fishery reforms amounts to 409 km, which represents 34 percent of the periphery of the lake[2]. By nature, fishing fences are meant to trap fish and increase the catch rate, thereby decreasing the overall fish survival rate. However, the lack of information on the size or composition of the fish stock and on the critical migration corridors does not allow estimates of the length of fences that should achieve the best compromise between high catches and sustainability.

Figure 19: Aerial view of one of the 82 fishing lots currently in operation in Cambodia. (Photo E. Baran)

[2] This figure is higher than the figure shown in Table III, which only covers the main study areas that have been digitized in great detail.

☞ RECOMMENDATION 18

Decisions on where and how large-scale lot systems are implemented should take into account economic, social, and ecological trade-offs as compared to other management options such as community fisheries.

In the case study area, there are two fisheries management systems (fishing lots and community fisheries). How they differ in terms of their actual impact on fisheries resources is unclear. In practice, social equity is not a priority for the lot management. Access to fishing grounds within the lot is limited to those who work for the lease owner or who can afford the fees, and the benefits are concentrated among a small number of individuals. On the other hand, community fisheries were created specifically to provide more equitable access to fisheries among local community members. Fishing practices under these management systems differ, but how these differences influence fisheries sustainability is unclear.

Both management systems suffer from a prevalence of highly destructive fishing practices, such as electro-fishing, damming and pumping water out of streams. These destructive practices have an adverse impact on dry-season habitats as they reduce the size of flooded areas and streams and increase the turbidity of other water bodies. The dry-season habitats are important refuges, especially for the "black" fish species like trey ros (*Channa striata*) and trey kranh (*Anabas testudineus*). While community fisheries seem to permit greater connectivity of habitats within the overall system due to an absence of large-scale fishing fences, the poor capacity to combat destructive fishing methods in community fisheries areas is adversely affecting fish and habitats.

The case study illustrates that there are trade-offs between productivity, equity and possibly sustainability in the two management systems in operation at the site. These trade-offs need to be better understood when management options are selected for particular fishing grounds. More investigation is needed on the relative sustainability of the management systems used in the Tonle Sap Lake in terms of their effects on fish recruitment and survival, and the effects of the gears used on fish and fisheries.

☞ RECOMMENDATION 19

When fishing lots are released and access opened to local communities, there are opportunities for relatively wealthier households to capture more of the benefits. Pay specific attention to institutional mechanisms to ensure equity and manage conflicts.

In the study area, the release of a fishing lot following the 2001 fisheries reform has given both local villagers and outsiders access to new fishing grounds which are now more crowded. Local villagers said the benefits of the release have been less than expected. Our surveys indicated a reduction in the contribution of fish to average household incomes of between 10 and 16 percent depending upon the area. Open access to the fishing grounds during the previously-restricted season from October to May has attracted not only locals but also growing numbers of migrants from upland and other areas, competing over fish. Social tensions have subsequently emerged.

Fishing remains the main source of income in villages of Prek Toal and Thvang but accounts for a declining share of total income. Catches have fallen among poor households in recent years. The decline may reflect more intense fishing pressure caused by migrants from other provinces. Among rich households, catches have recently increased.

Community fishery members in the study area are mainly from wealthier and more educated households with significantly higher catches than non-members. Interviews indicated that richer fishing households had maintained their relatively high incomes and that intensive commercial fishing had continued despite community regulations allowing family-scale fishing only. Several indicated that a wealthier minority had captured the community fishery's best locations and restricted access by poorer people.

3.2.4. LOCAL INFLUENCE OF BUILT STRUCTURES IN GENERAL

The case studies found a number of common lessons applicable to the various types of built structures. The following are the lessons and recommendations.

☞ **RECOMMENDATION 20**

Ensure that negative impacts of built structures are addressed through the management and operational aspects of projects in addition to technical and engineering measures.

All the case studies show clearly that management and social issues associated with built structures, such as access to benefits, use rights and regulations, and operations, can be perceived at the local level as much more crucial than the technical design of the structure itself. This aspect is essential and calls for an approach to built structures that does not focus only on engineering solutions as mitigation measures for possible negative impacts.

☞ **RECOMMENDATION 21**

Improve management of fisheries around built structures adapted to the newly created social dynamics and fishing environment, through better enforcement of regulations and coordination of stakeholders, including community fisheries, government agencies, donors, and non-governmental organizations.

