Department of Energy & Business

MINISTRY OF ENERGY AND MINES - LAO PDR

PAK LAY FEASIBILITY STUDY REVIEW
Fish Passage & Water Quality and Aquatic Ecology

FINAL REPORT

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Fish Passage & Water Quality - Aquatic Ecology
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GLOSSARY

BDP	Basin Development Plan (MRC)
BOD	Biological Oxygen Demand
CA	Concession Agreement
CFD	Computation Fluid Dynamics
CNR	Compagnie Nationale du Rhône
COD	Chemical Oxygen Demand
CODS	Committee on Dam Safety (ICOLD)
DEM	Digital Elevation Model
DFS	Definite Future Scenario
DO	Dissolved Oxygen
DEB	Department of Energy and Barrages (Lao PDR)
DSMS	Dam Safety Management System
DSRP	Dam Safety Review Panel
DWT	Deadweight tons
EA	Edible Algae
EdL	Electricite du Laos

EIA	Environmental Impact Assessment
EFA	Environmental Flow Assessment
EMMP	Environmental Management and Monitoring Plan
EG	Expert Group
EP	Environment Programme (MRC)
EPC	Engineering Procurement Construction
EPP	Emergency Preparedness Plan
FEG	Fisheries Expert Group
FFS	Foreseeable Future Scenario
FS	Feasibility Study
FSL	Full Supply Level
GoL	Government of Laos
HEC	Hydrologic Engineering Centers (USACE)
HNL	Highest Navigable Level
HOL	Highest Operating Level
IBFM	Integrated Basin Flow Management
ICOLD	International Commission on Large Dams
ICCS	International Cooperation and Communication Section (MRC)
IKMP	Information and Knowledge Management Programme (MRC)
ISH	Initiative on Sustainable Hydropower (MRC)
IUCN	World Conservation Union
IWRM	Integrated Water Resources Management
JC	Joint Committee
JCWG	Joint Committee Working Group
LEPTS	Lao Electrical Power Technical Standards
LMB	Lower Mekong Basin
LNL	Lowest Navigable Level
LOL	Lowest Operating Level
MCE	Maximum Credible Earthquake
MEM	Ministry of Energy and Mines (Lao PDR)
MNL	Mean High Navigable Level
MRC	Mekong River Commission
MRCS	Mekong River Commission Secretariat
MASL	Meters Above Sea Level
N	Nitrogen
NOL	Normal Operating Level
O&M	Operation and Maintenance
OAA	Other Aquatic Animals
P	Phosphorous

PC	Prior Consultation
PDG	Preliminary Design Guidance (MRC)
PMF	Probable Maximum Flood
PMFM	Procedures for Maintenance of Flows on the Mainstream
PNPCA	Procedures for Notification, Prior Consultation and Agreement
PWUP	Procedures for Water Use Monitoring
PWQ	Procedures for Water Quality
RAS	River Analysis System (USACE)
SEA	Strategic Environmental Assessment – Final Report (2010)
SEG	Sediment Expert Group
TG	Task Group
UAP	Useful Aquatic Plants
USACE	United States Army Corps of Engineers
WG	Working Group

1 FOREWORD

The Mekong River is the tenth-largest river in the world. The basin of the Mekong River drains a total land area of 795,000 km² from the eastern watershed of the Tibetan Plateau to the Mekong Delta. The Mekong River flows approximately 4,900 km through three provinces of China, continuing into Myanmar, Lao PDR, Thailand, Cambodia and Viet Nam before reaching the South China Sea.

The Mekong River Basin includes seven broad physiographic regions featuring diverse topography, drainage patterns and geomorphology: the Tibetan Plateau, Three Rivers Area and Lancang Basin form the Upper Mekong Basin; the Northern Highlands, Khorat Plateau, Tonle Sap Basin and Mekong Delta make up the Lower Mekong Basin.

In 1994, the Mekong mainstream run-of-river Hydropower Study, led by the Mekong Secretariat Study team and performed by CNR, identified and assessed opportunities for economic development without storage reservoirs along the Mekong River mainstream between the Myanmar border and Phnom Phen city. Thanks to this particular study and other studies achieved during the last twenty years, a list of hydropower projects considered in Lao PDR, based on run-of-river concept instead of large storage dam has been identified as best feasible option for the economic development of the whole LMB.

Since 2006, interest in hydropower has escalated in the Lower Mekong Basin (LMB) accompanied by increasing private sector investment in power infrastructure. Today most Mekong River tributaries are already implementing cascades of dams (planned, under construction or in operation) with around 71 projects expected to be operational by 2030.

Over the past few years, investors and developers mostly from China, Malaysia, Thailand and Viet Nam have submitted proposals for twelve hydropower projects on the LMB mainstream.

According to the 1995 Mekong Agreement, which established the MRC, member Countries need to hold prior consultations in order to address the trans-boundary impacts that mainstream Mekong development may have on neighboring countries, before any commitment is made to proceed. The consultation process aims to prevent adverse impacts on riverine communities and the environment downstream.

Among these twelve projects the GoL through the Department of Energy and Business (DEB) of the Ministry of Energy and Mines (MEM) decided to proceed to an internal review at Lao level and examine the Feasibility Study of PAK LAY project submitted by POWERCHINA Resources Ltd. (Powerchina, PR China).

Pak Lay is located around 240 km upstream of Vientiane and about 30 km from Pak Lay District. The hydropower project is located downstream the 1275 MW Xayaburi HPP project (under construction) and upstream the planned Sanakham HPP project (under evaluation). The project was initially developed by Sinohydro Corporation Ltd (Sinohydro) along with China National Electronics Imp&Exp Corporation (CEIEC) thanks to a MOU signed with GoL in 2007. Rights and obligations arising from Sinohydro have then been transferred to Powerchina Resources Ltd (hereafter called PCR).

The project features a dam of 52 m height enabling a normal water level at 240masl, navigation locks, spillway, fish passage and the powerhouse. The powerhouse is equipped with fourteen units of 55 MW each, totaling an installed capacity of 770 MW and expect yearly energy production of more than 4,140 GWh/y.

2 METHODOLOGY AND ORGANIZATION

2.1 Methodology and scope of the study

The Pak Lay run-of-river hydropower project proposed to Lao PDR by PRC along with CEIEC (China National Electronics Imp & Exp Corp.), is settled on the mainstream of the Lower Mekong Basin, 30 km far from Pak Lay district. The project implementation will bring potential opportunities for economic development of the region, mainly through enhanced electricity supply and improved conditions for inland navigation. The project should integrate the most suitable mitigation measures in order to prevent any social and environmental impacts or other potential risks development in the four MRC member Countries.

This review is held at National Level before any submission by the GoL to the MRC (see figure 2). The purpose of this study has been set up by the MEM in order to assess and optimize the project before submission, the compliance of the projects with the document "Preliminary Design Guidance for Proposed Mainstream Dams in the Lower Mekong Basin" (MRC, 2009).

The study proposed here will analyze the Feasibility Study submitted by the Developer to GoL in order to check its eligibility regarding the "Design Guidance". The two following technical topics will be assessed in particular by Brazilian experts:

1. Fish Passage on Mainstream Dams, by Dr. Sergio MAKRAKIS
2. Water Quality and Aquatic Ecology, by Dr. Helio FONTES JUNIOR

In parallel, the components regarding Navigation, Sediment Transport and River Morphology, and Safety of Dam, will be reviewed by CNR.

The review have been based on the documentation provided by the developer. It follows international guidelines, such as "Preliminary Design Guidance for Proposed Mainstream Dams in the Lower Mekong Basin" published by MRC in 2009.

The chart here-below highlights the context of the review (Figures 1 and 2).

Figure 1: The PNPCA process

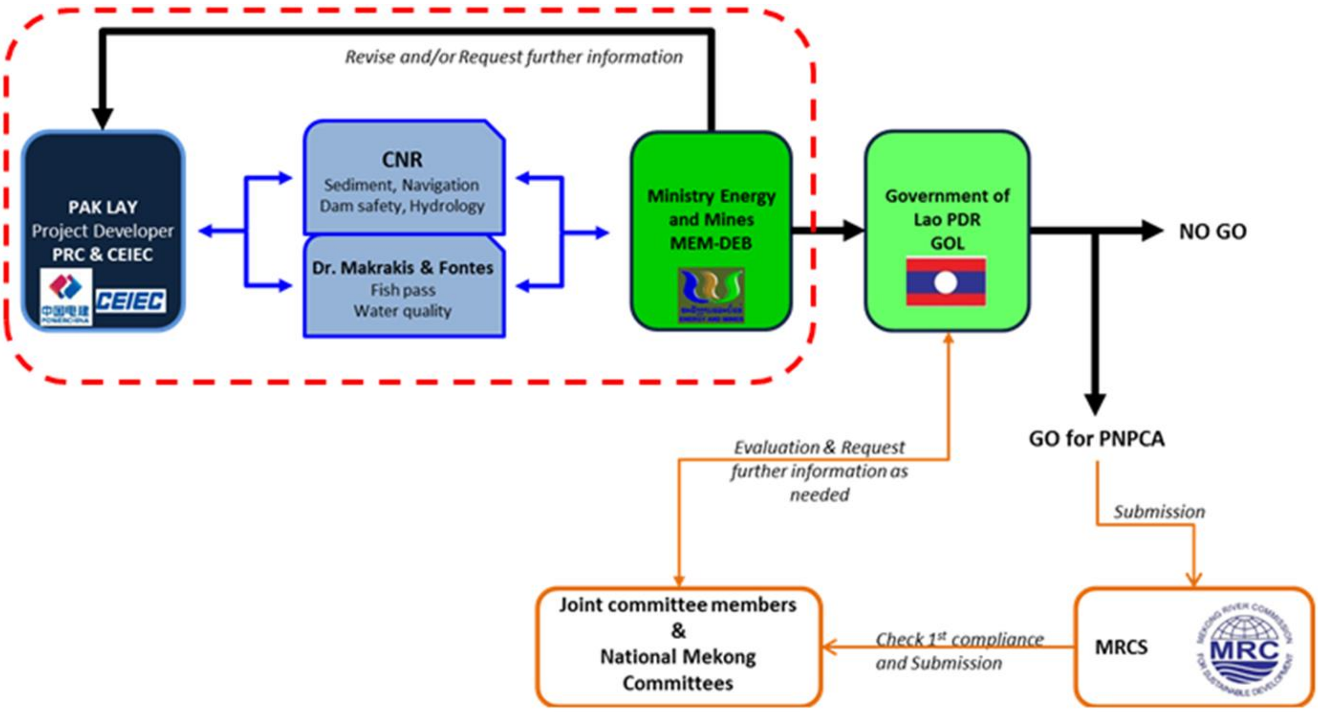

Figure 2: The project review before PNPCA process

Environmental issues with such level of coverage, involving cumulative and transboundary effects in a still poorly studied ecosystem as the Mekong basin are extremely complex. Usually there are no international standards applicable to any location interchangeably and most standards for environmental issues are national or regional. Therefore, the considerations presented here are far from covering the fullest recommendations for mitigation or management of the possible environmental effects of the project regarding aquatic ecosystem and should be understood as general guidelines to assist the submission to the prior consultation. We emphasize yet that our recommendations are inherent to only the environmental effects of Pak Lay project, such that potential cumulative effects due to reservoir cascade on the mainstream should be assessed in a broader context for all the projects taking into account the particular characteristics of each one.

Compliance analysis of the two components on the aquatic ecosystem was made taking mainly into account the recommendations of the SEA - Strategic Environmental Assessment of Hydropower on Mekong Mainstream – Final Report (Mekong River Commission Secretariat, October 2010).

According to the SEA report, here are four broad strategic options facing the LMB countries in deciding whether or not to proceed with one or more of the projects proposed for the mainstream Mekong River. Those strategic options lie at the heart of the SEA which has been conducted to support LMB countries to make a more informed choice between them based on the most up to date scientific analysis and views. The four strategic options are:

1	• Decide not to proceed with the mainstream projects
2	• Defer a decision on whether or not to proceed with mainstream projects
3	• Proceed with mainstream development on a gradual phased basis
4	• Proceed with market driven development of the proposed mainstream projects

Following the analysis of potential impacts and benefits associated with the mainstream projects, and following an intensive program of consultations with more than 100 government and non-government agencies, the SEA team has recommended that:

> **Decisions on mainstream dams should be deferred for a period of ten years (strategic option 2) with reviews every three years to ensure that essential deferment-period activities are being conducted effectively.**

The ten-year time frame for deferment is recommended because it allows sufficient time to reduce uncertainties about the changes in the natural and socio-economic systems, and uncertainties about the effectiveness of proposed avoidance and mitigation measures.

However, if Strategic Option 3 – *gradual development of mainstream hydropower development* - is chosen, implementation of all the measures suggested for option 2 should be undertaken to ensure sustainability of the plan, but within a much shorter time frame and more pressure for development than would be ideal. Especially important for Option 3 is the need to set in place a regional approach for coordination, management and regulation prior to commencement of any projects. For this option, *a **phasing and benefit sharing plan** for Mekong mainstream dams should be agreed by the LMB countries before any development proceeds*, incorporating:

(i) A clear policy commitment to ensure those adversely affected will receive benefits from mainstream hydropower development.

(ii) A review of the sustainability of all the proposed schemes with prioritization and phasing.

(iii) A coordinated programme for monitoring construction and operation of dams.

(iv) Compliance enforcement.

(v) Sharing of information and learning from experience in a structured and timely manner.

(vi) Flexibility in implementation with ability to change the plan, cancel certain projects or develop alternatives.

(vii) Consideration of alternative hydropower systems with partial damming of mainstream channel.

2.2 Consultants presentation

The Consultant team in charge of this Review is Dr. Sergio Makrakis and Dr Helio Martins Fontes Junior, with the support of Dra. Maristela Cavicchioli Makrakis.

Dr. Makrakis is Associate Professor at the State University of West Paraná (Unioeste), Brazil, undergraduate in Fishing Engineering, Program Master's and Doctorate in Fisheries and Fisheries Resources Engineering, and Masters in Conservation and Natural Resource Management. Dr. Makrakis is PhD in freshwater ecology by Maringá State University, Brazil (2007), sandwich by Mississippi State University, USA (2007), Postdoctoral in evaluation and monitoring of fishways by the USGS (United States Geological Survey - 2008) and Postdoctoral in design and construction of fishways at the University of Valladolid, Spain. He is also expert experienced in environmental studies at the Paraná River Basin, South America:

- ✓ **Partnerships with ITAIPU BINACIONAL - evaluation and monitoring the Canal da Piracema, the largest fishway in the world. Companhia Energetica de São Paulo (CESP) and NEOENERGIA to assess impacts on fish populations and monitoring fishways. Furthermore, assessing the impacts of boating activities on fish populations in the Iguaçu National Park - PNI.**

- ✓ **Expertise in Aquaculture, with course held in the Republic of China.**

Dr. Fontes Junior is Senior Biologist, PhD in freshwater ecology by Maringá State University, Brazil (2011), environment resources management expert with 27 year of experience on ecology of reservoirs, fish migrations, fish passage and water quality on a large Neotropical river basin as the Parana River, South America:

- ✓ **Manager of Reservoir Division from 1996 to 2006 at Itaipu Binacional (14,000 MV), the largest in the world in hydroelectric power generation and second in installed capacity. He coordinated several related ecology of reservoirs, limnology, fisheries, aquaculture, fish migration and fish passage projects.**

- ✓ **Responsible for implantation, evaluation and monitoring the Canal da Piracema, the largest fishway in the world with 10.3 km long and 120 m elevation gain, completed in 2002 at Itaipu dam.**

2.3 Documents reviewed

The Feasibility Study report of Mekong Pak Lay hydropower project that was reviewed is composed of the following documents:

- ✓ **FS report**
  - **General description**
  - **Hydrology**
  - **Engineering Geology**
  - **Project Planning**
  - **Project Layout and Structure**
  - **Mechanical and Electrical**
  - **Construction Organization Design**

- Project Cost Estimation
- Economic Evaluation
- **Drawings**

✓ **ESIA Pak Lay Final Report 3Dec2014**

- **Pak Lay EIA Final Report Nov2014**
- **Pak Lay EMMP Final Report Nov2014**
- **Pak Lay Exsum Nov2014**
- **Pak Lay RAP Final Report Nov2014**
- **Pak Lay SIA Final Report Nov2014**
- **Pak Lay SMMP Final Report Nov2014**
- **Pak Lay TBESIA & CIA Final Report Nov2014**

✓ **Complementary documents**

3 PAK LAY PROJECT PRESENTATION

3.1 Pak Lay HPP location

Pak Lay HPP is located in the Pak Lay District of Xayaburi Province in Lao PDR, upstream the city of Pak Lay (Figures 3 and 4). The catchment area is 278 400 km².

Figure 3: Location of Pak Lay HPP in Lao PDR

Figure 4: Location of Pak Lay HPP in the LMB.

3.2 Pak Lay HPP main features

The facility has a design capacity of 770 MW and the power production should be sold to EDL. The maximum dam height is 51.2 m. The power house features 14 bulb units for a design head around 14.5 m. The normal water level upstream the dam is 240 masl.

