Annex C

Prior Consultation for the Proposed Don Sahong Hydropower Project

TECHNICAL ASSESSMENT REPORT

Fish Passage and Fisheries Ecology

Based on submitted EIA Project Documents

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Preparation of this report

This report has been prepared following a preliminary screening of the DSHPP documentation provided by the Mekong River Commission to undertake the PNPCA on the proposed scheme. The report has involved no in depth discussion with the MRC, other sectors, stakeholders or the developers and represents only provisional assessment of key facts and information provided and may be subject to alteration and clarification.

This work was financed by the Mekong River Commission as part of the Prior Consultation process for the Don Sahong Hydropower Project. While every effort has been to ensure the veracity of the content and recommendations, the views are those of the authors. The authors cannot be held responsible for any interpretations of the content, not directly inferred by the text.

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1 BACKGROUND

1.1 Key fisheries issue at project site

The Khone Falls represents a keystone location in the Lower Mekong Basin as it acts as a natural partial obstruction to migratory fishes moving between spawning and nursery areas and feeding and refuge areas. While the Khone Falls has a series of channels that facilitate fish migration, these are not necessarily functional for fish passage at all times of the year. At present, **it is only the Hou Sahong channel that allows for year-round migration and is large enough to support migration of large numbers of fish and large fish species** (Baran et al. 2005). The Hou Sahong channel is thus critically important for basin-wide fish migration and the long-term sustainability of migratory fish stocks and species in the Lower Mekong Basin. In the above context, the submitted hydropower project on the Don Sahong channel has raised concern about the potential impact on fisheries both locally around the Hou Sahong channel/Khone Falls and in the LMB, and on the livelihoods of the many people dependent on fisheries through the basin.

1.2 Scope of this report

This report provides comments from the Fisheries Expert Group (FEG) on aspects related to Fish Passage and Fisheries Ecology (subsequently called "fisheries issues") based on a review of the EIA reports of the Fisheries Annexes C and D to the Environmental Impact Assessment (EIA) of the Don Sahong Hydropower Project (DSHPP) 2013, together with supplementary documents and presentations provided by the MRC submitted as part of the notification procedure. The FEG was provided with considerable supplementary information during the site visit and had fruitful discussion with the developers; this has been considered where specific issues have been raised. The review builds on the MRC's Draft Scoping Assessment of the Proposal for the preparation of the Don Sahong PNPCA Technical Review Report, the FEG Preliminary Assessment Report and utilises the PDG cross-check forms for fish passage (Annex 1).

The objectives of this report are

> To provide commentary about key issues to be addressed as part of the MRC's Prior Consultation assessment of fisheries issues related to DSHPP, and
>
> To propose areas that may need further detailed discussion and support information.

The review attempts to provide assessment of potential transboundary impacts, risks and consequences of the proposed DSHPP on fisheries, particularly migratory species that transcend the Khone Falls to complete their life cycles.

2 OVERVIEW OF DSHPP EIA DOCUMENTATION

The submitted documents as part of the PNPCA consultation process were reviewed in the context of understanding the potential impacts of the DSHPP on fish and fisheries in the region, together with evaluation of the proposed mitigation measures. The main documents formally submitted in relation to fish and fisheries were the EIA Annexes C and D.

The EIA Fisheries Annexes C and D are sectioned to provide the following information.

- Fisheries Annex C
    - Results and Interpretations from Field Monitoring Studies
    - Fish Migration Mitigation Measures
    - Proposed Channel Modifications to Provide Upstream Migration Pathways
    - Preliminary Details of Proposed Additional Fish Exclusion Measures
    - Fisheries Monitoring and Action Plan (FishMAP)
- Fisheries Annex D
    - Household Fish Catch Monitoring
    - Developments in the Fisheries Monitoring Programme
    - Channel Modification to Improve Fish Migration Pathways
    - Works to Minimise Project Impacts on Downstream Fish Migration
    - Alternate livelihood and fisheries management programs

In addition, a number of presentations referring to the 'fisheries issues' were provided. Finally during the site visit the FEG had fruitful discussion with the developers and was provided with considerable supplementary information. The latter documents were not consider to form part of the PNPCA as they were not passed through the formal consultation route. They were, however, considered where specific issues have been raised.

The submitted documents provide an overview of the proposed HP project design and modifications made to secondary channels to compensate for the lost fish migration pathway represented by the Hou Sahong channel.

The main empirical information provided on which to determine any likely impact, and therefore formulate mitigation measures, are from basic field monitoring studies, household catch surveys and larval drift studies. The reports, however, provide little baseline information on which to a make comprehensive evaluation of the impacts and measures to mitigate any likely impact. For example, the use of mean monthly catch data or household annual catch data prevent understanding of the temporal or spatial variability in the catches and thus the impact of DSHPP on environmental change. In addition, Annex D was expected to update the fisheries monitoring Action Plan [FishMAP] proposed in 2010 but offers little of the outputs of the survey programme between the two reporting periods.

The documents also provide a description of the justifications for and descriptions of mitigation measures, specifically provision of fish passage solutions given the most important migration pathway will be severely compromised by the scheme. These

descriptions are retrospectively assessing works already undertaken and justifying actions proposed and implemented, e.g. engineering of the Hou Sadam and Hou Xang Pheuak channels.

Many mitigation measures are proposed but no definite solutions are presented making it difficult to assess the likely effect of the project. This is true for upstream fish pass (no hydromorphological details are presented), fish-friendly turbines (no final solution with respect to type of turbine is proposed) and downstream fish passage (no solution developed). With respect to mitigation measures the project itself and the EIA is not complete.

The developers also suggest they will take an "adaptive approach" to fishery mitigation by continuing to conduct studies for a period of 10 years. Ongoing studies and ongoing improvement are essential aspects of project management, but this approach cannot be a surrogate for a fully–detailed mitigation strategy, which is required to assess the impacts and evaluate the effectiveness of the proposed mitigation. This is because:

- impacts are often not seen for many years after construction, especially considering that many large species in the Mekong are long-lived (>10 years) and iteroparous (do not die after spawning).
- and adaptive approaches are: poorly costed (in the Don Sahong EMMP 2013, Fish MAP has costed an average of $75,000 per year over 10 years for upstream passage, downstream drift, survival through turbines; and an unspecified sum for Optimisation of Fish Passage Mitigations); usually more expensive than anticipated; ownership of objectives and risk over time becomes diffuse; budget is often at annual risk (this risk can be mitigated by locking in a >10 year budget in the power station contract); hence, implementation of adaptive management is generally poor and financial resources fall away with time.

In summary, for any development on the Mekong mainstream there is a fundamental requirement to achieve the best possible design result before the Joint Committee would be fully enabled to arrive at an agreement that contains agreed upon conditions (PNPCA Art 5.4.3), and this is not the case for DSHPP. The present documentation and data made available do not allow for a robust, comprehensive evaluation of the impacts of DSHPP or the proposed fish passage solutions.

The EIA should be updated (or supplementary reports provided) to include the detailed fish migration pathway designs and research results on fish larvae drift and overall fish migration. In addition, further information on baseline conditions and migration behaviours should be provided. There is also a need to revisit the proposed mitigation measures, such as trap- and transport systems, turbine bypass screening and fish-friendly turbines, as these need to be examined in the context of Mekong fisheries.

3 FISH ECOLOGY AND FISHERIES

3.1 Fish biodiversity and migration

The Mekong fish communities are characterised by high diversity of fish species with many exhibiting complex life cycles that involve migration between different areas of the river, particularly upstream migration to spawning areas. The general understanding of migration patterns in the Mekong is that there are three main groupings: the lower zone below Khone Falls, the zone upstream from the falls to Vientiane and the third zone upstream of Vientiane (Figure 1). However, there are also a number of species that migrate between these zones, and some species (possibly as many as 30 and often commercially valuable

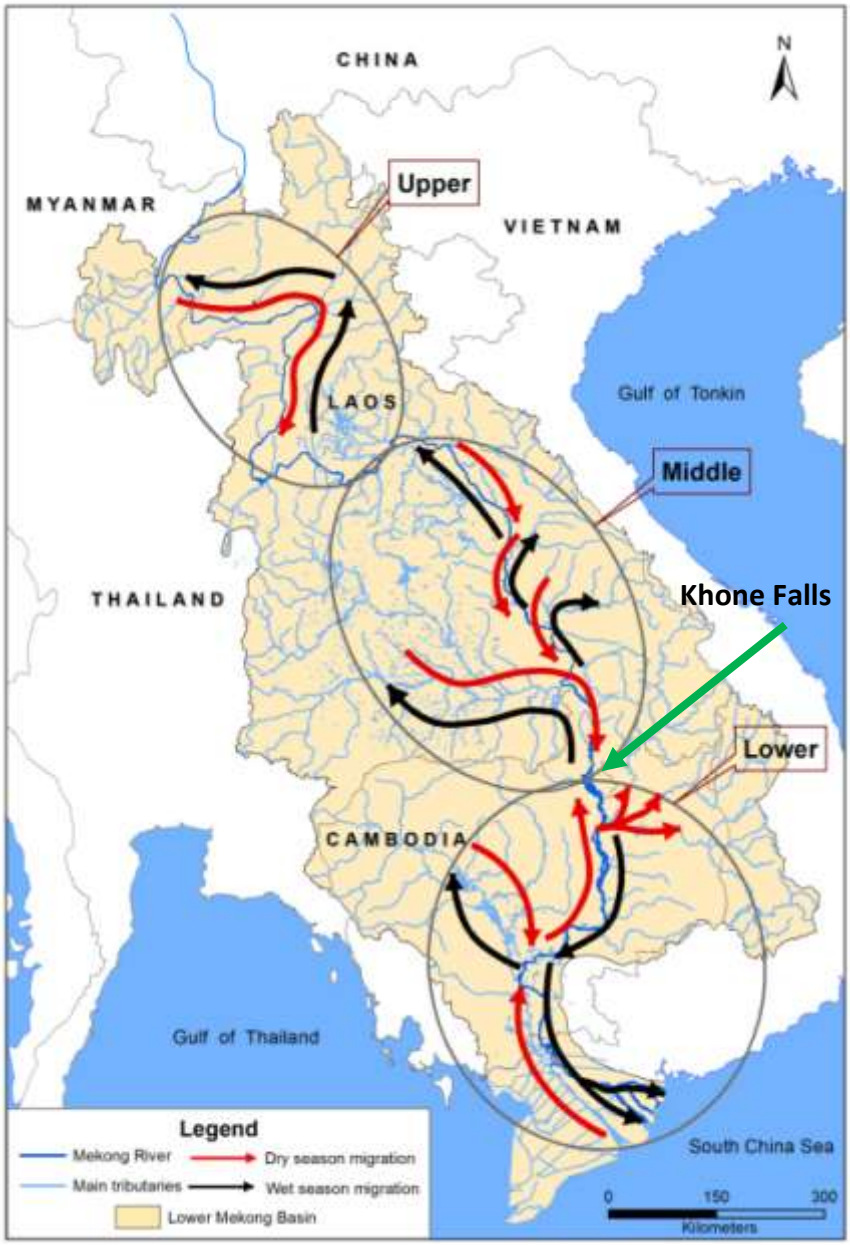

Figure 1. Map of migration systems in the Lower Mekong Basin (Source: Poulsen et al. 2002a)

white fishes) that migrate longer distances (Poulsen et al. 2002a). The generalized life-cycle and migration model (Figure 2) is applicable to many important riverine fish species of the LMB (Poulsen et al. 2004; Baird et al. 2003). As water levels on floodplains including the Tonle Sap system begin to fall, typically by mid–October, fish begin to migrate to refuge habitat including deep pools in the main channel. These migrations peak in January when catch rates in the dai fishery reach a maximum. As water levels begin to rise again in April, fish begin upstream migrations to spawning habitat in the main channel and tributaries. The lee trap fishery targets these upstream spawning migrations. Spawning typically occurs in June or July. Larvae and adults return (often drifting passively with the flow between June and September) to colonise downstream floodplain habitat where they feed and grow until water levels begin to fall again in October. Larvae drift between approximately 300 km and 600 km respectively from upstream locations, which includes the Khone Falls area (MRC 2013).

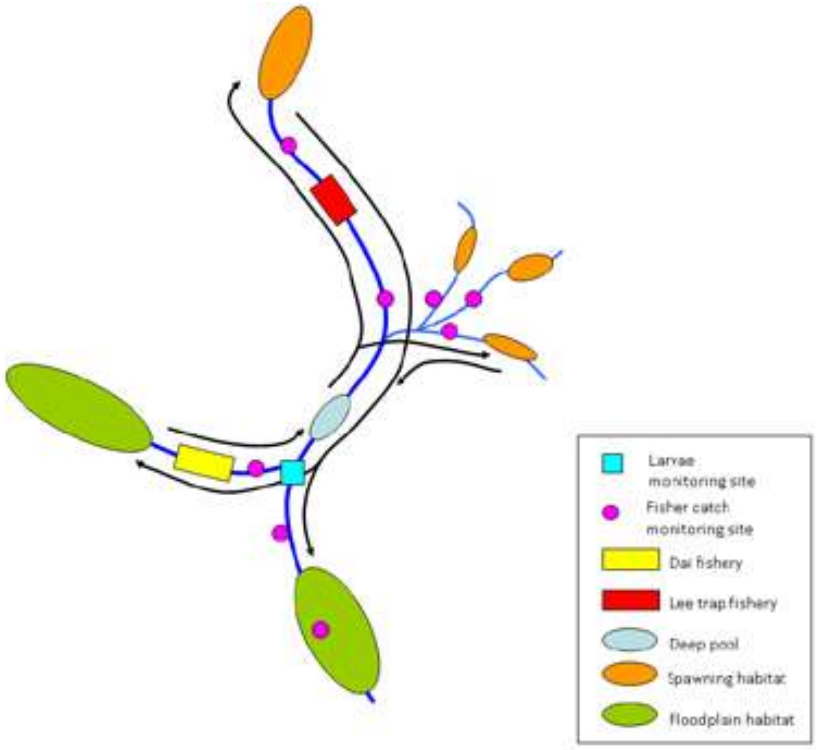

Figure 2. The generalized life-cycle and migration model for important whitefish species in the LMB (MRC 2013).

As an example, *Pangasius conchophilus* undertakes spawning migrations from the main channel in Cambodia from April arriving at upstream spawning sites in northern Lao PDR in May. Adults and juveniles may then return downstream to floodplain habitat in Cambodia to feed on young fish and molluscs in August. Refuge migrations to the main channel are likely to occur between December and January as waters recede from the floodplains (MRC 2013).

To complete these migrations requires unobstructed passage upstream, as well as the capacity for adults, larvae and juveniles to migrate or drift downstream. The timing of these upstream and downstream migrations is variable depending on fish life cycles, but importantly, there appears to be continuous spawning in the river with peaks, during the spring (February-March) as the most important, followed by the onset of the flood (June-July) and then when the water is receding (November). These spawning periods are

associated with continuous capture of larval and juvenile life stages in drift samples (although the main peaks were around the onset of the flood season) taken as part of the MRC Identification of spawning grounds in the LMB (RIS) project, and highlight the need to enable downstream drift throughout the year.

The DSHPP dam site and reservoir area are located in Zone 4 of the Mekong's Ecological Reach (MRC 2010) but also the transition between the middle and lower Mekong migration systems (Figure 1), immediately upstream and downstream of important fish spawning habitat and refuge areas for young of the year. It also has many deep pools that act as refuge for fish during the dry periods (Poulsen et al. 2002b; Baird 2006). This area is used by fish species that exhibit various migration patterns throughout the year, a major issue that is not fully considered in the EIA. Although the precise number of species in the region is unknown, 138 species have been recorded from the MRC's fisher catch monitoring near the Khone Falls (Baran et al. 2005). A complete inventory of the fish biodiversity and migratory behaviour of the key commercially exploited and conservation species in the region is lacking from the EIA.

The EIA recognises the need for downstream migration to complete the life cycle, but issues related to modified hydrology and disruption to the hydrodynamics of the various channels as a result of the dam design and channel modifications have been largely overlooked. In addition, flow velocity in the impoundment will be reduced from about 1m/s to 0.3 m/s within 2 km of the power station in the Hou Sahong channel and this will most probably cause disruption of the life cycles of many species and loss of recruitment to the fish stocks. The EIA needs to explore data from other reservoirs in the region to identify the species most likely to be affected by this problem and the impacts it has had in these systems.

