

EXECUTIVE SUMMARY

The present Cumulative Impact Assessment (CIA) and Management of Renewable Energy Development in the Sekong River Basin of the Lao People's Democratic Republic aims to support decision making for sustainable development of renewable energy resources. In the past, private sector interests have largely directed developments in the basin on a first-come, first-served basis. The findings of the CIA indicate the need for a Sekong Basin power development master plan incorporating renewable energy (hydropower, solar, and wind) and thermal power. There is an opportunity to establish the trajectory of future development based on a strategic assessment of local and regional power demand and with consideration of the range of potential uses of natural resources in the basin. This approach would result in greater investment efficiency, a close match between power production and demand, and more opportunities to address adverse impacts through the full range of options available in the mitigation hierarchy.

The Sekong River is an important transboundary river in the Lower Mekong region, with a total length of 516 kilometers. It originates in the mountains of Vietnam, flows into Lao People's Democratic Republic (Lao PDR), and continues into Cambodia, where it eventually joins the Mekong River. The Sekong River Basin (SRB) covers a total area of 29,000 square kilometers, of which 78 percent is within the territory of Lao PDR. It is one of the few remaining major Mekong River tributaries with high biodiversity value and relatively few hydropower projects in operation.

Topography in the basin comprises a mix of steep mountains in the upper watershed, high plateaus, lowland hills, and floodplains. Annual precipitation rates are high (1,400–2,900 millimeters) and seasonal, resulting in a large difference in flow in the Sekong River between the wet season—about 1,200 cubic meters per second on average in August and September—and dry season (about 100 cubic meters per second average in April). The Sekong, Sesan, and Srepok river basins, combined called the 3S basin, contribute approximately 23 percent of the annual flow and (in an unregulated state) up to 25 percent of the sediment load in the Lower Mekong River.

A rapid expansion of power generation in the SRB is planned for the next decade,

increasing from 12 hydropower projects today—1,550 megawatts (MW) of installed capacity—to 35 projects by 2030 (3,512 MW). Several feasibility studies for wind and solar projects in the SRB are under way; it is estimated that there will be at least 600 MW for each by 2030. A coal-fired thermal power plant is proposed in Kalum District, Sekong Province.

The focus of power generation is mostly export to neighboring Thailand, Vietnam, and Cambodia, where demand forecasts are strong. Lao PDR has an agreement to export 5,000 MW of electricity to Vietnam by 2030, and much of this could be sourced from the SRB, given the proximity to southern Vietnam, where population density and demand is considerable.

Although hydropower and renewable energy development has the potential to help Lao PDR meet national development targets, the pace of change carries risks of significant environmental and social impacts.¹ *Individually*, hydropower projects can affect the aquatic and terrestrial environment, ecosystem services, communities, and peoples' livelihoods. *Cumulatively*, multiple projects within the same river basin can magnify these adverse impacts by greatly altering the flow regimes of the rivers, water quality, and sediment transport, with effects on aquatic life and terrestrial habitats and natural resources, which in turn affect local people's livelihoods.

In recognition of these challenges, the government of Lao PDR has strengthened policies and regulations for assessment of cumulative impacts and promoting integrated water resource management. One such initiative has been preparation of Cumulative Impact Assessment (CIA) Guidelines for Hydropower Projects in Lao PDR by the Ministry of Natural Resources and Environment. The objective of the guidelines—currently in draft form—is to improve and strengthen CIAs for individual hydropower projects and to help developers and regulators go beyond individual project-level impact assessments for sustainable basin-scale planning and integrated management of natural resources.

IFC, in partnership with the Ministry of Energy and Mines and other stakeholders, has undertaken this CIA of renewable energy in the SRB to support decision making for sustainable development of renewable energy resources and to

¹ For the purposes of this cumulative impact assessment, renewable energy development focuses on hydro, wind, and solar power.

pilot the draft guidelines on CIAs. Specific aims of this CIA are the following:

- To plan and execute an integrated assessment of the cumulative impacts of renewable energy development in the SRB, including power optimization and development scenarios
- To lead the participatory design of a framework for ongoing river basin co-management in the SRB, including collaborative environmental and social impact monitoring and management
- To strengthen the skills of SRB stakeholders in CIA approaches and co-management.

Method and Approach

Successive and incremental environmental and social impacts from multiple developments over time can result in significant cumulative impacts that would not be identified through even the most thorough project-specific environmental and social impact assessment. A CIA is a systematic process of identifying and analyzing potential environmental and social risks and impacts resulting from past, current, and anticipated developments.

This is accomplished through a screening process that identifies environmental and social attributes that actions, projects, and activities within the scope of the CIA are likely to affect significantly. These attributes are termed *valued environmental components* (VECs).

VECs considered important in assessing risks may be the following:

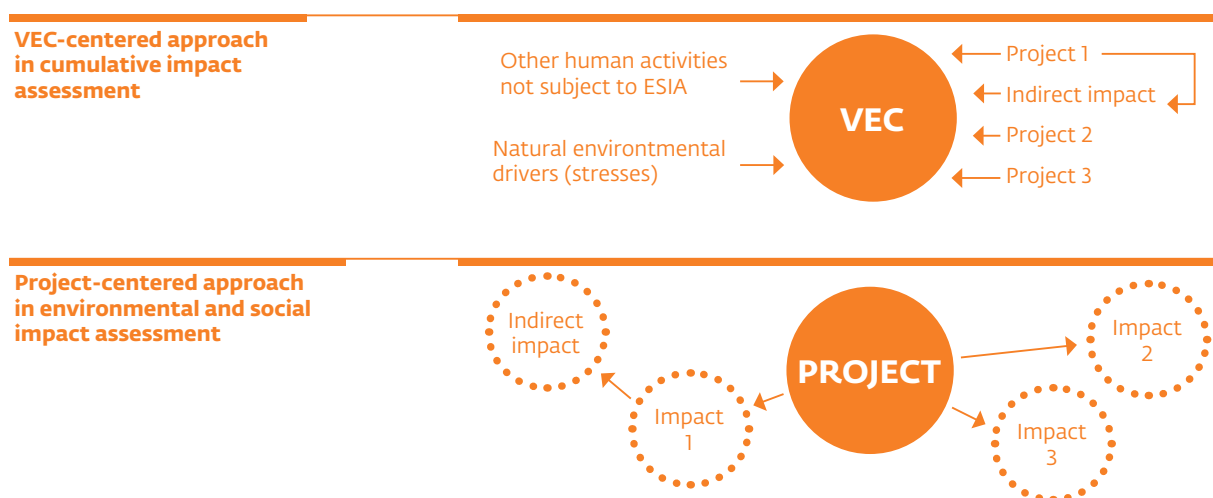
- Physical features, habitats, and wildlife populations (for example, biodiversity)
- Ecosystem services
- Natural processes (for example, water and nutrient cycles and microclimate)
- Social conditions (for example, health and economics)
- Cultural activities (for example, traditional spiritual ceremonies)

VECs are selected based on scientific data and feedback from stakeholders. The CIA guidelines for hydropower plants in Lao PDR define VECs as any part of the environment and social fabric that the proponent, local communities, environmental specialists, social scientists, and government consider important after a thorough assessment.

These VECs are the focus of the CIA process. The difference between a CIA and an environmental and social impact assessment (ESIA) is illustrated in Figure ES.1.

Substantial data modeling was undertaken for this CIA. Global satellite data were used in conjunction with available rain-gauge data to produce daily rainfall series across the SRB for a 24-year period, from 1991 to 2014. Together with climate-change modeling, this provided inputs for a hydrological model—U.S. Army Corps of Engineers, Hydrologic Engineering Center

Figure ES.1: Comparison of Cumulative Impact Assessment and Environmental and Social Impact Assessment



Note: VEC = valued environmental component; ESIA = environmental and social impact assessment.

Hydrologic Modeling System (HEC-HMS)—and the results of this model became the input for the Reservoir System Simulation Hydropower Model (HEC-ResSim), which was used to model sediment transport and simulate power generation for different configurations of hydropower in the SRB. Modeling was also conducted to explore opportunities to optimize power production through coordinated reservoir operations along the mainstream of the Sekong River.