More information is provided in the following tables (source: Pak Lay FS report). Figure 5 provides an overview of the project layout, and Figures 6 and 7 show the HPP general layout.

Hydrological Data		
Catchment area	km²	278 400
Location	km	1 829
Annual mean discharge	cms	4110
Design flood discharge (P=0.2%)	cms	31600
Check flood discharge (P=0.05%)	cms	34700
Phase 1 diversion (P=5%)	cms	23500
Phase 2 diversion (P=1%)	cms	27800
Sediment Data		
Annual average quantity of sediment transport	10^6 t	66
Annual average sediment concentration	kg/m^3	0.509
Reservoir		
Check flood level upstream	m asl	243.25
Check flood level downstream	m asl	235.45
Design flood level upstream	m asl	241.81
Design flood level downstream	m asl	234.56
Normal water level	m asl	240
Dead water level	m asl	239
Backwater length	km	70
Reservoir capacity	10^6 m3	890
Live storage	10^6 m3	58.4
Reservoir area	km²	60
Project benefit		
Installed capacity	MW	770
Annual utilization of installed capacity	h	5381
Annual average generating capacity	GWh	4.143
Improved channel length	km	-
Tonnage of ships	t	500
Total tonnage of ship passing	10^6 t/y	2.619

Table 1: Pak Lay HPP main features (1/3)

Main structures		
Dam		
Design aseismic intensity	g	0.08
Type	-	Concrete gravity dam
Dam crest elevation	m asl	245.2
Maximum dam height	m	51.2
Dam crest length	m	931.5
Spillway and sand flushing sluice		
Weir crest elevation	m asl	220
Spillway length	m	243.5
Number	-	12
Size (WxH)	m^2	20 x 15.5
Low level outlet		
Weir crest elevation	m asl	-
Number	-	-
Size (WxH)	m^2	-
Powerhouse structure		
Powerhouse designed working flow	cms	6101
Unit installation elevation	m	208.5
Powerhouse size	m^3	397x22.5x52.44
Navigation lock		
Size (WxHxwater depth)	m^3	120x12x4
Maximum working head	m	-
Reservation area for 2nd lock	-	No
Total length	m	164.5
Fishway		
Bottom slope	%	2.12
Width	m	6
total length	m	830
Flow velocity	m/s	1.08

Table 1: Pak Lay HPP main features (2/3)

Main Electrotechnical Equipment			
Type of units	-	Bulb	
Number of units	-	14	
Rated output	MW	56.41	
Maximum head	m	20	
Rated water head	m	14.5	
Minimum head	m	7.5	
Design discharge	cms	6101	
Rated discharge	cms	435.8	
Estimated cost			
Static Cost	MUSD	1408.5	73%
Other cost	MUSD	515.1	27%
Total Cost of the project	MUSD	1923.6	100%

Table 1: Pak Lay HPP main features (3/3)

Figure 5: Pak Lay HPP General Overview.

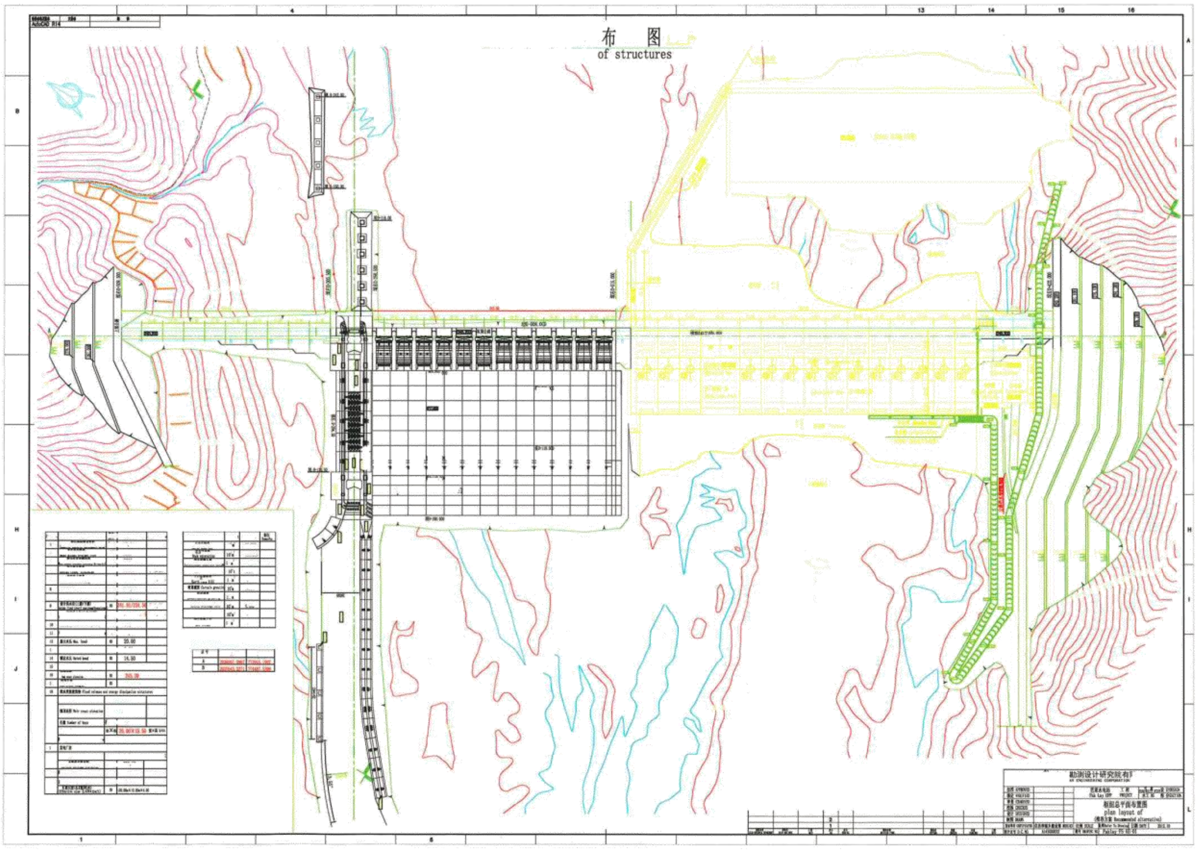

Figure 6: Pak Lay HPP General Layout (1/2).

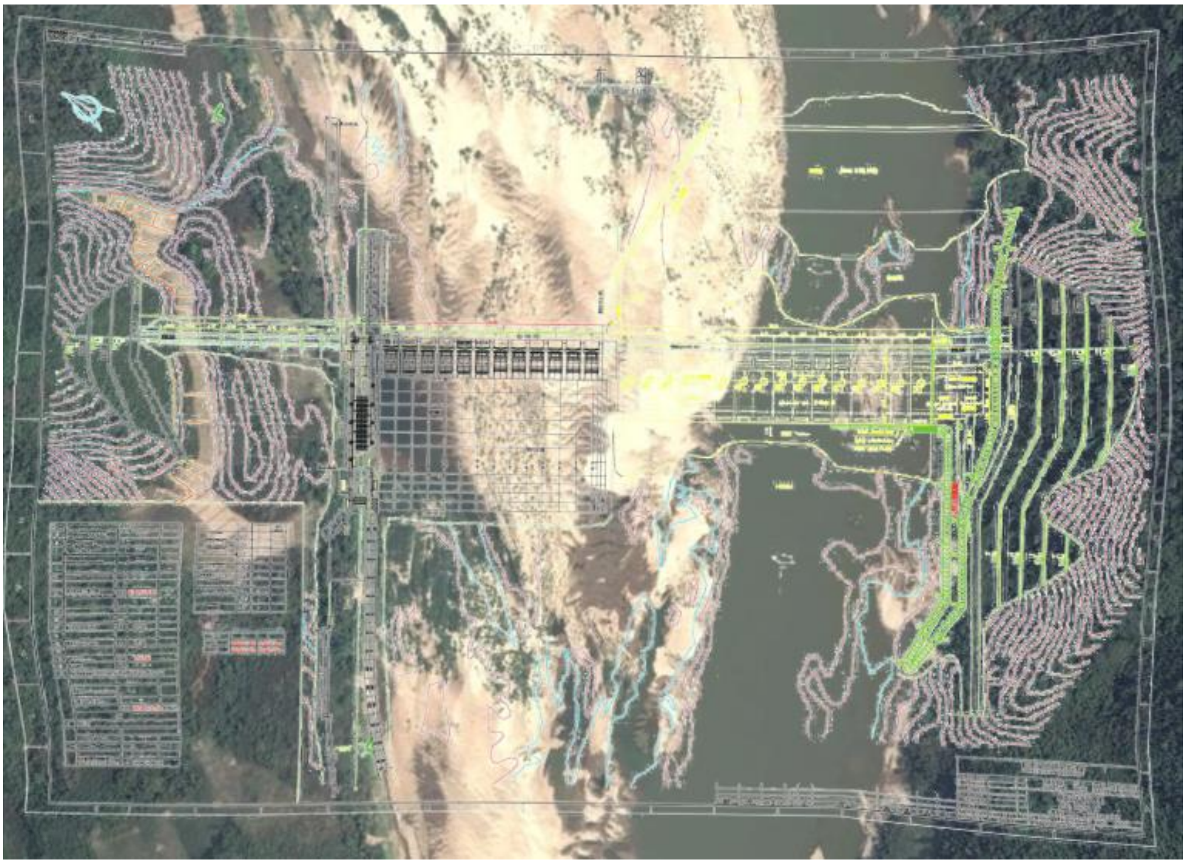

Figure 7: Pak Lay HPP General Layout (2/2).

4 RUN-OF-RIVER MANAGEMENT PRINCIPLE

4.1 Features and limitations of run of concept

Basically, the Run-of-River concept is based on the following principles:

- ✓ **The storage capacity of impoundments shall be neglected compared to river flow volumes, especially flood volumes,**
- ✓ **There is neither possibility of inter annual regulation nor seasonal regulation even weekly,**
- ✓ **There is no significant active storage, with regards to the large storage of the entire reservoir. Use of the total storage capacity would lead to low water level, i.e. not enough head at the power station, limited drought jeopardizing navigation, high head for pumping stations,**
- ✓ **Output flow sent downstream of the dam equals Input flow entering upstream the dam,**
- ✓ **The turbine flow equals the Mekong River flow for river flow inferior or equal to the design flow of the power station.**
- ✓ **Discharge through turbine is adjusted in real time to fit Mekong River flow fluctuations.**
- ✓ **When the river flow exceeds the design flow of the powerhouse, the flood & sediment discharging gates can be opened allowing excess water to flow downstream.**

It is nevertheless admitted that, some modulation of turbinated discharge could be possible with the implementation of a global coordinated operational management of the cascade. In this case, and with the implementation of an integrated hydro-meteorological network information system the operator can get the capacity to supply the electrical network at peak hours of the economic demand.

4.2 General statements of operating water level

In normal operating conditions (input flow less than flow capacity of the power station), small variations of the pond operating water levels are acceptable. The variations must be comprised between a maximum operating water level (MOWL) and a minimum water level (mOWL), also called dead water level (DWL) in Pak Lay HPP FS. These variations aim at optimizing the energy production and management taking into account PPA and operation constraints (figure 8). The variation of OWL upstream the dam is possible only when river flow is below the design flow of the powerhouse. Large water level variations are not acceptable because of following constraints on:

- ✓ Navigation: minimum draught is required for boats to reach the lock of the upstream dam. The tail of the reservoir must not be the weakest link of the navigable channel;
- ✓ Bank: bank stability can be affected by quick decrease of water level along the river;
- ✓ Environment: fauna and flora can be threatened by high daily water level variations along the river;
- ✓ Impact: OWL variations should not lead to any additional impact upstream the dam site.

When discharge values exceed the installed capacity of the powerhouse, a run-of-river hydropower station does not have available storage volume. The water level can be maintained at the normal value (NOL) as long as there is no major impact upstream the dam.

Then, for current floods (discharge above Qfl1 value and below Qfl2 value on figure 8), the operating water level should be slowly decreased by several meters in order to respect natural flow regime.

Finally, for major flood events (discharge above Qfl2 value), the operating water level should be similar to the natural flood regime of the river during such flood events. The dam should have no impact on the water level.

It is mandatory to anticipate inflows as soon as possible in order to have enough time to decrease the water when the discharge is increasing from Qfl1 to Qfl2.

This means that a hydrological monitoring and forecasting system must be implemented on site. The different water level and discharge values that are characteristic of a given run-of-river scheme (like Qfl1, Qfl2, gradient of water level decrease from Qfl1 to Qfl2… (see Figure 8) must be assessed before starting dam operation.

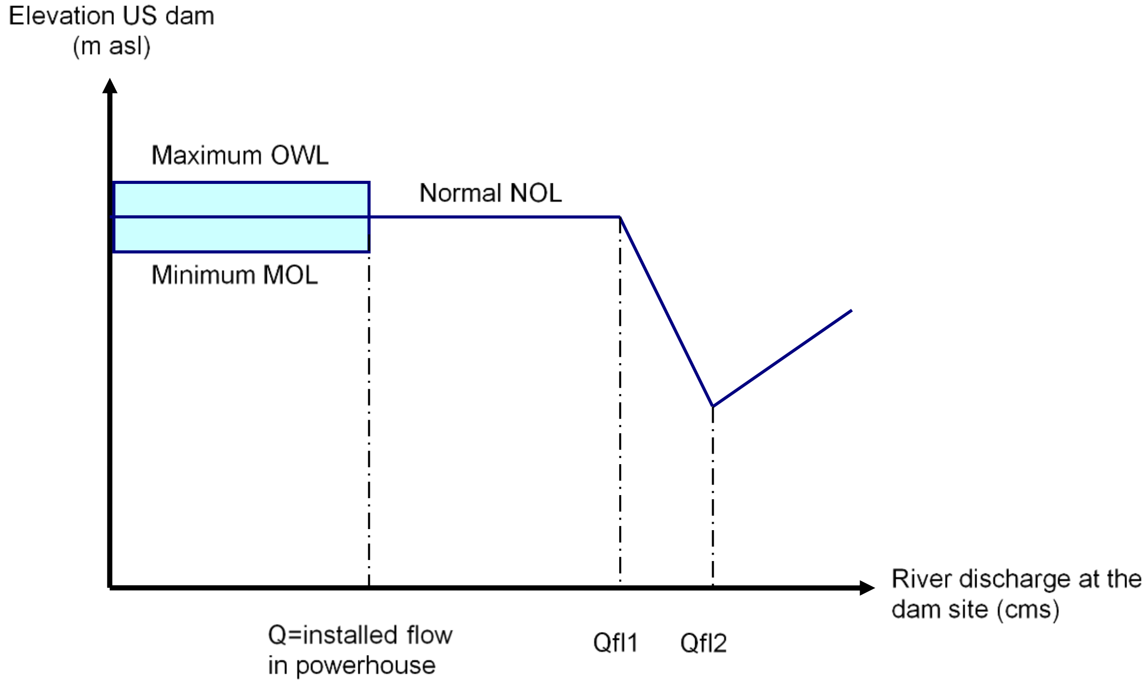

Figure 8: Diagram of OWL versus Discharge.

Qfl1: Flood discharge at which the OWL begins to decrease

Qfl2: Flood discharge at which the upstream water Level must be operated following natural conditions representative of high flood events.

5 FISH MIGRATION AND FISH PASS

This Final Report reviewed the **EIA, TBESIA & CIA, FSR – 5 Project Layout and Main Structures** for **Pak Lay Hydropower Project (HPP)**, and some additional documents provided by developer discussed with the consultant between Interim Report and Final Workshop, with respect to **Fish migration and Fish pass**. Particularly, we reviewed how these reports have covered the categories of **impacts on fish resources**, the **mitigations measures**, and the **monitoring and evaluation** of these impacts. The categories of impacts on fish resources revised were: 1) impacts on fish biodiversity and abundance; and 2) impact on fish migration.

We will discuss concisely how these issues were addressed in the **EIA, TBESIA & CIA and FSR – 5 Project Layout and Main Structures** (updated by developer – 5 Project Layout-EN-20161008.pdf) based on the design guidance recommended by:

--Mekong River Commission – MRC (2009) in “Preliminary Design Guidance for Proposed Mainstream Dams in the Lower Mekong Basin” regarding to items from 53 to 89.

Also, considerations recommended by:

--Mekong River Commission Secretariat – MRCS (2010) in SEA “Strategic Environmental Assessment of Hydropower on the Mekong Mainstream – Final Report”*;*

--Halls & Kshatriya (2009) – "Modelling the cumulative barrier and passage effects of mainstream hydropower dams on migratory fish populations in the Lower Mekong Basin - MRC Technical Paper No. 25";

--Schmutz, S. & C. Mielach (2015) – "Review of Existing Research on Fish Passage through Large Dams and its Applicability to Mekong Mainstream Dams. MRC Technical Paper No. 48. Mekong River Commission, Phnom Penh, Cambodia. 149 pp. ISSN: 1683-1489.

