REVIEW OF THE FISH AND FISHERIES ASPECTS IN THE FEASIBILITY STUDY AND THE ENVIRONMENTAL IMPACT ASSESSMENT OF THE PROPOSED XAYABURI DAM ON THE MEKONG MAINSTREAM

Report prepared for the WWF Greater Mekong
by

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EXECUTIVE SUMMARY

In September 2010, Lao PDR officially notified the Mekong River Commission of its intention to proceed with the development of the Xayaburi dam on the Mekong mainstream, 350 km upstream of Vientiane.

The present report is a review of the fish and fisheries section of the Feasibility Study (FS) and of the Environmental Impact Assessment (EIA) of the Xayaburi hydropower project, with a particular focus on the fish passes proposed as an environmental impact mitigation measure. Standards for this review reflect the guidelines issued by the Asian Development Bank, the International Association for Impact Assessment, the International Hydropower Association and the World Commission on Dams.

The present review is based on the 2008 Feasibility Study produced by AF Colenco and the August 2010 EIA report produced by TEAM Consulting. The review identifies the shortcomings of the FS and EIA regarding fish and fish passage and notes how and why those studies do not meet the standards expected for a sustainable hydropower project in reference to current best practices elsewhere in the world. The review gives some guidance on basic mitigation measures, but those guiding directions should by no means be interpreted as a replacement of the thorough studies required for a proper assessment of environmental impacts and of mitigation measures for fish passage. We recommend that in-depth studies and testing (in particular of flow requirements by fish species) are conducted so that the revised EIA is backed by clear evidence that proposed fish passage facilities are operational, effective year round, and feature a fish passage rate close to that recommended by the MRC's guidance for mainstream dams. As such this report strongly supports the conclusions of the Strategic Environmental Assessment on Mekong mainstream dams (SEA) that the Mekong should not be used as a test case. Project should move ahead only once it has been proven that impact is acceptable by all riparian countries or that mitigation will be effective.

As this report only addresses fish resources and fish passage, other important ecological dimensions identified by the MRC SEA (notably impacts of the project on flow dynamics, water quality, nutrients, sediment, habitat fragmentation and aquatic biodiversity) also need to go through a thorough review in order to evaluate if the revised impact assessment and the proposed mitigation options for these dimensions meet the standards of international best practice, and meet in particular the criteria of the MRC **"***Preliminary design guidance for proposed mainstream dams in the Lower Mekong Basin***"** and those of the Hydropower Sustainability Assessment Protocol led by the International Hydropower Association and endorsed, among others, by the WorldBank, the WWF and the Government of China.

Characteristics of the dam

This 1,260 MW dam would be 830 m wide and the dam structure would be 49 m high, with 32 m of water head. This dam would create a reservoir reaching 30 m in depth and stretching over 60 to 90 km; it would feature a navigation lock and two fish passes. The project is presented as a run-of-the-river dam.

Review of the Environmental Impact Assessment regarding fish and fish passage

EIAs usually cover impacts upstream, in the project zone and downstream of the dam. In contrast, the Xayaburi EIA does not consider the upstream catchment area, covers a third of the project zone and does not address impacts beyond a few kilometers downstream of the dam.

The description of Mekong fish migrations in the EIA is very poor: the literature review consists of 3 references (whereas more than 28 studies on Mekong fish migrations were available), and the EIA mentions only 5 migratory species from a list compiled in 1994. In contrast, ongoing research shows that 229 fish species exploit habitats upstream of the dam site for spawning and/or as dry-season refuge, 70 of them being migratory species. The EIA, as opposed to the Feasibility Study that acknowledged the importance of fish migrations and proposed fish passage facilities, does not make any conclusion about the fish migrations in the project impact area.

Upstream of the dam, the creation of a reservoir will modify at least 60 km of riverine habitat, with risks of deoxygenated water, changes in water quality and increased sedimentation. Although the creation of this permanent water body is acknowledged and detailed in the Feasibility Study, the EIA report denies it ("*Transformation of the habitat from a river with rapids into a standing ecosystem due to impoundment will not occur for Xayaburi Hydroelectric Power Project*", EIA page 5-11) and does not analyze its consequences for habitats and fisheries resources.

The Xayaburi EIA, ignoring published information and focussing on a very light field sampling effort, results in a biodiversity assessment representing less than a third of the actual species richness in the impact area. No conclusions are drawn from the field study. The assessment regarding the impact of the project on fish biodiversity is therefore insufficient.

No mention is made of capture fishing among the 2,184 persons who are living along the river in the project impact zone and are subject to displacement, nor among communities living downstream of the dam. The possible impact of the project on fish abundance is not addressed.

The Xayaburi EIA does not indicate, as expected from an Environmental Impact Assessment, i) whether the project will result in loss of fish biodiversity in the impact area and why; ii) whether the project will result in losses or gains in fish production and why; iii) what impact changes in fish resources may have on employment and income; iv) how effective and costly mitigation measures aimed at conserving biodiversity and fish production would be; v) what impacts cannot be mitigated and how important they would be; and vi) what the overall assessment of the proposed project is with regard to fisheries.

The regional dimension of the mainstream project is absent from the Xayaburi EIA, and possible transboundary impacts are not addressed. Similarly the EIA makes no mention of the 47 other dams present in the Mekong Basin by 2015 and of the sum of their environmental impacts.

In conclusion, the gaps of the assessment lead to the conclusion that the Xayaburi EIA does not meet the international standards for Environmental Impact Assessments. The Xayaburi EIA does not answer questions about the nature, magnitude and extent of possible impacts of the project, or concludes without evidence that these impacts would be insignificant.

As a consequence it is recommended to revise the Environmental Impact Assessment of the project so that transboundary impacts are covered and that questions about impacts and mitigation measures are answered in line with international best practice. Beyond the EIA, there is a need for a Cumulative Impact Assessment focussing on the possible impacts of the Xayaburi dam in addition to those of the 47 other dams that will be present in the Mekong Basin by 2015.

Review of the fish pass facilities proposed

The definition of target species and a review of Mekong fish swimming capabilities and flow requirements, recommended in the Feasibility Study, are absent from the EIA, as well as references to international experience in fish passes (in particular the Pak Mun experience is not reflected). As a consequence the fish passage options proposed are not underpinned by biological information.

Basic information such as technical drawings, location of fish pass entrances or details of pool design is missing in the EIA (e.g. specific design options within each pool, which have a strong influence on hydraulics and on the pass performance, remain to be defined).

The length and the slope of the fish passes are not appropriate: they imply a succession of 37 cm high steps, higher than what is acceptable even for salmonids and much higher that what is passable by dominant Mekong small cyprinids. In fact fish passes 3 times longer with less steep slope and lower steps should be considered. In addition, the proposed dimensions of pools, discharge and slope imply that the turbulence level in the pools would also be too high for these species. Last, it is essential that the EIA identifies the measures to be taken during the dam construction period so that fish migrations are not interrupted during these years.

EIA also omits consideration of the following measures:

- target species must be identified and swimming capabilities of these species must be specified;

- the pros and cons of each fish pass type must be discussed in relation to the species diversity, to the target species, to the fish abundance peaks, to the height of the dam and to the upstream and downstream variations in water level;

- hydraulic criteria for fish passes (range of discharges, maximum and average flow velocity, turbulence level, flow pattern) must be specified based on specific studies, as well as the dimensions of the design elements;

- the location and the number of fish pass entrances must be specified;

- the possibility of dam operation in hydropeaking mode and its hydrological consequences must be clarified; in particular the minimum water level left in the reservoir must be specified;

Overall the fish passage facilities proposed to mitigate the impact of the Xayaburi project on fish migration meet 4 out of the 30 guidance points of the MRC "*Preliminary design guidance for proposed mainstream dams in the Lower Mekong Basin*", but they do not meet or do not provide evidence of meeting 19 out of these 30 points. **The fish passage facilities are not based on experimentation, some of their features are not precisely detailed, and several of their characteristics are unlikely to be compatible with the passage of dominant Mekong fish species.**

While fish passage facilities can mitigate to a certain extent the impacts of the obstacle on upstream and downstream migration at the dam site, they do not solve all environmental problems created by the hydropower project, in particular potential changes in flow regime (depending on operation rules), in water quality, nor drastic changes to the habitat upstream of the dam.

1 INTRODUCTION

The Xayaburi project and the MRC procedures

The Xayaburi dam, proposed by the CH. Karnchang Public Company Ltd. from Thailand, would be constructed on the Mekong mainstream in Lao PDR. This 1,260 MW dam would be 830 m wide, creating a 60 km long reservoir; it would feature a navigation lock and two fish passes.

The Government of Lao PDR officially notified the MRC of the project on 20 September 2010. The project is now subject to the MRC *Procedures for Notification, Prior Consultation and Agreement* (PNPCA)[1]**.** This notification triggered a 6-month long review process characterized in particular by i) seven public consultations in Thailand, Cambodia and Vietnam and ii) a technical review including comparison with MRC's "Preliminary Design Guidance" and analyses by two Expert Groups on Fisheries and Sediments.

The MRC Joint Committee is scheduled to announce the MRC countries' official position with regard to the Xayaburi project on 22 April 2011.

This report

This report is a brief review of the fish and fisheries section of the Environmental Impact Assessment and of the Feasibility Study of the Xayaburi hydropower project, with a particular focus on the ecological context and the fish passes proposed as a mitigation measure. Standards for this EIA review reflect the guidelines issued by the Asian Development Bank, the International Association for Impact Assessment, the International Hydropower Association and the World Commission on Dams.

The present review is based on the 2008 Feasibility Study produced by AF-Colenco Ltd.[2] (referred to as FS hereafter)and the August 2010 EIA report produced by TEAM Consulting Engineering and Management Co. Ltd.[3] (referred to as EIA hereafter), the latter being considered as the reference report. The present review was done independently from that of the PNPCA Expert Groups on Fisheries and Sediments, based only on the above documents and completed before the results of the latter were made available on the MRC website on 27 March 2011. The review gives some guidance on basic mitigation measures, but those guiding directions should by no means be interpreted as a replacement of the thorough studies required for a proper assessment of environmental impacts and of mitigation measures for fish passage. As such this report strongly supports the conclusions of the Strategic Environmental Assessment on Mekong mainstream dams (SEA) that the Mekong should not be used as a test case and that decisions on mainstream dams should be deferred for a period of ten years. Projects should move ahead only once it has been proven that impact is acceptable by all riparian countries and that mitigation will be effective.

[1] http://www.mrcmekong.org/pnpca/PNPCA-technical-process.htm

[2] www.colenco.ch

[3] www.team.co.th

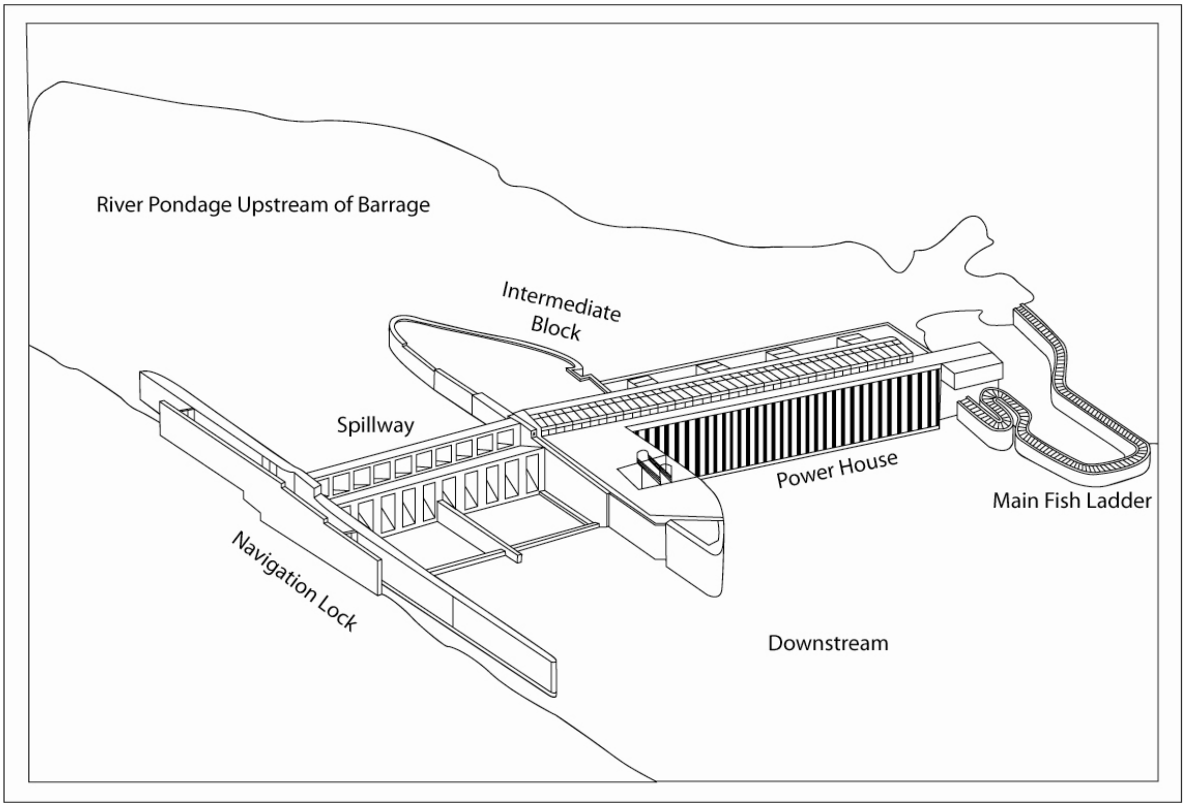

Figure 1: View of the dam (redrawn from the EIA, page 3-3)

2 THE XAYABURI PROJECT

2.1 MAIN CHARACTERISTICS

The Xayaburi dam has been proposed in a site located 350 km upstream of Vientiane and 770 km downstream of Jinhong, the last dam of the Chinese cascade of seven dams. By global standards the Xayaburi project is a *large dam*[4], like around 300 other dams in this category in the world. In terms of mean annual energy supply, it would be the third largest project among those considered for development in the LMB[5] (MRC Hydropower database 2009). The main features of the project are summarized in Table 1:

[4] The International Commission on Large Dams (ICOLD) defines "large dams" as dams with a height of 15 meters or more. The International Journal on Hydropower and Dams uses the term "major dam project" for projects featuring, like the Xayaburi project, a reservoir volume of more than 25 billion cubic meters or an installed capacity of more than 1000 MW. (Oud and Muir 1997)

5 after Sambor and Ban Kum respectively.