Assessment Steps

The CIA for the SRB follows the six-step process illustrated in Figure ES.2 as per IFC’s *Good Practice Handbook on Cumulative Impact Assessment and Management: Guidance for the Private Sector in Emerging Markets* (2013).

Step 1: Determining Spatial and Temporal Boundaries

The primary spatial boundary of the study area is the SRB, although downstream and transboundary impacts on the Mekong River in Cambodia and Vietnam as far as the Mekong Delta were also considered. On a sub-basin scale, hydrological modeling was conducted to evaluate the local effects of hydropower projects on river flows in Sekong tributaries.

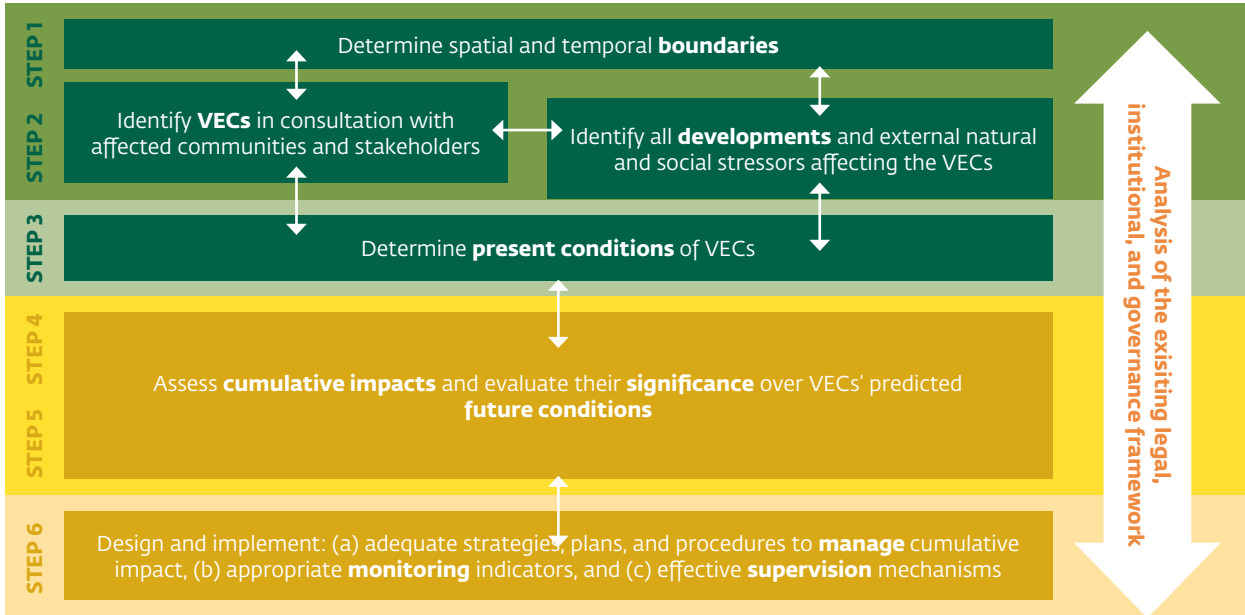
The primary timeframe for the CIA is 2030, when most proposed hydropower projects for the SRB are planned to be operational. Climate change effects are modeled over a longer period—until 2090.

Step 2: Identify VECs, Developments, and Stressors

The CIA focuses on four broad categories of environmental and social values (Table ES.1). These were identified through field visits, a literature review, specialist advice, and consultation with a diverse range of stakeholders. Key stakeholders in Lao PDR, Cambodia, and Vietnam included the following:

- Government—central government ministries and local authorities involved in planning, assessment, and permitting processes for renewable energy projects and infrastructure, such as roads, irrigation, and mining in the SRB
- Project developers—owners and operators of renewable energy projects in the SRB
- Development partners and other stakeholders—donors, lenders, non-governmental organizations, and research organizations with interest in the SRB and questions related to renewable energy, biodiversity, and rural livelihoods
- Local communities—riparian villages in the SRB

Figure ES.2: Cumulative Impact Assessment Process



Source: IFC 2013.
 Note: VEC = valued environmental component.

Table ES.1: Valued Environmental Components Identified and Evaluated

Component	Description
Aquatic biodiversity and ecosystems	<ul style="list-style-type: none"> • Aquatic habitats, flora, and fauna with important conservation status (threatened and endangered species) • Super endemic fish (found only in the SRB) and migratory species
Terrestrial biodiversity and ecosystems	<ul style="list-style-type: none"> • Habitats important for biodiversity and ecosystem functions • Designated protected areas and conservation sites • Endangered and critically endangered terrestrial species
Natural resource-dependent livelihoods	<ul style="list-style-type: none"> • Habitats, flora, and fauna (terrestrial, riparian, and wetland) important for rural livelihoods and food security • Timber resources, including wood for construction, firewood, and charcoal • Non-timber forest products for food security, medicine, construction, and trade • Capture fisheries in the Sekong mainstream and tributaries • Wet-rice agriculture on river flood plains, upland fields, and dry season riverbank gardens
Culture and heritage	<ul style="list-style-type: none"> • Cohesive communities • Linguistic and cultural diversity, traditional knowledge, and ethnic identity • Gender roles and opportunities

Within the SRB, a range of mainly human activities may affect the condition of VECs. For this CIA, the following were identified and examined:

- Large and medium-sized hydropower projects
- Wind and solar power projects
- Associated supplementary infrastructure (for example, transmission lines, and roads)
- Industrial and agricultural development (for example, mining and plantations)
- Water abstraction (irrigation, water supply, and water diversion)
- Extraction of river resources (fisheries, sand, and gravel)
- Extraction of forest and wetland resources
- Climate change effects on the hydrological regime of the SRB

Hydropower development is likely to be the single biggest stressor on most VECs in the SRB over the next decade due to the substantial hydropower development over the past decade and ambitious plans over the next 10 years (Table ES.2).

In addition to the 12 projects currently operational or nearing completion, private investors have proposed 23 projects for development.

Accurately predicting future developments in the SRB is challenging for two reasons. First, some proposed renewable energy projects at the early design stage may be unfeasible for technical or economic reasons. Second, limited domestic power demand in Lao PDR means that the commercial viability of many proposed projects will hinge on securing power purchase agreements for export to neighboring Vietnam, Thailand, and Cambodia (as well as construction of the necessary cross-border transmission infrastructure).

Given this uncertainty, this CIA compares three renewable energy development pathways for the SRB: conservative, intermediate, and full development. The present situation in 12 active projects is also considered. The pathways have been selected to demonstrate the difference in cumulative impacts created by varying the intensity and configuration of projects.

Figure ES.3 outlines the three development pathways in terms of their power generation. Map ES.1 depicts all existing and planned hydropower projects under the full development pathway.