--Pousen et al. (2002) in "Fish migrations of the Lower Mekong River Basin: implications for development, planning and environmental management – MRC – Technical Paper No 8*",* will be addressed*.*

The aspects revised in the EIA, TBESIA & CIA and FSR – 5 Project Layout and Main Structures were classified in relation to status of assessment on MRC guidance regarding Fish Passage on Mainstream Dams (MCR, 2009) into: COMPLIANT, PARTIALLY COMPLIANT, NOT FULLY COMPLIANT and NOT COMPLIANT.

COMPLIANCE	GOALS REACHED (%)
Compliant	**≥ 90**
Partially compliant	**≥ 50 to < 90**
Not fully compliant	**≥ 15 to < 50**
Not compliant	**0 to < 15**

The text was configured as follows: the phrases in italics refer to the extracted text of Pak Lay HPP reports and text in bold refer to our observations and recommendations. Also, it is designed a **Table of Compliance** with items 53 to 89, stating that information, compliance status in Interim and Final Stages, with our comments and Pak Lay HPP responses required, respectively.

5.1 Impacts on fish resources

This topic refers to the items 53 to 59 in "Preliminary Design Guidance for Proposed Mainstream Dams in the Lower Mekong Basin". They covered recommendations and concerns about largest fishery and high biodiversity in the Mekong River, migration habitats and movements, dams as physical barriers, impact of dams to fish species into different behavioral guilds, risk of dams to migratory fish resource, and fishways to allow movements of fish past the barriers.

5.1.1 Impact on fish biodiversity and abundance

The Mekong is the river with the second highest fish biodiversity in the world. Fish species diversity in the basin is current estimated at 1200 species, and could be as high as 1700 species (Coates et al., 2003). That diversity of life increases as one moves down the mainstream. It reflects the overall productivity and biological stability of the system. Also, it is expressed in the cultural diversity and patterns of life of riparian communities. Some argue that cultural diversity and social stability is closely linked to the maintenance of biological diversity and stability. Current understanding suggests that the China dams have had a relatively small direct impact on fish diversity in the Mekong River – however, little information is available on the importance of that 44% of the river's length in Yunnan province as a nursery and breeding ground and migratory route. Similarly, it is not known how 'clear' water entering the Lower Mekong, possibly with greater temperature variance than before, will affect biodiversity and natural system productivity.

In a multi-species fisheries environment, such as the Mekong system, it is useful to distinguish different species groups based on different life history strategies (Pousen et al., 2002): black, white and grey fish species (Welcomme, 1985; Welcomme, 2001).

Within the Mekong River system there are flourishing fisheries that exploit large number of species (Coates et al., 2003). Virtually all fishes of the Mekong are exploited and therefore constitute important fishery resources. All fishes are also vulnerable to impacts from development activities, including transboundary impacts. However, long-distance migratory species (i.e. white fish species) are particularly vulnerable, because they depend on many different habitats, are widely distributed, and require migration corridors between different habitats. For these important fishes, the term ‘transboundary’ has double meaning: they are transboundary resources that may be affected by transboundary impacts of human activities.

Estimates indicate that approximately 120 fish species are commercially traded, although the bulk of the fishery is based on 10-20 species. Large river ecosystems, as Mekong River, have immense value both in terms of high biodiversity and the numbers of people that depend upon that biodiversity for their livelihoods.

The TBESIA (pages 81-89) and FSR – 5 Project Layout and Main Structures (page 188) mentioned on fish species diversity occurring in the Mekong River. And in the TBESIA emphasized in the page 81 … *There are many tributaries along the Mekong River and with the variations of topography of the Mekong Region the Mekong River Basin is an area of high biodiversity. As reported by the World Fish Center (2011), the abundance of fish species in Mekong River Basin is the second highest in the world with 785 fish species compared to 1,262 species existing in the Amazon river of South America (World Fish Center, 2011, http://www.fishbase.org /search. php). With the 785 species, there are 726 native species, 21 endemic species, 10 introduced species, 26 questionable species and 2 misidentified species.* ...

The EIA related some concerns on fishery. In the page 213 is … *Project construction and operation may result in both direct and indirect impacts. An example of indirect project impacts would include rapid population growth which could result in increased pressure on local resources use such as the fishery, agricultural production, and forest and non-timber forest products (NTFP). …* **And in the page 230 are the potential impacts from the project on fishery during operation period relating required mitigation for that:** *… Implement a fish hatchery program that will raise and release important fish into the project area; Design and install a fish pass that meets or exceeds MRC’s guidelines; Institute conservation measures and management.* **The EIA says in the page 258-259:** *…Transformation of the habitat from a river with rapids into to standing ecosystem due to impoundment will not occur for MPLHPP due to the run-of-river design. Fish species which live in running water habitat will not be negatively impacted to the new conditions. There are number of species which appear in schools such as Henicorhynchus spp. and Cirrhinus spp. with a short life span and a fast rate of reproduction; normally their abundance in the catch appears to follow the level of floods from the upstream. … The creation of a barrage without any reservoir stagnant effects will improve the overall natural fish production capacity of the Mekong River in the project area, especially in the dry season; based on the information of the water quality and the existing aquatic organisms, species diversity and their quantities, a positive impact on fish biomass will occur for species that do not have long distance migration patterns. The increasing volume and regulation of the water level would be a benefit for many aquatic living organisms. After impoundment, fisheries activities would have to be adapted to using new fishing methods and gear.* …

Furthermore, impacts (more positive than negative ones) on fish population in Pak Lay HPP area are mentioned in the page 259-260: *…With regards to fish populations, the study on species composition and their abundance in the project area indicated that the fish populations in this stretch of river are already low and the number of species is relatively small, the change in hydrological conditions will not affect resident species that are able to live in impounded condition. Fish species with long distance migration patterns and those that spawn in rapids or submerged vegetation are likely to be affected. …*

However, the TBESIA in the page 245 emphasized several negative impacts of dam construction on fish diversity and fish population in the Pak Lay HPP area, such as: limitation to fish habitat, impacts on fish population, severe depletion of fish species as listed by IUCN Red of Threatened species, and fish migration to the tributaries would increase the risk of fish being caught.

In the EIA, pages 138-148, and in the **TBESIA**, **pages 99-105**, it is mentioned the fish species occurring in the Pak Lay HPP area based on **fish collections and field surveys** conducted on Pak Lay Hydropower area (**primary data**), and on the **secondary data** (from literature and related documents were reviewed). Primary data were obtained from field surveys (fish sampling) conducted by study team in **just 02 samplings (dry and wet season)** both upstream and downstream of the proposed dam site, and each survey covered 07 sampling stations (EIA, pages 130-131). **However, baseline data for Pak Lay area to diagnose fish diversity and fishery resources ARE NOT ENOUGH: the field survey must cover the annual cycle of Mekong River hydrology which is related to fish migration (as it is showed in TBESIA – page 98). We strongly recommend to conduct more fish samplings as additional baseline data in Pak Lay area.**

In the EIA, page 147 is … *A total of 56 fish species from 17 families were collected from seven sampling stations during the wet season and dry season. Widely distributed fish species found at almost all sampling stations in thet wet and dry season were Pa Pian (Barbonymus gonionotus), Pa sai tan tar khao (Cyclocylichthys armatus), Pa* *kee York or Knarm larnk (Mystacoleucus marginatus). The exotic fish found in the Mekong river during this study were Pa Nai (Cyprinus carpio) and Pa Nin (Oreochromis niloticus). These species have become valuable fish; found in the Mekong main stream, reservoirs and cultured ponds. The most abundant area of fish was upstream of the Pak Lay project area, particularly the upper area of Ban Pha Liap. This where local people go to fish during the early wet season and early dry season. …* **Also, in the TBESIA, pages 104-105**, it is mentioned …*1) Endemic species and Critically endangered species or Endangered species or Vulnerable species found in the Pak Lay HPP area: - Fish species found in some area included Thicklip barb (Probarbus labeamajor) which is an endangered species. Interviewees indicated that this species was still found except at Ban Muong Nuea; - Fsh species found everywhere at present were Scaphognathops bandanensis which is a Vulnerable species. … 2) Native species either critically endangered, endangered or vulnerable: - Fish species found in some parts of the area, Siamese tiger perch (Datnioides pulcher) which is critically endangered species; Mekong stingray (Dasyatis laosensis), Isok barb (Probarbus jullieni) which are endangered species; Mekong tiger perch (Datnioides undecimradiatus) which is a Vulnerable species; - Fish species found everywhere at present - Giant barb (Catlocarpio siamensis) which is a critically endangered species. From interviewing, this species could be caught everywhere, but in small numbers. The market survey at Ban Na Sawang saw Giant barb. It was a big fish with the length of 80 centimeters and 13 kilograms in weight (Figure below). Also, Bangana behri which is a vulnerable species. ...*

Across pages 101 to 103 in the TBESIA, list of fish species found in the one survey investigation (interviews) by study team is provided. And, a list of fish species caught in the two surveys (sampling fish) was provided including information of: 1) range of size of fish sampled by species, and 2) number of fish by sampling station. However, we emphasized to include a full list (fish sampled and by interviews) identifying: 1) "black", "white" and "gray" species, and 2) degree of threat by IUCN (Red list). We recommend including more information about impact on fishery in the Pak Lay HPP area, because it is unclear in the EIA and TBESIA. Also, we recommend to include sampling of fish eggs and larvae to determine spawning and nursery habitats: critical habitats in the Pak Lay area for conservation of the fish diversity and fishery resources; and deposit voucher specimens of fish species sampled in the Pak Lay area in a Museum Collection from a Public University.

According to the developer, *they are planning to work with LARREC to get more data, and they normally work with University Like Kasetsart University of Thailand, Khonkaen University of Thailand, National University of Laos. LARReC stand for : Living Aquatic Resources Research Center*

Status of assessment on largest fishery and high biodiversity: **PARTIALLY COMPLIANT**

5.1.2 Impact on fish migration

5.1.2.1 Migration habitats

A wide information on fish migration is in MCR Report on "Fish migrations of the Lower Mekong River Basin: implications for development, planning and environmental management" by Pousen et al. (2002). "Since the separation of critical fish habitats within the overall ecosystem that constitutes the lower Mekong Basin is the main cause for fishes to migrate, it is useful to identify these habitats before discussing migrations, i.e. the cause (habitats) first, then the response (migrations). Floodplains are important fish habitats during the monsoon season as "production sites", and dry season refuges are permanent floodplain lakes and swamps, and river channels. Although little is known about spawning habitat requirements for most Mekong fishes, spawning habitats are generally believed to be associated with: (1) rapids and pools of the Mekong mainstream and tributaries; and (2) floodplains (e.g. among certain types of vegetation, depending on species). River channel habitats are, for example, used as spawning habitats by most of the large species of pangasiid catfishes and some large cyprinids such as *Cyclocheilichthys enoplos, Cirrhinus microlepis*, and *Catlocarpio siamensis*. Floodplain habitats are used as spawning habitats, mainly by black fish species. Other species may spawn in river channels in the open-water column and rely on particular hydrological conditions to distribute the offspring (eggs and/or larvae) to downstream rearing habitats. Information on spawning habitats for migratory species in the river channels of the Mekong Basin is scarce. Only for very few species, such as *Probarbus* spp. and *Chitala* spp., spawning habits are well described because these species have conspicuous spawning behaviour at distinct spawning sites. For most other species, in particular for deep-water mainstream spawners such as the river catfish species, spawning is virtually impossible to observe directly..."

In the pages 90-98 in the TBESIA, several information of migratory species. And in the page 244 in mentioned about limitation of fish habitats: *… Construction of dam would cause a limitation of fish habitat. Fishes would tend to congregate in upstream and downstream areas, which would allow the fishermen to catch more fish. However, this higher fish catch would decrease the quantity of species, particularly in the Upper Migration Mekong Basin, which runs from the location of Pak Lay dam at Ban Moung, Tai Pak Lay District up to Luang Prabang and down to Chiangkan District, Loei Province, Thailand) the boundary of upper and middle migration of the Mekong Basin. …*

However, it is not clear in the EIA and TBESIA if these habitats will be affected or lost with dam construction. These reports must provide more information about fish species occurring in the Project area (black, grey, and white species?), because it is also unclear. This information is not detailed in the TBESIA.

According to the developer, *these issues will be added in the Final Report.*

Status of assessment on migration habitats: **PARTIALLY COMPLIANT**

5.1.2.2 Migration movements

Intense fish migrations occur in Mekong River (Baran, 2006). These migrations envolve great distances, large number and biomass of fish species (Dugan et al., 2010). At least a third of Mekong fish species need to migrate between downstream floodplains where they feed and upstream tributaries where they breed. However, dams currently planned for the Mekong will have a major impact on the fisheries of the basin (Dugan et al., 2010). In particular, the barriers created by the dams will disrupt upstream spawning migration of economically and biologically important species (Dugan, 2008).

Aspects concerning fish migration in Mekong River are in pages 90-98 in the TBESIA: *…* **and migration system in the Mekong River Basin (upper, middle and lower), are cited.** Poulsen et al. (2002) identified three main spawning system within the lower Mekong basin: lower, middle and upper**, with Pak Lay falling within the upper Mekong migration system**. **In the page 98 is:** *… The upper Mekong River Basin starts from the mouth of the Loei River in Thailand and moves upstream toward the boundary of Laos and China. It is a floodplain area but without connection to tributaries (unlike the Middle Mekong River basin), except some river sections connected with the Ing River in the north of Thailand. Migration starts at the beginning of the flood season. Fish migrate from dry areas in the main river to spawn upstream (Figure 67). In addition, some fish species migrate from downstream rapids and deep pools to spawn in the Mekong River upstream. An example of fish species in this migration system is the Mekong giant catfish (Pangasianodon gigas). In the past, upstream migrating fish could be caught at the end of April to May every year, which is at the beginning of the new water season or monsoon season. At Had Krai in Thailand, Mekong giant catfish caught in this period are mature fish, having eggs and sperm ready for spawning. In addition, some fish species (e.g. Henicorhynchus sp.) migrate at the beginning of the monsoon season to the tributaries (e.g. the Ing River) to spawn feed and then go back to the main river at the end of monsoon season. …*

The description of migratory fish species of Mekong River is good in the TBESIA, however, it does not mention how long-distance migratory in the project impact area will be affected upstream or downstream of the dam. Moreover, we recommend to conduct radiotelemetry (short-term) and mark-recapture (long-term) studies to provide migration routes. Also, sampling of fish eggs and larvae drifting in the area to determine more precisely spawning and nursery grounds, and when this happens. Studies of gene flow on fish populations, especially, on target species, will be the great value in the future.

According to the developer, *in the project construction and operation stages, study on the fish species in the river reach where Pal Lay HPP is located will be continuously conducted, and the specific implementation plan will be made in the project construction stage.*

However, it is very important to consider the methods and gears that will be used to assessment, and duration: short, medium and long term, in the wet and dry season.

Status of assessment on migration movements: **COMPLIANT**

5.1.2.3 Dams as physical barriers

The most obvious effects from placing dams on rivers result from formation of new lentic or semi-lentic environments upstream from the dam, and tailwater environments downstream from the dam (Jackson & Marmulla, 2001). The construction of a dam on a river can block or delay upstream fish migration and thus contribute to the decline and even the extinction of species that depend on longitudinal movements along the stream continuum during certain phases of their life cycle (Larinier, 2001).

The impacts on river fisheries resources are varied, often profound and typically mediated through two major pathways: (i) flow modification, and (ii) barrier and passage effects.

Barrier and passage effects on fish populations are particularly significant and form the primary focus of this study. Dams can deny or diminish fish access to critical or upstream spawning habitat but also have the potential to reduce population survival rates as adult fish and their progeny incur mortality passing through dam turbines, by-pass structures, or over dam spillways when returning to downstream feeding and refuge habitat. The combination of diminished survival rates and spawning success can lead to significant reductions in exploitable fish biomass and species extinctions as reported in river basins throughout the world.

Flow changes impact upon fish populations and fish communities by disrupting and diminishing spawning behavior and success, and by reducing growth and survival rates arising from diminished feeding and refuge opportunities and exposure to unfavorable environmental conditions.