The study highlighted local perceptions according to which household catches, fish abundance and species diversity are all falling. While the overall catch in an area may actually be steady or even expanding, household catches may be declining because more people are fishing or more fishing gears are being used. Local people interviewed in all study sites reported increased fishing pressure (use of larger and more efficient gears), increased domestic demand and increased exports. The exclusion of some people from certain fishing grounds has also reportedly led to the exploitation of new grounds which are often located in more distant areas.

Access to fisheries and their benefits is likely to become increasingly contentious. This raises the need for explicit considerations of what benefits are expected and how they are shared. Many of those interviewed also called for better enforcement measures and clampdowns on illegal practices such as electro-fishing.

The case studies found that coordination between fishing communities, local authorities, management committees and fisheries officers was either limited or absent at all three study sites. The unanimous view was that closer collaboration was needed between all stakeholders. In Prek

Toal, efforts are needed to control the illegal pumping of water and the expansion of fishing grounds in the fishing lot as well as unregulated activities and intensified fishing in the community fishery that have led to conflicts. In Stung Chinit, there was clear evidence of the potential for conflicts. Downstream villages are concerned about how water management will affect fisheries and flooding. Earlier water conflicts between farming and fishing communities were cited as one reason for the scheme falling into disuse before it was rehabilitated.

☞ **RECOMMENDATION 22**

Hold systematic consultations between national and local stakeholders throughout the project development and help local people articulate their needs and concerns. Evaluate and publicly debate the social, economic and ecological trade-offs arising from different development scenarios before deciding on a specific option.

Stakeholder participation in the planning of built structure development and environmental impact assessments is generally very limited. There is no systematic mechanism for involving local communities, provincial and district authorities, and non-governmental organizations. This raises issues of transparency and the need to allocate resources to communications at the local and national levels. The general conclusion among village stakeholders is that they are supposed to be consulted but that consultations aren't effective. This view needs to be treated cautiously, however, as it is based on a limited number of interviews.

The study found gaps in communications between ministries. For irrigation planning, cooperation needs to be enhanced between the Ministry of Water Resources and Meteorology and the Ministry of Agriculture, Forestry and Fisheries. For assessing the impacts of roads on fisheries, better cooperation is needed between the Fisheries Administration and the Ministry of Public Works and Transport.

☞ **RECOMMENDATION 23**

Link infrastructure planning to the decentralized institutions for rural development and natural resource management (commune, district, and provincial councils).

Commune Councils should play an active role in planning roads and irrigation canals. To improve fisheries management, community fishery committees must be strengthened and their links to Commune Councils clarified. Identifying formal and informal village networks and cooperating with locally-respected leaders is crucial at all stages of a project. Regular sharing of information is important to clarify the division of responsibilities and keep expectations realistic.

All three case studies found that institutions determine the costs and benefits of infrastructure development and deeply influence livelihood issues such as access to natural resources, income benefits and equity. With poor planning and management, benefits may be short term and the rich may benefit more than the poor. Some stakeholders - such as downstream fishing communities - may pay an unbearably high price. Adequate planning is therefore crucial for the equitable distribution of benefits and poverty reduction. The study also found that institutions such as user groups and community fisheries may be unable to secure more equitable long-term benefits if they are dominated by certain people or if they fail to include the poorest groups.

☞ RECOMMENDATION 24

Analyze how the costs and benefits of a project affect different social groups, taking the role of local institutions and differences in household assets into account. Considering the importance of poverty alleviation in Cambodia's development agenda, make special provisions to involve the poorest groups in project planning.

Different types of infrastructure benefit different groups of people. Most public roads, for example, are available to all users without a fee and access can be increased as the network of feeder roads expands. On the other hand, irrigation schemes deliver water to a defined area so the number of people who benefit directly is limited. At the other extreme, large commercial fishing structures exclude most people and benefit only a few.

The study found that most people's livelihoods were diversifying as new opportunities and risks arose from new infrastructure. However, all case studies showed that fishing and related activities were still the main source of income (Figure 20).