Table ES.2: Existing and Planned Hydropower Projects in the Sekong River Basin

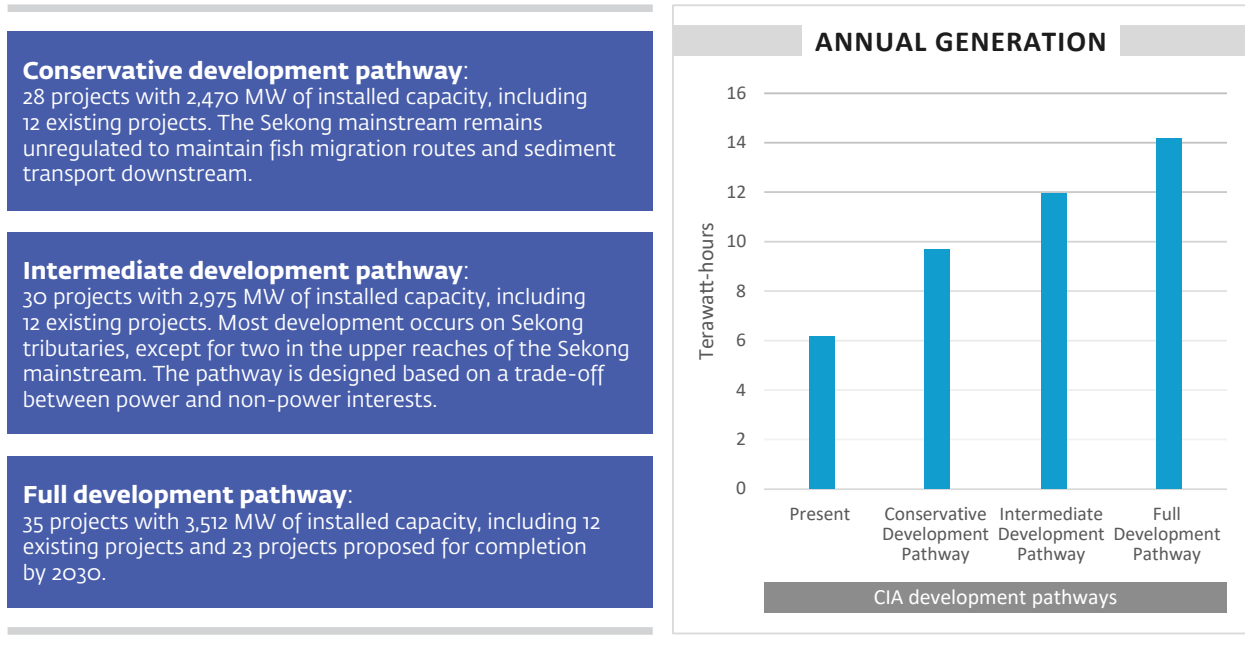
Project Name	Status	Date of commercial operation	Installed capacity (MW)	Mean annual energy (GWh)	Power destination	Pathway ²			
						Present situation	Conservative development	Intermediate development	Full development
A Luoi	Operational	2012	170	650	Vietnam	X	X	X	X
Houay Ho	Operational	1999	152	450	Thailand	X	X	X	X
Xe Kaman 3	Operational	2013	250	980	Vietnam	X	X	X	X
Xe Namnoy 6	Operational	2013	5	20	Lao PDR	X	X	X	X
Xe Namnoy 1	Operational	2014	15	80	Lao PDR	X	X	X	X
Houay Lamphan Gnai	Operational	2015	88	450	Lao PDR	X	X	X	X
Xe Kaman 1	Operational	2016	290	1,040	Vietnam	X	X	X	X
Xe Kaman Sanxay	Operational	2017	32	110	Vietnam	X	X	X	X
Nam Kong 2	Operational	2017	66	260	Lao PDR	X	X	X	X
Xe Katam 1 Xe Namnoy 2	Operational	2017	22	120	Lao PDR	X	X	X	X
Xe Pian Xe Namnoy	Construction	2020*	410	1,800	Thailand	X	X	X	X
Nam Kong 3	Construction	2020*	54	200	Lao PDR	X	X	X	X
Dakchaliou 1	Construction	2021	11	50	Unknown		X	X	X
Dakchaliou 2	Construction	2021	13	60	Unknown		X	X	X
Nam Kong 1	Construction	2022	150	560	Lao PDR		X	X	X
Nam Bi 1	PDA stage	2024	68	290	Vietnam		X	X	X
Nam Bi 2	PDA stage	2024	50	210	Vietnam		X	X	X
Nam Bi 3	PDA stage	2024	12	50	Vietnam		X	X	X
Nam Ang	PDA stage	2024	55	160	Lao PDR		X	X	X
Nam Emoun	Construction	2024	129	430	Lao PDR		X	X	X
Nam Pangou	PDA Stage	2025	33	140	Unknown		X	X	X
Xe Pian-Houysoy	PDA stage	2025	45	200	Lao PDR		X	X	X
Lower Xe Pian	FS ongoing	2030	15	60	Lao PDR		X	X	X
Xe Katam	PDA stage	2030	81	300	Lao PDR		X	X	X
Xe Kaman 2A	FS ongoing	2030	64	250	Lao PDR		X	X	X
Xe Kaman 2B	FS ongoing	2030	100	380	Lao PDR		X	X	X
Xe Kaman 4	PDA stage	2030	70	290	Vietnam		X	X	X
Xe Namnoy 5	Unknown	2030	20	90	Lao PDR		X	X	X
Sekong 5	FS completed	2030	330	1,500	Thailand			X	X
Sekong 4B	FS approved	2026	175	750	Thailand			X	X
Sekong 4A	FS approved	2025	165	780	Thailand				X
Sekong 3A	FS completed	2027	114	460	Lao PDR				X
Sekong 3B	FS completed	2028	122	400	Lao PDR				X
Sekong Downstream A	FS completed	2030	86	380	Lao PDR				X
Sekong Downstream B	FS completed	2030	50	210	Lao PDR				X

*at the time of the report preparation.

Note: MW = megawatt; GWh = gigawatt-hour; Lao PDR = Lao People's Democratic Republic; PDA = project development agreement; FS = feasibility study.

² Xs indicate which plants have been considered in respective pathways. If no Xs, the plant is not being considered.

Figure ES.3: Cumulative Impact Assessment Development Pathways in the Sekong River Basin



Map ES.1: Full Development Pathway in the Sekong River Basin—All Planned and Proposed Hydropower



Source: Shuttle Radar Topography Mission (SRTM), Mekong River Commission (MRC), Greater Mekong Sub-Region

Step 3: Determine Baseline Conditions of the VECs

Aquatic Habitats and Biodiversity

The Sekong River is home to more than 200 fish species, of which approximately one-third are migratory. As the last major free-flowing tributary to the Mekong River, the Sekong River provides passage for migratory fish between the Mekong mainstream, the Tonle Sap Great Lake, and the Vietnam Delta. International Union for Conservation of Nature data indicate the presence of 21 endangered and critically endangered fish species in the basin, including some endemic species unique to the basin. Villagers consulted for this study report a large decline in the number of many fish species over the past 15 years, which they attribute to combined pressures of overfishing, industry, mining, agriculture, and hydropower development.

Terrestrial Habitats and Biodiversity

The SRB is rich in terrestrial biodiversity and habitats. It is home to 89 globally threatened vertebrate species classified as critically endangered, endangered, and vulnerable. Many of these species have small populations and are threatened by hunting, habitat loss, land use change, and deforestation.

Four National Protected Areas (NPAs) have been established covering 39 percent of land within the SRB. The Xe Pian NPA, in the south of the SRB, ranks second in Lao PDR and among top 10 in Asia for biodiversity. The Dong Ampham NPA, in the east, adjoins a similarly rich biodiversity area in Vietnam and is considered a regionally significant conservation corridor. The Beung Kiat Ngong Wetland, in the west, is an internationally recognized Ramsar site comprising 2,360 hectares of swamps, lakes, and marshes important for spawning fish, turtles, and birds. Parts of the Sekong floodplain contain critical habitats for freshwater birds. These protected areas function as important refuges to sustain populations of endangered species.

Forest is an important habitat for many terrestrial species in the basin. Although forest cover is relatively extensive, comprising natural deciduous and evergreen forests, it has declined over the past decade mainly due to clearance for agriculture. Conversion of forest to agriculture also affects aquatic habitats because it increases surface water runoff, erosion, turbidity, and flash floods.

Natural Resource–Dependent Livelihoods

The population of the SRB is estimated at 324,000 (across Lao PDR, Cambodia, and Vietnam). Across the SRB in Lao PDR, the population is mainly concentrated in the lowland plains and engaged in livelihoods highly dependent on terrestrial and aquatic natural resources.

Subsistence and semi-subsistence agriculture are the mainstay of rural livelihoods in the basin, with more than 80 percent of households engaged in farming. Main crops are paddy rice (in lowland areas), hill rice and swidden crops (in upland areas), and riverbank gardens (in riparian communities). Many households also keep livestock (poultry and cattle). Growing of cash crops is limited, although coffee is widely grown in the Bolaven Plateau and provides an important source of income for local communities.

Non-timber forest products (NTFPs) are a significant component of rural livelihoods. Wild plants and wildlife (for example, bamboo, fruits, edible leaves, resins, nuts, birds, and insects) are collected to eat and in some cases to sell. NTFPs are particularly important during periods of rice shortage. Forests also provide firewood and construction materials. NTFPs such as bamboo shoots and rattan are an important source of cash income for women.

After agriculture, capture fisheries provide the second largest source of income—up to 40 percent of annual household incomes in some cases. Fish are also important for food security and nutrition; consumption is estimated at nearly one kilogram per week per person, providing 80 percent of dietary protein.