Some aspects on dams as physical barriers are in the TBESIA. In the page 244 is *… Construction of a big dam, like the one for the Pak Lay HPP at either alternative 1 or 2, would divide the river ecosystem causing separation of living organisms upstream and downstream. It would impact on the movement of living organisms that migrate for reproduction and spawning as part of their normal life cycle. Based on the study of Baran E (2006), there are a total of 768 fish species in the Mekong River consisting of 165 migratory fish species, 24 non-migratory and 579 fish species that have not been scientifically identified as either migratory or non-migratory....*

Impacts on migratory fish by dam-caused blockage are in the page 244-245 in the TBESIA: *... Evidently, the Mekong giant catfish (Pangasianodon gigas) migrate from their habitat in the middle Mekong Basin to spawn at the Upper Mekong Basin at Ban Had Krai, Chiang Khong District, Chiang Rai Province, Thailand during the end of April to May. Construction of the Pak Lay dam in the upper Mekong Basin would obstruct the Mekong giant catfish unless an appropriate fish pathway can be designed. However, so far, no study result has stated that a fishpass is suitable for the Mekong giant catfish, nor is such data available for other fish species in the Mekong. … A transboudary impact would occur at 2 areas; Middle Migration Mekong Basin and Upper Migration Mekong Basin, particularly on the fish that migrate between the connecting point of middle and upper basins such as the Mekong giant catfish and the Mekong stingray. However, negative impacts on the small scaled fishes in the Cynprinidae would be less as these fish could migrate to the tributaries (no need to pass through dam) for reproduction and spawning. However, it requires more data for migration of each type of fish in order to assess the impact level on fish migration. … Fish migration to the tributaries would increase the risk of fish being caught because the tributaries are not wide and deep like the Mekong River. A high fish catch would decrease the quantity of fish in the basin and the sustainability of such fish catches. In the tributaries, there are a variety of fishing equipments eliminating any chance of survival. A critical fish catch would have a grave effect on fish and aquatic organisms. …*

Status of assessment on dams as physical barriers: **COMPLIANT**

5.1.2.4 Impact of dams to fish species into different behavioral guilds

Not all species of fish caught in the basin are threatened by mainstream dams (Halls & Kshatriya, 2009). Some species have only limited migrations over short ranges which may not be impaired by dam structures whilst others are highly adaptable to habitat modification including impoundment. Species of fish most likely to be impacted will be those that undertake significant (passive and active) migrations between critical (spawning, feeding, and refuge) habitat to complete their life-cycles or to exploit seasonal variation in habitat quality and availability.

Dams have a different impact on fish species depending on the “guild” or ecological group they belong to. In a multi-species fisheries environment, such as the Mekong system, it is useful to distinguish different species groups based on different life history strategies (Poulsen et al., 2002). Mekong fish guilds have different physiological capabilities, requirements or behaviors and are characterized by three colors:

• “White fish” are very sensitive to damming because species of this ecological group need to migrate over long distances to complete their life cycle.

• “Grey fish” migrate between floodplains and local tributaries and are not very sensitive to mainstream dams.

• “Black fish” have a short home range, are very robust and can adapt to reservoir environment; they are the least at risk from damming.

There is some information on impact of dams to fish species in the TBESIA – pages 244-245. However, it is not clear in the EIA and TBESIA who are white, grey and black fish species occurring in the project area and how they will be impacted by dam. We recommend to provide a list of fish species caught in the two surveys (sampling fish), and this list must include information of: 1) white, black or grey species, and 2) degree of treat by IUCN.

According to the developer, *in the near future they are in contact with LARREC to get more samplings with capacity of LARREC.*

Status of assessment on impact of dams to fish species into different behavioral guilds: **COMPLIANT**

5.1.2.5 Risk of dams to migratory fish resources

This massive acceleration in plans for hydropower development in the Mekong has led to growing concern over the potential environmental, economic and social costs; in particular, there is acute concern over the impact on the basin’s fisheries (Dugan et al., 2010).

In Lao PDR more than 3 million people fish, mainly from the Mekong and its tributaries (Dugan et al., 2010). In Cambodia, 80% of the 1.2 million people living around Tonle Sap use the lake and its rivers for fishing (Ahmed et al. 1998).

In a river basin where 70% of communities are rural and where inland fisheries are the most intensive in the world, food security and livelihoods are still largely based on river-dependent natural resources. Risks and losses incurred by the Mekong terrestrial and aquatic ecosystems translate into threats to the livelihoods of millions of people – primarily through increasing food insecurity in the basin. If natural resources productivity is reduced, the most countries at risk are Cambodia and Lao PDR (MRCS, 2010).

The LMB mainstream projects enter the Basin at a time when tributary hydropower already threatens the diversity and size of the Mekong fishery. Fish yield in the Mekong is comprised of at least 35% of long-distance migrant species whose migrations would be barred by dams. The mainstream projects would fundamentally undermine the abundance, productivity and diversity of the Mekong fish resources, affecting the millions of rural people who rely on it for nutrition and livelihoods (MRCS, 2010).

There are some considerations on risk of the dam to fishery resources in the EIA, page 260: … *Operation of project will cause changes to freshwater ecosystem, altering flows, interrupting ecological connectivity, and fragmenting habitats. This will adversely affect fisheries, aquatic biota and aquatic biodiversity.* …

The EIA related some concerns on fishery and food security in the page 262 … *Therefore, the negative impacts that the MPLHPP will have on Fisheries and Aquatic Resources (FAR) will depend on many factors and variables. Not least of these will be the construction sequence of the 5-dam cascade projects are to proceed. Dams disrupt the continuity and linearity of riverine systems, and greatly impact migratory fish populations in a negative way. Without seasonal fish migrations, and the fisheries that rely on them, livelihoods and food security for riparian communities will be compromised to various degrees, and depending on circumstances may be serious.* …

According to the developer, *the fish caught in the project are for households consumption (and some are for selling to the restaurants and local markets). The mitigation for helping local people to maintain the nutrition from fish will be discussed with Local authorities (committee) for support and make sure they still can do fishing along the Mekong river in that particular area they familiar with. This information will be update in the final report.*

Status of assessment on risk of dams to migratory fish resource: **COMPLIANT**

5.1.2.6 Fishways to allow movements of fish past the barriers

Fish passes are not a realistic mitigation option for Mekong mainstream dams. Fish ladders may be a mitigation option for low dams on tributaries, but existing types and sizes of fish ladders cannot accommodate the intensity and diversity of fish migrations on the mainstream (MRCS, 2010). Eight of the proposed mainstream dams are higher than the maximum height at which fish ladders are operational. World-wide fish ladders are efficient when specifically designed for a few particular species that migrate once a year in limited numbers. The Mekong is characterized by more than 50 different migrant species, huge densities during migration peaks and several migration pulses per year. In addition, a cascade of dams would exponentially reduce the overall upstream fish passage rate.

Fish pass facilities are mentioned in the EIA, TBESIA & CIA and FSR - 5 Project Layout and Main Structures, to mitigate dam impact to migratory species. In the EIA, page 34 is mentioned the fish passages for Pak Lay HPP: *... A) Upstream fish passage - The upstream fish passage facilities of the hydropower project are a fishway, fish lock, fish lift, freight fishing boat and others. According to the constructed project experience at home and abroad, the fish lift and the freight fishing boat are generally applicable to the high dam and mainly passable for the large strongly migratory fish***.** *B) Downstream fish passage for Migratory Fish Pak Lay Hydroelectric Power Project is a runoff hydropower project. Its flood discharge structure has high frequency, with weir crest at elevation of 213.00m, only higher than that of the original river bed. Thus, the down passage of the migratory fish of the project is mainly as per that in case of flood discharge of the flood gate. …*

First: Pak Lay HPP must define how many fishways will be installed. Considering that the Mekong River has a large width, we strongly recommend placing fishways on both banks (right and left) of the river. Regarding downstream fish movements, there is no studies showing that most of the target species move to downstream efficiently through the spillways and turbines. Thus, the Pak Lay HPP project MUST consider building fishway that enables the drives towards downstream.

Therefore, the few studies that evaluated the elevators for tropical fish have shown that this type of fishway has been inadequate (Oldani et al., 2007). And, so far no studies have been proving the efficiency of the locks as fishway. There are many considerations on Fish Passages for Mekong River Fish Species in Schmutz & Mielach (2015).

During the discussions in the workshops and, also in the period between them, with the developer and consultant, there were improvements about the fishway to Pak Lay. See document in Annex.

According to the developer, *the riverbed downstream of Pak Lay HPP is about 450m wide. The main river channel is located on the left side, about 220m wide. In low-flow period, the riverbed on right side of the river is exposed (above El. 220m). Therefore, placing fishways on both sides (right and left) of the river would function little in low-flow period.*

In the updated scheme, a Fish Guidance Systems is arranged at the downstream entrance of the fishway, which can basically block the fish species in the whole river channel, and guide the fish species to the fishway entrance. A Fish Guidance Systems is also arranged at the upstream entrance of the fishway, which can block the fish species from entering the turbines, and guide them to the fishway.

In flood period, when the flow is less than 16,700m^3/s, the power station can operate normally, the fishway can operate normally, and the fish species can migrate upstream and downstream through the fishway. When the flow is more than 16,700m^3/s , the power station will stop power generation, the spillway gates will be opened for flood discharge. In this case, the river reach will restore its natural state, with an average flow rate of 5 to 6 m/s, and the flow is smooth, free from water rolling (similar to the status in Phase II construction stage). The natural river state will be basically restored, not damaging the fish species, and the duration will be very short. （*see the reports 5.10.2*）.

Status of assessment on fishways to allow movements of fish past the barriers: **COMPLIANT**

5.2 Mitigation measures of dam impacts on fish migration

This topic refers to the items 60 to 84 in “Preliminary Design Guidance for Proposed Mainstream Dams in the Lower Mekong Basin”. They covered recommendations and concerns about guidance on fish passage design

(60-63), planning and design phase (64-65), biological and ecological fish requirements (66-71), hydrology aspects (72-74), hydraulic environment (75-80), and operation of fishway (81-84).

5.2.1 Guidance on fish passage design and operation

5.2.1.1 Fish passage facilities for both upstream and downstream passage

Numerous upstream fish passage facilities have been developed with varying degrees of success including pool and Denil-type ladders, nature like by-pass channels, fish lifts, locks, and collection and transportation facilities (Larinier, 2001; Clay, 1995). Adult and juvenile fish can pass downstream to feeding and refuge habitat via three main flow through structures: (i) turbines; (ii) spillways and (iii) by-passes channels.

In other regions of the world, a suite of fish passage technologies has been developed to partially mitigate the impacts of dams, and investments would be needed in the Mekong before any level of certainty on their effectiveness could be determined (Dugan et al., 2010).

Serious concerns are in the SEA report (MRCS, 2010) about the construction of the cascade of 06 dams upstream of Vientiane that would cause very significant changes to aquatic ecosystems, and the biggest loss would be on connectivity between the sea and the Upper Mekong affecting long distance migratory species populations.

The Modelling the cumulative barrier and passage effects of mainstream hydropower dams on migratory fish populations in the Lower Mekong Basin MRC Technical Paper No. 25, reveals that: there are more than 1,300 kinds of fishes in Mekong basin, among which 233 kinds under 55 families are commonly found in mainstream, flood plain and estuary (Halls & Kshatriya, 2009).

The FSR - 5 Project Layout and Main Structures provides a general layout of the fish way. **In the page 191 is** mentioned that **upstream fish pass facilities for Pak Lay HPP consist of vertical slot fish way.**

Considering that the Mekong River has a large width, we strongly recommend placing fishways on both banks (right and left) of the river. Regarding to downstream fish movements, there is no studies showing that most of the target species move to downstream efficiently through the spillways and turbines. Thus, the Pak Lay HPP project MUST consider building fishway that enables the drives towards downstream.

The Denil fishway must not be used and this type of passage will not meet the requirements and sizes of tropical fish species. This is also emphasized by Schmutz & Mielach (2015). A subsystem of this type of fishway, built in the Canal da Piracema at Itaipu Binacional, has been a bottleneck for the upward movements of migratory fish (Makrakis et al., 2011).

During the discussions in the workshops and, also in the period between them, with the developer and consultant, there were improvements about in the Fishway Design to Pak Lay. One of them was the type of fishway, the denil fishway was changed to vertical slot.

According to the developer, *in the updated scheme, the fishway with vertical slots on both sides is employed, and is arranged on the left bank slope of the river. The fishway is 6m wide, 2.5m deep (water), and 970m long, with an average gradient of 2.2%, satisfying all the fish species moving upstream and downstream around the year.*

The downstream entrance of the fishway is arranged about 250m downstream of the tailrace of the power house, where a flood plain exist with an elevation of around 217m, and the flow is gentle. The invert of the downstream entrance is at El.217.5m, satisfying the normal operation at the lowest water level El.219.00m.

The upstream entrance of the fishway is arranged about 100m upstream of the power station, with an invert elevation of 237.50m, satisfying the normal operation at the upstream water level 239.0m~240.0m.

A 250m-long electric screen for blocking fish is respectively arranged at the upstream and downstream entrances of the fishway. The upstream fish screen can prevent the downward moving fish from entering the turbines, guide the fish to move downstream through the fishway, and prevent the upward moving fish species from entering into the power intake area. The downstream fish screen can make the upward moving migratory fish species to concentrate at the downstream entrance and move upstream through the fishway (see Attached Drawings 1 and 2).

We recommend to keep this information in the final report. Also, the report must regard that maximum velocities of water flow in fishway will not be more than 2.5m/s. The report must regard the minimum

discharge that will be occur in the fishway. For example, in Canal da Piracema the minimum discharge for a good attraction is 15.0 m³/s. Electrical current passes through the water from an anode to a cathode creating an electric field in the vicinity of the barrier, and fish barriers that use electricity derive much of their effectiveness through behavioral avoidance of electrical fields (Katopodis et al., 1994). Electric barriers have proven effective at preventing fish movement, particularly through constricted waterways. When used to stem the spread of fish, two major limitations must be considered. First, deactivation due to power outage, maintenance (or lack thereof), and human error precludes any single electric barrier from operating 100% of the time over prolonged deployments (Clarkson, 2004). In situations where it is critical that no movements across a barrier occur, redundancies and integrated deterrence systems are recommended. Second, small fish may be unaffected by electric fields, resulting in size-elective effectiveness that might not meet all management goals (Reynolds 1996). Because these information, we do not recommend the use of electrical screen to guide the fishes. It would be better to use curtain burbles or just bypass screen than electrical screen.

According to the developer, *the electric barriers will be canceled in this stage.*

Status of assessment on fish passage facilities for both upstream and downstream passage: **COMPLIANT**

5.2.1.2 Effective fish passage

Upstream passage success (or efficiency) may be defined as the proportion of the fish that succeed when attempting to pass the dam (Larinier, 2001). Experiences from projects worldwide reveal that estimates of upstream passage success rates vary between 0 – 100% and that they are species-specific (Marmulla, 2001). The facilities must be effective at all times of the year and therefore at all river stages (Baran et al., 2011).

Some information about operating water level of fish pass structure, general layout of it, hydraulic and structural design of the fish way are in the pages 192-199 in the FSR - 5 Project Layout and Main Structures. And **in the page 192 is:** *… The bilateral vertical slot fishway is adopted as the fish pass structure with a flow of 3.7m³/s approximately.* **We do not agree with these discharge values (***3.7m³/s approximately***) to meet the target species of the Mekong River. However, the developer improved achieving the total flow at the lower end up to 8.4m³/s.** … *In order to ensure sufficient flow at the lower end and good fish-guiding effect, a water charging system is furnished by the fishway to increase the flow by 4.7m³/s and make the total flow at the lower end up to 8.4m³/s. …* **And in the page 195, is:** *…The water drops into the river channel from the outlet and forms an artificial waterfall (Fig. 5.10-4).* **However, this flow should be distributed within the ladder (3.7m³/s) plus the rest of the flow at the end of the ladder. This is to improve the flow of attraction. The use of an artificial waterfall, proposed by the developer, is not a practice known to improve the attractiveness for tropical species (there are no studies to prove it), but for the temperate region.**

We must consider that fishways for the basin of the Mekong River should accommodate those large species such as the large catfish. These species have preference to swim under the bottom, avoid places and situations with higher light, usually inhabiting deep locations, such as the deep pools (Campbell, 2009). Thus, fishways should be wide and deep, which will require higher flow rates. Thus, it is expected that the fishway reproduce similar conditions of the natural environment, especially the huge importance for these species of Siluriformes, which are endemic and migratory long distance.

Also, there are no considerations and concerns on effective fishways in the EIA, TBESIA and FSR - 5 Project Layout and Main Structures. They don´t provide information about existing types and characteristics of fish passage facilities, an overview in another countries and analysis of them, and options of fish passages for Pak Lay HPP Project. Therefore, the downstream passage is not considered for the Pak Lay HPP project.

These issues are extremely poor in the reports. There are studies conducted for tropical fish species such as in the largest fish pass system in the world – Canal da Piracema at Itaipu Dam (Makrakis et al., 2011), and Porto Primavera fish ladder (Wagner et al., 2012), both in the Paraná River. There is a full review on that in Schmutz & Mielach (2015).

According to the developer, *the fishway with vertical slots on both sides is employed. The fishway has a width of 6m, a water depth of 2.5m, a vertical slot width of 0.5m, and a vertical slot flow of 1.4m/s. A 250m-long electric screen for blocking fish is respectively arranged at the upstream and downstream entrances of the fishway, guiding the upward moving and downward moving fish species to enter the fishway, and improving the fish pass* *effect. In reference to Chinese Standard Design Guidelines for Fishways of Water Conservancy and Hydropower Projects (SL609-2013) and the experience and practice of fishways in China, the fishway can satisfy the pass of the targeted fish species (see Appendix 1 Introduction of Fishway of Changzhou Hydropower Project in China).*

We recommend that the report must regard the minimum discharge that will be occur in the fishway. For example, in Canal da Piracema the minimum discharge for a good attraction is 15.0 m³/s. Electrical current passes through the water from an anode to a cathode creating an electric field in the vicinity of the barrier, and fish barriers that use electricity derive much of their effectiveness through behavioral avoidance of electrical fields (Katopodis et al., 1994). Electric barriers have proven effective at preventing fish movement, particularly through constricted waterways. When used to stem the spread of fish, two major limitations must be considered. First, deactivation due to power outage, maintenance (or lack thereof), and human error precludes any single electric barrier from operating 100% of the time over prolonged deployments (Clarkson, 2004). In situations where it is critical that no movements across a barrier occur, redundancies and integrated deterrence systems are recommended. Second, small fish may be unaffected by electric fields, resulting in size-elective effectiveness that might not meet all management goals (Reynolds, 1996). Because this information we do not recommend use of electrical screen to guide the fishes. It would be better to use curtain burbles or just bypass screen than electrical screen.