Many of the abundant species caught in the lower floodplain reaches of the Mekong River system spawn around the beginning of the flood season. This behaviour has been strongly selected for in the monsoonal 'flood-pulse' environment. Flood-related spawning results in the fish larvae and fry growing at a favourable time, when the available aquatic habitat is expanding and zooplankton (the essential food for most fish larvae) is becoming abundant. Other species, however, migrate and spawn at other times of the year, but flood-related spawning is the dominant pattern in the LMB (see next paragraph). The situation at DSHPP is not well-understood, because the river at thispoint is transitional between the lowland floodplain systems of Cambodia and the delta and middle systems with numerous large tributary rivers in Thailand and Laos. Species found at this site may be resident, some may be tributary fishes that move into the Mekong during the dry season (as described by Taki, 1978) and some may migrate into this zone from elsewhere in the Mekong. Nevertheless, the larvae/fry study carried out by fisheries agencies (supported by the MRC) at 11 sites along the Mekong mainstream in 2009 found the highest abundance of fish larvae was associated with the start of the flood season – May - August.

MRC's fisher catch monitoring also shows daily catches near DSHPP over several years and indicate migration patterns for many species and that movements occur throughout the year and passage facilities should accommodate this diversity of species and behaviours. Consequently any mitigation or compensation action must account for this inter-seasonal variation.

The stretch between Pakse and Kratie is recognized as an area that contains a relatively high number of deep pools, and these deep pools are key habitats during the dry season for

Mekong fishes, in particular the white fishes, and some species also rely on the pools for spawning (Poulsen et al. 2002b; Baird 2006). If for any reason these habitats are inaccessible to these species the consequence will likely be that dry season survival of important commercial fishes will be reduced. The EIA does not consider this issue fully.

3.2 Fishery activities

Considerable fishing activity takes place in the impacted area, mainly based on the migratory fish species using an array of fishing gears such as lee traps, gill nets and range of other fish traps. These generally operate during the period of upstream migrations of many species that is associated with increasing water levels during the rainy season. However, these species are not the only ones captured; a wide diversity of finfish species is found in the markets, plus a range of amphibians, snails and Crustacea. It should be noted these latter groups are not considered in the EIA as an important source of food and livelihoods.

It is estimated that between 2.8 and 3.3 million tonnes of fish and aquatic products, with about one-fifth of this consumption comprising OAAs (Hortle, 2007; MRC, 2010), are caught in the river system in the fisheries zones adjacent to the DSHPP and it is highly likely this production will be compromised by the construction of DSHPP (estimated to be 15-16% according to the BDP), and more so if further dams are constructed in the region (Strung Treng and Sambor), especially as these will become a cascade of dam impoundments.

3.3 DSHPP Ecological studies

EIA studies have been conducted in relation to the DSHPP scheme but there are a number of issues about these studies, particularly in relation to the wider impacts around and beyond the Khone Falls that need to be explored.

- It appears the studies carried out were exclusive to the Hou Sahong, Hou Sadam and Hou Xang Pheuak channels. There is little information about the other 14 main channels despite them also being important migratory pathways, contributing to the hydrological profile of the ecosystem and the fisheries in the other channels contributing to the livelihoods of numerous persons. This is particularly important during the early part of the flooding cycle when the other channels are being filled and allow passage of fish. It is unsure how modifications to the channel morphology and diversion of flows into the three targeted channels has altered the other channels and the subsequent effects of fisheries and ecosystem functioning.
- Fisheries surveys in the EIA have been largely based on aggregated data of some selected fishers' daily catch at a few selected villages. The monitoring was only conducted at a limited number of local sites close to DSHPP. This needs to be expanded to the wider Khone Falls area and put into the transboundary context. There is a need to further develop migration models to place the DSHPP and associated risk in wider biogeographic context, and clarify fish passage objectives as well as monitoring objectives.
- Limited information about fish migration for specific species in the Hou Sahong channel along with the other 16 channels in the Khone Falls area; it is necessary to

study the individual species along with the proportion of each species that use each of the 17 channels in different seasons.

- Few outputs of independent studies on fish ecology or migration are reported despite the developers apparently investing considerable support in independent research. Specific issues include, but are not exclusive to:
- The biological data of the project relies on catches from fishers, which is not an independent scientific sample of migrating fish. It represents fish that are easiest to catch and valuable to sell. It is an interesting study and the basis for further work but not the basis for providing fish passage mitigation for a US$ 679 million dam (Eng. Report estimate).
- A large fish passage project such as this needs a biological baseline, including the species and sizes of fish: a) approaching the site, b) their behaviour at the site (e.g. division between channels; do they search multiple channels or remain in one), and c) passage through the site, including hydraulic conditions, at different times and flows.
- Apart from species and weight, which is partly reported, also need gonad condition, which would provide an insight into migration and the potential species with larval drift at the site.
- No methods or experimental design is presented to get these data. FishMAP (Annex A EMMP) suggests that monitoring of fisher catches will continue "combined with direct sampling of accumulation zones" but no detail is provided. The project requires a much more thorough approach, especially since fishing is now prohibited in the 3 target channels; this also presents a significant flaw in the study design as no baseline for other parts of the falls are available for comparison.
- No process is suggested for independent review of the monitoring data.

Larval fish surveys need reporting in full. There is a need to know:

- Change in species of larvae drifting, temporally (seasonal) and spatially (distribution in each of the channels).
- Whether larvae have inflated swim bladders, which is critical to assess impacts on pressure through turbines.
- Position of larvae in the water column. Epibenthic (near bottom) larvae have a far greater risk of mortality from pressure in turbines than surface–oriented larvae.
- Whether physoclistous larvae (swim bladder connected to the gut) have a functioning opening, which can occur in early life stages.
- Whether cyprinid species have larvae with swim bladders that have developed separate chambers. Note: cyprinid adults have swim bladders connected to the gut (physostomous) but the two-chambered swim bladder can hold gas and act as a physoclistous fish under pressure.
    - Fishmap states that 'peak larval drift downstream will be monitored". However, no data are presented to show that the peaks have been identified.

As for upstream migration, these peaks are likely to vary from year to year and regular monitoring may be required initially. Larval work is intensive – are the budgets of $50k pre- and during-construction sufficient?

- Monitoring of fish survival through turbines is proposed but the budget of $15k per year for 10 years seems poorly resourced considering these techniques are still being developed.

4 REVIEW OF FINDINGS OF FISH PASSAGE FACILITIES – IMPACTS AND MITIGATION

4.1 Introduction

The primary impact of the DSHPP on fisheries and fish passage would be the loss of the critical Hou Sahong fish migration route. This is well documented as a year round migration pathway for small and large fish, but particularly in the dry, early wet and late wet season, when flows are low. In the peak of the wet season there are numerous alternative migration pathways through Hou Xang Pheuak but the efficacy of these and the flows at which they enable fish passage are unknown.

The main options proposed by the developer to mitigate this risk are to: i) re-engineer the Hou Xang Pheuak and Hou Sadam channels to improve the hydraulics and increase their fish passage capacity, so they serve as alternative migration routes, ii) reduce fishing pressure through these two channels, and iii) trap and transport of large-bodied fish from below the dam to upstream; trapping would be from purpose-built traps below the dam and purchased fish from fisherman.

This section reviews these components and provides recommendations for future actions.

4.2 Options Analysis

The analysis of alternative high-level options for dam location, power generation and environmental impacts is very limited. Four alternative options are presented:

1. Thakho (Khone Phapheng), 172 MW capacity
2. Don Sahong, 260 MW capacity
3. Hou Xang Pheuak, 260 MW capacity?
4. Tad Somphamit, 56 MW capacity

The Thakho (Khone Phapheng) option is discarded due to impacts on flows over the falls but the Don Sahong option has the same impact. The EIA notes that the Thakho option has a potential impact on tourism caused by the "reduction in flow over Khone Phapheng [that] may affect views in the dry season" but states that DSHPP has "no impact to Khone Phapheng falls [and] project may improve tourism". These statements appear inconsistent and need further explanation by the developer, especially as they form part of the decision matrix that results in Hou Sahong as the preferred option.

Evaluation of the Thakho option fails to mention the economic and biological value of maintaining Hou Sahong for fish passage, which the EIA and various scientists agree is the most important pathway for migratory fish.

The Hou Xang Pheuak option is not examined in any detail. The EIA mentions "adverse impacts on fish passage" but, like the Thakho option, fails to mention the economic and biological value of maintaining Hou Sahong for fish passage. The Hou Xang Pheuak would be costlier in dam construction but no value is placed on maintaining Hou Sahong, so the cost-benefit analysis is absent.

Recommendations

Re-examine the Thakho and Hou Xang Pheuak options, incorporating the value of maintaining Hou Sahong for fish passage, including a cost benefit analysis of the various alternatives in relation to cost of channel modification and allocation of water for maintaining flows for fish passage throughout the year.

4.3 Hydrology and Hydraulics

4.3.1 Background

A fundamental part of any assessment is evaluating the hydrology and hydraulics of the river channels that are likely to be affected by the design and operation of the hydropower scheme. *Hydrology* uses various measures of discharge (e.g. m^3/s) and *hydraulics* concerns the physical characteristics of discharge such as velocity, depth and turbulence. The DSHPP EIA describes changes in hydrology of some major channels but not the changes in hydraulics. Significantly, it is hydraulics that fish respond to and use in swimming and negotiating channels. As a consequence of this disparity the impacts and proposed mitigation measures relate to flow dynamics:

4.3.2 Review of MRC Fisheries EG

The key issues identify were:

- Hydrological modelling (2009-2014) pre- and post-dam is coarse with only discharge in each of the four main channels. No information is provided on how changing flow scenarios in different seasons will change the hydraulics of the channels. Present Mike 11 modelling is focused on the inlet condition of the Hou Sahong channel and the channel itself. The western boundary of the model does not include the main western channel of the Hou Xang Pheuak inlet or any other channels west of this point. The 2D (Mike 11) modelling of Hou Sahong (Eng. Status Report) uses a 10 m by 10 m grid which is appropriate for discharge rating but is much too coarse for fish passage evaluation.
- The hydrology of all channels and effects on hydraulics are not assessed.
- The modelling concludes that there are inlet impacts at Hou Xang Pheuak and that lowering of the inlet sill is required. Presumably this affects channels to the east of Hou Xang Pheuak if the same discharge is passing at a lower headwater level.

The main **impacts** identified were:

- Flows in the headwater near Hou Sahong including four main channels have been modelled and show an increase in Hou Sahong flows and a decrease in Phapheng flows (Figure 3).
- At low Mekong flows the upstream levels of Hou Xang Pheuak, Hou Sahong and Hou Sadam will be relatively lower.

The **mitigation measures** to improve hydrology of the proposed bypass channels are:

- Minimum flow at Khone Phapheng of 800 m^3/s.

- The inlets of Hou Xang Pheuak and Hou Sadam would be deepened to pass low base flows during low Mekong flows.

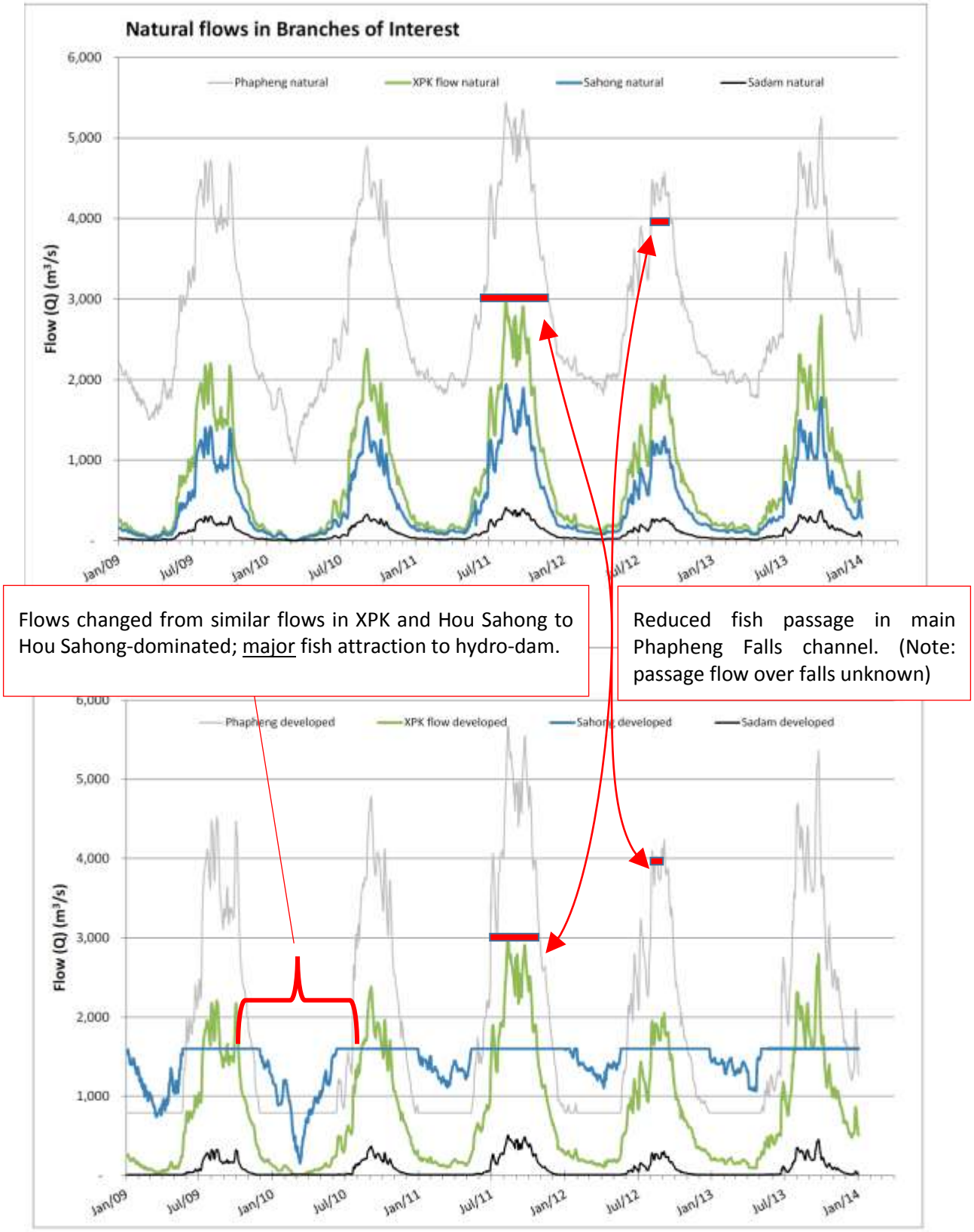

Figure 3. Comparison of flows in four channels showing the change at the junction of Hou Xang Pheuak and Hou Sahong, and the reduction in high flows in Hou Phapheng.

- The inlet of Hou Sahong would be deepened to enable high inflows to pass at low Mekong flows.

Recommendations

There is a need for comprehensive analysis of the flow regimes of each channel to understand how the hydrology and hydraulics will be altered by the project and thus the impact on fish and fisheries. Key information that needs to be provided include:

- Designs of the engineering aspects of the Hou Sahong Channel, including deepening of the channel and deepening of the mainstream in front of the Hou Sahong inlet to increase water flow (see engineering report 2011) to maintain power generation.
- Model hydrology of all channels to assess impacts.
- Need to consider all options to improve fish passage in the channels, including increasing discharge by deepening the inlets and channels. Presently only minor changes to channels are proposed.
- Undertake detailed hydraulic (1D, 2D, CFD) modelling of: Hou Sahong, to serve as a template for improving fish passage in other channels; and of Hou Xang Pheuak and Hou Sadam, to identify options for fish passage. This needs to be carried out at range of flows of all channels, but specifically the Hou Sahong, Hou Xang Pheuak and Hou Sadam channels before and after any modification.

4.4 Upstream migration and passage

4.4.1 Background - Principles of Fish Passage Design

Some major principles of fish passage design are outlined here to serve as background to the present review. In fishpass or fishway design, whether technical or nature-like, there are two essential functional criteria:

i. *attraction* (i.e. the fishpass entrance), and

ii. passage

These criteria are completely interdependent: if fish are not *attracted* to the fishpass or cannot locate it, they cannot use it; equally, if they can locate the fishpass but passage conditions are poor (shallow water or high water velocities beyond swimming capacity) fish also cannot use it.

Effective *attraction* is dependent on three characteristics:

i. Proportion of flow

The higher proportion of river flow in the fishway the greater the attraction for fish.

ii. Upstream limit of migration

Migrating fish swim upstream, usually attracted by the flow, to the limit of migration; this is where a fishway entrance needs to be located. The location of Lee

traps near natural migration barriers is an example of fishermen using this behaviour.

iii. *Discrete flow for fish to locate*

The flow from a fishway needs to be readily distinguishable to migrating fish and not masked by turbulence or competing flows.