Table 1: Main characteristics of the Xayaburi hydropower project

	Xayaburi project	Source
Location (deg/min/sec)	19°14'47.50"N 101°49'8.06"E	FS maps and Google Earth
Distance to sea (km)	1932	MRC navigation maps
Earliest potential commission date	Mid 2018	EIA p3-4
Length of dam (m)	830	EIA p3-3
Height of dam (m)	49	See below
Maximum Head (m)	32.6	FS p 9-2
Turbines	Kaplan, either 8 or 10 turbines	8: FS p 7-28, 8-2, 9-2, 11-2 10: EIA p 3-3, 5-3,
Maximum design flow through turbines ($m^3.s^{-1}$)	5000	FS p.9-2
Installed Capacity (MW)	1260 or 1280	1280: FS p 9-2, EIA p3-3 1260 EIA p5-3
Total annual energy (GWh)	7,406	FS p 7-34
Reservoir area (km^2)	49	FS p 9-2, EIA p 3-3
Reservoir length (km)	60 or 90	EIA p3.3 or ICEM 2010
Reservoir active storage (million cubic meters) [6]	224.7	MRC Hydropower project database
Reservoir total storage (million cubic meters)[7]	703.2	MRC Rule curve
Average reservoir depth (m)	7.4	ICEM 2010
Water level variability in the reservoir (drawdown in meters):	5m (between 270 and 275 masl)	MRC Hydropower project database
Navigation lock	2 step navigation lock for boats up to 500 tons	EIA p3.3
Fish pass	2 fish ladders, both 3m deep x 10m wide, one 600m long, the other one 800m long	EIA p 3.3 FS p. 8.25

masl: meters above sea level

2.2 REMARKS ABOUT THE XAYABURI PROJECT CHARACTERISTICS

Height of the dam. The dam structure height is not explicitly mentioned in any of the project documents; what is detailed is the maximum water head (difference between upstream water level and downstream water level), i.e. 32.6 meters (FS p. 9-2). However the structure itself will be much higher than this water head, as shown in Figure 2:

The total height of the construction, between crest (altitude 280 masl, FS p 9-2) and dam foundation (altitude 231 masl, TEAM 2008) **is actually 49 meters**.

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6 the active storage is the volume of water controlled by the dam and stored between the outlets and the spillway crest.

7 the total storage is the total volume of water stored behind the dam (active storage + dead storage)

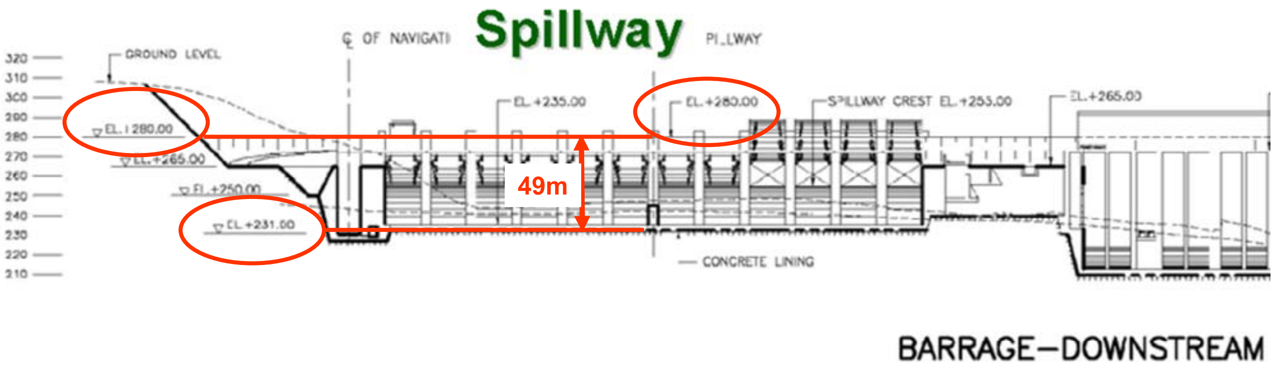

Figure 2: Total height of the Xayaburi dam (49 m), between 231 masl (base of the spillways) to 280 masl (crest), based on Team 2008.

Number of turbines. **The number of turbines is unclear**; in 2008 the Feasibility Study considered two options with respectively 8 and 10 turbines, before recommending **8 turbines** (FS p 11-2). However the EIA completed in 2010 is based on 10 turbines (e.g. EIA p. 3-3, p. 5-3), which has different ecological implications in terms of flows released downstream.

Creation of a reservoir. The construction of a 49 meters high barrage across the Mekong will create a reservoir. We calculate that the maximum depth of this reservoir will reach 34m (Annex 1); similarly, the Feasibility Study states that the maximum head (i.e. maximum difference between upstream and downstream water levels) will reach 32.6 meters (FS p 9-2); the common conclusion is that a reservoir exceeding at least 30 m in depth will be created at the dam site. According to the EIA the length of this reservoir will reach 60 km (EIA p3.3) but alternative estimates based on water levels and a digital terrain model (ICEM 2010) indicate that the reservoir would rather be 90 km long, reaching Luang Prabang city (see Annex 1). Overall the conclusion is that **a reservoir reaching at least 30 meters in its deepest point and stretching over at least 60 km will be created**. This has important ecological consequences in terms of transformation of riverine habitats and for the fish fauna.

Nature of the dam. As noted by IUCN and the WorldBank (1997), the term "run-of-river" means different things to different groups.

- "*Strictly,* run-of-river *means the river is not dammed; the river runs over and around any structure. A true run-of-the-river hydro can be an axial tube turbine either sitting on the river bed or at least below the surface of the river, but without a barrier to water movement*" (Goodland 1997).

  This strict definition implies no dam, no reservoir and no impact on flows. As noted by Hill and Hill (1994) in their review of mainstream "run-of-the-river" projects for the MRC: "*Engineering studies should also address (or reexamine) true run-of-the-river projects. Such projects do not require cross-channel dams.*" Thus the Xayaburi project is not a run-of-river dam by this definition.

- Definition by Electricité de France: "*a dam is a* run-of-the-river *dam if the time needed to fill the reservoir live storage with a discharge equal to the average annual discharge is less than two hours*[8]".

  With an average annual discharge of 3,900 $m^3.s^{-1}$ its live storage (224.7 mcm) would be filled in 16 hours, so the Xayaburi project is not a run-of-the-river dam.
- "Run-of-river *project: a hydroelectric project which does not have a reservoir to regulate the river flow (it must operate using the day to day water flows naturally available)"* (Mekong Secretariat 1994).

  This definition implies no reservoir aimed at regulating flows, but is ambiguous about the existence a reservoir that would not be aimed at regulating flows. This ambiguity has already been highlighted in the past:

  "*In 1994, the Mekong Secretariat published a major study for a series of half a dozen main-stem dams across the Mekong, entitled "Run of River", which concluded that "environmental impacts of the proposed projects are expected to be … not severe." This caused inter-national disagreement, partly because the same report (fish chapter) concluded the opposite: The proposed dams "may cause a wholesale decline in the fishery throughout the lower Mekong River." And partly because there is disagreement on how such dams could be labeled run-of-river*" (Goodland 1997).
- "Run-of-river*: projects that do not affect the natural river flow more than for daily storage".* WorldBank 2009. This definition is not explicit about the cross-channel dam, nor about the reservoir, and focuses on flows.

By a strict definition, the Xayaburi project, with a 830m long cross-channel dam and a reservoir stretching over more than 60km, **does not qualify as a run-of-the-river dam. By the MRC and WorldBank's definitions, the Xayaburi dam qualifies as a run-of-the-river dam if there is evidence that the daily outflow curves do not diverge from average natural curves by more than a day.**

[8] http://fr.wikipedia.org/wiki/Énergie_hydroélectrique

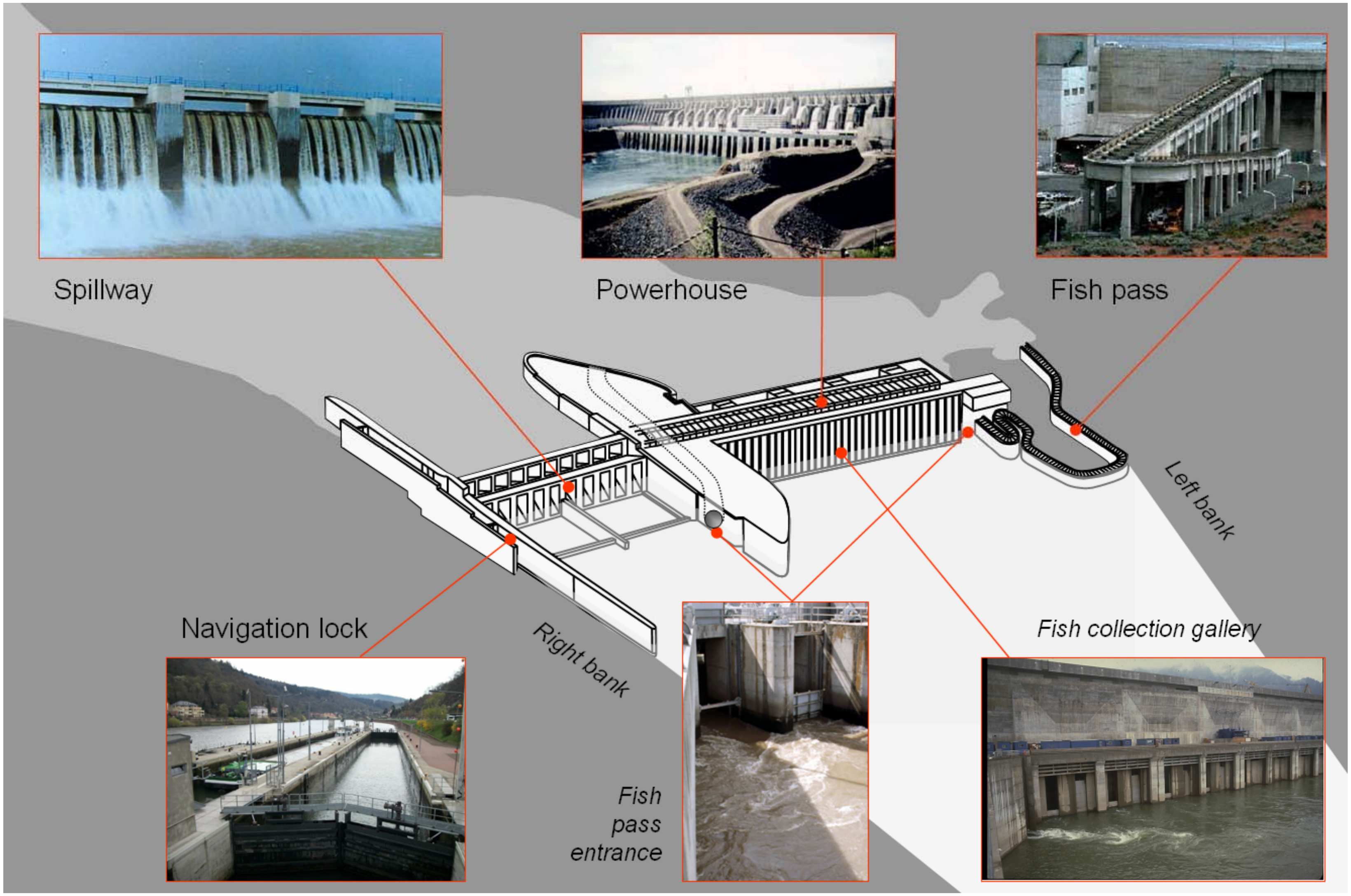

Figure 3: Proposed project (based on EIA p. 3-3), with illustrations of the main features (photos from existing dams elsewhere in the world are provided for illustrative purpose and may not reflect *exactly* the features of the proposed dam)

3 WHAT IS AN ENVIRONMENTAL IMPACT ASSESSMENT (EIA)?

An Environmental Impact Assessment (EIA) is the study of likely consequences of a proposed development project on the environment. More specifically, an *EIA is the "identification, description, and assessment of the direct and indirect effects of a project on: human beings, fauna and flora, soil, water, air, climate and the landscape, the interaction of these factors, and on material assets, and the cultural heritage* (IEA 2000a). An EIA ultimately tells decision-makers and stakeholders whether a project is environmentally acceptable. EIAs also include mitigation measures and monitoring of impacts.

Environmental Impact Assessments for major hydropower projects that are located on transboundary rivers and have the potential for regional consequences are expected to conform to international standards. The international standards for EIAs are detailed below; they are based on guidelines from the Asian Development Bank (Lohani *et al.* 1997, ADB 2006), the International Association for Impact Assessment (IAIA 1999), the World Commission on Dams (WCD 2000), the International Energy Agency (IEA 2000 a,b,c), the International Hydropower Association (IHA 2004), and are complemented by guidelines from experts and scientists (e.g. Verocai 2000, Bernacsek 2000, Wood 2003, Keskinen 2008, Kummu 2008).