According to the developer, *the electric barriers will be canceled in this stage.*

Status of assessment on effective fish passages: **COMPLIANT**

5.2.1.3 Mitigation options

Many concerns on fish passage facilities as mitigation option in the Mekong River are detailed in the SEA Report (MRCS, 2010):

-Only three of the 11 mainstream dam projects have explicit and detailed plans for fish pass facilities (MRCS, 2010). The inefficiency of fish passes on the mainstream as a mitigation measure is also predictable because of additional reasons:

i) in case of a cascade of dams the number of fishes able to cross several successive dams and passes decreases exponentially (e.g. out of 100 fishes having to migrate through 3 fish passes characterized by a good 50% passage rate, only 12 remain after the 3rd dam;

ii) the type and design of fish passes that work are based on behavioural studies of target fish species (where they swim in the river, their swimming capabilities, their attraction by a range of current speeds, etc); in the Mekong, there are no such studies available for any species; designing a fish ladder in absence of such information will lead to failure;

iii) even an efficient fish ladder does not guarantee the survival of a species if the environment upstream of the ladder is not suitable; upstream of Vientiane, if 6 dams are developed, 90% of the running river will be turned into a reservoir and specific target studies are need to determine whether Mekong migratory species can carry out their life cycle in these conditions.

-For low dams, fish ladders may be a mitigation option, but it is essential then that they are considered at the earliest planning stages during the determination of dam location and design. In all cases, knowledge of the requirements of target species is needed to ensure the efficiency of the fish pass considered.

There is some recommendation on mitigation of dam impact on migratory fish in the TBESIA. In the page 295 is … *Appropriate design for fish migration pathway should be made through the comprehensive study of fish migration behaviour and Fish Monitoring Program should be implemented to protect and possibly enhance the fisheries in the area of the Mekong River. …*

Also, the EIA, page 264, mentions options to mitigate impacts of the dam on migratory fish: *…* *It is possible to have a **project fishpass facility** to mitigate the migratory of fish. Any fishpass design is not considered to be a viable answer to the issues regarding fish migration as there is no known type of fishpass that could possibly cope with the large number of Mekong fish species that would need to use it during the critical time periods when fish need to move. **The maintaining downstream flows and upstream migration** is crucial to the sustainability of fish populations. Fishery research station at project area should be set up near project area. **Many activities will be related to breed the indigenous fish species** for release to the Mekong River in the project upstream* *pond.* ***The fish transport mobile unit*** *with large container with aeration system will set up for collected the fish from downstream or pond of fishpass way cross to upstream.* ***Adoption of aquaculture*** *within the headpond area would be a partial solution to the loss of migratory species. …*

Status of assessment on mitigation options: **COMPLIANT**

5.2.1.4 Multiple systems at each site

The "Preliminary Design Guidance for Proposed Mainstream Dams in the Lower Mekong Basin" (MRC, 2009) recommend that 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.

According to SEA Report (MRCS, 2010) "Strategic Environmental Assessment of Hydropower on the Mekong Mainstream", fish passes able to cope with Migrations corresponding ~50 species of commercial long-distance migrants; 8 pulses/year in Khone Falls; 30 tonnes/hour in Tonle Sap. And, it cites kinds of fish passages facilities:

1. Natural bypass channels - Made via excavation of one of the river banks; Can mimic a 'real' stream; Common in Europe and North America; Only possible in certain areas and for very low dams. Mekong Mainstream Dams (MMD): possible for Don Sahong.

2. Pool fish passes - Divides the height of the dam via a series of staggered pools (steps of 15-40 cm); Common throughout North America and Europe; Appropriate for passes that must accommodate numerous species; best for low dams (<10m). MMD: not suitable given the height of mainstream dams

3. Vertical slot fish passes - Vertical slots in the baffles allow fish to swim at any preferred depth through each slot; Good for migrations involving multiple species; No proven efficacy beyond 30m high dams. MMD: cannot accommodate the size and diversity of mainstream migrations

4. Weir-type passes - Notches and orifices modulate flow and provide different kinds of passages to fishes; Generally small in size, and often used for salmon in North America. MMD: cannot accommodate the size and diversity of Mekong mainstream migrations

5. Denil-type passes - Use spaced baffles on the sidewall and the floor so that current speed does not exceed swimming capability of target species; Useful for large fish species; Mainly used in N. America and W. Europe; Best suited for a maximum height of 30; can tolerate only moderate variations in upstream water level. MMD: too specific, cannot accommodate size of migrations and variabililty in reservoirs

6. Fish locks - When fish enter the lock, the lower gates close and the upper gates open; Can be used for dams up to 60m high; The locks have low capacity and depend on the ability to attract fishes. MMD: cannot accommodate the size of mainstream Mekong migrations

7. Fish lifts - Literally lift fish from tailwater up to reservoir; Can be used for very high dams; Suitable only for large fish species; need to attract fish; only a few dozen individuals are moved at a time. MMD: totally inappropriate given the size and diversity of Mekong migration…

According to Baran et al. (2011): …Because of the large number of species to pass in the Mekong and the lack of basic information concerning their behavior 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 years of construction).

The FSR - 5 Project Layout and Main Structures provides a general layout of the fish way. In the page 191 is mentioned that **…** *Vertical slot fish way can adapt to relatively large variation amplitude and is passable for surface and bottom fishes, and is also more favorable for the migration of various upstream and downstream fishes. Therefore, vertical slot fish way is adopted for the HPP.* **…**

First: Pak Lay HPP must define how many fishways will be installed. Considering that the Mekong River has a large width, we strongly recommend placing fishways on both banks (right and left) of the river. With regard to downstream fish movements, there is no studies showing that most of the target species move to downstream efficiently through the spillways and turbines. Thus, the Pak Lay HPP project MUST consider building fishway that enables the drives towards downstream.

Therefore, the few studies that evaluated the elevators for tropical fish have shown that this type of fishway has been inadequate (Oldani et al., 2007). And, so far no studies have been proving the efficiency of the locks as fishway. Also, there are many concerns on types of fish way for Mekong River in Schmutz & Mielach (2015).

According to the developer, *through analysis and demonstration, the fishway with vertical slots on both sides is employed for the Pak Lay HPP. The fishway will be in service when the inflow is less than 17500m^3/s. When the inflow is more than 17500m^3/s, the power station will stop power generation, all the flood release gates will be opened, the natural river state will be restored, and the fish species may move through the water release structures.*

The HPP will be constructed in two stages: in Stage I, the river water will flow through the left side river channel, not affecting the fish movement; in Stage II, the river water will pass through the water-release structures, and low inflow will not result in backwater basically, thus not affecting the fish movement. Therefore, temporary facilities for fish movement during construction period is not considered for this project (see Attached Drawings 3 and 4).

Status of assessment on multiple systems at each site: **COMPLIANT**

5.2.2 Planning and design phase

The planning and design of the fishways should be fully integrated into the dam design concept from the earliest stages of planning, and developers are encouraged to utilize 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 (MRC, 2009).

Whether considering either downstream survival or upstream passage, the diversity of fish species inhabiting the tropical systems including the Mekong is also likely to raise significant challenges to designing engineering solutions for species or groups of species sharing similar behaviour and swimming capacity often determined by body size.

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) (Baran et al., 2011).

According to these authors two prerequisites are to be considered in the design of an efficient upstream fish facility:

-The passability of the fish pass, i.e. the fact that all species can swim thorough the fish pass without stress and injury. The design of the fish pass should take into account the behavior and 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;

-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 behavior are very different, several entrances have to be installed in zones of different turbulence (Baran et al., 2011).

For Mekong Pak Lay Hydropower Project, **the FSR - 5 Project Layout and Main Structures** provides a general layout of the fish way and designs. **In the page 192 is** mentioned: … *For the Project, the fish pass structures in the HPP includes fishway, water charging system and large resting pool. …*

Careful attention should be given in the DESIGN and implementation of the PROJECT to fishway. For fish passage design, the definition of parameters such as maximum water velocity along the facility, minimum depth, minimum width at the bottom, the operation flows and the roughness coefficient are key to the development of the project. The location and geometry for both the entry and the fishway output are also critical for its functionality.

Therefore, the development of reduced model of the fishway and swimming performance tests of the target fish species simultaneously could be of great value; and the design of a Ecohydraulics and Hydrobiology Laboratory may be the key to success for the fish passage projects.

Also, we strongly recommend to consider the design of the fishway for wide width and depths that allows dimensions suitable for the large species, and to avoid level differences in the entrance of fish pass: it must be able to attract fish on the bottom - Large catfish swims on the bottom.

The information so far available on fish facility designed to Pak Lay HPP are insufficient for a conclusive assessment. We strongly recommend to provide a DESIGN REPORT of Fish Passage Facilities to Pak Lay HPP (see Design Report of Fish Passage Facilities For Sanakham Hydropower Project) that includes a project of site conditions for the construction of the fishway, and options of fishways to promote both downstream and upstream movements (see recommendations in the 5.2.1.1 Fish passage facilities for both upstream and downstream passage).

According to the developer, *the fishway with vertical slots on both sides is employed for the Pak Lay HPP. The fishway has a width of 6m, a water depth of 2.5m, a vertical slot width of 0.5m, and a vertical slot flow of 1.4m/s. A 250m-long electric screen for blocking fish is respectively arranged at the upstream and downstream entrances of the fishway, guiding the upward moving and downward moving fish species to enter the fishway, and improving the fish pass effect. In reference to Chinese Standard Design Guidelines for Fishways of Water Conservency and Hydropower Projects(SL609-2013) and the experience and practice of fishways in China, the fishway can satisfy the pass of the targeted fish species.*

We recommend to consider the minimum discharge in the fishway. For example, Canal da Piracema keeps the minimum discharge of 15.0m³/s. Also, according to the technical meeting (in the afternoon), after Final Workshop, the following items shall be supplemented: 1) The studies will be made by LARREC; 2) Biological/ecological requirements of target species; 3) Downstream movements; 4) Spawning grounds and nurseries - a sampling protocol should be proposed; 5) Attention for THE DEEP POOLS.

According to Poulsen (2001) and Chan *et al.* (2005), deep pools are:

- ✓ **Important habitat for the conservation of fish species in the Mekong River;**
- ✓ **Refuge habitats in the dry season for sedentary and migratory species, permanent habitats for other, spawning and feeding sites for certain species and an important link between habitat for fish migration;**
- ✓ **Important sanctuaries in the dry season for many giant fish of the Mekong River, endangered species such as the giant catfish, *Pangasianodon gigas.***

Status of assessment on planning and design phase: **COMPLIANT**

5.2.3 Biological/Ecological requirements of fish

At dams sites the design of fish passes is always adjusted to the swimming capabilities of target species (Baran et al., 2011). Thus, it is indispensable biological data on swimming performance of migrating fish species in the Lower Mekong Region to the development of suitable design criteria. However, Baran et al. (2011) emphasize that there are no studies of swimming performance or behavior for Mekong River species, and they suggest a preliminary study combining traditional knowledge and hydrological records in order to identify at the minimum the hydrological needs of local fish species before a specific fish pass design is proposed.

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 (Baran et al., 2011). Downstream fish passage technology is much less advanced than it is for upstream fih passage facilities, and downstream migration problems have only been recognized and addresses recently (Larinier & Travade, 2002).

For potamodromous species, downstream fish passage at hydroelectric power dams is generally considered less essential in Europe and North America (Larinier, 2001). However, certain potamodromous species can migrate over very long distances, so the need for mitigation to provide passage for potamodromous fish must be considered species- and site-specific.

The passability of the fish pass, i.e. the fact that all species can swim through the fish pass without stress and injury (Baran et al., 2011). The design of the fish pass should take into account the behavior and 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. In the case where the fish passage is intended for several species whose swimming abilities and migratory behavior are very different, several entrances have to be installed in zones of different turbulence.

The loss of the environmental cues that stimulate fish migration is another important factor to consider when assessing impacts on fish passage (Thorncraft & Harris, 2000). For example, if migratory cues such as increasing water temperatures in summer, or daily and seasonal flow variations, are suppressed by releases from a reservoir, fish may fail to migrate. Similarly, many species require natural daylight patterns to sustain their migration, and darkened areas create behavioural barriers. It is important to maintain migration cues, and to consider the potential effect on migratory fish when changes to seasonal water temperatures and stream flows are likely to occur.

Existing models of fish locks cannot accommodate intensive fish migrations but their dimensions, volume and discharge can be adapted to suit the migrations requirements of target species (Baran et al., 2011). According these authors, recent experiments using modified navigations 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 other pass.

Increased upstream and downstream predation on migratory fish is also linked to dams, fish being delayed and concentrated due to the presence of the dam and the habitat becoming more favorable to certain predatory species (Larinier, 2001).

Normal predation behaviour may become modified with the installation of a dam, and although few data exist to date, it appears that migrating species suffer increased predation in the vicinity of an installation, whether by other fish or birds, and human (Larinier, 2001). This may be due to the unnatural concentration of fish above the dam in the forebay, or to fish becoming trapped in turbulence or recirculating eddies below spillways, or to shocked, stressed and disoriented fish being more vulnerable to predators after turbine passage. In some rivers or hydroelectric schemes, predation may affect a substantial proportion of the fish population.

Larinier (2001) gives concerns on downstream movements. In the first stages of dam development, engineers and fisheries biologists were preoccupied with providing upstream fish passage facilities. Passage through hydraulic turbines and over spillways was not considered to be a particularly important cause of damage to downstream migrating fish. Experience has shown that problems associated with downstream migration can be major factors affecting diadromous fish stocks.

At dams, injury and mortality of juveniles occurs because of passage through turbines and sluiceways. Impact with turbine blades, rough surfaces, or solid objects can cause death or injury (Miranda, 2001). Changes in pressure within turbines or over spillways also can result in death or injury. Juveniles, frequently stunned and disoriented as they are expelled at the base of the dam, are particularly vulnerable to predation.

For Mekong Pak Lay Hydropower Project it is highly recommended that they be carried out further studies aimed at better understanding of the target species. The fish fauna of the Mekong River basin is highly diverse and possibly many species are still unknown or were not described. Even for species already cataloged many aspects of its biology are still poorly known, such as their life cycle, physiology, migratory behavior, size at first maturity; spawning type (whole or split), swimming performance, etc. Habitat fragmentation growing increasingly limits the populations with large home range. However, the implementation of a fish passage by itself does not guarantee the conservation of the target species.

Based on the field observations and on the information available on the hydrological conditions, geomorphology and structural characteristics of Pak Lay HPP, the overall design of the fish passage still requires many additional details for better evaluation.

In order to confirm the occurrence of migratory species and verify the potential of the area chosen to implement the fishway, additional studies must be done to characterize the fish fauna around the area of the fishway inlets in the Mekong River sampling with various fishing gears throughout the year and interviews with fishermen. This also will serve as a basis for future monitoring system.

The water inflow area design shall consider the range of possible level changes of the reservoir so as not to increase the water velocity during flood periods and keep a minimum depth on the dry season.

One of the most relevant criteria for decision on building fish passes is the presence of potentially adequate spawning grounds and nurseries that ensure sustainable populations above and below the dam.

The chances of downward movements must be evaluated considering the projects of each plant (type of turbine, the spillway geometry, the water inflow position, hydrological aspects and auxiliary structures).

Most of biological/ecological requirements of fish mentioned by MRC (2009) were not addressed. So, we recommend inserting these aspects in the report: target species (preferences, tolerances and biological attributes), peak of biomass, fish predation, and fish healthy.

According to the developer, *the baseline data has been collected, but more study with capacity of LARREC will be discussed, and they recommend that the design team should be discuss with LARREC as they are specific this area. The recommendation from experts should be consider to put in the report.*

We emphasize that this information should be included in the final report. Also, according to the technical meeting (in the afternoon), after Final Workshop, the following items shall be supplemented: 1) The studies will be made by LARREC; 2) Biological/ecological requirements of target species; 3) Downstream movements; 4) Spawning grounds and nurseries - A sampling protocol should be proposed; 5) Attention for THE DEEP POOLS.

According to Poulsen (2001) and Chan *et al.* (2005), deep pools are:

- ✓ **Important habitat for the conservation of fish species in the Mekong River;**
- ✓ **Refuge habitats in the dry season for sedentary and migratory species, permanent habitats for other, spawning and feeding sites for certain species and an important link between habitat for fish migration;**
- ✓ **Important sanctuaries in the dry season for many giant fish of the Mekong River, endangered species such as the giant catfish, *Pangasianodon gigas.***

Status of assessment on biological/ecological: **COMPLIANT**

5.2.4 Hydrology

The fishways should cater for the largest operational ranges practical, within the biological and hydrological requirements of the fish species concerned, and as a guideline, fishways should be fully operational from minimum low season flow of up to the 1:20 year flood level (MCR, 2009).