Effective *passage* is dependent on knowledge of:

i. *Fish behaviour*

Fish behavior relates to *attraction* and *passage*. In *attraction*, it includes search patterns below a structure, response to turbulence, and response to different channel morphologies.

In *passage* an important aspect is the minimum depth that fish require; this is not a single figure but interacts with width (e.g. channel width) and longitudinal spacing of different depths (e.g. resting pools may need to be deeper). Other behavioural aspects include the response of fish to light and tunnels, and diel movement patterns, but these are not critical aspects in the present project.

ii. *Swimming ability*

In rivers, channels and fishways, fish negotiate water velocity and turbulence. In fish passage design these characteristics need to be within the burst, prolonged and sustained swimming ability of fish. These swimming modes utilise anaerobic and aerobic metabolism and they vary between sizes and species. There is also a behavioural element to consider where some species use boundary layers (layers of low water velocities adjacent to surfaces) more effectively than others.

4.4.2 Review of MRC Fisheries EG

The main option proposed by the developer to facilitate upstream migration is to re-engineer the Hou Xang Pheuak and Hou Sadam channels to improve the hydraulics and increase their fish passage capacity, so they serve as alternative migration routes. Deepening of the inlets of the neighbouring Hou Xang Pheuak and Hou Sadam channels is proposed to mitigate the loss of flow due to lowering of the river caused by the increase in flow through Hou Sahong. The EIA claims the new channels will be able to accommodate all sizes of fish. However, no evidence is provided.

The EIA claims that the conditions in Hou Sahong will be replicated in Hou Sadam and Hou Xang Pheuak but these channels are vastly different (Figure 4; Figure 5). Hou Sahong is a single channel, whereas Xang Pheuak has several channels and hence the flow is divided between these channels and the Hou Sadam is narrow and carries considerably less flow. The EIA also states that the two systems are similar in width but the surveys and Google Earth image suggest otherwise.

No upstream fishway is proposed on Don Sahong Dam, which would eliminate this channel for upstream migration (see below). There is a need to consider constructing a fishway at Don Sahong Dam as flows associated with this outfall will be the greatest attraction for fish as there will be flows up to 1600 m^3/s. Early dismissal (2007 EIA) of a fishway at the dam is unwarranted and based on experience of fishways designed for salmon that were used in neo-tropical streams in South America.

Further details regarding each channel is given below.

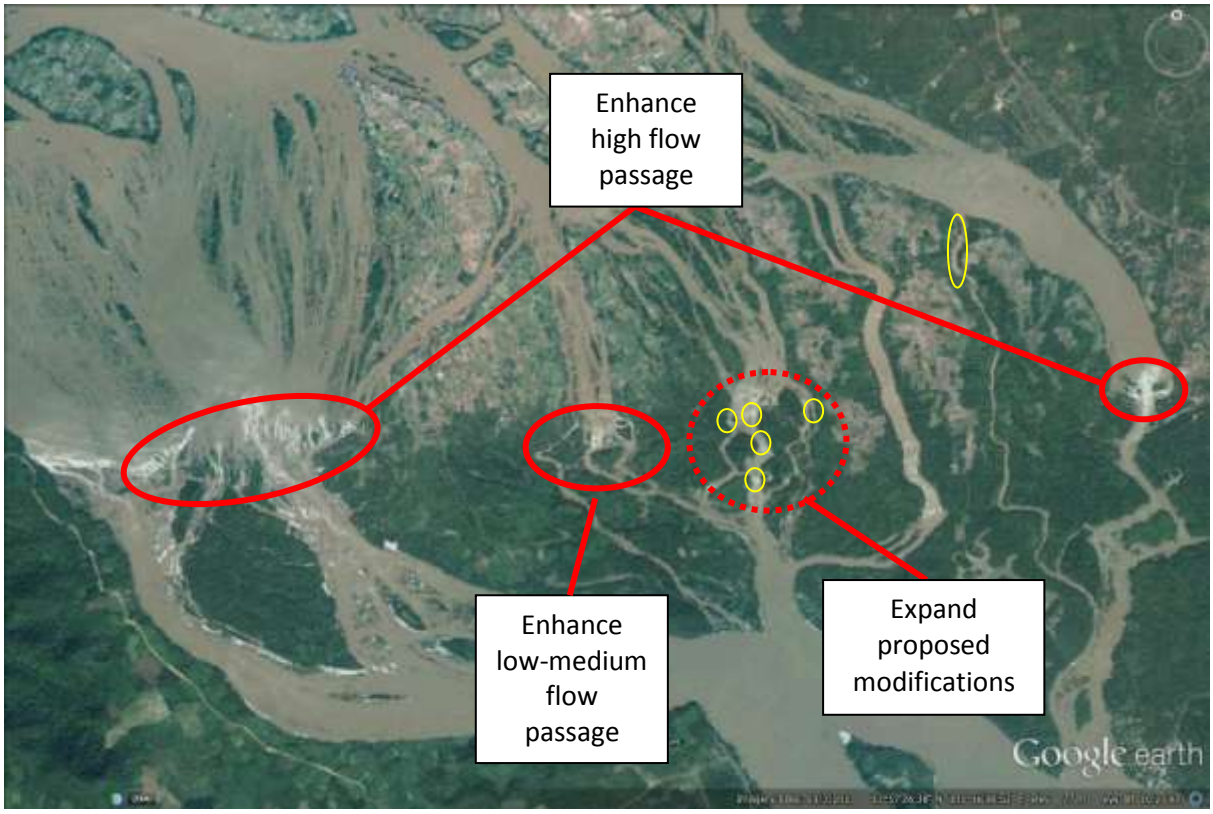

Figure 4. Options for expanding fish passage at Khone Falls to compensate for lost dry season and wet season fish passage in Hou Sahong. Yellow is existing and proposed by developer, red is recommended for investigation by EG.

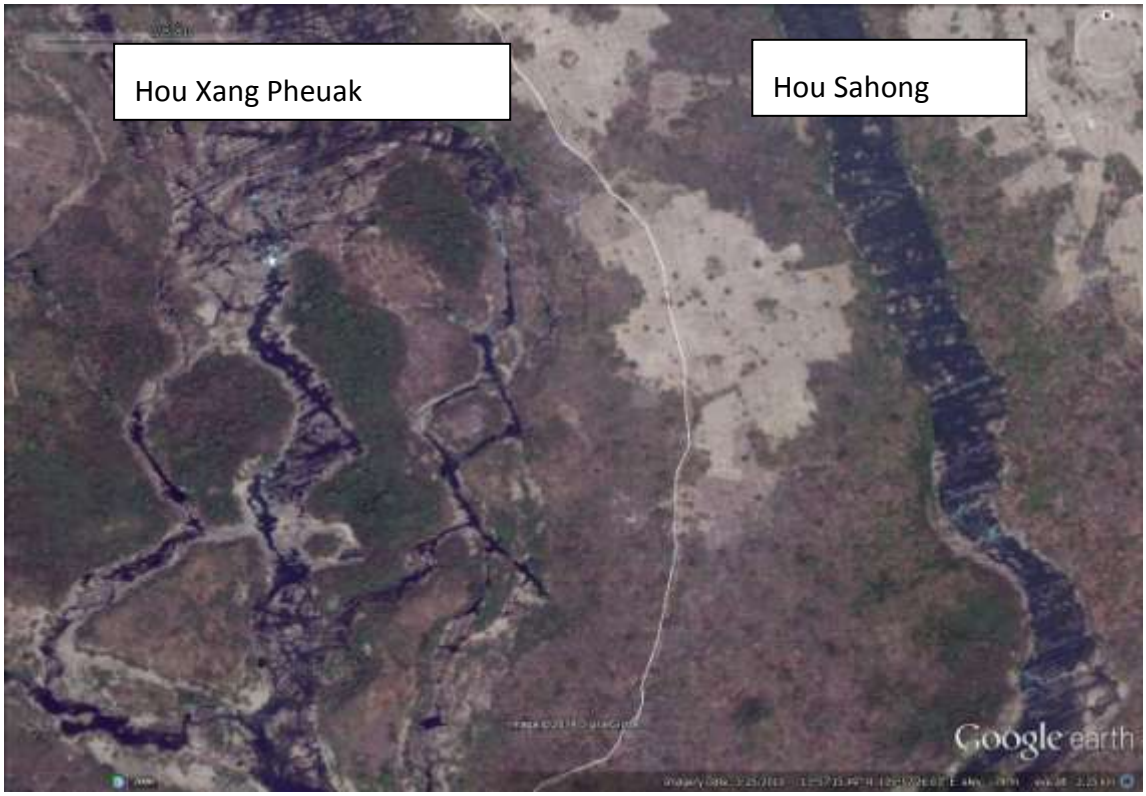

Figure 5. Comparison of Hou Sahong and Hou Xang Pheuak at low flows using Google Earth image.

Hou Xang Pheuak

Attraction

- The Hou Xang Pheuak fish pass entrance is 200 m downstream of the Don Sahong Dam which does not conform to modern standards of fishpass design (specifically locating the fishpass entrance at the *upstream limit of migration*), except when the fishpass has greater flow. Modelling in the EIA shows that Hou Xang Pheuak will have less flow than Don Sahong Dam for approximately 9 months of the year, from late wet, dry and early wet season (e.g. Nov to July) (Figure 3); in these periods fish will primarily be attracted to the dam – at the upstream limit of migration - and not Hou Xang Pheuak. The extent that fish move back downstream and try another route is likely to be species–specific but no data are presented by the proposal.
- A low rock wall is proposed to direct some flow from Hou Xang Pheuak toward the dam but this is still 200 m from the dam and no modelling is presented.
- Integrating flow from Hou Xang Pheuak and Don Sahong Dam is critical to the effectiveness of this proposed mitigation. Fish need to readily locate and enter Hou Xang Pheuak.
- Scale physical modelling of dams and fishway entrances in hydraulics laboratories is a common technique to investigate and optimise fish passage and need to be applied to the present project. The present dam is located to minimize cost, which is appropriate; the next step is to integrate the dam with fish attraction to Hou Xang Pheuak.

Passage

- Modification of "choke" points (small water falls) in the channels are proposed to improve passage of fish past the dam but, apart from photographs, no hydrological, hydraulic or biological data are presented. An EIA needs to provide an assessment of the impacts and a description of the mitigation measures so these can be evaluated. Given the fundamental issues associated with fish migration, and the major implications locally and regionally, these measures need to be detailed.
- The design philosophy is to mimic hydraulic characteristics of the Hou Sahong channel but these are not documented, and the channel is fundamentally different (Figure 5) and questions remain about whether the fish will find the entrance or pass through the channel year round.
- Scale of proposed modifications in Hou Xang Pheuak is small for the channel system, and small for the whole Khone Falls site, considering it needs to compensate for the loss of Hou Sahong. Fish passage across the whole site needs to be considered, including expanding the proposed work in Hou Xang Pheuak to include all channels and not only choke points in those channels, as well high flow passage routes at Lee Pee and Khone Phapheng (Figure 4).

Hou Sadam

Attraction

- The outlet of the channel is 2.5 km downstream of Khone Phapheng and the flow is approximately 5% of the main Phapheng channel.
- The location of Hou Sadam is remote from the Don Sahong channel and fishes attracted to the outfall of the hydropower development are unlikely to find Hou Sadam especially under low flow conditions.
- The outlet enters the river among ban shrubbery and trees and during medium to high flows is not an obvious alternative entrance and thus route for migrating fish.
- Attraction to enter Hou Sadam is very low and, while acknowledging that fish enter the channel and have been captured in the past, only a small proportion of fish would use this channel.

Passage

- The channel is very narrow (e.g. 35 m) compared to Hou Sahong (e.g. 150 m) and possibly shallow (but no depth data provided); hence, passage of large fish could be very restricted.
- The gradient is consistently low with no small waterfalls. The developer has cleared debris, fish traps, and excavated minor modifications to the bedrock near the inlet. It has improved flow and presumably fish passage through the channel, but it is fundamentally limited by the narrow channel morphology.
- Hydraulics and fish passage poorly documented (photos only) before and after modifications.
- There appears to be a fundamental problem of sediment loading. The channel will require continual maintenance because the channel is prone to deposition and blocking.

Khone Phapheng

- Fish migration at Khone Phapheng is not recognised or discussed in the EIA. The EIA notes that "the Don Sahong project . . . will not reduce the maximum flow over the Khone Phapheng falls" (p. 4-5). However, pages 5-29 and 5-30 shows that Don Sahong will affect minimum, mean and maximum flows of Phapheng in every month; and will likely be the largest hydrological impact of the project.
- The DSHPP increases flow through Hou Sahong causing less flow through Khone Phapheng, which may impact tailwater levels, drown-out out levels and hydraulic behaviour at the falls. This could affect the hydraulic conditions under which fish are able to migrate and reduce the time window for migration.
- Khone Phapheng has fish traps at a very high elevation, close to the upstream level, indicating that fish are migrating at high flows and likely able to pass the falls through side channels. This observation is contrary to the perception that fish cannot pass through the Khone Phapheng channel and therefore needs thorough investigation into the flow requirements to maintain channel passage.

4.4.3 Recommendations

To mitigate the loss of passage in Hou Sahong it is recommended that the scope of upstream passage be expanded to more sites and channels to provide for high flow and low flow passage (see below). The technical scope also needs to be expanded and it is recommended that fish passage experts are engaged to guide the final design of fish passage for upstream and downstream.

Flow management is an integral part of mitigating impacts on fish passage. Increasing the volume of water diverted into the alternative fish passage channels is likely to increase their capacity to allow for fish passage; hence, the operation of the DSHPP to increase the flows down these channels should be considered (see below). However, ensuring sufficient flow through the turbines over the annual cycle is central to the economic viability of the scheme. The more water that is required to ensure effective upstream fish passage, the less is available for hydropower production. Investigation into an appropriate balance would provide a useful surrogate measure for evaluating whether all reasonable efforts have been taken to *avoid, minimize and mitigate impacts on the environment* ('95 Mekong Agreement – Article 7). Other useful surrogate measures include describing the hydraulics (depth, velocity) of channels where fish passage presently occurs and using these parameters to measure whether "all reasonable efforts" have been taken in the modified channels. Ultimately, measuring the proportion of fish that actually approach, pass through and exit the modified channels provides a direct measure of the effectiveness and whether impacts on the environment have been mitigated.

Hou Xang Pheuak

<u>Attraction</u>

- If Hou Xang Pheuak is considered a viable alternative fish passage to Hou Sahong, the attraction flow needs to be beside the base of the dam, either through modifications to the river channel (given the topography this seems unlikely) or by changing the location of the dam to optimise fish location, although it is recognised that this location may not be viable from the engineering perspective.
- If the project proceeds, a physical scale model of the dam, lower Hou Xang Pheuak channel and tailwater conditions at the confluence, is a necessity to ensure fish attraction and the effectiveness of the proposed mitigation. The modelling will determine the dam location and orientation; hence, for detailed design it is on the critical path of project management.

<u>Passage</u>

- Need to consider all options to compensate for lost dry season and wet season fish passage in Hou Sahong, including: fish passage in all channels; high flow passage routes (e.g. Khone Phapheng) (Figure 4), increasing discharge by deepening the inlets and channels. Presently there are only minor changes to a few channels proposed.
- Needs detailed hydraulic modelling (including ADCP field data, current meter data, and 3D CFD modelling) at minimum and a range of flows of all channels, especially the Hou Sahong, Hou Xang Pheuak and Hou Sadam channels before and after any modification.

Hou Sadam

- Attraction to the Hou Sadam channel is considered poor and cannot be improved. The channel is also considered limited in capacity in terms of biomass and fish size that can pass. This channel can only be considered an adjunct and not a main mitigation channel.
- The channel also appears to be subject to sediment deposition problems such that ongoing maintenance of sediment is probably required. The cause of this heavy sediment loading should be investigated to find a long term solution.
- The location of the downstream channel entrance is remote from the Don Sahong channel and assumes that fish randomly migrate upstream and thus a proportion will find this route. This is not the case and evidence suggests that fish, especially long-lived species that migrate multiple times seek out the same optimal route. These long-lived migratory species have excellent navigation skills and memory, with the ability to return to exactly the same home site (i.e. high site fidelity), following the same migration paths (O'Connor *et al.* 2005; Koehn *et al.* 2009).

Khone Phapheng

- Investigate impacts of increasing Hou Sahong flows on hydraulics at Khone Phapheng.
- Investigate improving fish passage at high flows at Khone Phapheng, partly as a holistic view of fish passage compensation for the entire Khone Falls site and potentially to compensate for lost passage at this site if the hydraulic analysis reveals impacts.

4.5 Downstream migration

4.5.1 Review of MRC Fisheries EG

The evaluation of downstream passage (adults and juvenile life stages) and the likely impacts on fisheries has not been thoroughly investigated or reported. There are a number of fundamental issues that need addressing.