4 IMPACTS TO BE ASSESSED IN FISH-RELATED EIAS AND CASE OF THE XAYABURI EIA

Based on the above international guidelines and standards, we detail below the issues to be covered in an Environmental Impact Assessment meeting international standards, and we review how these issues are addressed in the Xayaburi EIA completed in August 2010 and submitted by the Ch. Karnchang Public Company Ltd to the four National Mekong Committees in September 2010.

4.1 STUDY AREA AND OPERATION RULES

The study area to be examined includes: i) the catchment area, including upstream tributaries; ii) the reservoir area; iii) the downstream area subject to changes in flows and water quality, and iv) the whole mainstream (usually as part of a Cumulative Impact Assessment).

As the introduction to the Xayaburi EIA indicates (page 1-2), the study area is comprised of "the watershed area of the proposed site to the extent as deemed necessary", the impoundment area and the downstream area about 10 km from the barrage site. However, the study area actually covered by the EIA is restricted to one site one kilometre downstream of the dam and five sites spread 22 kilometres upstream of the 60 km long reservoir (page 4-45).

This implies that **the upstream catchment area is not studied** (e.g. are there fish species in upstream tributaries that breed in the mainstream and that are at risk of disappearing when the reservoir alters their breeding habitat?), that **impacts in at least two-thirds of the reservoir are not studied**, and that **none of the downstream impacts are studied in the EIA**.

The filling of the reservoir and the operation of the turbines influence the impacts of the dam; for this reason, EIAs must specify, among other things, the reservoir filling schedule, the operational flow details such as minimum releases downstream, the peak generating flows and the daily/weekly generating time schedule. **None of the above indicators are detailed in the EIA.**

Overall quality of the assessment regarding the study area and operation rules:	Good	Insufficient	**Missing ☑**

4.2 IMPACTS ON WATER, HABITAT, FISH AND FISHERIES

According the World Commission on Dams (WCD 2000) and the MRC (Halls and Kshatriya 2009), EIAs should examine three categories of impacts on fish resources:

- first order impacts, i.e. changes to river hydrology, changes in water quality, obstruction of fish migrations, dam passage mortality;
- second order impacts, i.e. changes to fish habitats (availability and quality);
- third order impacts; i.e. changes in fish biodiversity and fish abundance.

We review below how the Xayaburi EIA has covered each of these categories.

4.2.1 FIRST ORDER IMPACTS ON WATER

4.2.1.1 Impact of the dam on hydrology

The Feasibility Study claims that the dam will be "run-of-the river" and thus have no impact on the downstream flow (feasibility Study p. 1-3, 2-2, 3-13). The EIA and the current review are both based on the assumption that the dam will not induce any change in the timing of the water released downstream.

Actually the term "run-of-the-river" can be used if it is demonstrated that the actual dam operation rules (i.e. the dynamics of storing water in the reservoir and releasing it in a controlled way through the turbines) do not modify the natural flow pattern by more than one day. Conversely, the term "run-of-the-river" cannot be used *a priori* to justify, without examination, that the natural flow pattern will not be altered. In absence of supporting evidence the latter point is actually an assumption, and therefore cannot be a reason for skipping the examination of hydrological impacts (as done on EIA pages 5-3, Hydrology section: "*The water will not be stored because project was designed with natural flow […] The* *downstream flow of Mekong River will not be changed due to project development*"). In the Fisheries section, the "run of river" dam is claimed to simultaneously regulate the water level ("*The increasing of water body and regulation of water level even in the dry season would benefit for the aquatic living organisms*", page 5-11) and not to regulate it ("*the flow of water pass barrage site in every season will not be changed*", page 5-12).

In general, dam operators may operate the turbines either at constant level, or sometimes at maximum capacity over a temporary period, in order to supply electricity during peak power demand; this latter operation option is termed "hydropeaking". In the case of Xayaburi dam, the assumption is that "at any moment the outflow from the project will be equal to the inflow, without any daily fluctuation" (FS p 7-9). However in case the operator considers "hydropeaking", then the environmental consequences would be very different and this would call for a new EIA taking hydropeaking into consideration. In case of hydropeaking, the number of turbines operating[9] (and thus releasing water downstream) would vary between 0 and 10 during the day/night, creating a large daily fluctuation in water level in the reservoir and downstream of the dam (a problem already faced with the Yali Falls dam in Vietnam; see also Gore *et al.* 1989). **The possible daily fluctuations in water level downstream of the dam and in the reservoir are not covered in the EIA.** Such fluctuations can reach several meters per day in the reservoir and downstream of the dam and are noticeable up to 50 km downstream (IEA 2000c; Poff and Hart 2002, ICEM 2010). **A reading of the rating curves provided in the EIA** (p. 4-40 and Annex 2 of the present report) **shows that the expected variation in downstream water level will reach at least 5 meters, depending on turbine operation** (although the time step is not detailed). During the Public Consultation on 28 February 2011, the MRC highlighted the "need to obtain clarity on operating constraints for power generation", and **we emphasize the need for the operator to clarify the planned operation mode, since hydropeaking may result in impacts to be covered, quantified and mitigated in the EIA.**

During the construction period, the retention of more than 225 million cubic meters of upstream flow for the creation of a reservoir is dealt with in four lines in the EIA *("The river will continue the flow as natural condition […] the project construction activities will have minor temporary impact on the hydrological regime"* (page 5-3)**. Actually the reservoir filling period** (stretching over several years)**, the degree of water retention behind the dam** (that can vary between 10%, as recommended by ADB 1997, and 100% when the river downstream is dried up –case of the Nam Lik 1-2 project) **and the impact of reduced flows on mainstream dry season water levels** (e.g. controversy about the impact of Chinese dam reservoir filling on dry season flows[10]) **are not detailed nor discussed in the EIA, although these are factors that could heavily disrupt local fish resources, transboundary migrations and downstream fisheries.**

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[9] This number is not fixed in the documents provided and varies between 8 and 10 (e.g. 10 turbines in the 2008 Feasibility Study page 1-5, 8 turbines finally recommended on p 9-2 but 10 turbines most often mentioned in the 2010 EIA, for instance on page 3.3)

[10] Financial Times 02-07-2010: "Thai officials condemn planned Chinese dams";
Phnom Penh Post 29-03-2010 "Low Mekong isn't caused by dams"

It should be noted that if the Xayaburi dam proceeds without delay, the filling of its reservoir will coincide with that of the giant Nuozhadu dam planned for completion in 2017 (EIA p. 4-34)[11]. However, **the impact on Mekong flows of simultaneously filling both the Nuozhadu and Xayaburi reservoirs, particularly in the dry season, is not mentioned in the Xayaburi EIA**[12]**.**

Overall, the conclusion that downstream hydrological impacts will be minor or nil is not substantiated.

Overall quality of the assessment regarding impacts on hydrology:	Good	Insufficient	**Missing** ☑

4.2.1.2 Impact of the dam on water quality

The creation of the 49 km^2 dam reservoir will flood trees and vegetation along 60 km of river banks. The full decay of this vegetation may take several decades. During this period the oxidation of vegetal debris will absorb oxygen, possibly resulting in degraded water quality downstream (Ploskey 1985, Agostinho *et al.* 2007). The surface area of vegetation flooded by the dam will represent 49 km^2 minus 29 km^2 corresponding to the area of the river within its banks during the dry season (measurement based on Google Earth, from the dam site up to 60 km upstream). Thus at least **2000 hectares of vegetation will actually be flooded by the dam reservoir and will decay over several years. In the EIA, the area studied is limited to the barrage area, corresponding to 21 hectares** (page 4-105)**. This represents a hundredfold underestimate of the upstream area impacted, and a flaw related to the impact of the project on downstream water quality. Actually the possible impact of decaying vegetation in the dam reservoir is not mentioned in the two pages dedicated to impacts on water quality downstream** (pages 5-4 and 5-5).

In addition to chemical impacts, the creation of at least 225 million cubic meters of active storage water (Figure 4) may result in stratification of the water column and a significant decrease in water temperature in the reservoir, making the habitat uninhabitable for fish and

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[11] although according the dam might be completed in 2014 according to the MRC IWRM-based Basin Development Strategy (2009)

[12] "*In the most simple terms possible, a reservoir's operation alternates between the following two activities: one is known as positive regulation, which consists of holding water to prevent flooding and releasing water to relieve a drought. […] The other mode of operation consists of discharging the flood waters and retaining limited flows in the dry season. This type of operation represents almost the exact opposite of the first type of operation discussed above. In this case, upstream reservoirs release turbid waters in the wet season and store water by cutting the upstream water flow in the dry season. Because flood waters carry much sediment and are likely to cause blockages, this way of regulating permits the flushing of sediment in the wet season and sustains reservoir capacity in the dry season. Beyond this consideration, such a mode of operation increases the efficiency of electricity-generation, which is dependent on the volume of water flows and the head or height of the water. As during the dry season, water flow volume is limited, storing water helps to sustain high water levels upstream, which is good for electricity generation, although bad for the downstream. Used to the maximum extent, this mode of operating will lead to extreme flooding in the wet season and extreme drought*." Qin Hui 2010. Reflections on a depleted Mekong River. The Economic Observer, 12 April 2010 [online: http://www.eeo.com.cn/observer/shijiao/2010/04/13/167385.shtml]

other aquatic life (Agostinho *et al.* 1999). This stratification would also result in bottom layers becoming anoxic. When such cold, anoxic bottom layer passes through the dam (e.g. during sediment flushing), it contaminates the stream tens of kilometers downstream, killing the benthic life and creating a chemical barrier to fish (Marmulla 2001).

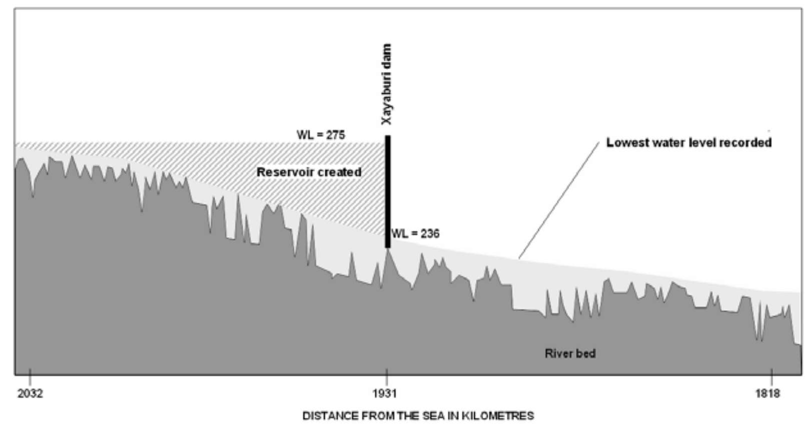

Figure 4: River profile upstream and downstream of the Xayaburi project (drawing based on the figure on page 7-17 of the Feasibility Study)

The EIA does not assess the impact of the project on water quality downstream of the dam; in particular, the impact of the deoxygenated and chemically altered water resulting from the slow decay of 2000 hectares of flooded vegetation on river life, irrigation and drinking water supplies is not addressed.

Overall quality of the assessment regarding impacts on water quality:	Good	Insufficient	**Missing** ☑

4.2.1.3 Impact of the dam on river continuity and fish migrations

The Mekong River is characterized by record fish migrations, in terms of distance, number of fish species involved and fish biomass involved (Poulsen *et al.* 2002, Baran 2005, 2010, Baran and Myschowoda 2009, Dugan *et al.* 2010). As the Feasibility Study correctly states, the impact of the Xayaburi dam on migratory fish species is perhaps among the major ecological concerns. Evidently, this issue was considered important by the designers, who proposed a couple of fish passes as part of the mitigation strategy. However, **the description of Mekong fish migrations in the EIA is extremely poor: the literature review consists of only 3 references** (Mekong Secretariat 1994[13], Poulsen *et al.* 2002[14], and Baran 2006)**, whereas other reviews have identified more than 28 studies and sources of information on Mekong fish migrations** (Baran

[13] Full reference not given and unclear; this may actually refer to the 1992 landmark study on Mekong fisheries (MRCS 1992)

[14] also cited as "MRC 2002"

2006)**, all accessible during the EIA process. As a consequence, the EIA does not draw any conclusions about the importance of Mekong fish migrations in the project impact area.**

Information about fish migrations in the Mekong is rapidly evolving. Baran (2010) identified at least 27 species migrating upstream of Vientiane. It can be noted that 61 fish species are found in both the Lower Mekong and the Upper Mekong in China (Kang Bin 2009), and that the latter country announced in October 2009 that it would not build the Mengsong dam so as not to obstruct upstream fish migrations in the Upper Mekong (Bin Kang *et al.* 2009). **Ongoing research** (Baran *et al.* in prep., Ziv *et al.* in prep.) based on a review of over 70 databases, articles and species lists, **shows that 229 fish species exploit habitats upstream of the planned dam site for spawning and/or dry-season refuges, 70 of them being migratory species (see Annex 3). Among these are some rare and critically endangered species such as the Mekong Giant Catfish (*Pangasianodon gigas*). In contrast, the EIA only mentions an old list of 16 fish species, including 5 migratory species, compiled by the MRC in 1994**[15] (pages 4-77 and 4-78).

Table 2 lists the 229 species we identified as potentially impacted by the Xayaburi project, divided into different ecological groups ("guilds"). The most impacted species would be migratory species that exploit the mainstream for spawning and/or as dry-season refuges. This category includes 43 species that would be affected both by the impediment to migration represented by the dam itself and by the changes in river conditions in the reservoir above it. Another 27 migratory species are known to exploit tributaries upstream of the dam study area, and their migration would also be interrupted by the Xayaburi dam. Furthermore, there are 159 non-migratory species in the mainstream sub-basin between Chiang Saen and Vientiane and the nearby Nam Ou sub-basin. Overall, the Xayaburi EIA mentions only 14% to 25% of the species in each of the ecological groups identified here (see Annex 3 for details).