The attractivity of a fishway is linked to its location in relation to the obstruction, and particularly to the location of its entrance(s) and the hydrodynamic conditions (flow discharges, velocities and flow patterns) in the vicinity of the entrance(s) (Larinier, 2002). The entrance must neither be masked by the turbulence coming from turbines or from the spillway, nor by recirculating zones, nor static water (Larinier, 2002).

The discharge through the fish passage facility must be sufficient to compete with the flow in the river during the migration period, and generally the flow passing through the fishway must be approximately 1 to 5% of the competing flow (Larinier, 2002). According to Larinier (2002), in large rivers, as Mekong River, an attraction flow of around 10% of the minimum flow of the river is used for the lower design flows, and it is satisfactory 1% and 1.5% of the highest design flows for fishway operation (Larinier, 2002).

Passage through spillways may be a direct cause of injury or mortality, or an indirect cause (increased susceptibility of disorientated or shocked fish to predation) (Larinier, 2001). According this author, mortalities have several causes: shearing effects, abrasion against spillway surfaces, turbulence in the stilling basin at the base of the dam, sudden variations in velocity and pressure as the fish hits the water, physical impact against energy dissipaters. Mitigations measures (adapted spillway, apron, stilling basin and dissipater design) must be considered in the HPP projects.

Considerations on hydrology conditions on fish passage facilities have improved in the FSR - 5 Project Layout and Main Structures (the version updated by developer).

Moreover, some concerns on dam operation on fish ascend the fish pass are in the EIA, page 272: … *The operation of the dam will however, have a series and adverse impacts on aquatic life. This will be difficult to mitigate using conventional ideas of fish passes due to the sheer magnitude and the difficulty of getting sufficient numbers of fish to ascend an unfamiliar structure. It will also be difficult to attract fish to the fish pass when they may be deflected by larger flows emanating from the powerhouse. …*

We recommend including in the reports more information on biological and hydrological requirements for fish species concerned, adequate flow to attract fish at the entrance of the fishway.

Also, Pak Lay HPP project must consider the location of the entrance of the fishway, avoiding the nearness from the discharge of the spillway and the water intake of the fishway must be distant from the spillways. Spillway must be designed to minimize the fish injury and entrapment.

Status of assessment on hydrology: **COMPLIANT**

5.2.5 Hydraulic environments

The position of a fishway at the dam is of a critical importance. A fishway sited on or near the riverbank is usually preferable to a location in the middle of the obstruction (Larinier, 2002), and it must be positioned at the bank river where the current is highest (FAO, 2002). Also, Larinier (2002) recommends that fishways should not be installed in areas where natural silting or sedimentation is occurring, particularly on the inside of bends. The efficiency of a fishway will be considerably improved by installing several entrances at points which appear to be most favorable, but it is recommended when a correct location of the fish pass entrances may not be obvious (Larinier, 2002).

The flow leaving the fishway should be detectable by the fish at the greatest possible distance from the entrance, and the attactivity will depend on the direction and the momentum (discharge x velocity) of the entrance jet (Larinier, 2002). At the spwillway, it is sometimes possible to adjust the flow through the control structures to improve the attraction of the fishways (Larinier, 2002).

Passage facilities for fish migrating downstream are installed to prevent fish from being entrained in the turbine intakes, and to guide them to a by-pass that will transport them safely downstream around the installation (Larinier, 2002). Barrier screens (perforated plates, metal bars, wedge-wire, plastic or metal mesh) are used to exclude fish from the turbines, they are positioned across the water intakes in such way that they guide fish towards a by-pass, and this is most effectively by placing the screens diagonally to the flow (Larinier, 2002). An important point is that flow in front of the screens must be slow enough to allow fish the time to find the by-pass, otherwise they may be impinged against the screens (Larinier, 2002). For protection and maintenance of screens, trashrack is used to limit debris accumulation at the by-pass entrance.

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 large fish species (Baran et al., 2011).

Some information about operating water level of fish pass structure, general layout of it, hydraulic and structural design of the fish way are in the pages 192-199 in the FSR - 5 Project Layout and Main Structures. And **in the page 192 is:** *… The bilateral vertical slot fishway is adopted as the fish pass structure with a flow of 3.7m^3/s approximately.* **We do not agree with these discharge values (***3.7m^3/s approximately***) to meet the target species of the Mekong River. However, the developer improved achieving the total flow at the lower end up to 8.4m^3/s.** … *In order to ensure sufficient flow at the lower end and good fish-guiding effect, a water charging system is furnished by the fishway to increase the flow by 4.7m^3/s and make the total flow at the lower end up to 8.4m^3/s. …* **And in the page 195, is:** *…The water drops into the river channel from the outlet and forms an artificial waterfall (Fig. 5.10-4).* **However, this flow should be distributed within the ladder (3.7m^3/s) plus the rest of the flow at the end of the ladder. This is to improve the flow of attraction. The use of an artificial waterfall, proposed by the developer, is not a practice known to improve the attractiveness for tropical species (there are no studies to prove it), but for the temperate region.**

Considerations on hydraulic conditions on fish passage facilities have improved in the FSR - 5 Project Layout and Main Structures (the version updated by developer). We recommend including more details

of the design of the fishway as drawn (top view, side view, measures, etc.), barrier screens guide downstream moving, and planning studying hydraulic conditions of the fishways in a reduced model.

Status of assessment on hydraulic environments: **COMPLIANT**

5.2.6 Operation of fishway

According to MRC (2009), the period of captivity and interruption to the normal movements of the fish should be as short as possible; water quality should be maintained within any holding enclosures to ensure fish health - oxygen levels should be maintained within the fishways at >5 ppm; 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 maximizing operating time; and entrance slot velocities should be adjustable, such that feedback from monitoring and observation of fish behaviour can lead to optimization of the fishway operation.

There are limited considerations on operation management of fish pass in the FSR - 5 Project Layout and Main Structures. There is few information in the reports concerning the other aspects (i.e. short period of captivity and interruption, water quality, appropriate volumes through the fishway, and entrance slot velocities) mentioned by MRC (2009). We strongly recommend including all these issues detailed in the FSR - 5 Project Layout and Main Structures.

According to the developer, *the fishway monitoring room is arranged downstream of the intersection of the fishway and dam, performing real-time monitoring of the fish passage effect and status, and taking corresponding measures to adjust the fish passage efficiency.*

We recommend to clarify how this monitoring will work in the final report. Also, considering the possibility that the upstream water level reaches less than 239, the developer must maintain the minimum discharge (~8.4m³/s) by pumping. Also, the use of the discharge for attraction through a pipe it will be embedded in the end of the fish ladder.

Status of assessment on operation: **NOT FULLY COMPLIANT**

5.3 Monitoring and evaluation of fishway

This topic refers to the items 85 to 89 in “Preliminary Design Guidance for Proposed Mainstream Dams in the Lower Mekong Basin”. They covered recommendations and concerns related to monitoring and evaluation of fishway:

- **Provisions for monitoring facilities at fishways are to be incorporated into the design and operation phase of environment management and monitoring programs. This should include the ability to sample fish safely from the fishways as well as monitor fish movements and water quality;**
- **Monitoring programs 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;**
- **The monitoring program should be funded by the developer for the duration of the concession period;**
- **Developers should utilize a core group of international experts to assist with the design and implementation of the monitoring programme, with all expenses covered by the developer;**

- **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.**

Travade & Larinier (2002) emphasize the importance of the monitoring of fishways and any functional controls associated with them to: verify the efficiency of fishways after they have been commissioned and to adjust their operation if necessary; to gather technical and biological information which will be indispensable for design and development of future fishways; quantify migratory fish populations and describe the pattern migration. Moreover, the techniques employed for monitoring of fishways are summarized in monitoring the hydraulic and mechanical operation of the fishway, collection qualitative biological information indicating the effectiveness of fish passage; count fish using the fishway, and comparing the number of fish using the fishway to the migrating population as a whole, thus expressing the true efficiency of the fishway. Quantitative and behavior (telemetric techniques – ultrasonic and radiotelemetry) methods can be used to evaluate the fishways.

The evaluation of fish passages is very important to:

- ✓ **Confirm hydraulic and biological performance of a structure**
- ✓ **Define operational range and characteristics**
- ✓ **Identify and correct problems**
- ✓ **Gain information for improving structures**
- ✓ **Assess success in meeting passage goals and population/ecosystem restoration**

And the goals of fish passage performance are:

- ✓ **Provide upstream and downstream passage past barriers**
  - **Maximize passage efficiency**
  - **Minimize delay**
  - **Minimize mortality, injury, and predation**
- ✓ **Exclude exotic/invasive species**
- ✓ **Restore/sustain natural populations and genetic diversity**

There are no considerations on monitoring and evaluation of fish passages in the EIA, TBESIA and **FSR - 5 Project Layout and Main Structures. We strongly recommend including all issues recommended by MRC (2009) detailed in the FSR - 5 Project Layout and Main Structures, and a proposal for evaluation and monitoring of the fishways regarding hydrological and biological aspects (attractiveness and efficiency of fishway; fish swimming behavior). Furthermore, it is essential to consider studies on spawning and early development areas of the target species to better understand the passage efficiency, i.e Da Silva et al. (2015), and Termvidchakorn & Hortle (2013).**

It is very important to clarify how the fish passage assessment will be done. When, Who and How will be held and the Universities in the region could help these studies. There are advanced technologies in order to assess and monitor the fishways with high precision (radio and pit telemetry, acoustic tags, videos, etc).

In South America region, studies were conducted for tropical fish species, i.e in the largest fish pass system in the world – Canal da Piracema at Itaipu Dam (Makrakis et al., 2007a, 2011), and Porto Primavera fish ladder (Makrakis et al., 2007b; Wagner et al., 2012), both in the Paraná River.

Also, we recommend to consider a monitoring program during the concession period, and consider the use of international experts to assist in the design and implementation of the monitoring program.

According to the developer, *the monitoring facilities will be constructed along with project construction, and the specific operation and management measures will be refined in the subsequent design.*

However, we recommend to clarify how this monitoring will work in the final report.

Status of assessment on monitoring and evaluation: **NOT FULLY COMPLIANT**

5.4 Conclusions

Considering the **EIA, TBESIA** and **FSR - 5 Project Layout and Main Structures** for Pak Lay Hydropower Project, according to items 53-89 of the MRC (2009) and summarized in the Table of Compliance, Pak Lay HPP has attended – COMPLIANT - 78% of these items. However, some were PARTALLY COMPLIANT - 3% and others were NOT FULLY COMPLIANT – 19%.

For Pak Lay Hydropower Project, it is highly recommended that it be carried out further studies aimed at better understanding of the target species. The fish fauna of the Mekong River basin is highly diverse and possibly many species are still unknown or were not described. Even for species already cataloged many aspects of its biology are still poorly known, such as their life cycle, physiology, migratory behavior, size at first maturity; spawning type (whole or split), swimming performance, etc. Habitat fragmentation growing increasingly limits the populations with large home range. However, the implementation of a fish passage by itself does not guarantee the conservation of the target species.

For fish passage design, the definition of types and parameters such as maximum water velocity along the facility, minimum depth, minimum width at the bottom, the operation flows and the roughness coefficient are key to the development of the project. The location and geometry for both the entry and the fishway output are also critical for its functionality.

The chances of downward movements will also be evaluated considering the projects of each plant (type of turbine, the spillway geometry, the water inflow position, hydrological aspects and auxiliary structures). Also, it is very important to clarify how the fish passage assessment will be done.

There are some gaps highlighted in the **EIA**, **TBESIA** and **FSR - 5 Project Layout and Main Structures** revised concern these aspects above. **So, they should:**

- ✓ **Conduct more fish samplings as additional baseline data in Pak Lay area - baseline data for Pak Lay area to diagnose fish diversity and fishery resources are not enough at the present;**
- ✓ **Include sampling of fish eggs and larvae to determine spawning and nursery habitats: critical habitats in the Pak Lay area for conservation of the fish diversity and fishery resources;**
- ✓ **Deposit voucher specimens of fish species sampled in the Pak Lay area in a Museum Collection from a Public University;**
- ✓ **Provide more information about fish species occurring in the Project area (black, grey, and white species), and discerning target species;**
- ✓ **Clarify whether there are critical habitats (spawning, growth, food) above or below the dam and what the actual risks to populations of migratory fish;**
- ✓ **Clarify if the habitats of migratory species will be affected or lost with dam construction, especially the deep pools;**
- ✓ **Provide a better description of migratory fish species, and it must mention which species are long-distance migratory in the project impact area and how they will be affected;**
- ✓ **Provide more information on biological and hydrological requirements for fish species concerned, flow of operation in the fishway at seasons, adequate flow to attract fish at the entrance, and spillway designed to minimize the fish injury and entrapment;**
- ✓ **Provide more information and details on fish friendly turbines;**
- ✓ **Consider provision of temporary fish facilities during the construction period, such as fish collecting and transporting (upstream and downstream), experimental fish ladder using material of dam construction;**
- ✓ **Consider provision of training in new fisheries techniques, annual stocking of reservoir and tributary fisheries.**

These actions could be summarized in a specific report (see Design Report of Fish Passage Facilities For Sanakham Hydropower Project).

Considering fish pass as mitigation measure to minimize impact of the dam project to fish, **the information so far available on fish facility designed to Pak Lay HPP are insufficient for a conclusive assessment.**

We strongly recommend inserting information in the FSR - 5 Project Layout and Main Structures to Pak Lay HPP:

- ✓ **Project of site hydraulic conditions for the construction of the fishway;**
- ✓ **Design of the fish passages;**
- ✓ **Consider the construction of fishways on both banks of the river;**
- ✓ **Consider the design of the fishways for wide width and depths that allows dimensions suitable for the large species;**
- ✓ **Avoid level differences in the entrance of fish pass: it must be able to attract fish on the bottom - Large catfish swims on the bottom;**
- ✓ **Considerations of fish movements - both upstream and downstream of the dam;**
- ✓ **Address biological and ecological aspects;**
- ✓ **Information on hydrology, simulation of hydraulic conditions and operations (flow velocity and discharge, slop, depth, etc.);**
- ✓ **Development of reduced model of the fishway and swimming performance tests of the target fish species simultaneously could be of great value;**
- ✓ **Design of an Ecohydraulics and Hydrobiology Laboratory may be one of the key to success for the fish passage projects;**
- ✓ **Proposal for evaluation and monitoring of the fishway regarding hydrological and biological aspects (attractiveness and efficiency of fishway; fish swimming behavior and swimming capacity). There are advanced technologies in order to assess and monitor the fishways with high precision (radio and pit telemetry, acoustic tags, videos, etc). Furthermore, it is essential to consider studies on spawning and early development areas of the target species to better understand the passage efficiency, i.e Da Silva et al. (2015). And Termvidchakorn & Hortle (2013) published a good guide to larvae and juveniles of some common fish species from the Mekong River Basin;**
- ✓ **Consider a monitoring program during the concession period;**
- ✓ **Consider the use of international experts to assist in the design and implementation of the monitoring program, and as well as professionals with skills in biology and fish ecology.**

Moreover, it is very important to clarify how the fish passage assessment will be done. When, Who and How will be held and the Universities in the region could help these studies. In South America region, studies were conducted for tropical fish species, i.e in the largest fish pass system in the world – Canal da Piracema at Itaipu Dam (Makrakis et al., 2007a, 2011), and Porto Primavera fish ladder (Makrakis et al., 2007b; Wagner et al., 2012), both in the Paraná River.

We also recommend to conduct radiotelemetry (short-term) and mark-recapture (long-term) studies to provide migration routes. Also, sampling of fish eggs and larvae drifting in the area to determine more precisely spawning and nursery grounds, and when this happens. Studies of gene flow on fish populations, especially, on target species, will be the great value in the future.