Downstream migration would be affected by passage through the turbines, which can injure and kill fish, and the change in hydrology between the different channels, which changes the hydraulics (depth, water velocity, tubulence). Downstream passage of fish through the turbines is a significant issue as up to 50% of Mekong flow passes through Don Sahong in dry season and 7% in the wet season (Figure 6).

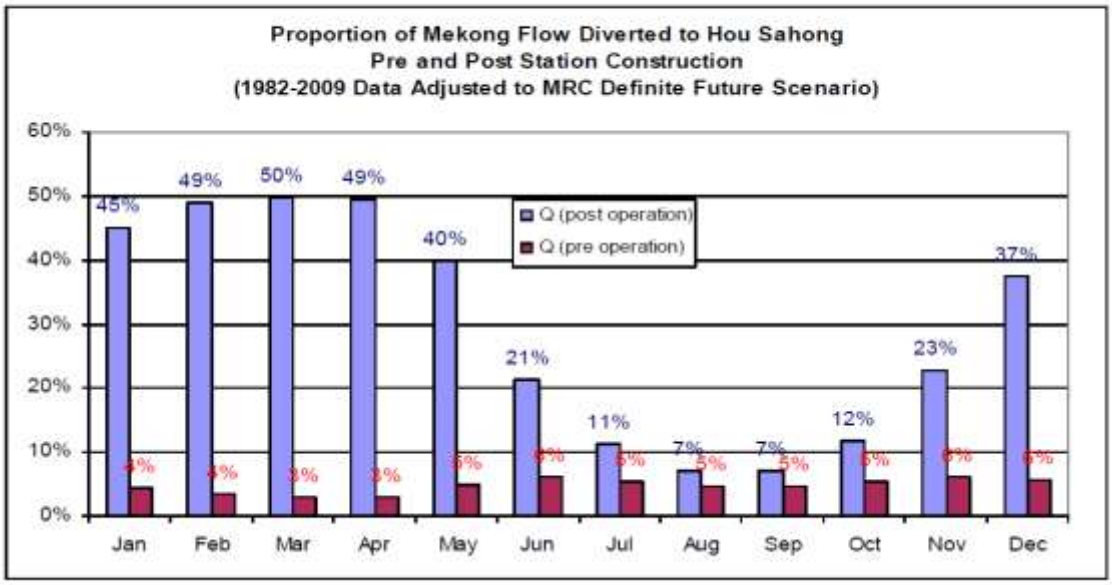

Figure 6. Proportion of Mekong flow passing through Hou Sahong pre- and post-operation.

There is an assumption in the developer's documentation that modern bulb turbine design is fish-friendly and therefore fish and larval survival is unlikely to be an issue. Specifications of fish-friendly turbines, including performance standards, need to be specifically included in the design to justify this assumption, and the impact thereof on the fisheries recruitment determined.

Fish can be injured and die from three main factors in turbines:

- blade strike,
- pressure changes, and
- shear.

Despite the engineering report describing the three major impacts on fish passing through turbines, the EIA only reports on a blade strike model. The model is completely dependent on the size range of fish approaching the turbines, of which there is no independent data, only fish catch data. Blade strike needs to be divided by sizes; what is the probability of blade strike of high-value, large bodied fishes (1-3m)? Additional criteria besides number blades and rotation speed have to be included in mortality assessments: blade thickness, blade shape, velocity during passage, turbine diameter, minimal and maximal pressure and pressure change ratio.

The Engineering Report states that salmonid juveniles have an expected mortality of 5% in turbines with a similar pressure regime (Abernathy *et al.* 2003) to the turbines proposed for Don Sahong. The Engineering Report acknowledges that there are no data for Mekong species but the EIA simplifies the report to "this analysis suggests that there is a reasonable likelihood [of] 95% safe passage". The Engineering Report, however, fails to report specifically on the 26 to 44% injury rate of two non-salmonid species tested in the same study (Abernathy *et al.* 2003), instead reporting that the pressure regime of bulb turbines was "minimally harmful" to one of these species (Eng Report p.150) and overall "the

conditions present at Don Sahong [turbines] will be relatively benign" for fish compared to other hydro dams.

Sudden changes in pressure in turbines affect fish species differently, depending on whether the swim bladder is open and connected to the gut (physostomous) – which can equalize rapidly by "burping" – or enclosed (physoclistous), which cannot equalise rapidly. In Cyprinids the swim bladder is open but has two separate chambers so they also do not equalise rapidly.

Mekong fish are diverse with both open, closed and chambered swim bladders. Salmon have an open swim bladder so present data on effects of pressure on these fish provide an indication only of that group of fishes.

Mortality of fish species with closed and chambered swim bladders can be high. Up to 20% of one species of freshwater fish (*Macquaria ambigua*, Percichthyidae, 415-496 mm) with a closed swim bladder died after subjected to pressure changes equivalent of 20 m to atmospheric (Hall *et al.* 2014), very similar to changes experienced in a dam the height of Don Sahong. In other recent work on non-salmonids (Boys *et al.* 2014) one species of larvae with a closed swim bladder had 50% mortality while another had less than 10%, when subjected to typical turbine pressure changes (exposure/acclimation pressure ratio = 0.4). In juvenile fish subjected to the same pressures, swim bladder rupture varied from zero in one species to 50% in another two species, including common carp *Cyprinus carpio* (Boys *et al.* 2013; Boys *et al.* 2014)

These results strongly suggest that turbine mortality in the EIA is significantly underestimated. Estimates need to include blade strike, shear and pressure.

The acclimation pressure of fish, both adults and larvae, strongly influences the rate of injures due to pressure in turbines. Benthic species have a much greater risk than surface-oriented species. These aspects of ecology and physiology are not presently discussed in the EIA but would have a significant influence on estimates of mortality and injury in turbines.

The DSHPP would take 50% to 7% of Mekong flow but this does not necessarily reflect the proportion or species that will enter the Hou Sahong channel.

As stated earlier, long-lived migratory species have excellent navigation skills and memory, with the ability to follow the same migration paths. At Khone Falls there is an obvious advantage for downstream-migrating fish to avoid Khone Phapheng, which would cause high mortality of large fish, and use a channel that has provided safe upstream and downstream passage for many years. It is very likely that long-lived fish migrating downstream will enter the Hou Sahong channel until a new long-term route is established. Hence, the proportion of these fish entering the Hou Sahong channel is very likely to be much higher than the proportion of flow.

Large fish have higher mortalities in turbines so the option of fish screening is highly recommended and, if the project proceeds, should be explored immediately. Screens were also recommended by the independent reviewer Poyry in the engineering report.

The proportion of larvae entering DSHPP may also not directly relate to the proportion of flow. Larvae are not entirely passive drifting particles in a river that are uniformly distributed. Drifting larvae are often more common on the edges than in the stream middle (De Graaf *et al.* 1999; Reichard *et al.* 2004) which suggests that the inlet of Hou Sahong,

which is on the edge of the main channel, is likely to collect more larvae that the proportion of flow.

Larval drift studies have not been reported in the EIA and need to include the state of development of the swim bladder. The risk of damage to fish larvae that have a closed swim bladder increases with age. Very young larvae initially have the swim bladder open which then closes after initial inflation; once closed, these fish are more susceptible to injury from pressure changes in turbines.

The dam does not have a large reservoir of static water which would trap drifting larvae. However, water velocities drop from 1m/s to 0.3 m/s within 2 km of the power station in the Hou Sahong channel, which may cause larvae and fry to settle out (fall to the bottom). Further investigation is recommended and a mitigation strategy needs to be developed and included in FishMap. This is particularly pertinent during the dry season (in March) when up to 50% of the total flow will be diverted through the Don Sahong channel. This would have to be offset against the relative importance of larval drift and the species involved in that period.

The adaptive management approach to screening – that is, include screens if monitoring shows an impact – could be very costly in construction and loss of power generation. Foundations and footings for the screens would require dewatering of the Hou Sahong channel with no flow to the power station. Dewatering and remobilisation adds considerable cost after dam construction is complete. The channel would be dewatered for dam construction and it would be much more cost effective to install screens at the same time.

4.5.2 Recommendations

The blade strike model is inadequate for an estimate of mortality, without a model for pressure and shear. Further work is needed on total mortality of Mekong fish through turbines, especially due to pressure changes, to assess the potential risk for downstream fish passage.

Bulb turbines, rather than Kaplan turbines, have been chosen because of greater power efficiency and lower cost. Bulb turbines may have less fish mortality due to slightly less pressure change, but this has not been proven for salmonids or Mekong fish; significantly, carp species (cyprinids), which form a major proportion of the migratory fish species, appear sensitive to these pressure changes.

Final choice of bulb turbines is not given in the EIA but slower rotation speeds and less blades should be prioritised, are these are characteristics that reduce fish mortality. Also the turbine comparison in the EIA and engineering report does not include the Voith Alden turbine which may have superior characteristics for passing fish.

A diversion screen for fish would be provided if monitoring shows the 95% target is not met. This is not considered appropriate and a full evaluation of fish screening options is highly recommended if the project proceeds. The diversion screen, if applied, would be in the upper channel and not near the dam. Screens need to be fully costed and a provisional estimate needs to be part of the project.

Other mitigation strategies need to be developed for turbine mortality. For example, switching the power station off during peaks periods of larval drift; installing and engaging a small spillway gate adjacent to the power station to pass downstream migrants; and operating the power station below peak capacity to reduce pressure differentials in turbines.

Testing of downstream drift and settlement is required to determine if fish will settle in the low velocity in the power station impoundment and if a problem is detected a mitigation strategy (e.g. dewater channel to pass fish downstream) needs to be developed.

4.6 Fish passage during construction

4.6.1 Review of MRC Fisheries EG

Impacts during the construction phase concern environmental degradation, disruption of fish migration and loss of fish production. Impacts during the operational phase are equally important and encompassed in the impacts of the dam itself in terms of barriers to fish migration and mortality through turbines, together with superficial commentary on loss of biodiversity and fish production. These impacts arise from a number of sources:

During construction, the Hou Sahong channel will be blocked by coffer dams at the upstream and downstream ends which will be the first time for thousands of years (probably much more) that this migration pathway has been blocked. Once the Hou Sahong channel is blocked the flow will naturally redistribute to other channels.

The developer proposes to improve fish passage through Hou Xang Pheuak before blocking Hou Sahong, which has a sound logic. However, as stated earlier no details of channel modifications are provided and the scope of modifications appears very narrow.

Construction inevitably increases sediment loading and pollution (e.g. oil leakages) in the downstream reaches and these clog gills of fish and invertebrates (food of fish) leading to increased mortality and reduced growth rates.

Most of the Mekong fishes are substrate spawners (either lithophils or phytophils), therefore, sediment and silt in the water can bury and harm fish eggs. It is unlikely (as mentioned in the EIA Page 5-12) that there will be no significant change on spawning activities of fish.

Primary producers become less abundant in the impacted area because of the higher turbidity and siltation from the earth works. This will not only affect the low trophic level fauna but eventually the whole ecosystem. Thus there is likely to be considerable impact on plankton and benthic fauna that will cascade to higher trophic levels and eventually fish productivity.

4.6.2 Proposed Mitigation

The main mitigation measure proposed for maintaining fish migration is to develop the Hou Xang Pheuak channel for fish passage before the Hou Sahong is blocked. Hou Sadam would also provide fish passage but, as stated above, it is a minor channel with limited capacity.

4.6.3 Recommendations

- A broader mitigation strategy for the loss of Hou Sahong needs to be developed and this needs to be fully implemented before Hou Sahong is blocked.
- Stronger provisions need to be made in the design proposal to mitigate the issues highlighted above, including timing of the construction and commissioning of the fish passage facilities to overcome any potential problems arising. The developers should also stage earthworks and implement appropriate measures to minimise erosion.
- Part of fully implementing a fish passage mitigation strategy is monitoring, to ensure it is fully functional before Hou Sahong is blocked. The programme schedule needs to include monitoring of alternative fish passage channels before Hou Sahong is blocked.

4.7 Trap and transport

One of the mitigation measures proposed for DSHPP is trap and transport for large sized fishes. This proposed trap and transport measure lacks detail, apart from purchasing fish from fisherman and using large mesh traps at the base of the dam.

The concept is poorly formulated. Details are needed on how will fish be caught and the ethical and logistical practicalities. There will be a range of large fish sizes, passing in all seasons and all diel periods.

Critically, there are likely to be negative effects of handling large pre-spawning fishes. Lifting large fish out of water can cause stress, haemorrhaging, broken ribs, and mortality after release. These fish may not spawn once handled or will migrate back downstream after the stress of capture. Immediate release by fisherman, minimizing handling, has some merit but not transport of fish upstream of the dam.

Passage of large-bodied fish would be better accommodated by volitional (technical solution) fish passage. If Hou Xang Pheuak is the proposed alternative migration route for large-bodied fish then this reaffirms that the hydraulics of Hou Sahong need to be replicated in Hou Xang Pheuak for volitional passage.

Note that the standard for trap-and-transport to minimise stress and mortality in fish is water-to-water transfer. This requires a hopper of water and significant infrastructure to lift the hopper with the weight of water. The same infrastructure is used in a fish lift.

Using traps below the dam and using fishers to capture and transport large-bodied fish will very likely to lead to higher mortality of these fish. It is recommended that this option should not proceed.

5 SOCIO-ECONOMIC ISSUES

5.1 Importance of fisheries resources

Fisheries resources (i.e. fish, other aquatic animals, and useful aquatic plants) have long been central to the lifestyles of four riparian countries of the Lower Mekong Basin (LMB), particularly to communities living in and around the corridor 15 km either side of the river and its dependent floodplains. Some 40 million people or about two-third of the LMB population are involved in the Mekong's fisheries at least part-time or seasonally. In Lao PDR, more than 70% of rural households are dependent on fishing and collecting other aquatic animals (OAAS) and useful aquatic plants (UAPs) to varying degrees for subsistence livelihoods and additional cash income. Similarlym Cambodian fish consumption is 54-63kg/person/year, the second largest dietary component at about 18% of the total food intake but importantly providing 76%-81.5% of Cambodian animal protein intake. The economic value of freshwater fish and aquatic products is estimated at 1billion $US ($1.6/kg), exclusive of multipliers. Consequently any risks and losses incurred by the Mekong terrestrial and aquatic ecosystems brought about by dam developments translate into threats to the livelihoods of millions of people – primarily through increasing food insecurity in the basin.

Unfortunately, there is limited information on the socio-economic dimensions of the dam proposal in the impacted region, including the importance of the fishery to food security and rural livelihoods, number of people affected and loss of ecosystem services to rural communities. In particular the DSHPP EIA reports provide only limited baseline and impact information on socioeconomic conditions of people living in the mainstream hydropower project-affected areas and did not provide any information and data on water resources related livelihoods, food security and nutrition. Furthermore, and critically, trans-boundary baseline and impact information on socioeconomics and livelihoods were given little attention in the EIA report. This prevents a realistic assessment and formulation of (1) effective mitigation measures, (2) a practical and scientific standardized monitoring programme, and (3) an environment management plan to minimize negative impacts and gain positive impacts from the DSHPP development.

5.2 Recommendations

There is a need for a detailed baseline study on the socio-economic impacts both in the immediate DSHPP reach and any trans-boundary areas likely to be impacted by the development. This is fundamental because the information will support the design of alternative livelihoods options. Fundamental components include:

- Tourism, which is likely to be a major future source of local cash income and a possible alternative livelihood for displaced fishers.
- Assessment of the impact of reduced dry season flows over the Khone Phapheng Falls on tourism.
- Two aspects make waterfalls attractive to tourists: height and discharge. The greatest hydrological impact of the project is decreasing discharge through Khone Phapheng, due to increasing discharge through Hou Sahong. The minimum discharge

for the falls in the 2007 EIA was set at 1000 m^3/s, which is the present natural minimum that occurs only briefly. In the 2013 EIA this was reduced to a minimum of 800 m^3/s, which corresponds to the lowest water level recorded at the falls between 1923 and 2011. Both flows, if sustained for much longer periods than is currently the case may result in are a major reduction in the tourism amenity of the falls. The Project has a visual representation of the Don Sahong Dam but not one of the falls at 800m^3/s. Tourist operators need to be consulted on the visual and economic impact of reduced flow for long periods, as modelled. Similarly, options to increase the tourism amenity of the falls through improved on site access could also be explored.