Table 2: Impact of Xayaburi dam on fish migration

<table>
<tr><td colspan="2" rowspan="2">Fish guilds</td><td rowspan="2">Number of species in our study*</td><td rowspan="2">Number of species in the EIA</td><td colspan="2">2015 "Definite future" scenario of the MRC BDP2</td><td colspan="2">2015 "Definite future" scenario + Xayaburi dam</td></tr>
<tr><td>Endangered♦</td><td>Critically Endangered♦</td><td>Endangered♦</td><td>Critically Endangered♦</td></tr>
<tr><td rowspan="2">Migratory</td><td>Mainstream users</td><td>43</td><td>6</td><td>7</td><td>1 (Pangasianodon gigas)</td><td>9</td><td>1 (Pangasianodon gigas)</td></tr>
<tr><td>Tributary users</td><td>27</td><td>7</td><td>2</td><td>1 (Pangasius sanitwongsei)</td><td>7</td><td>2 (Pangasius sanitwongsei + P. nasutus)</td></tr>
<tr><td rowspan="2">Non migratory</td><td>Mainstream species†</td><td>95</td><td>16</td><td>N/D</td><td>N/D</td><td>N/D</td><td>N/D</td></tr>
<tr><td>Nam Ou species†</td><td>64</td><td>10</td><td>N/D</td><td>N/D</td><td>N/D</td><td>N/D</td></tr>
<tr><td colspan="2">Total</td><td>229</td><td>54‡</td><td>9</td><td>1</td><td>16</td><td>3</td></tr>
</table>

[15] or possibly in 1992, see previous foot note

Notes:

♦ The terms "Endangered" and "Critically endangered" refer to the IUCN definition of species experiencing a population reduction greater than 50% and 80% respectively. The population decline modeled here is based on discharge and habitat reduction.

* This analysis considers only species that can be affected by the Xayaburi dam. Several more species would be endangered in the MRC BDP2 "definite future" scenario because of other dams.

†The analysis in Ziv *et al.* (in preparation) allows estimation of the potential biodiversity loss only of migratory species. We note, however, that the Xayaburi dam would cause habitat fragmentation for non-migratory species too. Isolated communities have larger local extinction rates and lower recolonization rates, which lead to decreased local species richness. Thus, non-migratory species can (and probably would) be impacted by Xayaburi. None of these species are listed in IUCN 2010 list of endangered species.

‡ The EIA fish survey reports on two migratory species, *Cirrhinus caudimaculatus* and *Brachirus harmandi,* which had not been detected so far upstream and hence are not listed in the first row of this table. Another 10 species listed in EIA are non-migratory species reported elsewhere in the basin, but not in this area. Finally, *Garra cyclostomata* was reported in the EIA but has not been confirmed to exist in the Mekong based on scientific literature.

Overall quality of the assessment regarding impacts on river continuity and fish migrations:	Good	Insufficient	**Missing ☑**

4.2.2 SECOND ORDER IMPACTS ON HABITATS

Upstream of the dam, at least 60 km of riverine habitat will be modified by the creation of a reservoir, with risks of deoxygenated water, changes in water quality and increased sedimentation (which justifies the construction of four twin sediment-flushing outlets – Feasibility Study p. 8-12)**. However, the very creation of a permanent water body,** illustrated in the Feasibility Study (page 7-17; see also Figure 4 and Annex 1 of the present report)**, is denied in the EIA report** ("*Transformation of the habitat from a river with rapids into a standing ecosystem due to impoundment will not occur for Xayaburi Hydroelectric Power Project due to run-of-the river scheme*", EIA page 5-11). This statement is at odds even with the Project Feasibility study (p. 8-37) and with the EIA Appendix 3.1 (p. 12) where it is acknowledged that "***Hydropower development on the Upper Mekong System of Lao PDR will submerge spawning and rearing habitats of migrating fish species. It is therefore recommended to identify and describe the physical characteristics of these habitats** for future habitat recovery before impoundment*"[16].

Similarly, the EIA does not mention the potential impact on mainstream fish habitats of sediment retention, of the release of low quality water and of the potential daily variation in water levels downstream of the dam. Specific impacts on fish spawning grounds and feeding

[16] This, and the other discrepancy noted in section 4.2.3.3, incidentally highlights the disconnection between the section on fish passes (EIA Appendix 3.1, by Terraplant Ltd.) and the main EIA (in particular the Mitigation section, by TEAM Ltd).

grounds, on fish refuges and on deep pools (mentioned without follow up on page 4-79) **are not addressed.**

More generally, all recent EIAs of quality include an analysis of environmental flows, i.e. the hydrodynamics (in terms of quantity and timing) that allow maintaining "all ecological functions, services and socioeconomic goods provided by rivers" (Dyson *et al.* 2003, Arthington *et al.* 2007). In the case of the Xayaburi EIA, the term "environmental flows" is not even mentioned.

Overall quality of the assessment regarding impacts on habitats:	Good	Insufficient	**Missing ☑**

4.2.3 THIRD ORDER IMPACTS ON FISH BIODIVERSITY AND ABUNDANCE

4.2.3.1 Impacts on fish biodiversity

In all EIAs, comprehensive fish species lists (drawn from the literature or from specific field surveys) are a preliminary requirement for any analysis of possible impacts of the project on local biodiversity. In the case of the Xayaburi EIA, a list of 16 species was identified from the literature (p. 4-77). A brief field survey done over only two months (p. 4-86 and 4-95), during one single season (November and March, see on pages 4-10 and 4-35 that both months belong to the dry season) and with only one gear (gillnet) produced a list of 54 species[17], leading to the improper conclusion that "*fish biodiversity in the impact area is quite low*" (EIA p 6-8). By comparison, the species richness sampled in the lower reach of the Chinese Mekong amounts to 142 species (Kang Bin *et al.* 2009) and that of the Mekong mainstream in Northern Laos to 140 species (Dubeau 2004). It can be deduced that **the Xayaburi EIA, ignoring existing published information and based on a very light sampling effort, resulted in a biodiversity assessment representing less than a third of the actual species richness in the impact area. The conservation status of each species (endangered, etc) is not detailed; the case of the flagship giant catfish migrating from Vietnam up to Luang Prabang (MFD 2003) is ignored** (EIA p. 5-11), **and no conclusions are drawn from the field work.**

Overall quality of the assessment regarding impacts on fish biodiversity:	Good	**Insufficient ☑**	Missing

Acknowledging that floodplain habitats downstream of Kratie/Sambor are not exposed to damming and that river habitats upstream of Ganlanba Dam in China are already inaccessible to migratory fish, an analysis based on the BDP2 "Definite Future" scenario for 2015 and on the

[17] actually 51 species and 3 genera with undetermined species

MRC GIS map of Mekong sub-basins shows that **the construction of Xayaburi would obstruct about 125,000 km^2 or 36% of habitats in upstream watersheds that were not already obstructed by other dams in 2015 and thus were previously accessible to migratory fish**[18] (Figure 5). The impact on different species would vary depending on the way they use other areas of the Mekong Basin.

Estimation of the biodiversity impacts of Xayaburi dam is possible using the distribution of species in the Mekong (Baran *et al.* in preparation) and the IUCN definition of species becoming endangered and critically endangered species when their population is reduced by >50% and >80% respectively (IUCN red list of threatened species, version 2010.4. www.iucnredlist.org). We estimate that **in 2015** (year corresponding to the MRC BDP2 "definite future" scenario in absence of Xayaburi dam), **nine of the 70 migratory species exploiting the impact area and/or its catchment will become classified as endangered, and that the construction of the Xayaburi dam will bring this number to 15** (Table 2, Annex 3 and Ziv *et al.* in prep). Furthermore, **one more catfish species (*Pangasius nasutus*) will join the two species currently critically endangered** (*Pangasianodon gigas* and *Pangasius sanitwongsei*) **because of the dam construction**. This analysis focuses only on migratory fish species, and **there may be an additional loss of non-migratory species dependent on riverine habitats;** thus Baran (2010) identified 41 species found only in the mainstream upstream of Vientiane, and these species typically found in running waters are threatened by habitat alteration following the reservoir creation.

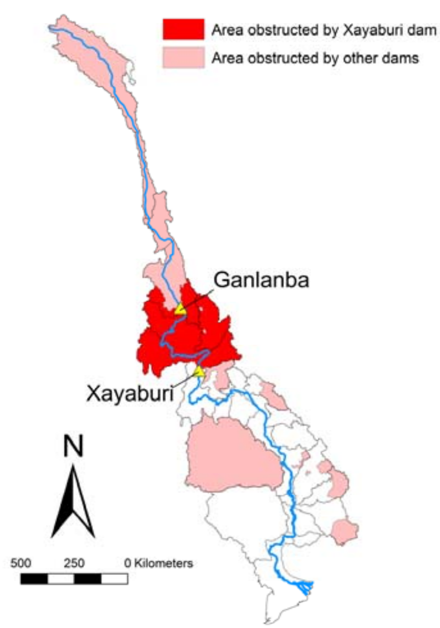

Figure 5: Habitat that will be made inaccessible to migratory fish following the construction of the Xayaburi dam. This habitat represents the watersheds between Xayaburi and Ganlanba, the last dam of the Chinese cascade.

[18] 125,000 km^2 is close to the size of the state of Mississippi or more than the size of Luzon, the main island of the Philippines.

4.2.3.2 Impact of the dam on fish life stages

The requirements of species vary depending on their life stage: the needs of larvae and juveniles (in particular in terms of diet and currents) are not the same as those of the adults of the same species. **The EIA does not make any mention of the different requirements of the different life stages of the fish species in the impacted area and does not detail the potential impacts of changes triggered by the project on these life stages.**

Overall quality of the assessment regarding impact on fish species life stages:	Good	Insufficient	**Missing** ☑

4.2.3.3 Impact on fish abundance

All EIAs try to assess the fishing effort in a project area, and the possible impact of the project on fishing. **In the Xayaburi EIA, no mention is made of preexisting artisanal fishing in the project impact zone despite the acknowledgement in the Feasibility Study that 2,185 persons live in the project area, i.e. along the river.** Fishing downstream of the dam is equally absent in the EIA study (although it might be covered in the Social Impact Assessment, that was not available at the time this report was completed)**.**

One of the roles of an EIA is to provide fisheries baseline data before a project is developed. **The assessment of annual fish abundance, based of just three gillnets set 12 hours each at 6 stations on two separate occasions** (March and November, p. 4-76) **is not, by any standard, a serious baseline for the assessment of impacts once the dam is constructed**. The absence in the EIA of a credible assessment of fish abundance in the project impact area is even at odds with the recommendation of the project Feasibility Study (p. 8-37) and of the EIA Appendix 3.1 (p. 12): "*It is recommended to exactly identify the fish species composition (number of species) and abundance (number of individuals) for the Upper Mekong System of Lao PDR*". The Feasibility Study also specifies that "*the period of survey shall cover at least one full year*". In the absence of actual field sampling, recording log books given to fishermen, as done for Nam Ngum project, would have been a possible option.

A review of the Xayaburi provincial economic and social development plans from 2000-2009 would have shown that in the project area alone, local authorities estimated capture fish production to about ten tonnes a year (Baran 2010) and that a study of fish consumption by the MRC in Luang Prabang province (Sjorslev *et al.* 2000) concluded that more than 10,000 tonnes of fish were consumed annually in Luang Prabang province. The per capita consumption figures for Xayaburi (12.8 kg/person/year, FAO-PADP 1998) multiplied by the population of the province indicate that more than 4,500 tonnes of fish are consumed in this province annually. The contribution of capture fish to the local people's protein supply is not mentioned in the EIA.

When a reservoir is created, turning a portion of a river into a lake, there is usually a dramatic change in fish species composition (development of small pelagic fish, loss of migratory species), with important consequences in terms of fishing gears needed, catch rates, and socio-economic impacts. **In the Xayaburi EIA, the creation of a permanent water body is ignored and there is no mention of the consequences for the fisheries resources of transforming at least 60 km of running river into a lake**.

Overall quality of the assessment regarding impact on fish abundance:	Good	Insufficient	Missing ☑

4.2.4 IMPACTS BEYOND FISH AND FISHERIES

According to FAO data, the freshwater *fish catch* per inhabitant in Cambodia, Lao PDR, Thailand and Viet Nam is nearly four times the world average (Baran 2010). The average f*ish consumption* of freshwater fish per person in these countries amounts to 13.8 kg/person/year, i.e. six times more than the world average. Seven studies in Lao PDR (reviewed in Hortle 2007) have highlighted the high dependence of rural populations on capture fish, in particular in Northern Laos around Luang Prabang (Sjorslev *et al.* 2000). However, **the Xayaburi EIA does not even mention the role of river fish in the food security of riparian people in the project impact zone and the possible impact of the project on this resource**.

The Xayaburi dam is a large hydropower project proposed on a large transboundary river managed by an active river basin organization. However, **the Xayaburi EIA ignores all transboundary aspects of possible impacts.** The field study does not extend beyond 10 km downstream of the project, and as detailed above, the EIA does not even mention possible impacts on downstream hydrology, on sediment load basinwide, on river structure, on riverine habitats and on transboundary fish migrations. This contravenes all international recommendations for EIAs of hydropower projects on transboundary rivers.