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5.6 Table of Compliance

		Interim stage					Final stage		
N°	Guidance regarding Fish Migration and Fish Pass	Status concerning compliance (Compliant, Not Fully Compliant, Not Compliant)	Consultant's Comments	Answer / Adress of the issue by the developper	Consultant's Comments II	Answer / Adress of the issue by the developper II	New status concerning compliance (Compliant, Not Fully Compliant, Not Compliant)	Consultant's Comments III	Answer / Adress of the issue by the developper
Background									
53	**Impact on fish biodiversity and abundance** - The Mekong supports the world's largest inland fishery, with an average of approximately 2.6 million tonnes harvested annually from the Lower Mekong Basin (LMB). Fisheries supply 49-82 percent of the animal protein consumed in the LMB. The livelihood benefit of the resource, in terms of nutrition, income and employment is critical, particularly for millions of the rural poor, who have few other livelihood options. The Mekong is second only to the Amazon River in terms of biodiversity.	NOT FULLY COMPLIANT	Baseline data for Pak Lay area to diagnose fish diversity and fishery resources ARE NOT ENOUGH: the field survey must cover the annual cycle of Mekong River hydrology which is related to fish migration (as it is showed in TBESIA – page 98). We strongly recommend to conduct more fish samplings as additional baseline data in Pak Lay area. Across pages 101 to 103 in the TBESIA, list of fish species found in the one survey investigation (interviews) by study team is provided. However, we strongly recommend to provide a list of fish species caught in the two surveys (sampling fish), and this list must include information of: 1) range of size of fish sampled by species, 2) if it is white, black or grey species, 3) degree of treat by IUCN, 4) number of fish by sampling station. We recommend including more information about impact on fishery in the Pak Lay HPP area, because it is unclear in the EIA and TBESIA. Also, we recommend to include sampling of fish eggs and larvae to determine spawning and nursery habitats: critical habitats in the Pak Lay area for conservation of the fish diversity and fishery resources; and deposit voucher specimens of fish species sampled in the Pak Lay area in a Museum Collection from a Public University.	We are planning to work with LARREC to get more data, Since Sanakham and Pak Beng use the same sampling methods and we collected samples for 2 seasons.	Please, let us know what means the abreviation LARREC. We emphasize that the involvement of Public University because would attend the PNPCA, item 3 and subitem e - Transparency.	We normall working with University Like Kasetsart University of Thailand, Khonkaen University of Thailand, National University of Laos. LARREC stanf for: Living Aquatic Resources Research Center Lao People's Democratic Republic Address: Ministry of Agriculture and Forestry, P.O. Box 9108 City: Vientiane	PARTIALLY COMPLIANT	According to the technical meeting (in the afternoon) the following items shall be supplemented: 1) Sampling of fish eggs and larval; 2) Deposit voucher specimens; 3) Identify “black”, “white” and “gray” species; 4) Degree of threat by IUCN (Red list).	

54	**Migration habitats** - Migration between spawning and feeding habitats in different locations in the river system is an inherent part of the life history of many commercially important species in the Mekong. If these fish populations cannot complete their natural migrations, breeding is reduced and fish populations decline; in many cases this may lead to a complete loss of migratory fish.	NOT FULLY COMPLIANT	In the pages 90-98 in the TBESIA, there are several information of migratory species. And in the page 244 in mentioned about limitation of fish habitats. However, it is not clear in the EIA and TBESIA if these habitats will be affected or lost with dam construction. These reports must provide more information about fish species occurring in the Project area (black, grey, and white species?), because it is also unclear. This information is not detailed in the TBESIA.	The information provied in EIA and TBESIA are from two sources (1) from sampling upstream and downstream of the project for two seasons. (2) interview local fishermen, and fish sellers at the local markets (3) secondary data from various sources. The ty pe of fish caught have the list attached.	The reports must clarify the habitats that will be affected with dam construction. Also, it must identify black, gray and white species in the list of fish cautght (inserting a column in the Table 10 in the TBESIA).	Since the ESIA is not yet get appproval from MONRE the report will be updated the provide information will be added to the Final Report.	PARTIALLY COMPLIANT	According to the technical meeting (in the afternoon) the following items shall be supplemented: 1) Sampling of fish eggs and larval; 2) Deposit voucher specimens; 3) Identify “black”, “white” and “gray” species; 4) Degree of threat by IUCN (Red list).	

55	**Migration movements** - Fish migration occurs in both an upstream and downstream direction. Upstream migration generally consists of adults, actively swimming to spawning grounds. Downstream migration involves all life history stages, including eggs and larvae which drift in the current, juveniles of limited swimming ability and adult fish. This varies depending on the species concerned.	NOT FULLY COMPLIANT	Aspects concerning fish migration in Mekong River are in pages 90-98 in the TBESIA: and migration system in the Mekong River Basin (upper, middle and lower), are cited. Poulsen et al. (2002) identified three main spawning system within the lower Mekong basin: lower, middle and upper, with Pak Lay falling within the upper Mekong migration system. The description of migratory fish species of Mekong River is good in the TBESIA, however, it does not mention how long-distance migratory in the project impact area will be affected upstream or downstream of the dam. Moreover, we recommend to conduct radiotelemetry (short-term) and mark-recapture (long-term) studies to provide migration routes. Also, sampling of fish eggs and larvae drifting in the area to determine more precisely spawning and nursery grounds, and when this happens. Studies of gene flow on fish populations, especially, on target species, will be the great value in the future.	In the project construction and operation stages, study on the fish species in the river reach where Pal Lay HPP is located will be continuously conducted, and the specific implementation plan will be made in the project construction stage.	It is very important to take into account the methods and gears that will be used to assessment, and duration: short, medium and long term, in the wet and dry season.	The implementation programme will be draft before implement and we will be considered as the recommendation.	COMPLIANT		
56	**Dams as physical barriers** - Dams and falls are physical barriers across rivers that interrupt fish migrations both upstream and downstream. They also alter flow regimes in the river, which impacts on the capacity of fish to migrate.	COMPLIANT					COMPLIANT		

57	**Impact of dams to fish species into different behavioral guilds** - Not all Mekong fish species will be affected by dams. Grouping Mekong fishes into different behavioural guilds shows the different levels of vulnerability to the effects of dams, as listed below. Table 1 shows fish guilds in the Mekong and the likely impact of mainstream dams on migrations. Highly vulnerable guilds are shaded grey.	NOT FULLY COMPLIANT	There is some information on impact of dams to fish species in the TBESIA – pages 244-245. However, it is not clear in the EIA and TBESIA who are white, grey and black fish species occurring in the project area and how they will be impacted by dam. We recommend to provide a list of fish species caught in the two surveys (sampling fish), and this list must include information of: 1) range of size of fish sampled by species, 2) white, black or grey species, 3) degree of treat by IUCN, 4) number of fish by sampling station.	We have information of fish caught in two seasons attached. In the near future we are in contact with LARREC to get more samplings with capacity of LARREC.	Please, clarify the abreviation LARREC.	Living Aquatic Resources Research Center (LARREC) Tag countries: Lao People's Democratic Republic Address: Ministry of Agriculture and Forestry, P.O. Box 9108 City: Vientiane	COMPLIANT		
58	**Risk of dams to migratory fish resources** - The size of the migratory fish resource at risk from dams (guilds 2, 3, 8 and 9 above) on the Mekong mainstream has been estimated at 0.7-1.6 million tonnes per year (equivalent to approximately 30-60 percent of the annual catch in the Mekong). The analysis also indicates a first sale value for the resource	COMPLIANT		As we may awared that the number of fish reduces by many reasons, in our project the fish caught are for households consumption (and some are for selling to the restaurants and local markets. The mitigation for helping local people to maintain the nutrition from fish will be discussed with Local authorities (committee) for support and make sure they still can do fishing along the Mekong River in that particular area they familiar with.	It is plausible to keep these information in reports.	Since the ESIA is not yet get approval from MONRE the report will be updated the provide information will be added to the Final Report.	COMPLIANT		

	of US$1.4 – 3 billion per year. This is a conservative estimate, because it does not take into account the economic benefits that flow through the economy from the trade and processing of fish products.								

59	**Fishways to allow movements of fish past the barriers** - Movement of fish past the barriers may be possible only if effective fishways can be designed to accommodate the biology and numbers of migratory fishes in the Mekong. On hydropower dams (or any dams greater than approximately six metres in height), fish ladders or natural fish passages are unlikely to be effective for upstream migration. Fish lifts or fish locks are theoretically a possibility, but the technology has not yet been successfully applied elsewhere in the world, and the systems would not be able to cope with the large volumes of migratory fish in the Mekong. Problems are also encountered for downstream migration, mainly because of the	NOT FULLY COMPLIANT	Fish pass facilities are mentioned in the EIA, TBESIA & CIA and FSR - 5 Project Layout and Main Structures, to mitigate dam impact to migratory species. In the EIA, page 34 is mentioned the fish passages for Pak Lay HPP: ... A) Upstream fish passage - The upstream fish passage facilities of the hydropower project are a fishway, fish lock, fish lift, freight fishing boat and others. And in the FSR - 5 Project Layout and Main Structures, page 143, is emphazed: … B) Channel for downstream migration of migratory fishes – the construction of fish pass structure for the downstream migration of fish is not considered for the Project. … Pak Lay HPP must define the type and how many fishways will be installed. Considering that the Mekong River has a large width, we strongly recommend placing fishways on both banks (right and left) of the river. With regard to downstream fish movements, there is no studies showing that most of the target species move to downstream efficiently through the spillways and turbines. Thus, the Pak Lay HPP project MUST consider building fishway that enables the drives towards downstream. Therefore, the few studies that evaluated the elevators for tropical fish have shown that this type of fishway has been inadequate (Oldani et al., 2007). And so far, no studies have been proving the efficiency of the locks as fishway.	The riverbed downstream of Pak Lay HPP is about 450m wide. The main river channel is located on the left side, about 220m wide. In low-flow period, the riverbed on right side of the river is exposed (above El.220m). Therefore, placing fishways on both sides (right and left) of the river would function little in low-flow period. In the updated scheme, a 250-m long fish screen is arranged at the downstream entrance of the fishway, which can basically block the fish species in the whole river channel, and guide the fish species to the fishway entrance. A 250m-long fish screen is also arranged at the upstream entrance of the fishway, which can block the fish species from entering the turbines, and guide them to the fishway (see attached drawings 1 and 2). In flood period, when the flow is less than 17,500m3/s (a three-year return period flood), the power station can operate normally, the fishway can operate normally, and the fish species can migrate upstream and downstream through the fishway. When the flow is more than 17,500m3/s (a three-	It is plausible to keep these informations in reports. Also, the fishway project must regard to build several resting pools along fishway.	The riverbed downstream of Pak Lay HPP is about 450m wide. The main river channel is located on the left side, about 220m wide. In low-flow period, the riverbed on right side of the river is exposed (above El.220m). Therefore, placing fishways on both sides (right and left) of the river would function little in low-flow period. In the updated scheme, a Fish Guidance Systems are arranged at the downstream entrance of the fishway, which can basically block the fish species in the whole river channel, and guide the fish species to the fishway entrance. A Fish Guidance Systems is also arranged at the upstream entrance of the fishway, which can block the fish species from entering the turbines, and guide them to the fishway. In flood period, when the flow is less than 16,700m3/s the power station can operate normally, the fishway can operate normally, and the fish species can migrate upstream and downstream through the fishway. When the flow is more than 16,700m3/s, the power station will stop power generation, the spillway gates will be	COMPLIANT		

	mortality of fish passing through turbines and over spillways. Consequently, a number of different options for fish passage upstream and downstream need to be considered for the range of species, volume of migrations and flow conditions encountered at a dam site.			year return period flood), the power station will stop power generation, the spillway gates will be opened for flood discharge. In this case, the river reach will restore its natural state, with an average flow rate of 5 to 6 m/s, and the flow is smooth, free from water rolling (similar to the status in Phase II construction stage, see Attached Drawing 4). The natural river state will be basically restored, not damaging the fish species, and the duration will be very short.		opened for flood discharge. In this case, the river reach will restore its natural state, with an average flow rate of 5 to 6 m/s, and the flow is smooth, free from water rolling (similar to the status in Phase II construction stage). The natural river state will be basically restored, not damaging the fish species, and the duration will be very short.（see the reports 5.10.2）			

Guidance on fish passage design and operation									
60	**Fish passage facilities for both upstream and downstream passage** - The following section provides preliminary guidance on fish passage design and operation for developers planning dams for the mainstream of the Mekong. The guidance have been developed by the Mekong River Commission Secretariat, based on extensive consultation and review of dams around the world, their impact on fisheries, and measures developed to facilitate fish movement past dams.	NOT FULLY COMPLIANT	The FSR - 5 Project Layout and Main Structures provides a general layout of the fish way. In the page 142 is mentioned that upstream fish pass facilities for Pak Lay HPP consist of fish way, fish lock, fish lift, and boat for collection and transportation of fish. However, the downstream passage is not considered for the Pak Lay HPP project. Considering that the Mekong River has a large width, we strongly recommend placing fishways on both banks (right and left) of the river. With regard to downstream fish movements, there is no studies showing that most of the target species move to downstream efficiently through the spillways and turbines. Thus, the Pak Lay HPP project MUST consider building fishway that enables the drives towards downstream.The Denil fishway must not be used and this type of passage will not meet the requirements and sizes of tropical fish species. A subsystem of this type of fishway, built in the Canal da Piracema at Itaipu Binacional, has been a bottleneck for the upward movements of migratory fish (Makrakis et al., 2011).	In the updated scheme, the fishway with vertical slots on both sides is employed, and is arranged on the left bank slope of the river. The fishway is 6m wide, 2.5m deep (water), and 970m long, with an average gradient of 2.2%, satisfying all the fish species moving upstream and downstream around the year. The downstream entrance of the fishway is arranged about 250m downstream of the tailrace of the power house, where a flood plain exist with an elevation of around 217m, and the flow is gentle. The invert of the downstream entrance is at El.217.5m, satisfying the normal operation at the lowest water level El.219.00m. The upstream entrance of the fishway is arranged about 100m upstream of the power staion, with an invert elevation of 237.50m, satisfying the normal operation at the upstream water level 239.0m~240.0m.A 250m-long electric screen for blocking fish is respectively arranged at the upstream and downstream entrances of the fishway. The upstream fish screen can prevent the downward moving fish from entering the	Keep these information on reports. Also, the reports must regard that maximum velocities of water flow in fishway will not be more than 2.5m/s. The report must regard the minimum discharge that will be occur in the fishway. For example, in Canal da Piracema the minimum discharge for a good attraction is 15.0 m³/s. Electrical current passes through the water from an anode to a cathode creating an electric field in the vicinity of the barrier, and fish barriers that use electricity derive much of their effectiveness through behavioral avoidance of electrical fields (Katopodis et al. 1994). Electric barriers have proven effective at preventing fish movement, particularly through constricted waterways. When used to stem the spread of fish, two major limitations	In the updated scheme, the fishway with vertical slots on both sides is employed, and is arranged on the left bank slope of the river. The fishway is 6m wide, 2.5m deep (water), and 970m long, with an average gradient of 2.2%, satisfying all the fish species moving upstream and downstream around the year. The downstream entrance of the fishway is arranged about 250m downstream of the tailrace of the power house, where a flood plain exist with an elevation of around 217m, and the flow is gentle. The invert of the downstream entrance is at El.217.5m, satisfying the normal operation at the lowest water level El.219.00m. (see the report 5.10.3.1).	COMPLIANT		

			turbines, guide the fish to move downstream through the fishway, and prevent the upward moving fish species from entering into the power intake area. The downstream fish screen can make the upward moving migratory fish species to concentrate at the downstream entrance and move upstream through the fishway (see Attached Drawings 1 and 2)	must be considered. First, deactivation due to power outage, maintenance (or lack thereof), and human error precludes any single electric barrier from operating 100% of the time over prolonged deployments (Clarkson 2004). In situations where it is critical that no movements across a barrier occur, redundancies and integrated deterrence systems are recommended. Second, small fish may be unaffected by electric fields, resulting in size-elective effectiveness that might not meet all management goals (Reynolds 1996). Because these information, we do not recommend the use of electrical screen to guide the fishes. It would be better to use curtain burbbles or just bypass screen than electrical screen.				

61	**Effective fish passage** - Fish passage facilities for both upstream and downstream passage must be incorporated into all dams on the mainstream. 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.	NOT FULLY COMPLIANT	Some information about operating water level of fish pass structure, general layout of it, hydraulic and structural design of the fish way are in the pages 140-145 in the FSR - 5 Project Layout and Main Structures. And in the page 145 is mentioned the discharge of two vertical slots of 3.23 m3/s, and the average flow velocity in the vertical slot of 1.08 m/s, as satisfactory to the migration requirements of target fishes. However, we do not agree with these discharge values to meet the target species of the Mekong River. We must consider that fishways for the basin of the Mekong River should accommodate those large species such as the large catfish. These species have preference to swim under the bottom, avoid places and situations with higher light, usually inhabiting deep locations, such as the deep pools (Campbell, 2009). Thus, fishways should be wide and deep, which will require higher flow rates. Thus it is expected that the fishway reproduce similar conditions of the natural environment, especially the huge importance for these species of Siluriformes, which are endemic and migratory long distance. Also, there are no considerations and concerns on effective fishways in the EIA, TBESIA and FSR - 5 Project Layout and Main Structures. They don´t provide information about existing types and characteristics of fish passage facilities, an overview in another countries and analysis of them, and options of fish passages for Pak Lay HPP Project. Therefore, the downstream passage is not considered for the Pak Lay HPP project. These issues are extremely poor in the reports. There are studies conducted for tropical fish species such as in the largest fish pass system in the world – Canal da Piracema at Itaipu Dam (Makrakis et	The fishway with vertical slots on both sides is employed. The fishway has a width of 6m, and water depth of 2.5m, a vertical slot width of 0.5m, and a vertical slot flow of 1.4m/s.A 250m-long electric screen for blocking fish is respectively arranged at the upstream and downstream entrances of the fishway, guiding the upward moving and downward moving fish species to enter the fishway, and improving the fish pass effect. In reference to Chinese Standard Design Guidelines for Fishways of Water Conservency and Hydropower Projects(SL609-2013) and the experience and practice of fishways in China, the fishway can satisfy the pass of the targeted fish species (see Appendix 1 Introductio of Fishway of Changzhou Hydropower Project in China).	The report must regard the minimum discharge that will be occur in the fishway. For example, in Canal da Piracema the minimum discharge for a good attraction is 15.0 m³/s. Electrical current passes through the water from an anode to a cathode creating an electric field in the vicinity of the barrier, and fish barriers that use electricity derive much of their effectiveness through behavioral avoidance of electrical fields (Katopodis et al. 1994). **Electric barriers have proven effective at preventing fish movement**, particularly through constricted waterways. When used to stem the spread of fish, two major limitations must be considered. First, deactivation due to power outage, maintenance (or lack thereof), and human error precludes any single electric barrier from operating 100% of	The fishway with vertical slots on both sides is employed. The fishway has a width of 6m, and water depth of 2.5m, a vertical slot width of 0.5m, and a vertical slot flow of 1.4m/s. In reference to Chinese Standard Design Guidelines for Fishways of Water Conservency and Hydropower Projects(SL609-2013) and the experience and practice of fishways in China, the fishway can satisfy the pass of the targeted fish species.	COMPLIANT		

			al., 2011), and Porto Primavera fish ladder (Wagner et al., 2012), both in the Paraná River.		the time over prolonged deployments (Clarkson 2004). In situations where it is critical that no movements across a barrier occur, redundancies and integrated deterrence systems are recommended. Second, small fish may be unaffected by electric fields, resulting in size-elective effectiveness that might not meet all management goals (Reynolds 1996). Because these informations we do not recommend use of electrical screen to guide the fishes. It would be better to use curtain burbbles or just bypass screen than electrical screen.				