Culture and Heritage

A diversity of ethnic groups with distinct cultures and beliefs populate the SRB. Ethnic Lao form the majority in some parts of the SRB (for example, in Pathoumphone District), whereas elsewhere the population is a mix of groups belonging to the Mon-Khmer language family (for example, Nya Heun, Brao, Ta-Oy, Katu, Jeh, and Kriang).

Socio-economic development within the SRB in recent decades has contributed to increasing cultural assimilation of Mon-Khmer minority ethnic groups into lowland culture. Use of ethnic languages is declining among the younger generation, particularly among men and in urban areas, as is wearing traditional clothing.

Step 4: Assess Cumulative Impacts on VECs and their significance

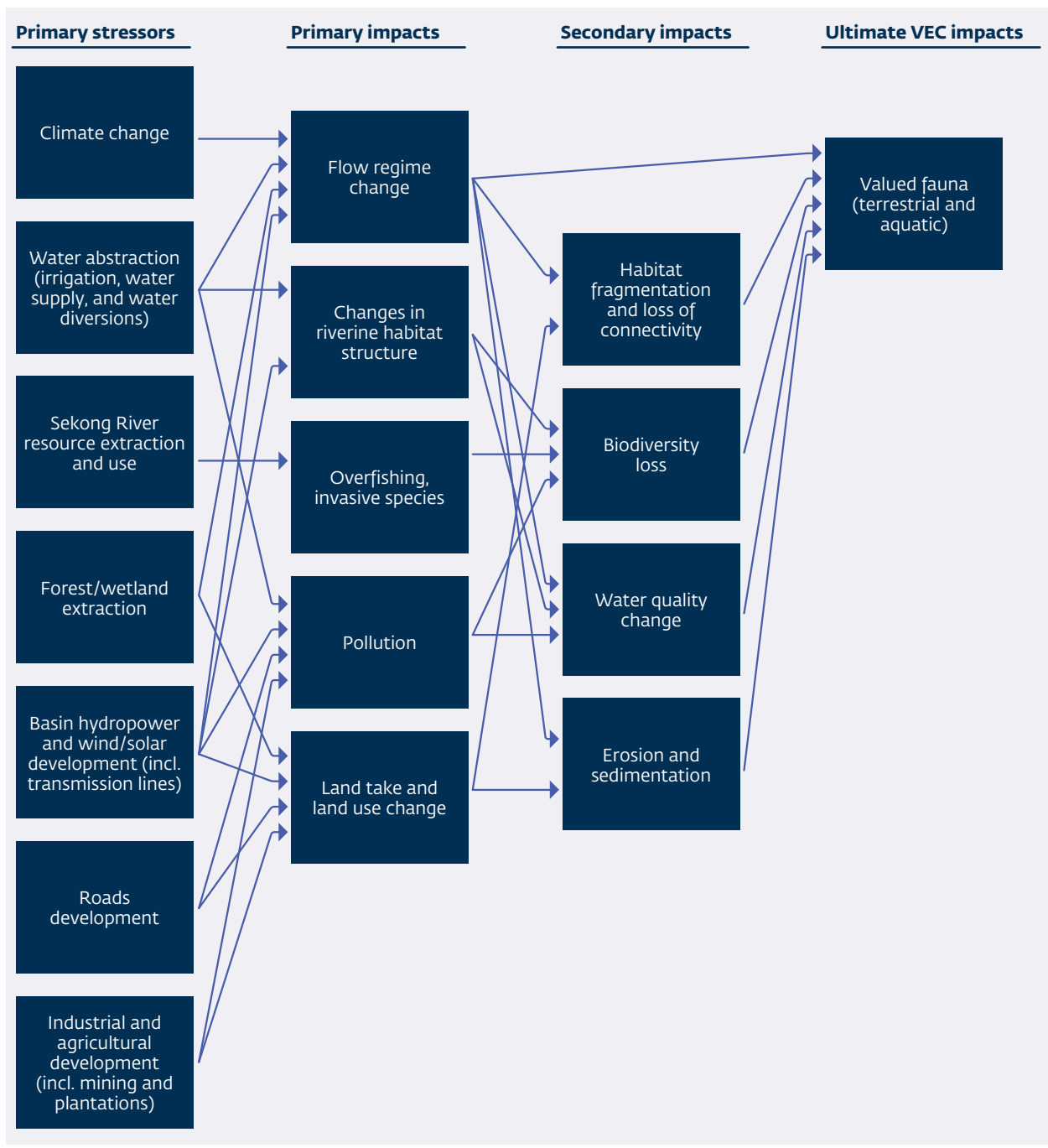
CIA identifies and evaluates multiple direct and indirect impacts on VECs that can be traced back through a chain of cause-and-effect to primary stressors (natural and human). An example of this cause-and-effect chain is illustrated in Figure ES.4. This step outlines the changes likely to occur from hydropower development in the SRB and will vary depending on the development pathway chosen for the SRB.

Flow Regime Changes

The greatest cause of flow alteration in the SRB is reservoir dams. Water extraction for irrigation has not been identified as significant, and climate change modeling predicts only small changes.

Reservoirs have been modeled using HEC-ResSim software to assess seasonal flow variations resulting from existing and planned hydropower projects. The results show a general pattern of lower wet season flows and higher dry season

Figure ES.4: Cause-and-Effect Chain for Cumulative Impacts on Aquatic and Terrestrial Valued Fauna



flows but with substantial variation in different sub-basins of the SRB, according to the number and scale of upstream dams.

Important flow regime changes due to hydropower development are of three types: flood frequency, dry season flows, and daily flows.

Flood Frequency

The SRB has historically experienced frequent flooding in lowland areas (due to factors including large catchment area, high rainfall, and steep topography in the upper watershed and extensive river plain). Large floods resulting in “bank full”³ conditions (about 5,000 cubic meters per second) occur on average every 20 years; before recent hydropower development in the basin, the average time between floods was eight years.

Development of additional hydropower projects with large storage reservoirs in the SRB will tend to reduce the size and frequency of flood events (assuming reservoirs have sufficient storage capacity to accommodate inflows during flood events). The degree of modification will depend on the number and type of hydropower projects and the operational practices.

Fewer large flood events would result in less damage and disruption to riverbank settlements and riparian livelihoods but also less deposition of nutrient-rich sediment on alluvial plains, which is important for agriculture development.

Dry Season Flows

In addition to moderating wet season flows and potentially regulating floods, large storage reservoirs tend to increase dry season flows because water stored during the wet season is released to generate power over the remainder of the year.

Analysis conducted for this CIA shows that, in recent years, average flow in the Sekong River in the dry season (low flow) has nearly tripled and additional hydropower development will result in further modest increases proportionate to the number and size of reservoirs constructed.

Higher river levels during the dry season may impede access to river crossings, sand bars, and other sites of human interest along the river, although additional flow may be beneficial for river navigation and crop irrigation.

Daily Flows

Hydropower storage reservoirs operated for peak power generation tend to cause river levels downstream to vary throughout the day. The degree of variation depends on the operating rules of individual hydropower projects and the combined effect of multiple projects operating within a river system. Most storage hydropower plants in the SRB (built and planned) provide peak power to neighboring Thailand and Vietnam, and in the absence of a re-regulating dam, daily flow variations can be expected to meet power purchase agreement commitments. Rapid daily flow variations can lead to riverbank erosion, degradation of aquatic habitats, stranding of fish, damage to riverbank gardens, and—in extreme cases—community safety risks.

Changes in Sediment Transport

Reservoir dams tend to collect sediment and substantially reduce movement of sediment downstream. In a cascade of dams, the effect tends to be cumulative. Modeling conducted for this CIA indicates a 60 to 70 percent reduction in sand and courser grain sizes in the lower part of the Sekong River if all planned hydropower projects are built, although silt and clay fractions will be less affected. The significance of reduced sediment transport by the Sekong River will depend on hydropower developments elsewhere in the Lower Mekong region. The Sekong River contributes approximately 5 percent of total sediment in the Mekong River in northern Cambodia, but if all proposed dams along the Lower Mekong mainstream are built, the contribution of the Sekong River’s sediment would increase to 40 percent.