There is also a need for an Ecological/Social Risk Assessment which identifies not only the *likelihood* and *consequence*, but also the *ease and cost of mitigation*. For example:

- What are the risks and likelihood of only a low proportion of fish locating the entrance of the improved Hou Sadam and Hou Xang Pheuak channels?
- What are the risks and likelihood of not passing a fish guild upstream?
- What are the risks of turbines impacting adult fish? This risk is recognised and the intent of the developer is to monitor and install screens if needed. However, assessment and monitoring methods have no detail and there are no details of the scope of the screening solution which could be 5 times the FishMAP budget of $5 mil. This is a financial risk for the project as well as a biological and social risk.
- What are the risks of turbines impacting juvenile fish and larvae, which cannot be screened? What is the mitigation?

This should include information and data on socioeconomics and water resources-related livelihoods of people living within a corridor of 15 km either side of the Mekong River and its dependent tributaries and Siphandone Wetlands floodplains in Lao PDR (particularly the southern Champassak Province), Thailand (particularly the major tributaries in Thailand such as Pak Mun), Cambodia (particularly the Cambodian Tonle Sap Great Lake areas) and Vietnam (particularly the Vietnamese Mekong delta areas). The baseline information required from a long term monitoring programme to assess the impact of the DSSHPP should include the following indictors:

- Baseline vulnerability of water resources-dependent communities
- Dependency on fish
- Dependency on OAAs
- Dependency on irrigation and riverbank cultivation
- Resilience
- Risks/shocks and trends

In cases where it is not possible to mitigate the impacts of major infrastructure on people's livelihoods, it may be necessary to compensate the impacted households financially. No estimate of compensation costs by the developer for loss of people's socioeconomic conditions and livelihoods is considered. In the DSHPP proposal, only a few households and fishers will be displaced and these will be offered alternative housing. Whilst it is not proposed that the DSHPP developer compensates for losses beyond the immediately impacted area, the trans-boundary impacts should be identified to enable appropriate compensation strategies to be developed. This is discussed further in Section 7. The

data/indicators collected through the proposed monitoring programme should be used to compute the likely costs of such compensation both locally and regionally.

6 RISK ASSESSMENT RELATED TO DSHPP

Usually before any proposal for a run-of-river hydropower scheme is approved, a thorough assessment of the risks associated with the development should be undertaken. Risk assessment is a qualitative analysis of the *consequence* or scale of risk and the *likelihood* or probability of the risk occurring (Table 1). These two values are combined to produce an overall risk score (Table 2). A risk management framework operates by establishing the context (i.e. proposed hydropower development); identifying the risks on the existing situation (consequences and likelihood); assessing the risks; and treating the risks. Consequently, it is a useful tool to prioritise actions and resources, and to identify knowledge gaps, which then inform the monitoring programme. A measure of risk is typically derived by multiplying likelihood by consequence. The ratings refer to the probability (likelihood) of the impact (consequence) occurring if a scheme is proposed based on attributes about the ecology of the fish and other aquatic species and the riverine environment in which the development is being proposed. The consequence refers to the scale of the potential impact based on knowledge of ecological impact of the scheme from previous similar schemes. The ratings are, where possible, based on scientific evidence otherwise expert judgment is used, but this carries a higher degree of uncertainty in the assessment procedure that must be accounted for. Where possible, information should be drawn from approved documentation or case studies of existing schemes. Where knowledge is deficient or uncertainty high, the precautionary principle should come into force to prevent unforeseen impacts.

Table 1. Consequence and Likelihood scores.

Consequence	Likelihood
Extreme	Very likely
Major	Likely
Moderate	Possible
Minor	Unlikely
Very minor (insignificant)	Very unlikely (rare)

Table 2. Risk matrix.

Key: Low | Moderate | High | Very High

		Consequence				
		Very minor	Minor	Moderate	Major	Extreme
Likelihood	Very likely	M	M	H	VH	VH
	Likely	M	M	H	H	VH
	Possible	L	M	M	H	VH
	Unlikely	L	L	M	M	H
	Very unlikely	L	L	M	M	H

In risk analysis we have assessed the risk of: i) the Proposed Design (Table 4) and ii) the Proposed Design after applying recommendations and mitigations from the present report (Table 5); the latter assesses the *probability that the risk can be mitigated*, which not only reflects the recommendations but also assumes ongoing discussion between the developer and the MRCS that would result in the optimal design being presented.

In these two risk assessments only the most important risks have been examined so that the *consequence* of these is either *major* or *extreme* and hence, the risk scores, based on differing likelihoods are *Moderate*, *High* or *Very High*. The risk assessment of the Proposed Design reflects the issues raised in this review, but importantly it prioritizes where the design needs to be improved. Those risks that are *Very High* or *High* are the highest priorities to address in the design. The risks can also be viewed as links in a chain for upstream and downstream migration – attraction into, passage through and exit of a fish pass are all essential to complete fish passage, as are the components for downstream passage. Hence, all risks in a horizontal block within the table need to be addressed to enable the full migration of that group to be completed. Other ecological links to complete life cycles are also essential, such as access to spawning and refuge areas, and these are addressed elsewhere in this report.

The risk assessment shows that under the proposed design (Table 3) a major risk for upstream migration is "Limited attraction and entry". This is due to the dam location being upstream of the confluence with Hou Xang Pheuak and for 75% of the time there is more attraction flow from the dam. The risk can be almost fully mitigated (Table 4) using physical modelling to optimise dam location, orientation and tailwater conditions. There is high certainty concerning this risk – it follows known patterns of migratory fish behaviour – and significantly, it is **a risk that cannot be mitigated after construction** (except by not passing flow at the dam and not generating power). The risk is higher for the larger, long-lived species, which tend to follow known migration routes.

Attraction is poor because of the dam location, but the impact will vary depending on the seasonal proportion of flow through the power station; for those species that migrate at lower flows in the dry, early wet and late wet seasons the impact is very high compared to those species that migrate at high flows.

The risk of poor passage through the modified channels of Hou Sadam and Hou Xang Pheuak varies with fish size and longevity. Smaller fish are more easily accommodated and larger fish require larger, deeper channels. Long-lived fish have a higher risk of poor passage if they have previously used the Hou Sahong channel and the hydraulics and morphology and not replicated in the other channels. If these risks eventuate they can be mitigated after dam construction but this highlights the importance of quantitative and targeted monitoring, particularly of the larger, long-lived fish.

Exit of fishways and fallback can be a significant risk at large dams with fishways but in this project it is very unlikely because Hou Xang Pheuak inlet is 0.5 km upstream of Hou Sahong. There is a risk of fish exiting Hou Sadam falling back into the Hou Sahong channel because of the extra discharge but it is considered minor.

Table 3. Risk Assessment of Proposed Design based on criteria in Table 3, for each size class, longevity, behaviour category, migration flow and biomass.

	Upstream Migration			Downstream Migration			
	Limited attraction and entry into fish passage facilities	Limited ascent of fish pass	Ineffective exit – risk of fallback	Limited passage through impoundment	Limited attraction and entry into fish passage facilities	Mortality passing Khone Falls site – including dam turbines	Poor exit; risk of predation downstream
Life Stage							
Larvae & fry	N/A	N/A	N/A	Moderate	Moderate	High	Moderate
Small-bodied species (15 -30 cm)	High	High	Low	Low	Very High	High	Moderate
Medium-bodied (30-150 cm)	Very High	High	Low	Low	Very High	Very High	Moderate
Large-bodied (150-300 cm)	Very High	Very high	Low	Low	Very High	Very High	Moderate
Longevity							
Short-lived species	High	Moderate	Low	Low	Very High	High	Moderate
Long-lived species	Very High	High	Low	Low	Very High	Very High	Moderate
Behaviour							
Surface	High	Moderate	Low	Low	Very High	High	Moderate
Mid-water	High	Moderate	Low	Low	Very High	Very High	Moderate
Benthic (including thalweg)	High	Moderate	Low	Low	Very High	Very High	Moderate
Migration Flow							
Low (dry season)	Very High	Moderate	Low	Low	Very High	Very High	Moderate
Moderate (early wet, late wet)	Very High	Moderate	Low	Low	High	High	Moderate
High (wet season)	Low	Low	Low	Low	Low	Low	Low
High Biomass	High	High	Low	Low	Very High	Very High	High

Table 4. Reassessment of risk of Proposed Design after applying recommendations and mitigations outlined in the present report.

	Upstream Migration			Downstream Migration			
	Limited attraction and entry into fish passage facilities	Limited ascent of fish pass	Ineffective exit – risk of fallback	Limited passage through impoundment	Limited attraction and entry into fish passage facilities	Mortality passing Khone Falls site – including dam turbines	Poor exit; risk of predation downstream
Life Stage							
Larvae & fry	N/A	N/A	N/A	Moderate	Moderate	High	Moderate
Small-bodied species (15 -30 cm)	Moderate	Moderate	Low	Low	Moderate	High	Moderate
Medium-bodied (30-150 cm)	Moderate	Moderate	Low	Low	Moderate	Moderate	Moderate
Large-bodied (150-300 cm)	High	High	Low	Low	Moderate	Moderate	Moderate
Longevity							
Short-lived species	Moderate	Moderate	Low	Low	Moderate	Moderate	Moderate
Long-lived species	High	High	Low	Low	Moderate	Moderate	Moderate
Behaviour							
Surface	Moderate	Moderate	Low	Low	Moderate	Moderate	Moderate
Mid-water	Moderate	Moderate	Low	Low	Moderate	Moderate	Moderate
Benthic (including thalweg)	Moderate	Moderate	Low	Low	Moderate	Moderate	Moderate
Migration Flow							
Low (dry season)	Moderate	Moderate	Low	Low	Moderate	High	Moderate
Moderate (early wet, late wet)	Moderate	Low	Low	Low	Moderate	Moderate	Moderate
High (wet season)	Low	Low	Low	Low	Low	Low	Low
High Biomass	High	High	Low	Low	Moderate	Moderate	High

For downstream migration the risk of poor passage through the impoundment, due to a static water body, is low because the dam impounds a small volume and there is a velocity through the Hou Sahong channel of 1.0 to 0.3 m/s. As discussed earlier there is a moderate risk that larvae and fry will settle out near the dam itself and monitoring will be needed to quantify the risk. If the risk eventuates it is difficult to mitigate; lowering the impoundment to flush the larvae and fry out is possible but may need additional infrastructure at the dam such as a large sluice gate.

There is a very high risk of "limited attraction and entry into fish passage facilities" because under the proposed design there are no downstream fish facilities. Screening is proposed by the developer if monitoring shows there is an impact. As discussed earlier, based on the sensitivity of fish to pressure changes in turbines there is a high risk of mortality. Turbine passage has a higher risk for larger fish and for benthic fish acclimated to depth, and is higher when the proportion of flows passing the turbines is greater. Of particular concern for the present project is the data that show a high sensitivity of cyprinids to pressure changes. Mitigation of these risks involves screening, although running the turbines at reduced capacity and power generation can reduce pressure changes and fish mortality.

Table 4 shows the reduced risks if the recommendations in the present review are followed and all measures for fish optimised. The risks that remain high are the upstream passage of large and long-lived fish, and the passage of high biomass because Hou Xang Pheuak is unlikely to compensate fully for the loss of the Hou Sahong channel for fish migration. For downstream migration the risks that remain high are passage of larvae and fry that cannot be screened and small fish which are more difficult to screen; risks for these fish are higher in the dry season when there is more proportional flow through the turbines.

Importantly, the reduction in risks as shown in Table 4 is completely dependent on three key recommendations:

i) Refining the dam location with physical modelling to optimise attraction.
    - A key risk that cannot be mitigated after construction.

ii) Broadening the scope of upstream passage
    - Including broadening the spatial scale to include more of Hou Xang Pheuak and more channels, as well as broadening the engineering/scientific scope to include hydraulic modelling and documenting hydraulics in the field.

iii) Screening and fish diversion of the Hou Sahong channel.
    - Large deep dams are often difficult to screen but it is feasible to screen the upper Hou Sahong channel for surface, mid-water and benthic species.

iv) Monitoring.
    - The modified channels and particularly the screens will need intensive monitoring to evaluate fish passage and refine designs.

Without implementation of these recommendations the risks remain very high, as described in Table 3, and significant impacts on fish populations in the region can be expected.

Identifying where there is less certainty and more risk about the design enables transparency about impacts and expected fish passage performance. It also acknowledges that the solution developed would not likely be the optimum and would likely need to be

modified in the future. Where there is less certainty, an adaptive management approach should be taken, with intensive monitoring and ongoing reviews with workshops, aiming to reach an optimal solution. Whilst this procedure is proposed by the developer it lacks detail and the proposed budget for remedial action to adapt the design and construction is appears limited. The uncertainty also emphasizes the need for a flexible operating strategy and a process of review, so that new knowledge can be incorporated into operations as well as modifications to fish passage facilities.

The major issues highlighted in Table 4 following design modifications proposed in this report are related to channel modifications to facilitate upstream migration and issues concerning downstream migration, especially adult fish potentially passing through the turbines and drift of larval life stages, particularly during the low flow period. It illustrates where bottlenecks to maintaining fish life cycles, and thus sustainable fisheries, are likely to occur and where efforts to overcome these problems should focus. Unfortunately, there are no obvious design modifications beyond those proposed that can further mitigate these issues, but dialogue should continue between the developer and MRC through the design phase to try and identify opportunities that may arise. The potential disruption of downstream migration and drift could have ramifications for maintaining the fishery production for this region, as highlighted in Section 1.

7. FISHERIES MONITORING, MITIGATION AND COMPENSATION MEASURES

7.1 Monitoring programme mitigation measures as proposed by the EIA

A fisheries monitoring and action plan (FishMAP) is proposed in the EIA with an estimated budget of US$5 million for the (1) pre-construction, (2) construction and (3) operation (first ten years) period.

The pre-construction phase covers baseline data of daily trap catches and larval drift in the Hou Xang Pheuak, Sahong and Sadam channels (upper and lower end). Daily trap catches are monitored during wet season before and after modifications of the Hou Xang Pheuak, Sahong and Sadam channels to assess fish pass efficiency. Additionally, household fish-catches in the Siphandone area, and specifically the three main channels are monitored besides fish markets observations.

During the construction phase the monitoring continues, as described in the pre-construction phase. A water quality monitoring program is included that will be needed in areas adjacent to the construction areas to evaluate construction impacts and guide impacts reduction.

During the first 10 years of operations the monitoring of daily trap catches, households and fish markets is continued. Peak larval fish downstream drift of the three major channels is monitored across the GFL. Downstream passage of fish through turbines is monitored to quantify survival rate and evaluate performance.

It is proposed to negotiate with village and inter-village groupings to protect migratory pathway areas in and adjacent to the three channels during project construction and operational phase (Ban Hou Sadam, Hang Sadam, Hou Sahong, Don Phapheng, Hang Khone and Esom). A budget of $ 750,000 is foreseen to compensate for permanent loss of fishing right in Hou Sahong by renting all fixed fish-traps and general area fishing rights in Hou Sahong channels. Similarly, all fixed fish-traps and general area fishing rights are rented in Hou Xang Pheuak and Hou Sadam channels for duration of construction period.

Another mitigation proposed in the EIA is to reduce fishing pressure. In principle, fishing pressure is an impact on migratory fishes in the area and reducing pressure is one factor that would improve total passage of fish. However, the EIA makes a number of sweeping regarding the status of fisheries exploitation and the impact of DSHPP. Several of these appear as distractions of the key issues on the dam on fisheries and require empirical evidence for justification.

Annex C Page 3 states: 'It is frequently reported in public media in Lao that local fishers report that fisheries resources have already been impacted and that yield and species composition have declined recently. Therefore, an option exists to balance likely fish mortalities associated mainly with downstream passage through the project infrastructure (turbine mortality and impingement of screens etc) by reducing fishing pressure from local communities through the alternative livelihood programme and sustainable fisheries management practices.'

The Annexes also indicate the 'DSHPP Fisheries Monitoring Action Plan (FishMAP) proposed for inclusion in the EIA, aims to address impacts through direct mitigation and by developing improved fisheries management systems supported by the introduction of alternative non-fisheries dependant livelihood systems to reduce fishing pressure on the improved alternative channels and their adjacent villages'.

These statements need to be backed-up by empirical evidence and are unproven. There is no clear explanation of "alternative livelihood" options or compensation for local fishers impacted by the project or restricted from using lee traps. Whilst fishing pressure may have increased in recent years, there is no baseline data on which to justify the statement and the removal of fishing in the Don Sahong channel is only one dimension in the overall exploitation of the fisheries in the LMB. It is well established that much of the fisheries exploitation targets migratory species, that move considerable distance and one cannot isolate the fishing pressure elsewhere from that at Don Sahong. Indeed given the limited number of lee traps that have traditionally operated on Don Sahong their removal is unlikely to have any detectable difference, especially as the baseline reference condition is not provided in the EIA. For this to have any application, a wider approach that engages fisher communities in the Cambodian border area is necessary, but this has not been promoted let alone suggested.