By 2018, if the Xayaburi dam is built, it will be one of 48 dams in the Mekong Basin, and the biggest dam in the Lower Mekong Basin. What will the added impacts of this dam be, considering the on-going development of more than 20 other dam projects basinwide? In the context of multiple ongoing developments, *Cumulative Impact Assessments* (CIAs) are recommended so that additive or incremental effects can be taken into consideration during decision-making (Lohani *et al.* 1997; MRC and ERM 2002; WorldBank 2006). In Lao PDR the Nam Theun 2 project (1,075 MW), as well as the Nam Ngum 3 project (440 MW), have recently been subject to a CIA; however, **the EIA reviewed makes no mention of the cumulative impacts of the 1,260 MW Xayaburi project.**

5 MITIGATION MEASURES FOR FISH RESOURCES IN THE XAYABURI EIA

The Xayaburi project is one of only three mainstream dam projects in the Mekong Basin (out 18 such projects in total) to propose fish passes as a mitigation measure (Baran 2010). This proposal requires an examination of the generic requirements for fish passes. Most of the information presented here reflects the studies and conclusions of Bernacsek 1984, Gore *et al.* 1989, Mallen-Cooper 1994, Clay 1995, Amornsakchai *et al.* 2000, Jutagate *et al.* 2001, Marmulla 2001, Trussart *et al.* 2002, Larinier 2000, 2001, 2002, Larinier and Travade 2002, FAO/DVWK 2002, Larinier and Marmulla 2004, Thorncraft *et al.* 2006, Antonio *et al.* 2007, Jutagate *et al.* 2007, Cada 2008, and Agostinho *et al.* 2008.

Following an examination of these generic requirements, we review the specific case of the Xayaburi fish passes and to what extent they comply with the recommendations of the MRC “Preliminary Design Guidance for Proposed Mainstream Dams in the Lower Mekong Basin” (MRC 2009).

5.1 UPSTREAM FISH PASSAGE

5.1.1 GENERAL ISSUES ABOUT UPSTREAM FISH PASSAGE

The general principle of upstream fish passage facilities is to attract migrants to a specified point in the river downstream of the obstruction and to induce them to move upstream by opening a waterway (e.g. a fish pass) or to force them by trapping them in a tank and transferring them upstream (e.g. a fish lift).

Two prerequisites are to be considered in the design of an efficient upstream fish facility:

i) the passability of the fish pass, i.e. the fact that all species can swim through the fish pass without stress and injury. The design of the fish pass should take into account the behaviour and the swimming abilities of the target species. Flow velocities, flow pattern, turbulence level and flow discharge should be adapted to the concerned species, in particular small species with weaker swimming ability;

ii) the traceability, i.e. the fact that the fish can find the entrance to the facility. This depends mainly on the fish pass location, the entrance position, the hydraulic conditions at the entrance and the attraction flow. In the case of a large river, it may be necessary to provide not only several entrances but also more than one fish pass. In the case of a hydropower project, it is advisable to design several fish passes.

In the case where the fish passage is intended for several species whose swimming abilities and migratory behaviour are very different, several entrances have to be installed in zones of different turbulence.

Upstream passage can be provided through several types of fish passes: natural bypass channels, baffle-type fish passes (or “Denil” pass), fish lifts, fish locks and pool-type fish passes.

Natural bypass channels are not suitable for high dams due to their low slope (<1%) and their inability to accommodate significant variations in the upstream and downstream water level; Denil fish passes are not suitable for high dams (hydraulics conditions) and large rivers (limited discharge); fish lifts are adapted to high dams but cannot accommodate intensive fish migration, are costly and fragile, and their efficiency is generally low for small species such as Cyprinids.

Existing models of fish locks cannot accommodate intensive fish migrations but their dimensions, volume and discharge can be adapted to suit the migration requirements of target species. Recent experiments using modified navigation locks to pass fish are promising, and the main advantage of fish locks in high dams is the reduced transit time for fish in comparison to that of other passes.

The model proposed for the Xayaburi dam is a “pool” type, where each step is a pool (Figure 6). Among the “pool” type, the vertical slot fish pass type is the most appropriate to large rivers, provided that i) the dimensions of pools are suited to the size of the largest fish and the migration intensity to be accommodated, and ii) the turbulence, velocities and flow pattern in pools are acceptable to the smaller fish to be passed. Considering these two aspects, the maximum slope must be in the order of 1.5 to 3%. The major issue for pools fish passes installed at high dams with a huge number of pools is the transit time of the small species (the time required to ascend from the fishway entrance to the exit), considering the time necessary to cross each pool. This transit time may be longer than fish’s daily migration time, leading individuals to swim back downstream. Several large resting pools must be fitted between the pools.

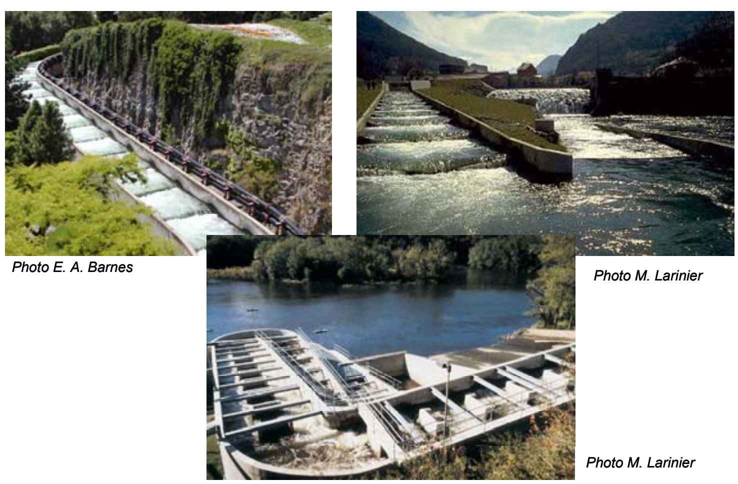

Figure 6: Different types of pool fish passes

Generally, the design of fish passes should meet certain basic criteria:

- the capacity of the fish facilities in each channel should be sufficient to pass several hundred of thousands fish per day; however, uneven fish activity during the day brings this requirement to a maximum passage rate of 10,000 to 100,000 fish per hour;

- fish facilities should be located and pass fish at both sides of the spillway channel and from the entire width of the powerhouse channel;

- the facilities must be effective at all times of the year and therefore at all river stages;

- because of the large number of species to pass in the Mekong and the lack of basic information concerning their behaviour and their swimming capabilities, and because of the size of facilities required, multiple fish passes and multiple entrances per pass must be planned;

- temporary facilities must be provided during the construction period (migration cannot be simply interrupted during the eight years of construction)

These basic rules are all reflected in the MRC "Preliminary design guidance on fish passage and operation".

5.1.2 Fish passes proposed for upstream fish passage at Xayaburi dam

The upstream fish passage facilities proposed by Terraplant Ltd.[19] consist of two separate fish ladders: one on the left river bank and one located in the concrete block between the spillway and the powerhouse (Figure 7).

Lack of underpinning studies

In general, since one single model of fish pass cannot accommodate all fish species, it is necessary to define the target species for which the fish passage facility is designed. The definition of these target species (endangered species, commercially dominant species, flagship species?) is usually based on the Assessment section of the EIA, in which important species and priorities are identified. Since this work has not been done in the "Aquatic ecology" section of the EIA, **the definition of target species is absent from the Mitigation section of the EIA, resulting in an unsubstantiated choice of fish pass models**[20]**.**

The fish passes proposed in the Xayaburi EIA are hardly mentioned in the body of the report (pages 3-3, 6-9 and 6-27), but are detailed in Appendix 3.1. However **there is not a single detailed plan or drawing of the proposed passes in the EIA, making the proposal unclear** and interpretation of the text in Appendix 3.1 difficult. The analysis below is largely based on drawings provided in the Feasibility Study although the latter are sometimes contradictory (e.g. right bank fish ladder absent on page 8-2 but present on page 8-25). More generally, **the fish passage facility proposed does not make reference to any relevant experience elsewhere in the world, nor does it give a single bibliographic reference to justify the choices made.** In particular the failure of the Pak Mun dam fish pass, the reasons for this failure and the lessons to be learned and integrated in the current Xayaburi fish pass design are not mentioned.

[19] www.terraplant.ch

[20] The Feasibility study (page 1-3) mentions 13 target species out of 35 commercially important fish species, but does not provide any list nor detail.

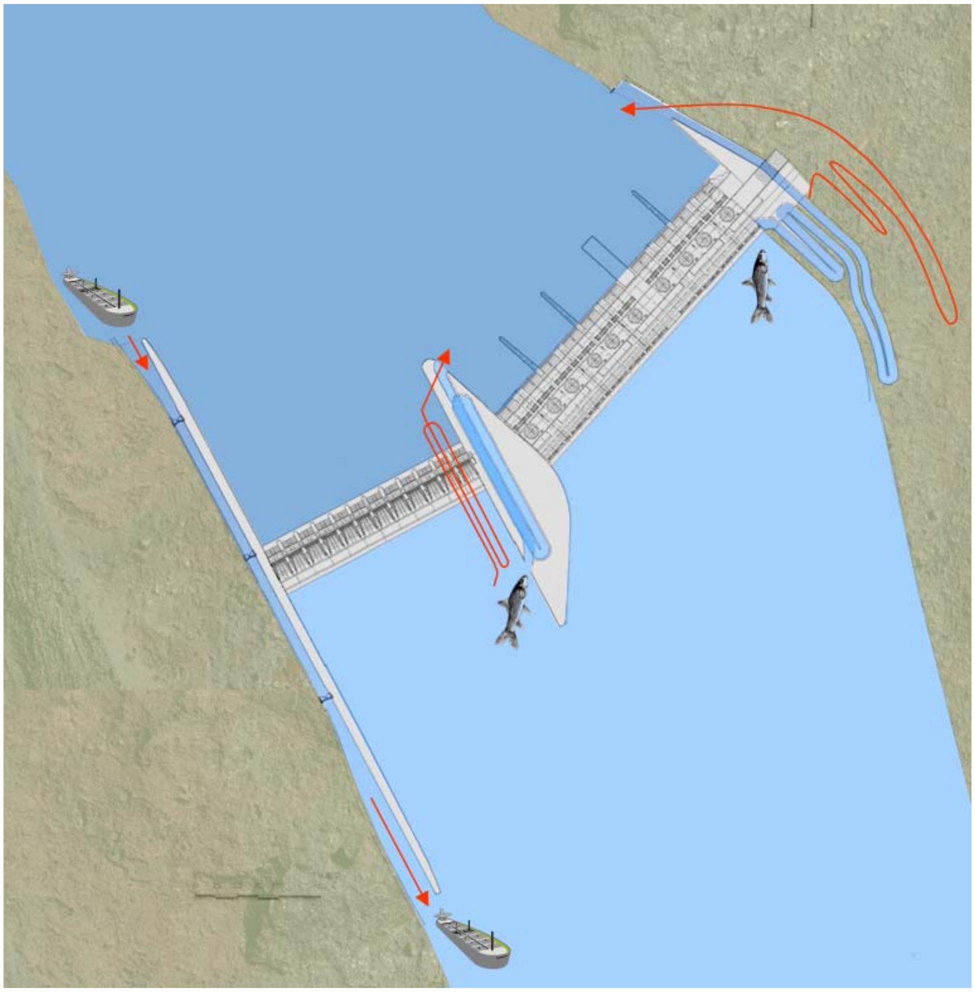

Figure 7: View of the fish passes and navigation lock proposed for the Xayaburi project (redrawn from the Feasibility Study, p. 7-28)

At dam sites the design of fish passes is always adjusted to the swimming capabilities of target species. This is acknowledged in the Feasibility Study (page 8-36): "*Due to the fact that indispensable biological data on swimming performance of migrating fish species in the Lower Mekong Region is limited the development of an optimised design would require as a first step to deepen the knowledge of the fish species swimming performance, as a basis for the development of suitable design criteria and technologies*" However **the EIA does not justify the fish pass design characteristics by any fish swimming behaviour or performance**. In the case of the Mekong fish species there are no studies of swimming performance or behaviour, but there is deep and extensive traditional ecological knowledge (Roberts and Baird 1995, Baird 2007), and **a preliminary study combining traditional knowledge and hydrological records (**e.g. Baran *et al.* 2005) **should be done in order to identify at the minimum the hydrological needs of local fish species before a specific fish pass design is proposed**.

Left bank fish pass

On the left bank, the fish ladder is a pool type ladder approximately 800 m long and 10 m wide. This ladder is designed to allow upstream fish migration with downstream water level between 236 masl (*m*eters *a*bove *s*ea *l*evel; 236 masl is the minimum water level in the river before downstream Pak Lay dam is commissioned) and 254 masl (exceeded 0.5% of the time) and a constant upstream water level of 275 masl.