Reduced sediment transport will have a variety of effects downstream. Sediment is an important conduit of nutrients important for fisheries and agriculture. Sediment also acts to maintain the geomorphology of the river system, so a reduction may lead to changes in substrate and riverbank and riverbed erosion. Transboundary problems include effects on alluvial sand extraction operations in Cambodia and stabilization of the Mekong Delta in Vietnam.

Dams can be designed with sediment-flushing mechanisms, but these tend to be of limited utility when reservoirs are large and long, as is the case of many of the proposed SRB dams. Sediment transport will decline from approximately

³ “Bank full” refers to the water level at which a river reaches top of its banks and any further increase would result in water spilling out into the floodplain.

5.0 million tons to 2.2 million tons per year by 2030 if all planned dams are built; sediment flushing will make only a slight difference (Figure ES.5).

Aquatic Habitats and Biodiversity

As a result of changes in flows during the dry and wet seasons, higher water levels in the dry season can harm fish because low flows support suitable habitat conditions for aquatic animals and facilitate different processes and life stages of aquatic and riparian animals. A reduction in high flows in the wet season would impede channel-floodplain connectivity, with adverse effects on species moving between these habitats.

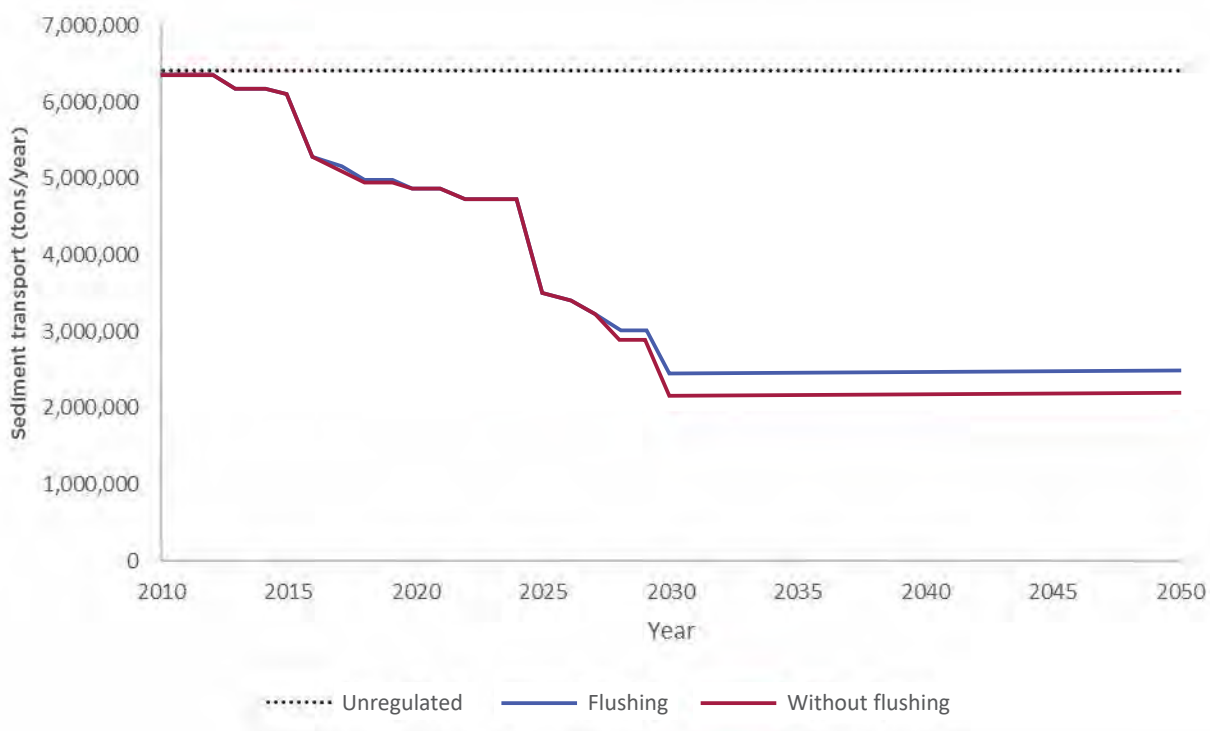
Physical blockages caused by dams and consequent modifications of aquatic habitats will fragment aquatic habitats and reduce river connectivity. Dams will decrease the length of rivers available to fish populations and fundamentally change the habitat from riparian to stagnant conditions. Substantial reductions in connectivity and fragmentation of habitats will threaten the survival of some fish species and populations if too little habitat remains available.

Terrestrial Habitats and Biodiversity

Development of reservoirs, powerhouses, worker camps, transmission lines, and access roads can reduce or affect forest habitats, conservation areas, and biodiversity directly through land conversion and indirectly through habitat fragmentation. Project access roads and transmission lines facilitate access, leading to more hunting, harvesting of forest resources, and habitat disturbance. Resettlement of communities may lead to pressures on forest resources in new locations.

For this CIA, impacts on terrestrial habitats have been assessed by measuring the extent of national biodiversity conservation areas and other conservation zones flooded by hydropower reservoirs and used for project infrastructure. Impacts on terrestrial biodiversity have been evaluated using a small number of reference species in the SRB that are globally endangered, are sensitive to large-scale infrastructure developments, and have habitat ranges that hydropower projects would affect. For each species, impacts have been estimated in terms of habitat loss (calculated as the proportion of designated conservation areas that project

Figure ES.5: Impacts of Full Development Pathway of Flushing on Sediment Transport Downstream of the Lao People’s Democratic Republic–Cambodia Border



footprints directly affect), habitat fragmentation (due to reservoirs, transmission lines, and access roads), and proximity of projects to conservation areas (weighted according to the number of globally threatened species present).

Proposed hydropower projects on the upper reaches of the Sekong mainstream and Nam Emoun tributary are likely to cause the most impact to the biodiversity-rich forests in the Xe Xap NPA and surrounding area. Project roads and tracks associated with construction and maintenance of transmission lines will facilitate access. The shape of the reservoir, two long, narrow fingers, will enable access deep into the NPA. It is unlikely that appropriate watershed management measures that hydropower projects elsewhere in Lao PDR practice will be sufficient to prevent access, habitat disturbance, and biodiversity loss.

Hydropower development is only one factor in forest loss, habitat modification, and changes to biodiversity as these are also under pressure by other stressors such as mining, plantation agriculture, road development, hunting, and illicit logging, all of which have led to the decline of the resource base over the past few decades.

Natural Resource–Dependent Livelihoods

Fisheries

Capture fisheries are important for local livelihoods in the SRB, and construction of hydropower projects are likely to alter their composition. For example, non-migratory species that can adapt to the ecological conditions found in a lake will flourish at the expense of migratory species that depend upon faster-flowing rivers. Reservoir fisheries may offset these impacts, if managed sustainably and equitably.

To assess impacts on local livelihoods, this CIA compared the productive potential of future reservoir fisheries (fish catch) with current fish consumption of local communities. Although the results vary with different configurations of reservoirs (large mainstream reservoirs, for example, could support large fisheries), overall, reservoir fisheries cannot provide even half the amount of fish currently consumed.

Agriculture

Local communities depend on agricultural lands for food security and livelihoods. These lands tend to be concentrated in river valleys, floodplains,

and surrounding hills, which are often also viable sites for storage reservoirs. Impacts on agricultural land have been quantified (in hectares) using information contained in project ESAs augmented by spatial mapping using satellite imagery. Types of agricultural land affected by hydropower development include paddy rice fields, riverbank gardens, and swidden fields. The degree of impact depends not only on the total area of land affected, but also the amount of remaining land available to villagers who stay behind and provision of adequate land for villagers who are resettled.

Forest Products and Non-Timber Forest Products

Hydropower development in the Sekong Basin will affect community access to timber, NTFPs, game, and other forest resources. The magnitude of impact is principally a function of forest loss and forest habitat depletion (as just noted in “Terrestrial Habitats and Biodiversity”) and so varies for each development pathway.

Hydropower is only one of several determinants of forest loss in the SRB. Between 2000 and 2012, as much as 140,000 hectares (1,400 square kilometers) of forest was converted to agriculture, logging, and other activities (5.2 percent of the entire basin). Direct impacts from hydropower are moderate by comparison.