7.2 Gaps and recommendations

While the proposed monitoring and mitigation programme covers some essential elements there are still significant gaps (Table 5). This limits the capacity to design mitigation measures for fish passage and offer opportunities to compensate for potential lost fish production and social disruption. It is therefore recommended that a comprehensive monitoring programme is established before and after dam construction, which includes:

The monitoring protocol needs to be targeted and more comprehensive to account for daily and seasonal variability in ecological characteristics related to hydrological conditions, as well as establishing an early warning system to be proactive to respond to potential impacts of the development. This requires a realistic and properly costed monitoring programme that should build on existing DSHPP and MRC larval drift surveys, fisher catch monitoring, household surveys and market studies. The financial resources allocated to the monitoring programme are inadequate given the high cost of such work and the scale of issues to be covered.

Estimations of fish stocks downstream of DSHHP are required to quantify the number and type of fish arriving downstream of the Khone Falls. These data are necessary to compare with passage data in order to calculate passage efficiency. Efficiency of attraction flow for upstream migration has to be monitored in detail, as it is one of the most important bottlenecks in fish passage. Water turbidity will limit any direct observation; therefore, there is a need to plan for a DIDSON acoustic system. This system enables underwater video observations in turbid water and reveals detailed information on migration and swimming behaviour.

Telemetry tracking studies for a range of species and sizes of fish is required. This would also provide insight to whether fish find entrance, estimates of proportions of fish that ascend and reveals whether fish pass is designed appropriately. The proposed upstream/downstream

comparison of trap catches will only provide yes or no results on passage efficiency but will not provide information on limiting cross sections within fish passes.

Table 5. Monitoring tasks, proposed monitoring within the EIA, identified gaps and overall assessment of the fish monitoring programme

Task	EIA-monitoring	Gaps	Overall assessment
Efficiency of attraction flow for upstream migration	Not considered	Estimation of migratory fish downstream of fish passes and entering the fish pass Migratory behaviour of fish downstream and at the entrance of fish passes including hydraulics	Missing
Upstream passage through Hou Xang Pheuak and Sadam	Downstream/upstream comparison of trap catches during wet season and larval drift	Longitudinal migration patterns within channels including hydraulics Dry season migration	Incomplete
Downstream passage	Turbine passage survival	Details on methodology for turbine passage survival Monitoring of screen and bypass efficiency including hydraulics	Incomplete
Reservoir effects	Not considered	Larval drift upstream and downstream of the reservoir including hydraulics	Missing
Transboundary, multi dam effects	Not considered	Migration distances and migratory behavior of medium and long-distance migrants, effects on population dynamics	Missing
Overall assessment	Not considered	Developer is committed to 95% passage in EIA but no methodology provided for overall assessment integrating upstream, downstream passage and multi dam / transboundary effects	Missing
Fisheries losses	Compensation for fisheries losses in directly affected channels	Assessment of likelihood or scale of loss of fisheries outside directly affected channels	Incomplete

Also downstream passage has to be monitored. More details are needed of how the monitoring will be carried out (e.g. bypass efficiency, turbine mortality) and the information used to adapt the designs.

In order to understand the functioning or failure of fish passage detailed hydraulic data (2- and 3-d models) are required for all important hydrological situations and at least for all potential bottlenecks (fish pass entrance, limiting cross sections in fish pass, bypass entrance, screens, turbine intake). As there is also important fish migration in the dry season monitoring has to be extended to dry season periods.

In order to assess transboundary and multi dam effects migration distances and migratory behaviour of important medium and long-distance migrants should be monitored and potential effects calculated based on population models. The developer is committed to 95% passage efficiency but no methodology is provided for overall assessment integrating upstream, downstream passage and multi dam / transboundary effects.

In addition, a complete overview of fishing activities and the contribution to livelihoods and food security in the region is needed. This should include details and plans of traps and other gears to be removed or restricted and detail “alternative livelihood” options and compensation for local fisherman that are impacted.

Developer funds monitoring, but funds are limited given the scale of programme needed (telemetry studies are expensive but reveal detailed information). It is mentioned that monitoring is assisted by international experts, although details are not provided. Adding external peer review would improve experimental design and collection of appropriate data. Data from preconstruction monitoring are not provided and summary of outputs is not reported.

Contingency funds for fish way modification are suggested in the EIA, if remedial action is required, but there is no indication how output of FishMAP will feed into this procedure to flag issues to which developer will respond. An assessment of likelihood or scale of loss of fisheries outside directly affected channels is required and contingency funds also have to be provided for the compensation of those losses.

8 FISHERIES, DSHPP AND ITS TRANS-BOUNDARY IMPLICATIONS

Impacts of multiple dams and transboundary effects have been analysed in detail in two studies: (1) BDP - Basin Development Plan Programme - Assessment of Basin-wide Development Scenarios (MRC 2010) and (2) SEA MRC Strategic Environmental Assessment of hydropower on the Mekong mainstream (SEA, ICEM 2010). The studies differ in terms of scenarios analysed and methodology used. While BDP covers 16 scenarios related to the countries, SEA focuses on three scenarios related to 6 hydro-ecological zones ((1) Lancang River; (2) Chiang Saen to Vientiane; (4) Vientiane to Pakse; (5) Pakse to Kratie; (6) Kratie to Phnom Penh).

BDP:	(1) Baseline scenario (BS) reflecting the situation in year 2000 with one dam in China and 26 dams in tributaries,
BDP and SEA:	(2) Definite Future scenario including 6 dams in China and 26 (BDP) - 40 (SEA) tributary dams by 2015 (2015-DF),
BDP	(3) Foreseeable Future (i) without mainstream dams but with 56 (BDP) – 71 (SEA) tributary dams by 2030 (2030-20Y-w/o MD),
BDP and SEA:	(4) Foreseeable Future (ii) with 6 mainstream dams in upper Lao and with 56 (BDP) – 71 (SEA) tributary dams by 2030 (2030-20Y-w/o LMD) and
BDP and SEA:	(5) Foreseeable Future 2020-30 (iii) with 11 mainstream dams and with 56 (BDP) – 71 (SEA) tributary dams by 2030 (2030-20Y).

To analyse the trans-boundary effects of DSHPP and the 2 mainstream dams in Laos, the BDP and SEA: (5) Foreseeable Future 2020-30 (iii) is considered the most relevant.

The DSHPP is a run of river reservoir with a relatively small impoundment restricted to the Hou Sahong channel. The design and operation is unlikely to have any impact on water levels in the delta or cause any alteration of the flooding cycle. The scheme will also not alter the habitat upstream or downstream and refuge and spawning habitats will unlikely be impacted in any way. There is also no significant effect on sediment and nutrient dynamics that will impact on fisheries downstream.

The main transboundary impacts are likely to occur from disruption to fish migration both in an upstream and downstream direction. The principal problem arises with potential disruption of long distance migrators that move considerable distances upstream to spawning grounds around the Siphandone Wetlands floodplains of Central Laos, especially in Champassak, Province, and major tributaries in Thailand, including Pak Mun. These species tend to be important food fishes for both subsistence and commercial fisheries. Three main migration systems have been postulated: the lower migration system (from the Delta up to Khone Falls), the middle migration system (from Khone Falls up to Vientiane) and the upper migration system (from Vientiane up to China) (Poulsen et al. 2002a).

However, these assemblages almost certainly support intermixing populations and some species will migrate between the units (e.g. Mekong giant catfish that spawns above Luang Prabang) and between the main river and tributaries and *Pangasius krempfi*, an important commercial species, spending a part of its life at sea and in the brackish water of the Mekong Delta before returning to spawn in fresh water. This anadromous fish travels at

least 720 km to the Khone Falls, and possibly further upstream (Hogan 2007) and depends on a free migratory corridor from the delta.

According to Poulsen et al. (2002a) at least one third of Mekong fish species need to migrate between downstream floodplains where they feed and upstream tributaries where they breed. This group, known as white fishes, undertakes long-distance migrations, particularly between lower floodplains and the Mekong mainstream and its major tributaries. These account for at least 37 percent of the total number of species or 34 percent of the catch. Furthermore, some fishery data underline the high importance of migratory fish: e.g. five species (*Pangasius krempfi, Pangasius conchophilus, Paralaubuca typus, Pangasius macronema* and *Botia modesta*) represent 47% of the total annual catch at Khone Falls (Baran 2006), and longitudinal migrants contribute 63% to the catch of the major Tonle Sap fisheries (Van Zalinge et al. 2003).

Although little is known about spawning requirements for most Mekong fishes, spawning habitats are generally believed to be associated with: (1) rapids and pools of the Mekong mainstream and tributaries; and (2) floodplains (e.g. among certain types of vegetation, depending on species). River channel habitats are, for example, used as spawning habitats by most of the large species of pangasiid catfishes and some large cyprinids such as C*yclocheilichthys enoplos, Cirrhinus microlepis*, and *Catlocarpio siamensis*. Floodplain habitats are used as spawning habitats mainly by black-fish species (Poulsen et al. 2002a).

Other species may spawn in river channels in the open-water column and rely on particular hydrological conditions to distribute the offspring (eggs and/or larvae) to downstream nursery rearing habitats. Information on spawning habitats for migratory species in the river channels of the Mekong Basin and described for only a few species, such as *Probarbus* spp. and *Chitala* spp., mainly because these species have conspicuous spawning behaviour at distinct spawning sites. For most other species, in particular for deep-water mainstream spawners such as the river catfish species, spawning is virtually impossible to observe directly. Information about spawning is instead mainly obtained through indirect observations such as presence of ripening eggs in fish. For fishes that spawn in main river channels, spawning is believed to occur in stretches where there are many rapids and deep pools, e.g. the Kratie–Khone Falls stretch and the Khone Falls to Khammouan/Nakhon Phanom stretch, both intrinsically linked to the DSHPP development. Furthermore, a recent study on migration of Siamese mud carp (*Henicorhynchus siamensis* and *H. lobatus*) using otolith microchemistry has suggested the populations originate from a single natal origin that bypasses the Khone Falls (Fukushima et al. 2014).

A further complication arises if upstream migration is maintained by the proposed bypass channel solutions but downstream migration is disrupted by low velocities in the impoundment preventing downstream drifting of fish eggs, larvae and juvenile life stages and potentially high mortality of these and adult life stages occurring through the turbines (see sections 4.5). Overall, the disruption to these migratory patterns could lead to local expiration of fish species, loss of production and fish yields of major food fish species, and possibly loss of genetic diversity in the LMB, although this is probably less critical that mainstem and tributary dams that block the entire river channel and rely on technical fish pass solutions.

9 IMPLICATIONS OF MULTIPLE DAMS

It must be recognised that Don Sahong is just one of 10 mainstem dams proposed or under construction (Xayaburi) in the LMB, in addition to 26 (40) new tributary dams by 2015 and 56 (71) tributary dams by 2030. There are concrete plans for at least 3 new mainstem dams in Lao PDR (Pak Beng) and Cambodia (Stung Treng, Sambor). The impacts of each individual dam are likely to be similar or potentially greater to those expounded throughout this report, although the spatial scale and intensity of the impact will vary depending of the dam design and operation, and success of proposed mitigation measures. The impact of the dams constructed in the middle and lower migration systems, i.e. above Khone Falls to Vientiane and below Khone Falls, will be greater than in the upper migration zone in the vicinity of Xayaburi. However, this does not mean that one should be complacent because the impact of each dam and the cumulative and additive impact of all dams is likely to be considerable. The key issues regarding the potential cumulative impact of multiple dams systems are as follows. These facts should be read in the context of DSHPP as a contributor to the overall impact and that the main fisheries impacts from DSHPP will result from disruption to fish migration if the proposed passage facilities do not compensate for the loss of the Don Sahong channel.

9.1 Multiple interruptions of fish passage

Effects of multiple barriers to migration: each dam will potentially reduce the number of fish that are able to move further upstream. Even if the fish passage facilities are 95% efficient for all species, which is highly unlikely to be so effective, the cumulative effects will be multiplicative not additive. In addition, fish tire from continuous swimming up fish passes and the probability of bypassing several dams in series decreases with each successive dam.

Each impoundment will individually disrupt drift to replenish downstream fisheries. The scale of this disruption will depend on the hydraulic regime in the impoundments and downstream passage facilities. Again the cumulative effects of several dams will be multiplicative not additive.

As indicated previously, substantial mortality is likely to occur through the turbines. The level of mortality is potentially high, irrespective of the assertion that the turbines are 'fish friendly'. The cumulative mortality rates through successive sets of turbines are likely to be considerable to the detriment of the fish recruitment and production.

Halls & Kshatriya (2009) modelled the cumulative barrier and passage effects of mainstream hydropower dams on migratory fish populations in the Lower Mekong Basin. In order to maintain viable exploited populations of the small species, fish ladders, locks or other structures would need to pass at least 60% to 87% of upstream migrating adults in the case of a single dam, rising to 80% to 95% if adult fish were obliged to cross two or more dams, to reach critical upstream spawning habitat. The results are based on estimated turbine mortality of 2% – 15%. However, much higher mortalities are expected to occur at LMB mainstream dams because of sudden pressure differences during turbine passage due to the high head of the dams. For large species (> 50 cm; *H. malcolmi, C. harmandii, P.conchophilus, P. jullieni* and *P. gigas*) passage of more than one dam would result in

extirpation of populations even if engineering solutions could be developed to re-direct 75% of downstream migrating adults away from dam turbines and if upstream migrations were completely unhindered, i.e. 100% upstream passage success which cannot be achieved in reality (Halls & Kshatriya 2009).

9.2 Impacts of reservoirs

The overall impact of a cascade of dams is modification of the riverine ecosystem into a series of lacustrine water bodies. This will result in flooding of spawning and nursery habitats and collapse of the traditional river stocks and fisheries. The fish community structure will inevitably change and productivity almost always declines, changing from large valuable riverine species to small still water species or a proliferation of alien invasive species such as Chinese carps or tilapia. The problem that is faced in the mainstream Mekong is that the impoundments that are created upstream of many of the dams are not conducive to natural fish production so there is the likelihood that yield from the modified river is heavily compromised and cannot be compensated by stocking or aquaculture. The situation could be further exacerbated by accumulation of sediments in the impoundments that smoother potential spawning habitat. The addition of the LMB mainstream projects will (SEA):

- Significantly reduce stream power and water velocity resulting in enhanced sedimentation and the formation of large deltaic - type deposits at the head of each of the reservoirs. This will see sediment accumulate in sections of the river where it has never accumulated in the past;
- Increase the rate of sedimentation in areas of the reservoir not influenced by scour flow from the spillway and sediment gates – dependent on the sequencing of construction;
- Change the mechanics of sediment transport, by reducing the velocity of mean annual flood flow through the reservoir so that medium-sized particles that moved in suspension will now move only partially in suspension and coarse-sized particles that moved partially in suspension and partially as bed load will now move as bed load or not at all, causing greater retention rates in the impoundment of both medium and coarse sediment;
- Increase down-cutting and channel bed and bank erosion in alluvial reaches of the Mekong (Zone 3); projects proposed for Zone 2 will further reduce the supply of bed load to the alluvial reach between Vientiane to Pakse, which will induce re-mobilisation of the channel and bed sediments within the reach, increasing loss of riparian vegetation and agricultural areas (islands and riverbanks) as well as altering the course of the river thalweg.
- The Lao cascade of 6 mainstream dams would transpose 90 % of Zone 2 into a cascade of reservoirs resulting in a loss of 39 % of riverine habitat within the LMB. During the dry season the flow velocity will be reduced to the level of stagnant waters, but during wet season flow conditions are likely improved but the size of most of the Mekong dam impoundments means these systems will act a hydraulic barriers to downstream drifting larvae and juveniles. Run-of the river impoundments

are therefore “hybrid systems”, which loose the function of rivers but do not fully gain those of natural lakes or stagnant reservoirs. Consequently, both riverine fish species and “stagnant” species have difficulties to develop viable populations. Even “generalists” have major problems to cope with the divergent flow conditions. Therefore, the expected fish production and potential fishery yield will be very low compared with current conditions (probably only 10 -30 %).

- A further problem that arises from the shift in habitat characteristics and species assemblage is the direct impact on fishing communities and food supply. Traditional capture methods will no longer be appropriate and the fishers will have to cope with change in capture methods and prevalence of more static water species. The loss of productivity and collapse of major traditional river fisheries could lead to social disruption. Mitigation measures such as cage culture or stocking are unlikely to compensate for this change or loss (see below).