The length of pools is 7.5 m and their depth 3 m. The slope is 5%, and the flow through slots and orifices is 7 $m^3.s^{-1}$. Details about the geometry of the pools are not given but this means that the difference of water level between two successive pools is close to 37 cm (Figure 9). **Such 37 cm steps are higher than what is usually acceptable for salmonids** (30 cm is usually the upper limit acceptable for these strong swimmers, but much lower values have to be applied if other species are concerned), **and would be much too high for the vast majority of Mekong species, in particular the dominant small Cyprinids. In addition, the proposed dimensions of pools, discharge** (7 $m^3.s^{-1}$) **and slope imply that the turbulence level in the pools would also be too high for these species.**

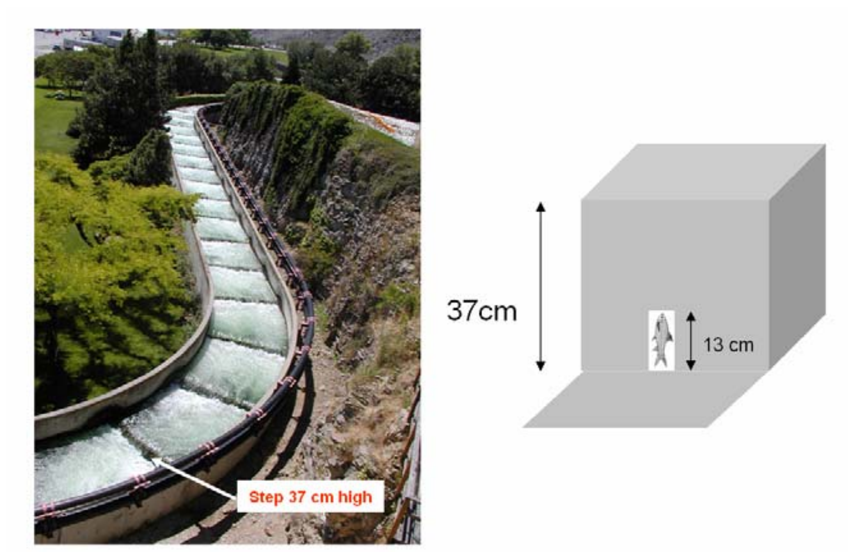

Figure 8: Water level drop between pools planned in the Xayaburi EIA. The right part of the figure shows the proposed height of each step and, at the same scale, the size at maturity of *Henicorhynchus siamensis*, the dominant cyprinid in the Mekong. Photo E.A. Barnes

For this ladder "*when the tailwater level is below the elevation 245 the complete ladder will be working, [whereas] when the tailwater level exceeds the elevation 245 the upper part, above elevation 242 will be directly connected to the main entrances and to the downstream collecting gallery, while the lower part will be completely submerged and taken out of operation.*" This concept is very unclear, would be technically very difficult if not impossible to put into practice, and is contradictory with the drawings of the Feasibility Study (pages 7-23, 7-28 or 8-2) showing no entrance at mid-level.

In the EIA, basic information such as the location of the entrances of the fish passes or the criteria and details of the pool design is missing. Location of the entrances is essential to the accessibility of the pass by fish in a river characterized by strong variability in water levels, and specific design options within each pool have a strong influence on hydraulics and the pass performance. Clearly **the criteria and detailed characteristics of the fish passes have not been worked out, leaving great uncertainty about their final design, performance and passage rate.** In fact the design of the passes is much less advanced than the design of the dam and the power plant, which contradicts the MRC design guidance, point 64.

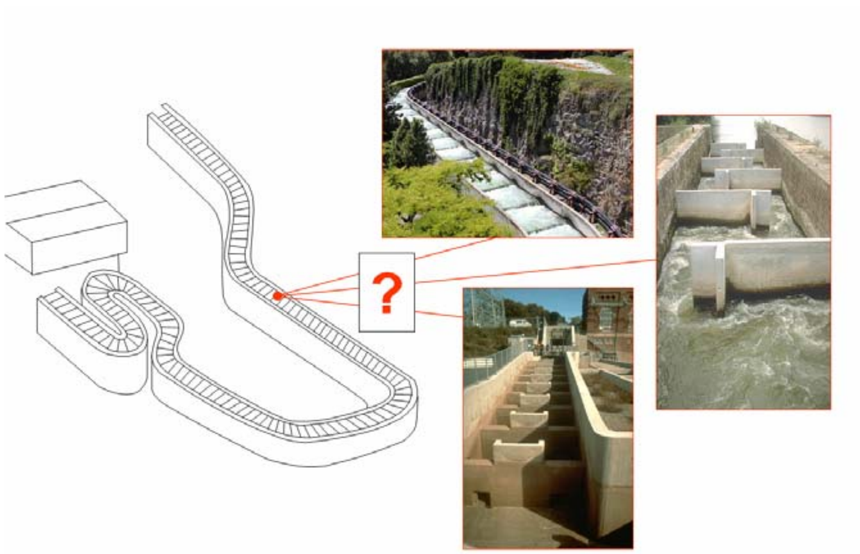

Figure 9: Some of the fish pass design details left unspecified in the Xayaburi EIA. Photos E.A. Barnes and M. Larinier.

Fish pass between the spillway and the power plant

In the middle of the river, the fish ladder in the block built between the spillway and the power plant is a pool type ladder approximately 600 m long and 10 m wide. The pools have the same characteristics as the left bank fish ladder: the length of pools is 7.5 m and their depth 3 m. The slope is 5%, and the flow through slots and orifices is 7 $m^3.s^{-1}$. This ladder is designed to allow upstream fish migration for downstream water level between 245 masl (corresponding to maximum turbine discharge of 5000 $m^3.s^{-1}$) and 254 masl (high value exceeded 0.5% of the time). For water levels lower than 245 masl, the spillway will not be operating and fish will not be attracted towards the entrance of the fish pass. Experience shows that spillways may work with lower river flow discharges than the maximum turbine discharge, especially in case of turbine maintenance.

Furthermore **the exit of this fish pass, located between the spillway and the turbines, is not safe:** most fish exiting the pass (particularly the small species) are likely to be caught by the turbulence and wander back towards the spillway or through the turbines.

Need for a fish pass on the right bank

Since fish tend to migrate upstream along the banks of rivers (where counter-currents make water velocity lower and swimming easier; Wootton 1991), fish passes located along the banks are usually much more efficient than passes located in the middle of the river, where currents and turbulence are stronger and fish density is much lower. The design proposed in the EIA, with no pass on the right bank, will trap many fish migrating along the right bank between the navigation lock and the spillway; these fishes will never reach the ladder located in the middle of the river. **It is essential that the options for a fish pass on the right bank are carefully considered.** The technical constraints of installing a fish pass on the right bank should be carefully examined, and a solution should be proposed, in line with the MRC guidance points 61 and 64.

Navigation lock as a fish pass

The possibility for the navigation lock to also constitute an additional fish passage should be carefully examined, in line with the MRC Design Guidance point 63. This is possible provided that downstream attraction flow can be achieved by opening the filling gate, partially or fully, while the downstream lock gate is kept open. This may imply an additional release of water downstream in the dry season to accommodate the dry season migrations, and that the lock and its gate system are designed specifically to meet that requirement.

Construction period

The fish passes proposed are likely to be completed and operational at the end of the construction period. However **the EIA does not specify how fish migrations will be affected during the construction period** (eight years, EIA p. 3-1), **and does not identify any mitigation measure during that period**. **It is essential that the EIA identifies the measures to be taken** (temporary fish passes? derivation canals?) **so that fish migrations are not completely interrupted during eight years of dam construction**.

Fish passage facility proposed and the MRC Design Guidance

Last, **the fish passes of the Xayaburi project either do not meet or ignore several points of the MRC "*Preliminary design guidance for proposed mainstream dams in the Lower Mekong Basin*"**, in particular Points 63, 64, 65, 66, 68, 69, 70, 72, 74, and 78. There is no evidence of compliance or not testing confirming compliance for Points 61, 71, 73, 75, 76, 77, 80, 82 and 83. Observance of points 62, 67, 81, 84, 87, 88, 89 is either not specified or unclear. Points for which guidance is met are Points 60, 79, 85 and 86. See Annex 4 for details about these points.

5.1.3 WATER DEMAND AND UPSTREAM FISH PASSAGE TO DEGRADED HABITATS

The EIA rightly states (Appendix 3.1, page 10) that "*the water discharge through the fish pass facilities must be sufficient to accommodate the different fish species and to compete with the flow in the river during the migration period. […] Therefore flow distribution and operational* *patterns of the fish pass facilities depend entirely on the migration timing of fish. […] Fish migration occurs throughout the whole year*". As a consequence, **the EIA should provide a recommended percentage of flow for upstream fish facilities, in relation to the total river flow. As a general rule, this percentage should vary between 10% (during low river flow) and 1-1.5% for the maximum river flow considered for upstream fish passage.** The EIA also pretends (Appendix 3.1, page 11) that "*fish can tolerate some hours delay in passing the dam*" and that "*it might be also possible and reasonable, particularly in the dry season, to operate the fish pass facilities mainly during the night hours*". However, experience clearly shows that **it is not possible to act on the hours of migration activity of the fish species. As a consequence, the fish facilities should be operational all day long during migration periods, since the fish will not adjust to the fish facilities working hours***.*

While fish passage facilities can mitigate to a certain extent impacts of the obstacle on upstream and downstream migration at the dam site, they do not solve all environmental problems created by the hydropower project. In particular fish ladders do not mitigate potential changes in flow regime (depending on operation rules), water quality, nor drastic changes to the habitat upstream of the dam. Hence, despite upstream and downstream fish passage facilities this reservoir is likely to become a barrier for both the upstream and downstream migration. In particular the downstream drift of fish eggs, larval and juvenile stages that sustain fisheries recruitment may be trapped in the impoundment. The accumulation of these factors may compromise the balance and the survival of migrating fish populations, even with the installation of efficient fish passage facilities at the dam site.

5.2 DOWNSTREAM FISH PASSAGE

5.2.1 GENERAL ISSUES ABOUT DOWNSTREAM FISH PASSAGE

Downstream passage facilities consist of devices and techniques allowing fish to pass through the dam on their way downstream without being blocked or injured by passage through the turbines or the spillway.

Downstream fish technology is much less advanced than it is for upstream fish passage facilities. This is mainly due to the fact that downstream migration problems have only been recognised and addressed more recently and it is much more difficult and complex to develop effective facilities for downstream migration. Problems concerning downstream migration have been thoroughly examined in North America and Europe with regard to a few species, mainly salmonids and more recently silver eel. Little information is available on other migratory species.

Behavioural barriers aimed at avoiding passage of fish through turbines or spillways consist of underwater lighting or sound screens but these devices are not considered as efficient.

Physical barriers stopping fish at water intakes require a sufficiently small mesh or grill size to prevent small species from passing through, but also sufficiently low velocities to avoid fish being crushed against the grill or screen. Installing such screens on large Kaplan turbines is generally difficult considering the high velocities and the maintenance issues. Surface bypasses associated with relatively deep turbine intakes may be efficient for species which migrate in the surface water layers.

Figure 10: Surface bypass at Lower Granite dam, Snake River, USA. Photo M. Larinier

5.2.2 FISH PASSES PROPOSED FOR DOWNSTREAM FISH PASSAGE AT XAYABURI DAM

The use of a surface bypass collector is proposed; this would be a channel 6 m wide with gated orifices installed at the upstream channel wall providing multiple entrances for fish along the intake wall. **Surface bypass collectors, as well as all surface bypass systems, are mainly used in North America and Europe for species which migrate near the water surface, such as salmonids and clupeids. Such surface bypass collectors are the best solution for surface species, but their efficiency for the species in the Mekong River has yet to be assessed.**

The mortality of fish passing through turbines can be highly variable, and in the case of Mekong species, Halls and Kshatriya (2009) have estimated mortality rates for Mekong species, based on a several options of turbine design, and have concluded that adults of small species would experience relatively low mortality rates ranging from approximately 2% to 15% *per dam*, assuming that all individuals pass through the turbines. However, adults of the large species would experience very high mortality rates ranging from approximately 35% for *Hypsibarbus malcolmi* to 70% for *Cosmochilus harmandii*, 80% for *Pangasius conchophilus* to 100% for critically endangered large species such as *Pangasianodon gigas* or *Probarbus jullieni* passing through turbines

In the case of the Xayaburi dam, it not realistic to consider installing fine screens in the turbine intake. The "fish friendly" turbines option must be carefully examined, and the turbine type, the power performance of these turbines and the turbine provider must be identified and chosen before any technical decision is made about the dam design because such turbines are not ready made, are usually less efficient and take more time to design and build than standard turbines. **Recommending such turbines might be in vain if these practical**

considerations are not part of the project design, and in all cases these turbines would not be a mitigation measure for large fish species.

The possible damage to fish passing through the spillway can be significant, and mitigation measures (adapted spillway, apron, stilling basin and dissipator design) are not considered in the study.

6 CONCLUSIONS

The coverage by the Xayaburi EIA of the study area and of operation rules is insufficient, as well as the assessment of the project impacts on fish biodiversity. The assessment of project impacts on hydrology, on water quality, on river continuity, on fish habitats, on fish migrations, on fish species life stages and on fish abundance is actually not done in this EIA.

The examination of the Xayaburi EIA in relation to the criteria for sustainability assessment of the International Hydropower Association (IHA 2006) leads to the following conclusions and scores (Table 3):

Table 3: Aspects of new energy projects relevant to fish and fisheries to be covered in sustainability assessments (IHA 2004), and performance of the Xayaburi EIA

Aspects	Process	Score
Water quality (B20, C19)	No planning for water quality management program during construction and operation	0
	Absence of water quality management program, by either the scheme owner or other organization, e.g., government organisation.	0
Biodiversity and pest species (B17, C18)	Major gaps in plans for understanding of relevant catchment, in-reservoir, and downstream biodiversity issues.	1
	Major gaps in understanding of issues.	1
Environmental flows and reservoir management (B18, C16, C17).	No plans to research and define environmental (including biodiversity) objectives.	0
	No research or absence of program or plans or no process to understand concerns.	0

Score: 5 Outstanding / strong / comprehensive; 4 Good to Very good; 3 Satisfactory; 2 Less than satisfactory; 1 Poor / Very limited; 0 Very poor

More generally a full EIA dealing with fish and fisheries is intended to answer some specific questions regarding the impacts of dams and possible mitigation measures (Bernacsek 2000). However, **the Xayaburi EIA reviewed does not indicate i) whether the project will result in loss of fish biodiversity in the impact area; ii) whether the project will result in losses or gains in fish production; iii) what impact changes in fish resources may have on employment and income; iv) how effective and costly mitigation measures aimed at conserving biodiversity and fish production would be; v) what impacts cannot be mitigated and how important they**

would be; and vi) what the overall assessment of the proposed project is with regard to fisheries.

The gaps highlighted in this review lead to the conclusion that the Xayaburi EIA does not meet the international standards for Environmental Impact Assessments.