Physical Displacement and Resettlement

Numerous villages within reservoir inundation areas and immediately downstream of dams will be displaced because of hydropower developments. It is estimated that up to 11,500 people may need to be resettled depending on the scale of development. Almost half the total resettlement required is associated with two Sekong mainstream projects: Downstream A and Downstream B (about 5,000 people displaced). These two projects have the highest ratio of resettled people to megawatts of power capacity (32:1 and 47:1, respectively).

Culture and Heritage

Traditional customs, languages, belief systems, and other elements of traditional culture associated with ethnic groups in the SRB will be affected by renewable energy development through diverse and diffuse processes. Based on stakeholder consultations for this study and experiences of recent hydropower projects in other parts of Lao PDR, impacts are likely to be both positive and negative, and sometimes mixed.

- There will be interactions between communities and non-locals attached to development projects (workers, camp followers, and economic migrants), resulting in exchanges of knowledge and experience that may enhance or erode traditional values.
- It has been common in recent years for hydropower projects to result in resettlement of ethnic groups previously living in homogenous communities into mixed communities. This can be expected to further the integration of smaller ethnic groups into mainstream lowland culture. There is a potential for loss of tradition but also a chance to share beneficial new ideas and practices.
- Social development programs that hydropower projects sponsor as part of resettlement plans typically result in better education and health services for communities. It is likely that this will be beneficial to girls and women, narrowing the gender gap that is common in Mon-Khmer communities.

- Employment and other economic growth associated with project development may provide new opportunities for women, leading to a more equal role in household decision making.

Impacts of hydropower projects on VECs are summarized in Table ES.3.

Step 5: Evaluate Significance of Cumulative Impacts on VECs

The number, scale, design features, location, and configuration of hydropower development in the SRB will largely determine the significance of the cumulative impacts on the VECs described. The effects of other infrastructure developments (related, for example, to urbanization, agriculture, and mining) are likely to be less, at least during the 2030-time horizon of this assessment. Significant impacts associated with the three development pathways covered in this CIA are compared in Table ES.4.

Table ES.3: Summary of Impacts on Valued Environmental Components

VEC	Baseline conditions	Other development stressors and impacts	Hydropower-induced stresses and impacts
Aquatic habitats and biodiversity	Relatively good current conditions exist, but local communities report declining fisheries.	<ul style="list-style-type: none"> • Overfishing • Water abstraction • Climate change • Urbanization 	<ul style="list-style-type: none"> • Less connectivity for fish • Habitat fragmentation • Loss of migratory fish species • Flow regime change • Changes in water quality
Terrestrial habitats and biodiversity	Substantial forest habitats remain, but there has been rapid reduction in recent years; rich biodiversity and globally endangered species are under threat from multiple stressors.	<ul style="list-style-type: none"> • Clearance for agriculture • Logging • Wildlife hunting • Mining and agroforestry concessions 	<ul style="list-style-type: none"> • Habitat loss and fragmentation • Impacts on designated conservation areas • Facilitation of unsustainable exploitation of forests and wildlife caused by greater access
Natural resource-dependent livelihoods	Rural communities depend greatly on floodplain agriculture, capture fish, and non-timber forest products.	<ul style="list-style-type: none"> • Overexploitation • Forest clearance for agriculture, plantation forestry, and mining 	<ul style="list-style-type: none"> • Forest loss • Loss of migratory fish species and decline in fish stocks • Physical resettlement
Society and culture	Rich ethnic cultures currently exist.	<ul style="list-style-type: none"> • Gradual social and economic integration into mainstream culture 	<ul style="list-style-type: none"> • In-migration • Resettlement • Social development projects

Table ES.4: Summary of Cumulative Effects of Valued Environmental Components for Each Pathway

VEC	Full development	Intermediate development	Conservative development
Aquatic habitats and biodiversity	● Large reduction in aquatic biodiversity due to disruption of migratory routes and inundation of riparian habitats important for spawning and feeding	● Moderate impact on aquatic biodiversity because of fragmentation of Sekong tributaries; fish migration to and from Mekong supports continued connectivity along most of Sekong mainstem	● Little impact on aquatic biodiversity because connectivity is maintained along the full length of the Sekong mainstem and several tributaries to support fish migration to and from the Mekong
Terrestrial habitats and biodiversity	● Moderate impact on terrestrial biodiversity because of impacts on forests and protected areas	● Moderate impact on terrestrial biodiversity due to impacts on forests and protected areas	● Little impact on terrestrial habitats and biodiversity—important protected areas avoided
Natural resource-dependent livelihoods	● Large adverse impact on livelihoods, particularly agriculture, fisheries, and resettlement	● Moderate impact on livelihoods, particularly resettlement	● Little impact on livelihoods overall but significant for directly affected communities
Society and culture	● Moderate impact on culture and heritage, particularly because of resettlement	● Mixed impact on culture and heritage—adverse and beneficial	● Mixed impact on culture and heritage—adverse and beneficial

Step 6: Design and Implement Strategies to Manage Cumulative Impacts, Indicators, and Supervision Mechanisms

Effective mitigation and management of cumulative risks and impacts from renewable energy development in the SRB can be achieved at various stages of the project development process (Figure ES.6). Impact avoidance measures are more feasible in early stages, whereas later it is more realistic to focus on minimization, compensation, and offsets.

In the context of the SRB, opportunities for impact avoidance and minimization are limited for the 12 hydropower projects that are already operational or at an advanced stage of construction. Retrofitting environmental and social mitigation measures is not usually a technically or economically viable option, especially considering commitments and obligations under concession agreements and power purchase agreements; more mitigation options are available for the many projects not yet built or in earlier stages of design and feasibility study.

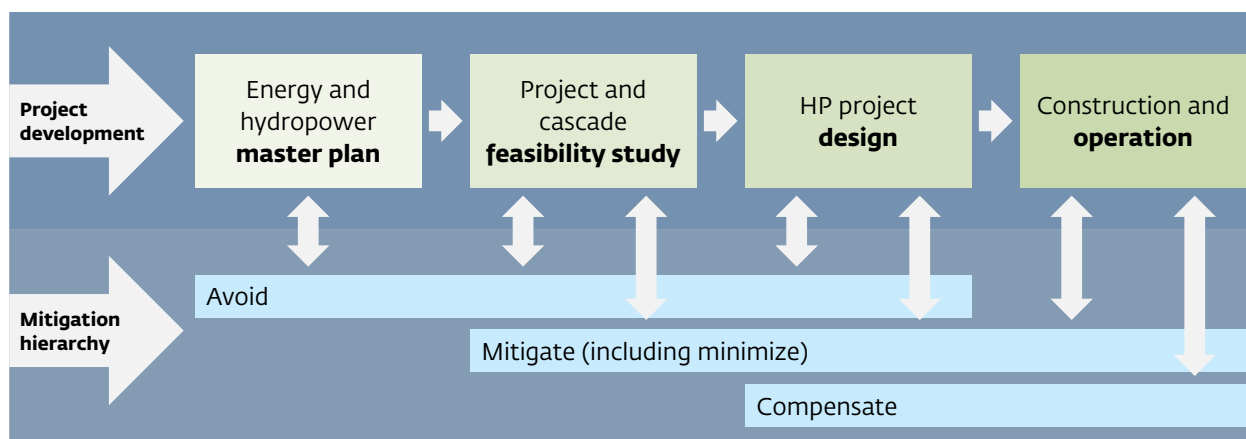
Impact management and mitigation should ideally begin with an integrated SRB power development master plan. Effective environmental mitigation and management cannot be undertaken on a project-by-project basis. It requires a basin-wide approach to address interdependencies related to energy generation and environmental and social impacts.

The SRB power development master plan would involve selection of hydropower projects through careful assessment of candidate project interactions to meet power demand while limiting environmental and social impacts. Basin-scale planning allows for coordination and optimization of hydropower projects, particularly those operating in cascades on the same reach of river.

Assessment of power development pathways in the SRB conducted for this CIA demonstrates how different project configurations result in substantially different levels of environmental and social impacts and power-generating capacity.

Power development planning should be informed by principles of integrated water resource management. Consideration of power generation alongside other uses of water resources can

Figure ES.6: Risk and Impact Mitigation over the Development Cycle



Source: MRC 2019a

support a robust decision-making process based on opportunities and trade-offs. Integrated water resource management can, for example, help hydropower deliver benefits such as increased water for irrigation to support agriculture, enhanced reservoirs to support fisheries, and improved river navigation to support tourism and trade.