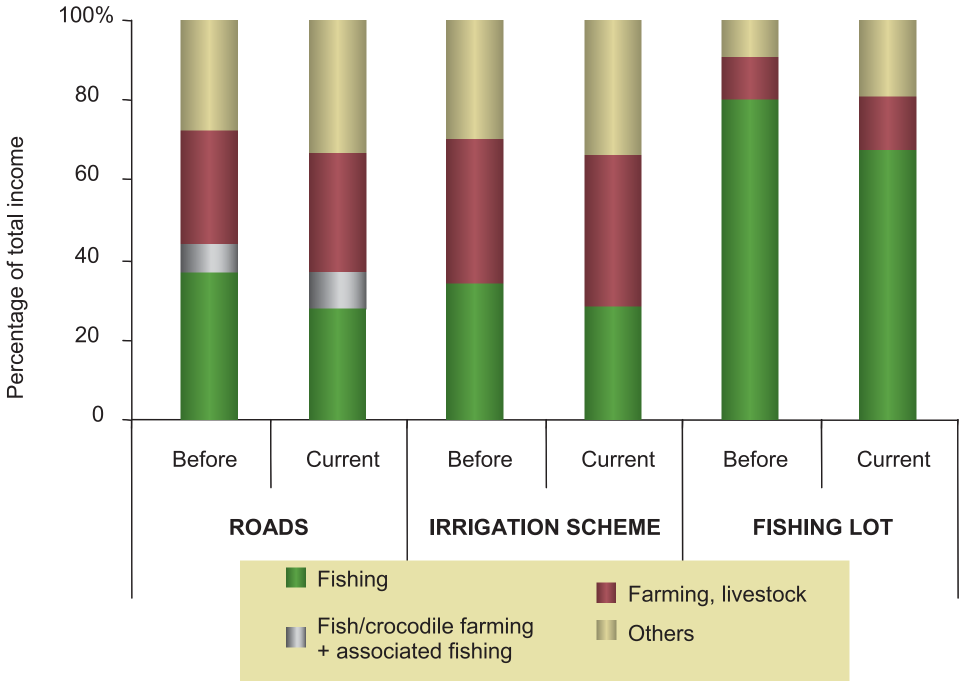


Figure 20: Sources of livelihoods and changes after a new structure.
Source: Report "*Influence of built structures on local livelihoods: case studies of roads, irrigation, and fishing lots*"

Infrastructure development is generally benefiting richer households. Many poor households are also benefiting but not at the same rate. The three case studies found that rural households had different capacities to benefit from opportunities arising from infrastructure development. The chronic poor - those who remained in poverty throughout the period studied - saw a modest increase in household incomes. The average income gains for other groups were more than three times higher. Although road development in Pursat has led to a sharp decline in the percentage of people living in poverty, the chronic poor are generally not yet benefiting enough. In the villages around the irrigation scheme in Kampong Thom, the poorest households are more affluent but are still below the poverty line.

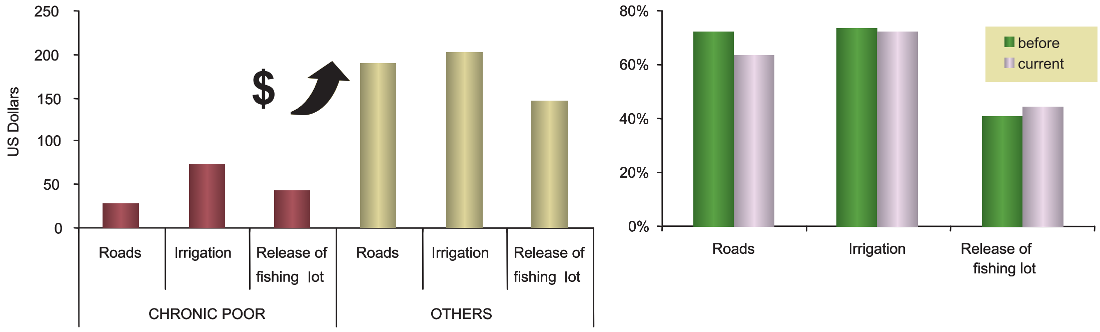


Figure 21: Incomes are rising and poverty declining, but the changes are uneven. The left graph illustrates the change in household income for poor and non-poor households, comparing the period before and after the change in built structures at the three study sites. The right graph shows the change in incidence of poverty.

Source: Report "*Influence of built structures on local livelihoods: case studies of roads, irrigation, and fishing lots*"

☞ **RECOMMENDATION 25**

Complement infrastructure projects with investments in basic education, training and technical support.

The three case studies showed strong ties between household assets, especially education, and the ability to take advantage of new opportunities. After education, the next most significant asset explaining the ability of households to get out of poverty was livestock, a form of savings. Financial capital also seems to play a crucial role in the influence of infrastructure development on chronic poverty. It was also found that social capital was a key factor in explaining the degree to which benefits were more broadly shared or enjoyed by privileged households.

Setting priorities for complimentary investments in areas such as education should be part of livelihood assessments associated with infrastructure planning. Special attention should be given to the phasing of such investments. In many cases, it may be wise to start making complementary investments even before the construction of physical infrastructure begins.

Notes

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INFLUENCE OF BUILT STRUCTURES ON TONLE SAP FISHERIES

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