As a consequence it is recommended that the Environmental Impact Assessment of the project is redone. The new EIA should in particular assess, with due justifications, the impact of the dam far upstream and downstream of the site. It should provide specific details about impacts of the project on hydrology, water quality, river continuity, fish habitats, fish migrations, fish species life stages, fish biodiversity and fish abundance. The new EIA should also specify:

- whether the project will result in loss of fish biodiversity in the impact area and why;
- whether the project will result in losses or gains in fish production and why;
- what impact changes in fish resources may have on employment and income;
- how effective and costly mitigation measures aimed at conserving biodiversity and fish production would be;
- what impacts cannot be mitigated and how important they would be; and
- what is the overall assessment of the proposed project with regard to fisheries.

More generally, in a river where there is ample evidence of large scale fish migrations basinwide and where river fish consumption is a major element of national food security in Cambodia and Laos**, the EIA should also cover transboundary impacts of the project on fish resources, on fisheries and on the livelihoods** of people who depend on these natural resources.

Beyond the EIA, **there is a need for a Cumulative Impact Assessment focussing on the impacts of the Xayaburi dam in relation to those of the 47 other dams that will be present in the Mekong Basin by 2015**. Such CIA, already done for smaller projects on tributaries, is fully justified for a 1,260 MW project on the mainstream.

The fish passes proposed as a mitigation measure are not related to any specific target species. The characteristics of the passes are not underpinned by any study about the migration behaviour and the swimming capabilities of Mekong species. Furthermore, **the fish passage facilities of the Xayaburi project either do not meet or do not provide evidence of meeting 19 out of 30 points of the MRC "*Preliminary design guidance for proposed mainstream dams in the Lower Mekong Basin*"; only four out of the 30 guidance points are clearly met**. **More generally, the characteristics of the fish passage facilities currently proposed are either fuzzy or clearly inappropriate** to mitigate the impact of the dam on fish migrations. In this context, **the EIA does not currently propose convincing measures to mitigate the impact of the dam on the fish resource.**

EIA also omits consideration of the following measures:

- target species or target fish groups ("ecological guilds") must be specified, and if species-specific swimming capabilities are not known, at least groups of sizes must be defined;

- the pros and cons of each fish pass type (natural bypass channels, pool fish passes, fish lifts or fish locks) must be discussed in relation to the species diversity, to the target species, to the fish abundance peaks, to the height of the dam and to the upstream and downstream variations in water level;

- the range of discharges for upstream and downstream migrations through selected fish pass facilities must be specified;

- hydraulic criteria for fish passes (maximum and average flow velocity, turbulence level, flow pattern) must be specified based on specific studies, and some dimensions of the design elements must also be specified, in particular for big fish species;

- the location and the number of fish pass entrances must be specified and justified;

- the possibility of water management in hydropeaking mode must be clarified; in particular the minimum water level left in the reservoir must be specified because it determines the characteristics of the fish pass upstream control section, essential in limiting the flow, velocities and turbulence in the fish pass to an acceptable level;

- the navigation lock should be designed to also accommodate fish passage.

- with regard to downstream migration, “fish friendly” turbines options need to be precisely evaluated. Measures to mitigate possible damage to fish passing through the spillway (adapted spillway and gates, apron, stilling basin and dissipator design) should also be considered.

In conclusion, we recommend that in-depth studies and testing (in particular of flow requirements by fish species) are conducted so that the revised EIA is backed by clear evidence that proposed fish passes are operational, effective year round, and feature a fish passage rate close to that recommended by the MRC guidance for mainstream dams.

As this reports only addresses fish resources and fish passage, other important ecological dimensions identified by the MRC Strategic Environmental Assessment (notably impacts of the project on flow dynamics, water quality, nutrients, sediment, habitat fragmentation and aquatic biodiversity) also need to go through a thorough review in order to evaluate if the revised impact assessment and the proposed mitigation options for these dimensions meet the standards of international best practice, and meet in particular the criteria of the MRC “*Preliminary design guidance for proposed mainstream dams in the Lower Mekong Basin*” and those of the Hydropower Sustainability Assessment Protocol led by the International Hydropower Association and endorsed, among others, by the WorldBank, the WWF and the Government of China.

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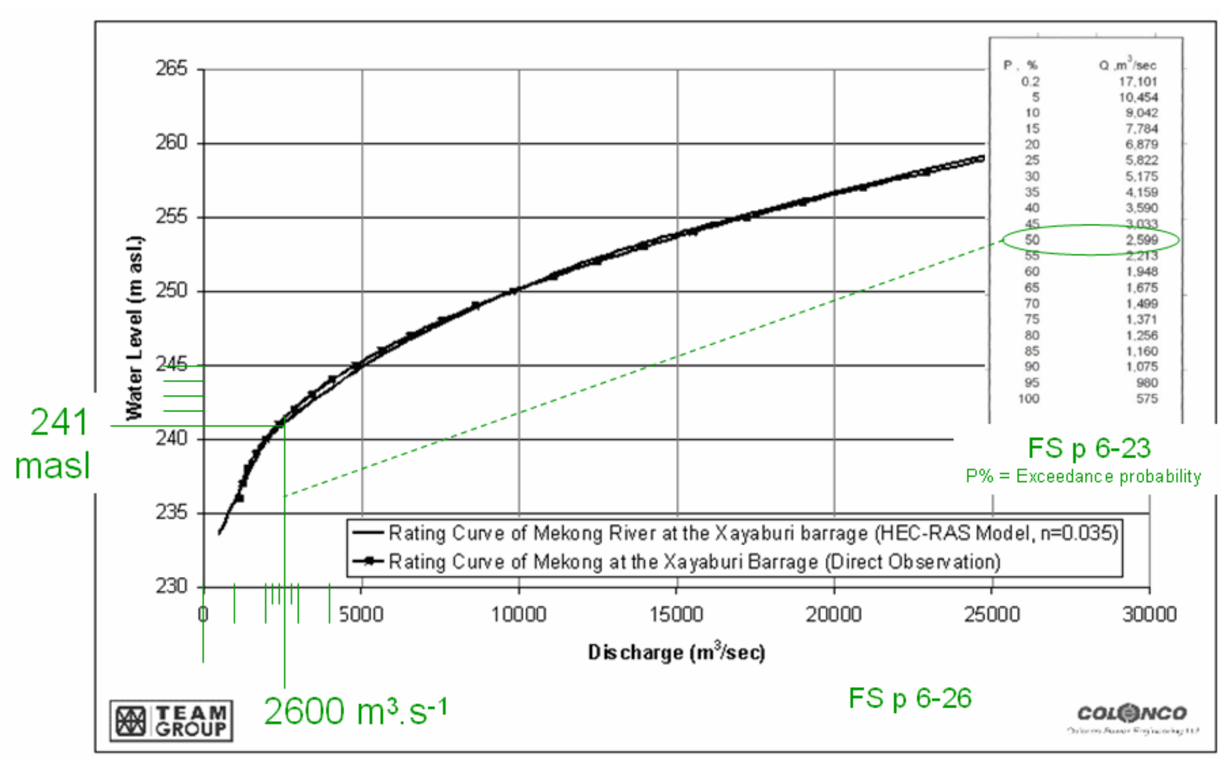
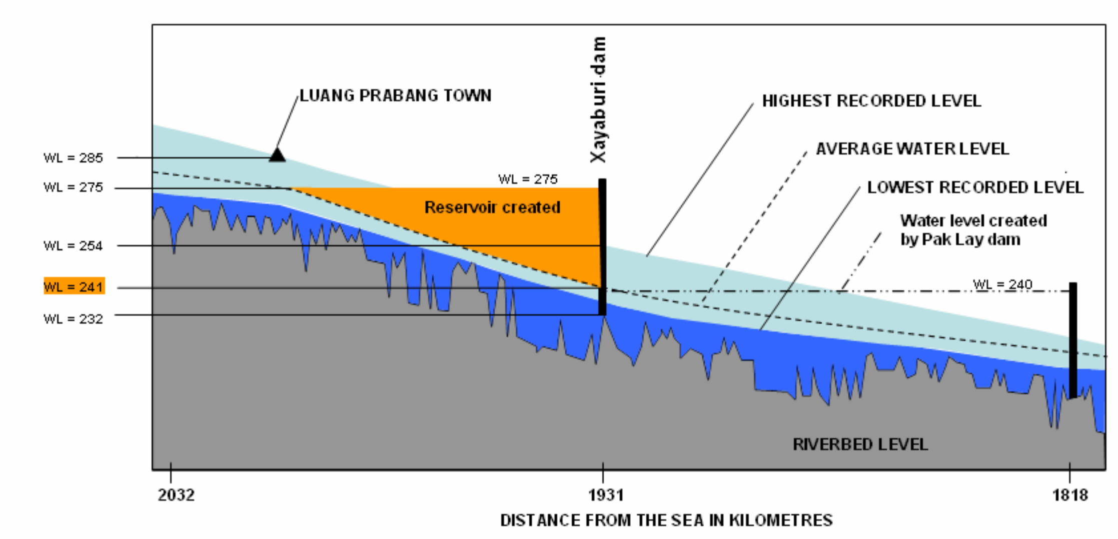
8 ANNEX 1: RESERVOIR CREATED

Hydrological curves of the Feasibility Study (found also in the EIA) allow calculating the average water level of the Mekong at the dam site:

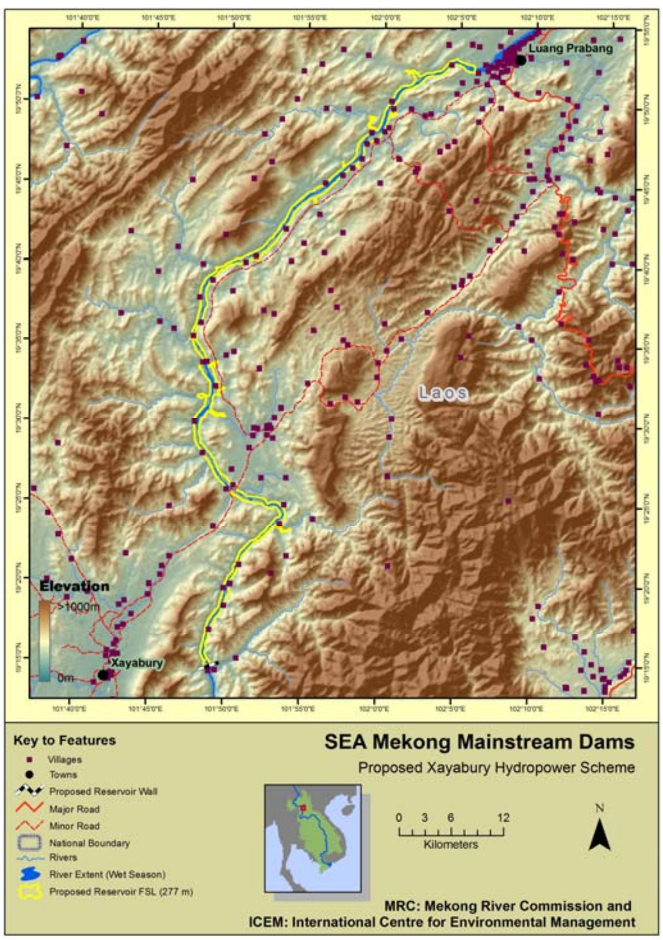
the average discharge corresponds by convention to the discharge reached 50% of the time; the probability curve is given on page 6-23, and the discharge reached 50% of the time is 2600 $m^3.s^{-1}$. Curve page 6-26 gives the corresponding water level: 241 masl. Thus the water level reached 50% of the time is 241 masl, and water above this level can be considered as created by the dam.



This allows picturing the reservoir created by the dam 9 (in orange in the figure below), based on the profile on page 7-17 of the Feasibility study. The maximum depth of the reservoir created will reach 275 – 241 = 34 meters at the spillways

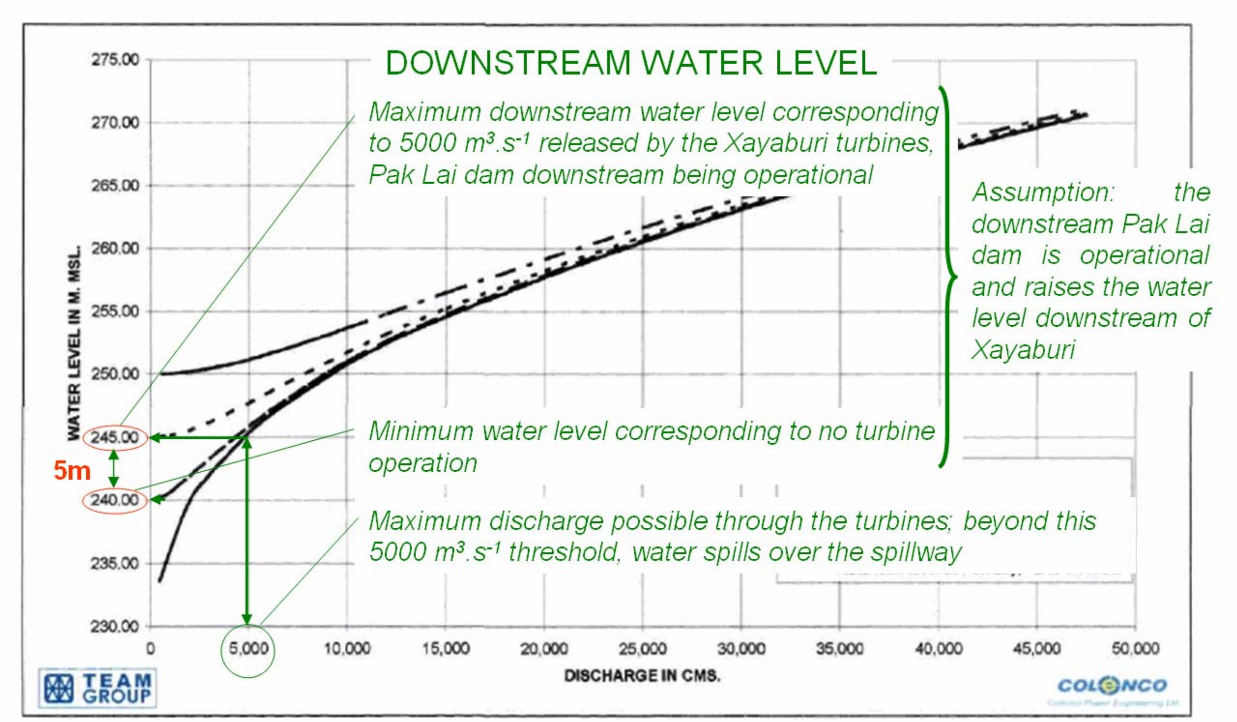


Length of the reservoir created (ICEM 2010). Note the top end of the reservoir reaching Luang Prabang city according to this estimate.