Basin-scale power development planning also provides an opportunity to establish basin and catchment specific requirements and targets for hydropower, such as the following:

- Environmental flows (EFlows) requirements (for example, releases to sustain ecosystem dynamics, seasonal releases to trigger fish migration, and irrigation releases)
- Limits on rapid fluctuation in power generation (ramping rates)
- Water quality targets such as dissolved oxygen levels and seasonal temperature ranges
- Sediment concentration limits or targets associated with coordinated sediment flushing and sluicing operations
- Limits on lake-level operating ranges (for example, to facilitate other water uses)
- Identification and protection of ecosystem, biodiversity, and wetland hotspots
- Identification of potential intact river routes for fish migration and other water uses

During the design of individual hydropower projects and cascades, harm can be avoided by adhering to design requirements defined within basin master plans. In addition, project-specific

mitigation measures related to such decisions as siting, dam height, reservoir operating rules, sediment flushing facilities, fish passages, powerhouse location, and transmission line routing can be incorporated into feasibility studies.

For operational projects, mitigation and management measures are generally defined through project specific ESIA, which are required also to address cumulative impacts. In relation to significant impacts identified in this CIA, key operation-phase management and mitigation measures may include catchment protection, water quality monitoring, sediment flushing, maintenance of fish passages, and adherence to agreed EFlows.

Individual project-level operational measures are vital but are unlikely to be sufficient. Experience shows that mitigation and management of cumulative impacts require coordination of hydropower operations, especially for cascade operations on the same stretch of river and for clusters of projects within a sub-basin. Sediment flushing, for example, calls for coordinated action among projects so that sediment can pass from one dam to the next; failure to coordinate could cause sediment to become trapped in downstream reservoirs and reduce generating capacity. In many cases, coordination among operators is also important for fish passage, EFlows, and river navigation. To meet the need for coordination among developers, a framework for the SRB hydropower co-management platform is suggested (Figure ES.7).

This would be a voluntary, company-led initiative coordinated closely with the Ministry of Energy and Mines that would have the following core functions:

- General communication among SRB hydropower operations, particularly within the same sub-basin
- Coordination of projects on specific questions of shared relevance (for example, sediment flushing, fish passages, and EFlows)
- Sharing of selected data sets (for example, hydrometeorology and water quality) to support operational decision making and power optimization
- Pooled funding arrangements for joint-management measures where appropriate (for example, watershed management and biodiversity offsets)
- Engagement with other SRB stakeholders consistent with requirements of integrated water resource management

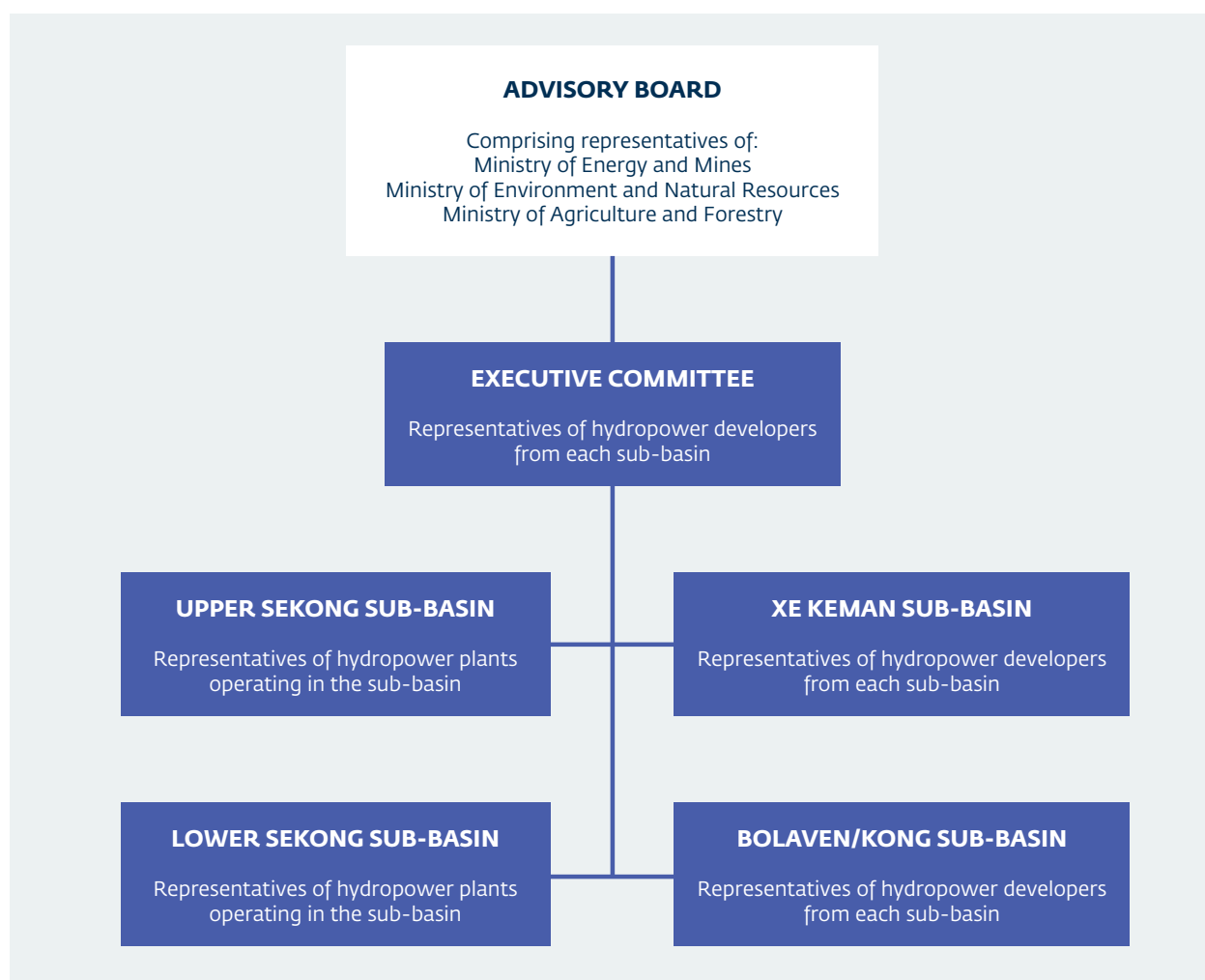
A basin-scale perspective also suggests that local authorities may benefit from new mechanisms to

communicate and coordinate at the basin scale across administrative boundaries. The SRB, for example, spans three provinces in Lao PDR, each with separate agencies responsible for sectors such as environment, energy, and forestry of direct relevance to environmental impact mitigation. It also has transboundary implications.

Where hydropower development is highly concentrated, as in the SRB, there are also opportunities to streamline local authority regulatory oversight. For example, rather than the current approach in Lao PDR of establishing project-specific resettlement and environmental management units, it might be more efficient to establish a unified management unit in each province with pooled funding from local hydropower operations.

Pooled contributions from projects operating within the same basin or sub-basin could also be used to support integrated programs of watershed management, environmental monitoring, and biodiversity offsets.

Figure ES.7: Proposed Structure for the Sekong Basin Co-Management Platform



CIA Recommendations and Conclusions

The Sekong Basin has undergone environmental and social changes in recent years because of hydropower, other infrastructure developments, and population growth. It is a dynamic situation even in the absence of further renewable energy development over the next decade. In 2010, the Sekong Basin had a virtually undisturbed river system with no barriers to fish migration and very little flow regulation. The Houay Ho Hydropower Plant (HPP) was the only hydropower project in the entire basin. Substantial hydropower development has taken place during the past decade, and several projects are under construction, including the Xe Pian–Xe Namnoy, Nam Kong 1, and Nam Kong 3.