9.3 Loss and fragmentation of flowing water habitats

The main channel of the Mekong River is a flowing water (lotic) habitat; combined with associated floodplains it creates linked habitats that are hydraulically diverse with a network of interconnected lentic (stillwater) and lotic habitats. Migratory riverine fish that have drifting larval stages are specifically adapted to using the flowing water of the Mekong to distribute eggs and larvae. For these species there is a minimum spatial scale of drift that is required for the larvae to find suitable nursery habitats; often the hydraulically complex littoral zones of flowing waters provide these habitats. The minimum spatial scale is likely to be hundreds of kilometres and if larvae settle in reservoirs their survival is generally very poor. Hence, a dam has devastating impacts on lotic species not only on the immediate impounded area but also on the lotic habitats for hundreds of kilometres upstream. Once the lotic habitats of the river have been fragmented to less than the minimum spatial scale of larval drift, many key species will rapidly decline. The corollary of this is that there is a spatial scale of lotic habitats that needs to be preserved for fish production in the Mekong, and dams could be spatially separated sufficiently to preserve critical reaches of these habitats and minimise impacts on fish production.

9.4 Estimated fisheries losses for dam scenarios

A preliminary estimation of the likely impacts of dams on the extent and condition of habitats important for fisheries has been provided by the BDP (MRC 2010) for (i) river-floodplain wetlands, (ii) rainfed wetlands and (iii) reservoirs. Fisheries yield per unit area is much higher in river-floodplain wetlands than in the rainfed zone, but the river-floodplain zone is much smaller, so total yield from the two main zones is similar. Reservoirs are of minor importance and contribute only 10 % to the overall yield (for details see “BDP Technical Note 11 - Impacts on Fisheries; MRC 2010).

If all dams would be built the total loss to river-floodplain catches is hypothesised as 593,000 tonnes per year or about 58% of the total yield from this habitat class (Table 6). The country experiencing the largest impact as a percentage of existing catches would be Lao PDR, with a loss of 84% of its baseline of 92,000 tonnes, because of the likely high

proportion of river-dependent fish. However, the highest loss in absolute terms and the largest component of total losses will be in Cambodia, which would lose 354,000 of 565,000 tonnes, a 63% loss. Thailand (48,000 of 117,000 tonnes) and Viet Nam delta (105,000 of 260,000 tonnes) would experience smaller but nevertheless significant impacts by 2030 if all dams are built.

Table 6. Estimated loss of fish production in the LMB as a result of different dam construction scenarios. (Source MRC, BDP 2010).

	Dams				Lost habitat		Estimated loss in fish production		
Scenario	Tributaries	China	up Vientiane	down Vientiane	Lost accessible tributary and mainstream habitat (%) (SEA)	Lost mainstream riverine habitat (%) (SEA)	Estimated loss of river/floodplain fish production Lao PDR (%) (BDP)[1]	Estimated loss of total fish production (t) (SEA)	Estimated loss of total fish production (%) (SEA)
2015-DF: Definite Future 2015	41	6	0	0	35	0	57	150,000-480,000	7-23
2030-20Y-w/o MD: Foreseeable Future 2020-30 (i)	77	6	0	0	37	0	64	210,000-540,000	10-26
2030-20Y-w/o LMD: Foreseeable Future 2020-30 (ii)	77	6	6	0	69	39	73	270,000-600,000	13-29
2030-20Y: Foreseeable Future 2020-30 (iii)	77	6	6	5	81	55	85	550,000-880,000	26-42

[1] estimated from Figure 25 BDP main report

However, these estimates need to be put into context with respect to DSHPP. The larger part of these losses are caused by basin development after 2000 and by already under construction projects (Definite Future Scenario) and thus are inevitable, and the impacts of other habitat modifications considered in the 2010 scenario assessment (rain-fed areas and reservoirs). Thus the estimated loss of fish production that can be attributed to DSHPP are likely considerably less at 3-6% in Lao PDR compared to the 2000 baseline. This lower value is because the loss of areal coverage of the floodplains/wetlands is likely to be negligible as result of the mainstream dams and DSHPP in particular. The significant losses will result from disruption to fish migration if the proposed passage facilities do not compensate for the loss of the Don Sahong channel.

9.5 Aquaculture

The contribution of aquaculture to total fish production in the Mekong River Basin has increased from an estimated < 10% in 2000 to 33 % in 2008 and is projected to rise to about 50 % in the period of 2015-2030 (BDP Technical Note 11). Aquaculture will play an increasingly important role in the Mekong. However, the extent to which it will sustain or increase total fish production in the longer-term is debatable, and will depend primarily upon the extent to which capture fisheries are sustained. Culture and capture fisheries are linked by the use of wild fish stocks (source of brood-stock, as fry, and for fish feed) in industrial aquaculture and small-scale aquaculture ("rice-fish culture") (Coates et al. 2003). Hence it is risky to simply accept the loss of a significant part of the capture fishery in the hope that fish or OAAs can be fully domesticated; rather maintaining viable habitat and capture fisheries is complementary to and supportive of aquaculture (BDP Technical Note 11). Consequently, estimated future aquaculture production is only feasible if the wild stocks of the river-floodplain system do not collapse.

One of the main mitigation strategies proposed for dam development in the Mekong against loss of fisheries is aquaculture in cage culture and culture-based fisheries in the

impoundment. Whilst these measures may provide some compensation they are not a substitute for lost production. Hortle (2005) estimated yields from the impoundments in the Mekong were on average some 200 kg/hectare/year, but these data have been contested. Data from de Silva and Funge-Smith (2005) found a very rapid decline in productivity with increasing lake area with a yield level of about 200 kg/ha for only small reservoirs, and a mean yield of 21.9 kg/ha – considerably below the Hortle figures. These lower production figures are consistent with understanding about how "run of the river" reservoirs are operated.

With respect to DSHPP, there is no opportunity to replace lost fisheries by aquaculture as the impoundment is too small and the topography not conducive to aquaculture production. In addition the operation of the dam is unlikely to support stock enhancement because of the short retention time of water in the reservoir. Consequently, tis measure has not been consider by the DSHPP EIA.

9.5 Missing scenario for river floodplain restoration and improved fisheries management

The scenarios investigated in the BDP and SEA do not take into account the future fishery potential increased by restoring the Mekong and improving fisheries management. Fish productivity of tropical river/floodplain systems mainly depends on the hydrological connectivity between the river and the floodplain. Nowadays, many floodplains of the Mekong and tributary system are disconnected by levees and water-gates, preventing or greatly restricting recruitment from the main rivers. Overfishing might have reduced fish stocks, e.g. individual fishermen catches in the Tonle Sap are nowadays about half of historical values (Baran et al. 2001). Large migratory species have significantly declined in comparison to the small migratory and non-migratory species (Van Zalinge et al. 2003). Regulations for fishing are slowly developing, i.e. fishing ban for giant catfish in Cambodia and special permit requirement in Thailand (MGCWG 2008) or ban on the use of dais for juvenile catfishes by Viet Nam, bans on the use of destructive gears, restrictions on fishing effort (Coates et al. 2003)

Restoring or at least partly rehabilitating the hydrological connectivity between the mainstream river and the tributary/floodplain system and combating overfishing could increase fishery productivity. First attempts to reconnect floodplain habitats to the mainstream river are on the way and seem to be very promising. A small scale pilot study demonstrated successful passage of over 15,000 fish from 108 species through an experimental structure (fish pass) at irrigation sluice gates (Boys et al. 2013).

9.6 Social impacts (BDP)

For the definite future scenario combined impacts of principally reservoir construction and wetland productivity reduction are estimated to put the livelihoods at risk of some 887,000 people within the LMB (Lao PDR - 297,000; Thailand - 46,000; Cambodia - 102,000; Viet Nam - 442,000).

In the foreseeable future scenario with 6 mainstream dams estimated livelihoods at risk are some 2,015,000 people within the LMB (Lao PDR - 782,000; Thailand - 210,000; Cambodia - 262,000; Viet Nam - 770,000).

In the foreseeable future scenario with 11 mainstream dams productivity reduction are estimated to put at risk the livelihoods of some 4,360,000 people within the LMB (Lao PDR - 907,000; Thailand - 516,000; Cambodia – 1,212, 000; Viet Nam – 1,725,000.

Construction activities, new reservoir fisheries and aquaculture forecast are predicted to generate new jobs (370,000 - 1,240,000). However, any jobs created are unlikely to substitute for the loss of fisheries as they are different sectors often requiring capital investment that will not be available to rural poor. Aquaculture in particular requires both capital investment and recurrent financing for feed that will unlikely be available to the fishing communities. It should also be recognised that reservoir fisheries rarely achieved expected outputs and these figures are based on best case scenarios (see above).

10 Conclusions and recommendations

10.1 Fish Ecology

One of the major problems highlighted by the FEG review of DSHPP is paucity of empirical data on how important the area is to fish migration in terms of biomass and species diversity. This partly arises from difficulties in studying fish populations in large rivers, but also the lack of output from primary studies in the region prior to submission of proposal. The PDG is also not explicit in the information required to make such assessment.

It is recommended fundamental gaps in knowledge about the ecology of the fish, status of the fisheries, livelihoods analyses in relation to operational design of the dam and upstream and downstream fish passage are undertaken by the developer and made available to the MRCS. This should include evidence to justify the assumptions made in the design of the fish bypass channels.

Where such data are not available, they should be collected before and during the construction phase and where necessary used to adapt the design criteria to ensure ecological needs of the fish, fisheries and other aquatic biodiversity are addressed.

Full appraisal of the fisheries, species assemblage life cycles, migratory behaviour and biomass should be undertaken to underpin decisions made on mitigation measures proposed. This should include a meta-analysis of the composition and ecology of the fauna in areas adjacent to dam site.

10.2 Modifications to Upstream Fish Passage Design

The submitted design and feasibility assessment of the fishways (both in upstream and downstream) are limited in both detail and scope. The developers have opted for modifying two channels (Hou Xang Pheuak and Hou Sadam) but have not carried out a feasibility study of the potential likelihood of this design functioning or whether alterative options would be more appropriate.

The documents submitted lack details of hydraulic conditions that are likely to be experienced or assessment of whether the target species will be able to tolerate the conditions encountered.

The design of the upstream fishway entrances and exits lack detail, particularly the hydraulic conditions, to evaluate fully whether the fish would be able to find the entrance and whether they would be entrained by the turbine inflows.

Fish pass entrances are a critical part of fishway design and physical modelling is recommended to optimise entrances. These entrances need to cover a variety of depths and locations to enable passage of surface, midwater, benthic and thalweg-oriented fishes.

There is no definitive information on the operating rules and hydrology associated with hydropower production at the dam. This is a fundamental requirement to understand how the fish by pass channels will function. This is also required to determine the effectiveness of any fish passage as it will be heavily influenced by the planned modification to the Hou Sahong channel to maximize production.

Implement a feasibility study of fish passage by experts, with the results being used to guide the final designs of fishways. This feasibility study should include:

- Detail of technical aspects of assessment of fish passage.
- Further hydraulic modelling, including use of the existing physical model, to understand the conditions to be overcome and optimise the design of the fish passage facilities in relation to all fish species and sizes.
- Mitigation measures and their costs and benefits, including measures at critical locations for life-cycle completion.

A workshop is recommended with the MRC and the Developer's Design Team to further evaluate the design and risks, and develop solutions.

10.3 Downstream fish passage

Similar issues exist with the downstream passage facilities. The limited information provided makes it difficult to interpret the design criteria and whether they would function as intended. This is particularly important given that all life stages (including eggs and larvae) and a range of sizes need to be accommodated and that one of the greatest risks to maintaining fish stocks is facilitating downstream movement.

It is recommended that a more detailed technical analysis of downstream fish passage facilities appropriate to all species, life history stages and sizes, including benthic species, is carried out and mechanisms to improve downstream passage are integrated into the dam design.

There is a basic, unsubstantiated assumption that modern bulb turbine design is fish-friendly and therefore fish survival is unlikely to be an issue. Specifications of fish-friendly turbines, including performance standards, need to be specifically included in the design to justify this assumption.

Assessment of turbine damage to Mekong species needs to be evaluated.

Fish passage during construction

- Fish passage during construction is not presently considered and needs to be incorporated into the project.
- A full appraisal of impacts of dam development on fish and fisheries during and after construction phase, including appraisal of loss of ecosystem services, is recommended.

10.4 Fisheries management and monitoring

There is limited information on the socio-economic dimensions of the dam proposal in the impacted region, including the importance of the fishery to food security and rural livelihoods, number of people affected and loss of ecosystem services to rural communities. In particular the DSHPP EIA report provides only limited baseline and impact information on

socioeconomic conditions of people living in the mainstream hydropower project-affected areas

There is a need for a detailed baseline study on the socio-economic impacts both in the immediate DSHPP reach and any trans-boundary areas likely to be impacted by the development.

Full social and economic impact analysis of livelihoods of those dependent on the fisheries coupled with an alternative livelihoods analysis to identify options to compensate the fishing communities is also required.

Only basic information is given on monitoring the fish populations and management of fisheries during and after the construction phase. The monitoring protocol proposed does not address some of the essential issues, such as downstream passage success and survival through turbines, and appears to be underfunded. It is not clear how either would be maintained for the life of the project.

It is recommended a detailed monitoring programme is developed, which addresses knowledge gaps in fish biology that can improve dam and fish pass design and operation and assesses the impact of the dam on fish and fisheries, together with a response strategy for adverse impacts.

The options of management of the fishery post construction are considered weak and fail to address a number of aspects of management of the fishways, for example how to control fishing in and near the fish-ways; how to limit predation in and near the fish-ways; what prevents upstream-swimming fish from immediately returning downstream, maintenance requirements and others.

It is strongly recommended that a comprehensive appraisal of measures to mitigate loss of fisheries and biodiversity, targeting both upstream and downstream fishing communities, together with realistic associated costs is carried out as a matter of urgency.

Details on how a fishery management system will be developed, monitored and sustained in project area is required.

10.5 Decommissioning

One aspect that is not covered in the PDG is that of decommissioning the dam. This is a very real issue and prominent in places like the USA where dams are being removed following the end of their useful life. Although the natural physiographic conditions of the Hou Sahong channel will be completely altered during its construction and life of the HPP, consideration about how to decommission and recover the channel for migration is recommended. This should include setting aside contingency funds to facilitate any action.

10.6 Future actions

The submitted documents provide an overview of the proposed HP project design and modification made to secondary channels to compensate for the lost fish migration pathway represented by the Hou Sahong channel. However, the EIA has not provided expected baseline information on the status of the fisheries, wider transboundary issues and or wider

impacts of the project on fish and fisheries across the Khone Falls area. The EIA does not appear to have reported all studies conducted such information needs to be provided to enable a robust assessment. This should include the following actions.

- Detailed design of capture fisheries monitoring methods to provide robust reliable baseline information. DSHPP monitoring data and analyses should be shared with all to assess reliability and suitability for assessing impact and adapting design to ameliorate issues raised.
- Review of baseline information on fish migration patterns and behaviour, both up-stream and down-stream, and drift of fish larvae and juveniles down-stream.
    - Requires full assessment of impact on impact across migration pathways on recruitment and production; emphasis on long-distance migratory species, including into major tributaries and floodplain habitats
    - Assessment of impact on resident guilds and small-sized species, especially of conservation value.
    - More comprehensive assessment and reporting of fish larvae and juvenile drift
- Detailed hydraulic modelling of all channels across Khone Falls before and after DSHPP installation
- Detailed hydraulic modelling of all proposed measures to minimize negative impacts from dam construction and optimise mitigation strategies, including
    - proposed bypass channels, entrance designs, turbine by-pass screening devices to ensure they are functional all times of the year, but especially in low flow and raising flood periods. Need to be related to swimming capacities and behaviour of a number of key fish species of commercial importance.
- Review dam location to optimise fish attraction to Hou Xang Pheuak
- Conduct experiments to assess the efficacy of so-called “fish-friendly turbines” for Mekong fish and fisheries conditions and identify alternative solutions.
- Carry out options analysis for various mitigation measures, including fish passage facilities.
- Undertake full transboundary impacts in terms of lost income, livelihoods, food security and nutrition security as well as replacement costs from loss of fisheries to understand the magnitude of the risks and impacts.
- Undertake a full economic analysis of fisheries, especially long-distance migratory fish species, including impact in regions remote from DSHPP.
- Provide analysis of decommissioning of DSHPP.
- DSHPP needs to be integrated into wider cumulative impact statement of other HPPs in construction or proposed and include tributary dams. This should include impact of sediment delivery on downstream fisheries productivity.