9 ANNEX 2: WATER LEVEL FLUCTUATION DOWNSTREAM OF THE XAYABURI DAM

The figure below, based on Figure 1.1.2-19 of the EIA, shows that the water level downstream of the dam will vary at least by 5 meters, depending on turbine operation.



Reading of the rating curve provided in the EIA (page 4-40): the water level downstream will vary at least between 240 and 245 masl. Elements in green have been added to the original figure.

10 ANNEX 3: LIST OF 229 FISH SPECIES POTENTIALLY IMPACTED BY THE XAYABURI PROJECT

Using IUCN definition based on population size loss within 10 years, we label those species expected to become endangered (EN) or critically endangered (CR) by 2025. Species added to this list because of Xayaburi dam are underlined. Asterix marks species reported in EIA. We combine these results, which are based on habitat loss, to the IUCN 2010 classification of these species that accounts for other factors such as overfishing etc. Details of analysis will be reported elsewhere (Ziv *et al.* in prep)

Migratory species (mainstream users)

Aaptosyax grypus (EN)
Bangana behri
Catlocarpio siamensis (EN)
Chitala blanci
Cirrhinus molitorella
Clupisoma sinense
Cosmochilus harmandi
Crossocheilus atrilimes
(*) Cyclocheilichthys armatus
(*) Cyclocheilichthys furcatus
Dasyatis laosensis (IUCN EN)
Garra fasciacauda
Helicophagus waandersii
Hemibagrus filamentus
Hemibagrus wyckii
Henicorhynchus lobatus
(*) Henicorhynchus siamensis
Hypsibarbus lagleri
Hypsibarbus malcolmi
Hypsibarbus vernayi (EN)
Hypsibarbus wetmorei
<u>*Labiobarbus siamensis (EN)*</u>
Lobocheilos melanotaenia
<u>*Luciocyprinus striolatus (EN)*</u>
(*) Mekongina erythrospila
Pangasianodon gigas (IUCN CR)
Pangasianodon hypophthalmus
Pangasius krempfi
Pangasius larnaudii
Pangasius macronema
Paralaubuca typus
Probarbus jullieni (IUCN EN)
Pseudolais micronemus (EN)
Pseudolais pleurotaenia
(*) Puntioplites falcifer
(*) Puntioplites proctozystron
Puntioplites waandersi (EN)
Scaphognathops bandanensis
Scaphognathops stejnegeri
Syncrossus helodes
Thynnichthys thynnoides
Wallago leerii
Yasuhikotakia modesta

Migratory species (tributary users)

<u>*Acanthopsoides delphax (EN)*</u>
Amblyrhynchichthys truncatus
Anguilla marmorata
Bagarius yarrelli
Bangana pierrei
Cirrhinus jullieni
(*) Crossocheilus reticulatus
Cyclocheilichthys apogon
<u>*Epalzeorhynchos munense (EN)*</u>
<u>*Helicophagus leptorhynchus (EN)*</u>
(*) Hemibagrus wyckioides
Hemisilurus mekongensis
<u>*Hypsibarbus pierrei (EN)*</u>
(*) Labiobarbus leptocheilus
<u>*Labiobarbus lineatus (EN)*</u>
Osteochilus microcephalus
Pangasius nasutus (CR)
Pangasius sanitwongsei (IUCN CR)
Phalacronotus apogon
(*) Phalacronotus bleekeri
(*) Raiamas guttatus
(*) Sikukia gudgeri
<u>*Sikukia stejnegeri (EN)*</u>
Syncrossus beauforti
Tenualosa thibaudeaui (IUCN EN)
Tor sinensis
(*) Tor tambroides

Resident species in Chiang Saen – Vientiane sub-basin possibly impacted by dam reservoir

Abbottina rivularis
Acanthopsoides gracilentus
Acheilognathus barbatulus
Acheilognathus deignani
Achiroides leucorhynchos
Albulichthys albuloides
Anabas testudineus
Badis ruber
Bagrichthys macracanthus
(*) Barbonymus altus
(*) Barbonymus gonionotus
Barbonymus schwanenfeldii
Belodontichthys truncatus
Brachirus orientalis
Brachirus panoides
Carassius auratus auratus
Ceratoglanis pachynema

Channa gachua

Channa striata

Chitala lopis

Chitala ornata

Clarias fuscus

Crossocheilus oblongus

(*) Cyclocheilichthys repasson

Cynoglossus feldmanni

Cyprinus carpio carpio

Dermogenys siamensis

Devario annandalei

Devario chrysotaeniatus

(*) Devario fangfangae

(*) Discherodontus ashmeadi

Discherodontus schroederi

(*) Garra cambodgiensis

Glossogobius aureus

(*) Hampala dispar

(*) Hampala macrolepidota

Hemibarbus labeo

Kryptopterus cheveyi

Kryptopterus cryptopterus

Labeo chrysophekadion

Labeo dyocheilus

Laides longibarbis

Laubuca laubuca

Lepidocephalichthys berdmorei

Lepidocephalichthys hasselti

Lycothrissa crocodilus

Macrochirichthys macrochirus

Macrognathus taeniagaster

Mastacembelus armatus

Mastacembelus erythrotaenia

Misgurnus anguillicaudatus

Monopterus albus

Mystacoleucus greenwayi

(*) Mystacoleucus marginatus

Mystus atrifasciatus

Mystus multiradiatus

Mystus mysticetus

(*) Neolissochilus stracheyi

(*) Notopterus notopterus

Ompok bimaculatus

(*) Opsarius pulchellus

Oreochromis niloticus niloticus

Osphronemus exodon

Osphronemus goramy

Osteochilus vittatus

(*) Oxyeleotris marmorata

Oxygaster anomalura

Pangio fusca

Pangio myersi

Pangio oblonga

Parachela williaminae

Paralaubuca barroni

Parambassis apogonoides

Parambassis wolffii

Pseudohemiculter dispar

(*) Pseudomystus siamensis

Puntius brevis

(*) Scaphiodonichthys acanthopterus

Scaphognathops theunensis

Sundasalanx mekongensis

Tetraodon abei

(*) Tetraodon turgidus

Thryssocypris tonlesapensis

Tor laterivittatus

Toxotes chatareus

Trichogaster microlepis

Trichopsis schalleri

Trichopsis vittata

Tuberoschistura cambodgiensis

Wallago attu

Xenentodon canciloides

Yasuhikotakia caudipunctata

Yasuhikotakia eos

Yasuhikotakia longidorsalis

Yasuhikotakia nigrolineata

Resident species in Nam Ou sub-basin

Bagarius bagarius

Balitora lancangjiangensis

(*) Bangana elegans

Bangana lippus

Channa marulia

Channa micropeltes

Clarias batrachus

Clarias macrocephalus

Ctenopharyngodon idella

Cyprinus rubrofuscus

Devario laoensis

(*) Esomus metallicus

Folifer brevifilis

Garra theunensis

(*) Glyptothorax fuscus

Glyptothorax lampris

(*) Glyptothorax laosensis

Glyptothorax macromaculatus

Glyptothorax zanaensis

(*) Hemibagrus nemurus

Hemibagrus spilopterus

(*) Hemibarbus maculatus

Hemiculterella macrolepis

Hemimyzon papilio

Hemimyzon pengi

Himantura chaophraya

Homaloptera yunnanensis

Labeo barbatulus

Labeo rohita

Macrognathus siamensis

Mystus bocourti

(*) Onychostoma fusiforme

Onychostoma gerlachi

(*) Opsarius koratensis

Pangio anguillaris

Papuligobius ocellatus

(*) Parambassis siamensis

Physoschistura meridionalis
Poropuntius angustus
Poropuntius carinatus
(*) Poropuntius laoensis
Pseudorasbora parva
Puntius jacobusboehlkei
Puntius semifasciolatus
Puntius stoliczkanus
Rasbora atridorsalis
Rhinogobius albimaculatus
Rhinogobius mekongianus
Schistura aramis
Schistura athos
Schistura bucculenta
Schistura globiceps
Schistura kengtungensis
Schistura melarancia
Schistura pertica
Schistura poculi
Schistura porthos
Schistura procera
Sikukia flavicaudata
Tetraodon cambodgiensis
Tetraodon cochinchinensis
Tor tambra
Trichogaster trichopterus

11 ANNEX 4: MRC PRELIMINARY DESIGN GUIDANCE FOR PROPOSED MEKONG MAINSTREAM DAMS

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.

61. The developer should provide effective fish passage upstream and downstream. Effective fish passage is usually defined as "providing safe passage for 95% of the target species under all flow conditions." The success rate for fish passage both upstream and downstream necessary to ensure continued population viability can be refined for the particular species concerned, based on its life history and the number of dams the species may have to pass to complete its life-cycle

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.

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.

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. Many aspects of dam design need to be integrated with fish behaviour and fish passage facilities, including the dam axis; abutments; training walls; gate design; hydro draft tubes; and sill level in tailwaters. These elements need to be designed to ensure fish are guided to the fishways by creating flows that are laminar and parallel with the river centreline and by minimising lateral and rolling flows. Numeric and physical models of the dam and adjacent river are necessary to accurately predict flow patterns, and hence dam and fish passage design.

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.

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. Target species should be selected based on considerations of commercial and livelihood importance, broad coverage of ecological guilds, as well as conservation of threatened species.

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. These variations will have significant implications for fish passage design, and will likely necessitate multiple systems at each site.

68. The preferences, tolerances and biological attributes of the target fish species relevant to successful movement through the facilities should be clearly established. Of particular importance are size at time of migration; swimming capabilities (prolonged and burst swimming speeds); depth and horizontal positioning in the river

channel downstream or the impoundment upstream of the dam wall; diurnal movements; and cover, substrate and light preferences.

69. The peak biomass likely to be using the facilities must be determined and the appropriate structure sizing of fishways, cycle time of fish locks and/or lifts, and water availability established.

70. Predation within the fish passages should be minimised. Therefore, predator-prey relationships within the target species and other species that may use the facilities, or benefit from the reduced fitness of fish that have traversed the pass, should be determined. Adequate shelter for smaller species while within the confines of the fishways should be considered, and actual residence time in the fishways should be minimised.

71. Fish exiting fishways both upstream and downstream should be sufficiently healthy to continue their natural patterns and migration routes. Direct and indirect mortality combined, as a result of movement through the fishways, should be less than 5 percent. Similarly, human fishing in the vicinity of the fishways should be managed to ensure mortality caused by fishing is not excessive.

Hydrology

72. The fishways should cater for the largest operational ranges practical, within the biological and hydrological requirements of the fish species concerned. As a guideline, fishways should be fully operational from minimum low season flow of up to the 1:20 year flood level.

73. Particular attention must be given to ensuring that the entrances to fishways effectively attract fish. This will require that adequate flows are available to attract fish to the entrances. Adequate flows must be directed through the fishways to ensure they function effectively in both the high and low flow seasons, and at all times are sufficient to ensure optimal effectiveness for fish passage targets.

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.

75. Fishway entrances should be:

- sited to take maximum advantage of the hydraulic conditions created by spillways, outlets and channel structures. Conversely, the entrance should not be located where water velocities or turbulence are likely to hamper fish attraction to the facility.
- suitably located to be accessed by fish over the full operational range of the fishway. Consequently, it may be necessary to have multiple entrances to the one fishway.
- located where the morphology of the river, as well as the substrate and cover, promote fish attraction to the facility.

76. Spillways should be designed so that extra flows initiate and terminate adjacent to the fishway entrance(s) to maximise attraction to the fishways.

77. Fish attracted to the spillway need to be able to access the fishway entrance without needing to double back to find the entrance.

Hydraulic environment

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.

79. Barrier screens should be designed to guide downstream moving fish away from turbines and towards the fish passage facilities. The screens must be sized to ensure that fish cannot pass through or become trapped within the mesh, and water velocities at the screens must be low enough to prevent fish being trapped against the mesh surface. Self-cleaning traveling or rotating screens should be used where there are high debris loads.

80. The use of fish friendly turbines should be investigated and adopted where feasible.

Operation

81. The period of captivity and interruption to the normal movements of the fish should be as short as possible.

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.

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.

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.

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. This should include the ability to sample fish safely from the fishways as well as monitor fish movements and water quality.

86. Monitoring programmes should be established to quantify the effectiveness of the fishways. Determining their effectiveness requires sampling upstream of the dam wall, within the fishway, and downstream; such data will allow determination of the proportions of species and biomass attempting to migrate that successfully negotiated the fishway.

87. The monitoring programme should be funded by the developer for the duration of the concession period.

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.

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. The contingency fund is 20 percent of the initial cost of building the fishways. A guideline figure for the contingency fund should be replenished as it is drawn down, to ensure that funds are always available for modification works.