The present situation can be summarized as follows:

- The Sekong mainstream provides a long distance of unrestricted river flow that makes it accessible to long-distance Mekong migratory fish.
- The Sekong mainstream has no reservoirs, which enables sediment transport downstream to the Sekong floodplain and further to the Mekong.
- Since the impoundment of the Lower Sesan 2 dam and reservoir in Cambodia, sediment transport has been interrupted from the other two rivers of the 3S basin (Sesan and Srepok), which no longer make significant contributions to the Mekong.
- Apart from the trans-catchment water transfer from the A Luoi dam to the Bo River in Vietnam, no hydropower dams or reservoirs affected the main Sekong River and its northern tributaries.
- Construction of four dams and a large reservoir providing seasonal regulation of the flows passing down the Xe Kaman has heavily altered the Xe Kaman tributary basin. This has also interrupted sediment flows, with only a reduced fine silt fraction passing downstream of the Xe Kaman–Sanxay Dam, although it is still possible for migrating fish from the Sekong and Mekong to reach the Xe Xou and Nam Pa tributaries, whereas construction of several dams in cascade has fragmented the Xe Kaman mainstream and Nam Kong River.
- The Xe Pian and Xe Nam Noy tributaries have had their flows radically altered and water transferred directly to the Sekong River through new power plants. Flows along the natural courses of these tributaries have been reduced substantially, perhaps most noticeably by reduced frequency and magnitude of floods because of the high regulating volume of the Xe Namnoy and Houay Ho reservoirs.⁴
- New roads have been constructed to the uppermost dam site, Nam Kong 3, and to the various dam sites along the Xe Kaman. Roads to the new dams and diversion dams on the Bolaven Plateau have opened access to its resources, but road access north along the main Sekong River remains difficult, especially in the wet season.
- The Houay Lamphan Gnai HPP is the only Sekong Basin power project providing power exclusively to the local grid. Most existing hydropower projects are export orientated. Transmission lines have been constructed from hydropower projects in the Xe Kaman and Nam Kong sub-basins to the Vietnam border. A 220-kilovolt (kV) transmission line runs from the Xe Pian–Xe Namnoy project to Thailand.
- Forests face multiple pressures, including hydropower, new roads, agriculture, and mining. Mining is concentrated in the Xe Kaman sub-basin (Map 3.6 in page 64), but exploration permits have been issued covering most of the basin, so mining may significantly affect land use change in the future.
- There are currently no wind or solar energy projects in the basin.

The three alternative development pathways assessed were:

- *Full development pathway*, with 23 additional projects operational by 2030
- *Conservative development pathway*, with 16 additional projects by 2030
- *Intermediate development pathway*, with 18 additional projects by 2030

These three pathways will have different degrees of environmental and social impacts and risks.

The full development pathway will have large impacts on certain VECs, especially fish, livelihoods that rely on river fisheries and

⁴ Houay Ho discharges directly to the Sekong River through a tunnel, altering the Sekong River flow some 25 to 30 kilometers further upstream.

agriculture, or are affected by resettlement. Bank and bed erosion may increase in alluvial parts of the river, and less variability in river levels and smaller loads of nutrient-rich silt will restrict vegetable horticulture. Harvests from floodplain fisheries will probably fall, with some years seeing no floodplain inundation at all. The full development pathway is likely to come at the cost of loss of unique, highly valued biodiversity. Social costs will be in the form of resettlement of several thousand people.

The conservative development pathway, which excludes the seven mainstream projects, will entail hydropower development on a smaller scale and at a slower pace but will still provide a significant boost to the local and national economy. Assessment of the conservative development pathway indicates few notable additional impacts from the present situation, especially with regard to the Sekong mainstream, although local impacts will be experienced in the tributaries.

The intermediate development pathway will have more impacts on some VECs, especially as a result of the development of Sekong 4B and 5. Overall, impacts will be less than under the full development pathway but greater than the conservative development pathway. Table 9.2 (page 125) synthesizes the cumulative impacts on VECs under alternative pathways.

The findings of this study indicate the need for a Sekong Basin power development master plan incorporating renewable energy (hydropower, solar, and wind) and thermal power. Private sector interests have largely directed past developments in the basin on a first-come, first-served basis. The government should establish the trajectory of future development based on a strategic assessment of local and regional power demand and with consideration of the range of potential uses of natural resources in the basin. This approach would result in greater investment efficiency, a close match between power production and demand, and more opportunities to address adverse impacts through the full range of options available in the mitigation hierarchy. A master plan would be consistent with the 2017 Electricity Law, which requires power development planning on a five-year cycle, and the 2017 Law on Water Resources, which requires basin planning.

Important considerations for a Sekong Basin power development plan include the following:

- *Power demand:* up-to-date, realistic domestic and regional demand forecasts taking into account power development plans of

neighboring countries, bilateral agreements (for example, memoranda of understanding), and a trend of rapid diversification of renewable energy solutions

- *Integrated water resources management:* incorporating integrated water resources management to ensure that needs and interests of multiple stakeholders in the basin are accommodated
- *Cumulative impacts:* environmental and social cumulative impacts as elaborated in this study
- *Avoidance by design:* reducing environmental and social impacts by modifying designs of particular projects (for example, Sekong 4A)
- *Trade-offs:* reaching a rational balance between economic benefits of power generation, adverse environmental and social impacts (particularly residual impacts and risks that cannot be fully mitigated), and opportunity costs of alternative natural resource uses foregone
- *Optimization:* achieving power generation enhancements and investment efficiencies by optimizing design and operating rules of hydropower cascades and in other circumstances where optimization benefits exist
- *Grid development:* shared transmission lines among power projects to reduce construction costs, improve grid efficiency, and reduce environmental and social impacts; co-funding by developers of transmission lines and cross-border interconnectors using this infrastructure
- *Integrating solar and wind:* identification of transmission grid and power supply and demand management improvements so that other renewable energy sources can be absorbed into the power system while maintaining balance

This master plan would provide parameters within which individual projects would be designed, assessed, and approved. Project proponents would need to integrate mitigation measures identified in the master plan into feasibility studies and environmental and social impact assessments.

This study has identified several opportunities for coordination and collaboration during the operation of renewable energy projects. A simple, practical co-management platform should be established to promote coordination among hydropower operations and to implement collaborative measures to mitigate cumulative impacts. Examples of opportunities for coordination among power developers in the

Sekong Basin include the following:

- *Coordinated environmental and social mitigation measures*: pooled funding and management arrangements for catchment protection, environmental offsets, and resettlement
- *Coordinated and joint operations*: information exchange and coordination among plant operators within the Sekong Basin, especially for dams in cascades on the same tributaries and within sub-basins to maintain EFlows and fish migration
- *Coordinated flood monitoring and warnings*: sharing hydrological data, collaborating on flood risk forecasting and preparedness, and establishing a warning system to notify local authorities and local communities of flood risks
- *Coordinated dam safety analyses*: cooperation of operators of cascading projects and pooling of resources to assess dam safety risks

Master planning and coordinated power operations will require that data and information gaps be addressed. Some priority areas for data, information, and analysis are summarized as follows:

Hydrological modeling

- Hydrological and meteorological monitoring data from existing hydropower projects should be collated and analyzed to enable precise calibration of the basin hydrological model developed for this study using satellite rainfall records.
- Meteorological and water gauging stations should be installed throughout the basin to provide a more complete set of measured data.
- Future climate change and hydrological models developed for the Sekong Basin should be made available to developers and government agencies responsible for planning, regulating, and monitoring hydropower development.

Sediment management

- The effectiveness of joint flushing and sluicing in cascades on the Sekong mainstream and tributaries should be further studied.
- Sediment load should be measured within the Sekong Basin to provide empirical data for design of effective flushing, sluicing, and other management options.

Hydropower operating rules

- Hydropower modeling of the type conducted for this study can be refined with additional information about the operating rules of individual dams, improving the accuracy of the model, and helping the effectiveness and benefits of joint operation of cascades in the tributary systems.

Fish passages

- More empirical data on the efficacy of fish passages in the Lower Mekong Region are needed. Data will soon become available from the Xayaboury HPP on the Mekong mainstream, which incorporates several fish pass design features.

EFlows

- A study to determine an appropriate EFlow regime for the entire Sekong Basin is needed.

The Sekong River Basin CIA highlights the key issues, management challenges, and trade-offs at a basin scale that are not captured through individual EIAs. It provides users opportunities to consider which pathway to develop to balance conservation and development as well as highlights the importance of the Sekong mainstream, the last free-flowing tributary in the Lower Mekong Basin.