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Annex 1: Completed "Fish Passage and Fisheries Ecology" PDG Cross-Check Form

PDG chapter 3 - Fish Passage on Mainstream Dams	*Is paragraph relevant*		*Does the project conform to PDG*			*Remark*
	No	**Yes**	**Yes**	**Not enough info to assess**	**No**	
3.1 Background						
53-58.				Needs additional information		▪ Does not provide background information on species diversity, migration guilds or strategies, migration behavior of long-lived and short-lived species, the scale of fisheries in the affected region, specific contribution of Khone Falls fishery, migratory fishes that are at risk upstream and hence populations downstream, livelihoods fishing activities. ▪ DSHPP is a development on one of 14 main channels on the falls. Options analysis of possible development on other channels has very limited assessment. ▪ It will not have a fish passage solution on the dammed channel but relies mainly on modifying one adjacent channel (Hou Xangphueak) and a smaller channel (Hou Sadam near Hou Phapheng) for mitigating fish migration issues throughout the year. ▪ EIA states that there will be no "reservoir effect" i.e. lotic to lentic habitat. This is true compared to dams with large reservoirs, but water velocity is reduced to 0.3 m/s near dam which may trap larvae and other large life stages. ▪ Hou Sahong channel would take more flow for DSHPP; 50% of Mekong flow in dry season down to 7% in wet season
3.2 Guidance on fish passage design and operation. General:						
60. Fish passage facilities for both upstream and downstream passage must be incorporated into all dams on the mainstream.		YES		Needs additional design information		▪ General outline for upstream - downstream (u/s) passage considered in design, but needs much more technical details. Presently these are considered unlikely to mitigate the migration issues identified. ▪ Upstream passage restricted to two channels that do not have the dimensions and capacity of the lost channel. ▪ Downstream passage only presented as optional solution but has

PDG chapter 3 - Fish Passage on Mainstream Dams	*Is paragraph relevant*		*Does the project conform to PDG*			*Remark*
	No	**Yes**	**Yes**	**Not enough info to assess**	**No**	
						to be mandatory, general design provides little information on screening solutions or how downstream drifting larvae will be accommodated (especially in dry season and early wet season when increase spawning occurs).
61. The developer should provide effective fish passage upstream and downstream; "95% of the target species under all flow conditions"		Yes		Clarification needed		▪ Review and details of design of fish passage facilities inadequate and does not relate to species or guilds. ▪ No appraisal of effectiveness of u/s passage or likelihood of and survival during d/s passage. ▪ Developer is committed to 95% passage in EIA but no methodology provided for measurement.
62. Where fish passage rates are unlikely to be adequate to maintain viable populations, the developers must develop and propose mitigation options as one element of compensation programs for lost fisheries resources.		Yes			No	▪ No assessment of likelihood or scale of loss of fisheries to determine compensation programmes. ▪ No true mitigation or compensation measures proposed. There will be no possibility of developing a reservoir fishery or aquaculture units because of the nature of the impoundment and operating regime. ▪ No budget for any significant mitigation compensation measures, if required.
63. Consideration should be given to multiple systems at each site to cater for the large number of species and high biomass, especially given the variable flow regime and lack of biological knowledge on behaviour of migrating species.		Yes		Clarification needed.		▪ Upstream fish passage solution relies on one major adjacent channels (Hou Xangphueak) and a minor channel (Hou Sadam) for mitigating fish migration issues throughout the year. ▪ These solutions are not considered technically adequate to compensate for loss of migration through Hou Sahong channel. ▪ No channel morphology or hydraulic modelling carried out to optimise solutions. ▪ No consideration given to other solutions using alternative channels.
Planning and design phase						
64. The planning and design of the fishways should be fully integrated into the dam design concept from the earliest stages of planning.		Yes			NO	▪ The dam location and alignment has been designed to optimise construction. No options analysis of dam location to consider optimal solution to protect fisheries or provide fish passage.

PDG chapter 3 - Fish Passage on Mainstream Dams	*Is paragraph relevant*		*Does the project conform to PDG*			*Remark*
	No	**Yes**	**Yes**	**Not enough info to assess**	**No**	
						▪ Fish are attracted to flow from a dam and hence, effective fish passage is completely dependent on integrating the dam and fishway design; if fish cannot locate the fishway they cannot use it. ▪ Planning and design of fish bypass solutions not integrated at present, particularly the entrance of Hou Xang Phueak and the dam. This will be less of an issue in the peak wet season as more flow comes from HXP. ▪ Options beyond the two channels chosen are not considered and no evidence that criteria outline in Para 64 have been considered. The proposed solutions are modifications of existing channels but few details of the modifications are given. In-channel works have not been planned and no hydraulic modeling of channels or attraction flows to entrances provided. It is unlikely that a high biomass or many species of Mekong fish will be attracted to the Hou Sadam channel ▪ No evidence of physical or hydraulic modelling to assess these characteristics. Physical modelling (common practice in dam design) is likely to be essential to optimise entrance attraction. ▪ Downstream passage design characteristics limited. No criteria to show larval and drifting juveniles considered from older life stages and large sized fish. ▪ No account of impounding effect or how deepening of Hou Sahong upper channel will effect downstream fish migration/passage.
65. Developers are encouraged to utilise best international practice in fish passage design and be aware of the outputs of the MRC Fisheries Programme and ensure that a "core expert group" is retained.		Yes		Most information concerns fisheries monitoring with little input to channel		• Developers have engaged with several international consultancy groups for advice, but first evidence suggests this expertise needs widening to provide optimal design solutions for both upstream and downstream passage

PDG chapter 3 - Fish Passage on Mainstream Dams	*Is paragraph relevant*		*Does the project conform to PDG*			*Remark*
	No	**Yes**	**Yes**	**Not enough info to assess**	**No**	
				design		
Biological/ecological:						
66. Facilities should be designed to cater for the upstream and downstream movement of the most important species at any site, under the seasonal flow conditions during the periods when the species migrate.		Yes		Further information needed	No	▪ The Fish passage designs have considered all species in all seasons but little information of the channel hydraulics under different flow conditions and whether suitable to account for seasonal variability in species and sizes of fish. Issue for both upstream and downstream migration
67. The maximum standard length of the target species moving upstream will vary from around 20cm to more than 100cm. For downstream migration, the size will vary from eggs and larvae a few millimetres long, to adult fish.		Yes			No	▪ Limited consideration of swimming capacities and behaviour of various and size and species against hydraulics of bypass channels. ▪ No design criteria or plans for modifications to proposed bypass channels given. ▪ Downstream facilities do not consider life history stages and assume most fish will pass over the falls in other channels. ▪ No consideration of the entrainment aspects associated with modification (deepening upstream entrance) of Hou Sahong channel.
68. The preferences, tolerances and biological attributes of the target fish species relevant to successful movement through the facilities should be clearly established.		Yes			No	▪ Basic information on the biology of a few target species provided in SEA report but not carried through to EIA. ▪ No further biological information provided, although some information is available, especially from MRC reports, and reasonable assumptions could be made for this aspect. ▪ No information relating to ecology of downstream movements.
69. The peak biomass likely to be using the facilities must be determined and the appropriate structure sizing of fish-ways, cycle time of fish locks and/or lifts, and water availability established.		Yes			No	▪ Peak biomass data in both upstream and downstream migration not presented. ▪ DSHPP need to make assumptions to establish monitoring procedures. MRC fisher monitoring data would provide species and seasonal pattern.

PDG chapter 3 - Fish Passage on Mainstream Dams	*Is paragraph relevant*		*Does the project conform to PDG*			*Remark*
	No	**Yes**	**Yes**	**Not enough info to assess**	**No**	
70. Predation within the fish passages should be minimised.		Yes			No	▪ Predation within fish pass not considered, but likely to be no greater than existing situation. ▪ Residence time in pass not considered but key issue given length of passes and design.
71. Fish exiting fishways both upstream and downstream should be sufficiently healthy to continue their natural patterns and migration routes.		Yes		Need further information		▪ No information on direct or indirect mortality during movement upstream and downstream, just statement that fish-friendly turbines will keep it to the minimum. This has not been proven for Mekong fishes and design of turbine is critical. High mortalities are also expected for large fish passing through proposed fish-friendly turbines ▪ Downstream passage - most fish assumed to pass through other routes, however no consideration given to entrainment into Hou Sahong channels as a result of channel modifications.
Hydrology						
72. The fishways should cater for the largest operational ranges practical, within the biological and hydrological requirements of the fish species concerned.		Yes			No	• Hydrological modelling (2009-2014) pre- and post-dam is coarse with only discharge in each of the four main channels. No information on how changing flow scenarios in different seasons will change the hydraulics of the channels. • Pages 5-29 and 5-30 of EIA shows that DSHPP will affect minimum, mean and maximum flows of Phapheng in every month; and will likely be the largest hydrological impact of the project.
73. Particular attention must be given to ensuring that the entrances to fishways effectively attract fish.		Yes			No	▪ At present the bypasses have very poor attraction during dry season compared with Hou Sahong, which represents the standard to maintain. ▪ No information on entrance designs of the alternative fish pathways is available as part of the submitted documents. In addition, (i) assessment regarding flow attractions and access to proposed bypass channels, (ii) fish behavioural studies and (iii) physical or CFD model study of tailwater are lacking.

PDG chapter 3 - Fish Passage on Mainstream Dams	*Is paragraph relevant*		*Does the project conform to PDG*			*Remark*
	No	**Yes**	**Yes**	**Not enough info to assess**	**No**	
74. Dam and fish passage design should minimise fish injury or entrapment. Spillway design, aprons, stilling basins and dissipater design should seek to minimise fish injury, mortality and entrapment.		Yes		Needs further information		▪ Evaluation of downstream passage and the likely impacts on fisheries have not been thoroughly investigated or reported. ▪ Inadequate information on downstream passage mitigation facilities. ▪ No information about fish injury and mortality, impingement, entrapment.
Hydraulic environment						
75. Fishway **entrances** should be: • Sited to take maximum advantage of the hydraulic conditions created by spillways, outlets and channel structures. • Suitably located to be accessed by fish over the full operational range of the fishway. • Located where the morphology of the river, as well as the substrate and cover, promote fish attraction to the facility.		Yes			No	▪ Problems finding pass entrances likely when most flow is through DSHPP. ▪ Hou Sadam channel remote from DSHPP and likely overridden by flows from Khone Phapheng. ▪ Little consideration of morphology and hydraulics of the river, apart from rock wall proposed to divert Hou XangPheuak flows toward DSHPP. ▪ No evidence of 2-d or 3-d computer modelling or physical modelling of velocity and turbulence conditions at entrances to alternative channels Hou Sadam and Hou Xangphueak under different flow and water level conditions to estimate accessibility and attraction for fish.
76. Spillways should be designed so that extra flows initiate and terminate adjacent to the fishway entrance(s) to maximise attraction to the fishways.		Yes	Yes			• The spillway is only for emergency situations, as normally the floods will spill through the other channels in the wet season. The embankment is lowered in one section for extreme events and flows into the Hou Xang Pheauk.
77. Fish attracted to the spillway need to be able to access the fishway entrance without needing to double back to find the entrance.	No				No	▪ Dam located two hundred metres up Hou Sahong channel; fish need to double back. ▪ Modelling in the EIA shows that Hou Xang Pheuak will have less flow than Don Sahong Dam from late wet, dry and early wet season. Fish will primarily be attracted to the dam and not Hou Xang Pheuak in these periods. ▪ The extent that fish move back downstream and try another route is likely to be species–specific but no data are presented by the proposal.

PDG chapter 3 - Fish Passage on Mainstream Dams	*Is paragraph relevant*		*Does the project conform to PDG*			*Remark*
	No	**Yes**	**Yes**	**Not enough info to assess**	**No**	
78. Fish exiting upstream fishways should not be drawn back over the spillway during overtopping. Exit conditions should be sufficient to provide stimulus for fish to exit the fishway. The combination of suitable attractive water flows, substrate and protection from predators is important.		Yes			No	▪ Spillway at dam rarely operational (emergency only) ▪ Fish will not be drawn back over this spillway ▪ Exit condition: no information on upstream exit design of modified channels for fish included. ▪ Varying water levels of reservoir impacts inflow depth at channel exits. Upstream exit out of Hou Xangphueak is likely to require enlargement, as proposed by developer, so as to ensure passage of large-bodied fish species at lowest water level in dry season, as well as flow down fishway.
79. Barrier screens should be designed to guide downstream moving fish away from turbines and towards the fish passage facilities.		Yes			No	▪ Minimal information on design of downstream passage – minimal review of screens made available. ▪ Needs more information on hydraulic conditions, approach velocities, screen/deflector designs. ▪ Adaptive management is quoted, but the way this will be implemented needs clarification.
80. The use of fish friendly turbines should be investigated and adopted where feasible.		Yes		Further research is needed		▪ Standard bulb turbines are used because of their lower overall project cost and slightly greater efficiency and generation. These have slow rotation and few blades are suggested but specific designs and operating regimes are not included. ▪ EIA states “there is a reasonable likelihood [of] 95% safe passage” but provides no evidence and assumes data from salmonids (in Northern hemisphere) is transferrable to Mekong fisheries conditions. ▪ Low mortality quoted for “Fish friendly turbines” is misleading. It refers to blade strike and not pressure. This figure would be under the best circumstances for physostomous fish (swim bladder open to the throat) such as salmon, herring, cyprinids but would be much higher for physoclistous fish (swim bladder closed).
Operation						

PDG chapter 3 - Fish Passage on Mainstream Dams	*Is paragraph relevant*		*Does the project conform to PDG*			*Remark*
	No	**Yes**	**Yes**	**Not enough info to assess**	**No**	
81. The period of captivity and interruption to the normal movements of the fish should be as short as possible.		Yes		Clarification needed		• The design of the passage facility allows for fish movements at all times if adequate flows done bypass channels provided. • Potential issue hydropeaking has been missed. This could affect fish attraction and the stimulus for migration.
82. Water quality should be maintained within any holding enclosures to ensure fish health. Oxygen levels should be maintained within the fishways at >5 ppm.		Yes	Yes			• Water quality in fishway– no information. Assume from flows and baseline data that this would not be a problem, although this needs to be checked against sediment dynamics and when flows through fishway are low.
83. Where an environmental flow downstream of the dam is required, the appropriate volumes should be directed through the fishway as a first priority, thereby ensuring fish are attracted to the fishway entrance as well as maximising operating time.		Yes		Clarification needed		• Flows diverted through bypass channels by lowering sill but no details on hydraulics and impact of dam operational procedures. • No estimates of attraction flow (% of Mekong river flow) provided. • Assurance is needed that sufficient flows will be allowed down the fish passage channels.
84. Entrance slot velocities should be adjustable, such that feedback from monitoring and observation of fish behaviour can lead to optimisation of the fishway operation.		Yes		Further information needed		• No plans of entrance design but nature-like channels so slot velocities not required. • Entrance localities very poor, especially as problems with attraction flows highlighted earlier. • Unclear how fish behaviour is monitored at entry and exits.
Monitoring and evaluation						
85. Provisions for monitoring facilities at fishways are to be incorporated into the design and operation phase of environment management and monitoring programmes.		Yes		Need full specification of monitoring		• Monitoring of fisheries proposed but not of fish passage efficacy. • Fisheries monitoring may not be best design. Water turbidity will limit any direct observation. Need to plan for a DIDSON acoustic system. • Tracking studies for a range of species and sizes of fish required. This would also provide insight to whether fish find entrance and proportions of fish that ascend is designed appropriately. • Also downstream passage has to be monitored.

PDG chapter 3 - Fish Passage on Mainstream Dams	*Is paragraph relevant*		*Does the project conform to PDG*			*Remark*
	No	**Yes**	**Yes**	**Not enough info to assess**	**No**	
86. Monitoring programmes should be established to quantify the effectiveness of the fishways.		Yes		Requires monitoring protocol		• Monitoring of fish passes is allowed for in EIA –through FishMap, but it is appears inadequate and more details are needed of how the monitoring will be carried out and the information used to adapt the design of the fish bypass channels.
87. The monitoring programme should be funded by the developer for the duration of the concession period.		Yes	Yes			• Monitoring funded by developer for only 10 years (not for the duration of the concession period) –but funds limited given scale of programme needed. • Monitoring assisted by international experts, although details not provided and adding external peer review would improve experimental design and collection of appropriate data. • No data from preconstruction monitoring provided or summary of outputs reported. • Contingency funds for fishway modification suggested if remedial action required but no indication how output of FishMap will feed into this procedure to flag issues to which developer will respond. No information.
88. Developers should utilise a core group of international experts to assist with the design and implementation of the monitoring programme, with all expenses covered by the developer.		Yes	Yes			
89. Developers should set aside contingency funds for modification of the fishway facilities, which may be identified as necessary based on the results of the monitoring programme as well as new information from other Mekong fishway programmes.		Yes		Clarification needed		