62	**Mitigation options** - 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.	COMPLIANT					COMPLIANT		

63	**Multiple systems at each site** - 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.	NOT FULLY COMPLIANT	The FSR - 5 Project Layout and Main Structures provides a general layout of the fish way. In the page 142 is mentioned that upstream fish pass facilities for Pak Lay HPP consist of fish way, fish lock, fish lift, and boat for collection and transportation of fish. Pak Lay HPP must define the type and how many fishways will be installed. Considering that the Mekong River has a large width, we strongly recommend placing fishways on both banks (right and left) of the river. With regard to downstream fish movements, there is no studies showing that most of the target species move to downstream efficiently through the spillways and turbines. Thus, the Pak Lay HPP project MUST consider building fishway that enables the drives towards downstream. The Denil fishway must not be used and this type of passage will not meet the requirements and sizes of tropical fish species. A subsystem of this type of fishway, built in the Canal da Piracema at Itaipu Binacional, has been a bottleneck for the upward movements of migratory fish (Makrakis et al., 2011). Therefore, the few studies that evaluated the elevators for tropical fish have shown that this type of fishway has been inadequate (Oldani et al., 2007). And so far, no studies have been proving the efficiency of the locks as fishway. Also, they don´t consider temporary facilities during construction period.	Through analysis and demonstration, the fishway with vertical slots on both sides is employed for the Pak Lay HPP.The fishway will be in service when the inflow is less than 17500m3/s. When the inflow is more than 17500m3/s, the power station will stop power generation, all the flood release gates will be opened, the natural river state will be restored, and the fish species may move through the water release structures. The HPP will be constructed in two stages: in Stage I, the river water will flow throug the left side river channel, not affecting the fish movement; in Stage II, the river water will pass through the water-release structures, and low inflow will not result in backwater basically, thus not affecting the fish movement. Therefore, temporary facilities for fish movement during construction period is not considedered for this project (see Attached Drawings 3 and 4).	COMPLIANT	Through analysis and demonstration, the fishway with vertical slots on both sides is employed for the Pak Lay HPP.The fishway will be in service when the inflow is less than 16700m3/s. When the inflow is more than 16700m3/s, the power station will stop power generation, all the flood release gates will be opened, the natural river state will be restored, and the fish species may move through the water release structures. The HPP will be constructed in two stages: in Stage I, the river water will flow throug the left side river channel, not affecting the fish movement; in Stage II, the river water will pass through the water-release structures, and low inflow will not result in backwater basically, thus not affecting the fish movement. Therefore, temporary facilities for fish movement during construction period is not considedered for this project (see the report 5.10.4).	COMPLIANT		

Planning and design phase									
64	**Planning and design phase** - 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 minimizing lateral and rolling flows. Numeric and physical models of the dam and adjacent river are necessary to accurately predict flow patterns, and	NOT FULLY COMPLIANT	For Mekong Pak Lay Hydropower Project, the FSR - 5 Project Layout and Main Structures provides a general layout of the fish way. In the page 143 is mentioned that the fish pass structure consists of fish way, fish collecting system and water supplementing pipes. However, this report has only two layouts (Layout 53 and 54), with few details, difficult to see and understanding (written Chinese language). It recommended the development of a new design, considering all the information recommended in this report.Careful attention should be given in the DESIGN and implementation of the PROJECT to fishway. For fish passage design, the definition of parameters such as maximum water velocity along the facility, minimum depth, minimum width at the bottom, the operation flows and the roughness coefficient are key to the development of the project. The location and geometry for both the entry and the fishway output are also critical for its functionality.Therefore, the development of reduced model of the fishway and swimming performance tests of the target fish species simultaneously could be of great value; and the design of a Ecohydraulics and Hydrobiology Laboratory may be the key to success for the fish passage projects.Also, we strongly recommend to consider the design of the fishways for wide width and depths that allows dimensions suitable for the large species, and to avoid level differences in the entrance of fish pass: it must be able to attract fish on the bottom - Large catfish swims on the bottom.The information so far available on fish facility designed to Pak Lay HPP are insufficient for a conclusive assessment. We strongly recommend to provide a DESIGN REPORT of	The fishway with vertical slots on both sides is employed for the Pak Lay HPP. The fishway has a width of 6m, and water depth of 2.5m, a vertical slot width of 0.5m, and a vertical slot flow of 1.4m/s.A 250m-long electric screen for blocking fish is respectively arranged at the upstream and downstream entrances of the fishway, guiding the upward moving and downward moving fish species to enter the fishway, and improving the fish pass effect. In reference to Chinese Standard Design Guidelines for Fishways of Water Conservency and Hydropower Projects(SL609-2013) and the experience and practice of fishways in China, the fishway can satisfy the pass of the targeted fish species.	I recommend to consider the minimum discharge in the fishway. For example, Canal da Piracema keeps the minimum discharge of 15.0m³/s.	see the report 5.10.2.	COMPLIANT		

	hence dam and fish passage design.		Fish Passage Facilities to Pak Lay HPP that includes a project of site conditions for the construction of the fishway, and options of fishways to promote both downstream and upstream movements (see recommendations in the 4.2.1.1 Fish passage facilities for both upstream and downstream passage).						
65	**Best international practice in fish passage design** - Developers are encouraged to utilize 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.	NOT FULLY COMPLIANT					COMPLIANT	According to the technical meeting (in the afternoon) the following items shall be supplemented: 1) The studies will be made by LARREC; 2) Biological/ecological requirements of target species; 3) Downstream movements; 4) Spawning grounds and nurseries - A sampling protocol will be proposed; 5) Attention for THE DEEP POOLS.	

Biological/Ecological

66	**Target species** - 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.	NOT FULLY COMPLIANT	For Mekong Pak Lay Hydropower Project it is highly recommended that they be carried out further studies aimed at better understanding of the target species. The fish fauna of the Mekong River basin is highly diverse and possibly many species are still unknown or were not described. Even for species already cataloged many aspects of its biology are still poorly known, such as their life cycle, physiology, migratory behavior, size at first maturity; spawning type (whole or split), swimming performance, etc. Habitat fragmentation growing increasingly limits the populations with large home range. However, the implementation of a fish passage by itself does not guarantee the conservation of the target species. Based on the field observations and on the information available on the hydrological conditions, geomorphology and structural characteristics of Pak Lay HPP, the overall design of the fish passage still requires many additional details for better evaluation.	The fish passage should targeted on local species and economics species.			COMPLIANT		
67	**Maximum standard length** - 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	NOT FULLY COMPLIANT	In order to confirm the occurrence of migratory species and verify the potential of the area chosen to implement the fishway, additional studies must be done to characterize the fish fauna around the area of the fishway inlets in the Mekong River sampling with various fishing gears throughout the year and interviews with fishermen. This also will serve as a basis for future monitoring system. The water inflow area design shall take into account the range of possible level changes of the reservoir so as not to increase the water velocity during flood periods and keep a minimum depth on the dry season. One of the most relevant criteria for decision on building fish passes is the presence of potentially adequate spawning grounds and nurseries that ensure sustainable populations above	The baseline data has been collected, but more study with capacity of LARREC willbe discussed, we recommend that the design team should be discuss with LARREC as they are specific this area. The recommnedation from experts should be consider to put in the report.	We emphasize that these information should be included in the final report. Please, let us know what means the abreviation LARREC.		COMPLIANT		

	likely necessitate multiple systems at each site.		and below the dam. The chances of downward movements must be evaluated considering the projects of each plant (type of turbine, the spillway geometry, the water inflow position, hydrological aspects and auxiliary structures). Most of biological/ecological requirements of fish mentioned by MRC (2009) were not addressed. So, we recommend inserting these aspects in the report: target species (preferences, tolerances and biological attributes), peak of biomass, fish predation, and fish healthy.						
68	**Preferences, tolerances, biological attributes- target species** - 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	NOT COMPLIANT				Since the ESIA is not yet get appproval from MONRE the report will be updated the provide information will be added to the Final Report.	COMPLIANT	According to the technical meeting (in the afternoon) the following items shall be supplemented: 1) The studies will be made by LARREC; 2) Biological/ecological requirements of target species; 3) Downstream movements; 4) Spawning grounds and nurseries - A sampling protocol will be proposed; 5) Attention for THE DEEP POOLS.	

	cover, substrate and light preferences.								
69	**Peak of biomass** - 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.	NOT COMPLIANT				Living Aquatic Resources Research Center (LARREC) Tag countries: Lao People's Democratic Republic Address: Ministry of Agriculture and Forestry, P.O. Box 9108 City: Vientiane	COMPLIANT	According to the technical meeting (in the afternoon) the following items shall be supplemented: 1) The studies will be made by LARREC; 2) Biological/ecological requirements of target species; 3) Downstream movements; 4) Spawning grounds and nurseries - A sampling protocol will be proposed; 5) Attention for THE DEEP POOLS.	

70	**Fish predation** - Predation within the fish passages should be minimized. 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 minimized.	NOT COMPLIANT					COMPLIANT	According to the technical meeting (in the afternoon) the following items shall be supplemented: 1) The studies will be made by LARREC; 2) Biological/ecological requirements of target species; 3) Downstream movements; 4) Spawning grounds and nurseries - A sampling protocol will be proposed; 5) Attention for THE DEEP POOLS.	
71	**Fish healthy** - 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	NOT COMPLIANT		To be supplemented later in the preparation of the operation and management plan.	We emphasize that this information should be included in the final report.	Since the ESIA is not yet get approval from MONRE the report will be updated the provide information will be added to the Final Report.	COMPLIANT	According to the technical meeting (in the afternoon) the following items shall be supplemented: 1) The studies will be made by LARREC; 2) Biological/ecological requirements of target species; 3) Downstream movements; 4) Spawning grounds and nurseries - A sampling protocol will be proposed; 5) Attention for THE DEEP POOLS.	

	percent. Similarly, human fishing in the vicinity of the fishways should be managed to ensure mortality caused by fishing is not excessive.								
Hydrology									
72	**Hydrological requirements of the fish** - 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.	NOT FULLY COMPLIANT	We recommend including in the reports more information on biological and hydrological requirements for fish species concerned, adequate flow to attract fish at the entrance of the fishway. Also, Pak Lay HPP project must consider the location of the entrance of the fishway, avoiding the nearness from the discharge of the spillway and the water intake of the fishway must be distant from the spillways. Spillway must be designed to minimize the fish injury and entrapment.	In the updated scheme, the fish pass facilities for different flows are considered.		See the reply in Item No.59.	COMPLIANT		
73	**Entrances to fishways effectively attract fish** - Particular attention must be given to ensuring that the entrances to fishways effectively attract fish. This will	NOT FULLY COMPLIANT		Fish screen is employed for collecting the fish species.	We do not recommend the use of electrical screen. See item 61.	Fish Guidance Systems is employed for collecting the fish species.	COMPLIANT		

	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 minimize fish injury or entrapment** - Dam and fish passage design should minimize fish injury or entrapment. Spillway design, aprons, stilling basins and dissipater design should seek to minimize fish injury, mortality and entrapment.	NOT FULLY COMPLIANT		Already considered in the updated scheme.		Fish Guidance Systems is employed for collecting the fish species.	COMPLIANT		

Hydraulic environment										
75	**Fishway entrance** - 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.	NOT FULLY COMPLIANT	Considerations on hydraulic conditions on fish passage facilities is still poor. We recommend including more details of the design of the fishway as type, location, fishway entrance, fish attracted to spillway, barrier screens guide downstream moving, and planning studying hydraulic conditions of the fishways in a reduced model. Therefore, the Pak Lay HPP must consider using friendly turbines.	See the reply in Item No.59.		See the reply in Item No.59.	COMPLIANT		

76	**Spillways** - Spillways should be designed so that extra flows initiate and terminate adjacent to the fishway entrance(s) to maximise attraction to the fishways.	NOT FULLY COMPLIANT		Fish screen is mainly considered for collecting the fish species and guiding them to the fishway.	We do not recommend the use of electrical screen. See item 61.	Fish Guidance Systems is mainly considered for collecting the fish species and guiding them to the fishway.	COMPLIANT		
77	**Fish attracted to spillway** - Fish attracted to the spillway need to be able to access the fishway entrance without needing to double back to find the entrance.	NOT COMPLIANT		A 250m-long fish screen for blocking fish is arranged at the upstream entrance of the fishway, preventing the fish species from entering the high-velocity flow area.	We do not recommend the use of electrical screen. See item 61.		COMPLIANT		
78	**Exit conditions for fish to exit of the fishway** - 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.	NOT COMPLIANT		A 250m-long fish screen for blocking fish is arranged at the upstream entrance of the fishway.	We do not recommend the use of electrical screen. See item 61.		COMPLIANT		

79	**Barrier screens guide downstream moving** - 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. Selfcleaning travelling or rotating screens should be used where there are high debris loads.	NOT COMPLIANT		A 250m-long fish screen for blocking fish is arranged at the upstream entrance of the fishway	We do not recommend the use of electrical screen. See item 61.		COMPLIANT		
80	**Fish friendly turbines** - The use of fish friendly turbines should be investigated and adopted where feasible.	NOT COMPLIANT		A 250m-long fish screen for blocking fish is arranged at the upstream entrance of the fishway, preventing the fish species from entering the high-velocity flow area.	We do not recommend the use of electrical screen. See item 61.		COMPLIANT		

Operation

81	**Short period of captivity and interruption** - The period of captivity and interruption to the normal movements of the fish should be as short as possible.	NOT COMPLIANT	There are limited considerations on operation management of fish pass in the FSR - 5 Project Layout and Main Structures. There is few information in the reports concerning the other aspects (i.e. short period of captivity and interruption, water quality, appropriate volumes through the fishway, and entrance slot velocities) mentioned by MRC (2009). We strongly recommend including all these issues detailed in the FSR - 5 Project Layout and Main Structures.	The fishway monitoring room is arranged downstream of the intersection of the fishway and dam, performing real-time monitoring of the fish passage effect and status, and taking corresponding measures to adjust the fish passage efficiency.	We recommend to clarify how this monitoring will work in the final report.	Since the ESIA is not yet get appproval from MONRE the report will be updated the provide information will be added to the Final Report.	COMPLIANT		
82	**Water quality** - Water quality should be maintained within any holding enclosures to ensure fish health. Oxygen levels should be maintained within the fishways at >5 ppm.	NOT COMPLIANT					COMPLIANT		
83	**Appropriate volumes through the fishway** - 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.	NOT COMPLIANT					NOT FULLY COMPLIANT	Considering the possibility that the upstream water level reaches less than 239, the developer must maintain the minimum discharge (~5.0m³/s) by pumping. Also, the use of the discharge for attraction through a pipe it will be embedded in the end of the fish ladder;	The ecological basic flow of Paklay HPP will preferentially adopt the fishpass flow so as to extend the cooperation time of the fish pass (see Section 5.10.2 b)

84	**Entrance slot velocities should be adjustable** - Entrance slot velocities should be adjustable, such that feedback from monitoring and observation of fish behaviour can lead to optimisation of the fishway operation.	NOT COMPLIANT					NOT FULLY COMPLIANT		A water outlet is added in the water supplementary system which leads to the downstream section of the fishpass. During the operation, proper means of water supplementation can be adopted based on the fish pass effiency (see Section 5.10.3.2).
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	NOT COMPLIANT	The evaluation of fish passages is very important to: • Confirm hydraulic and biological performance of a structure • Define operational range and characteristics • Identify and correct problems • Gain information for improving structures • Assess success in meeting passage goals and population/ecosystem restoration And the goals of fish passage performance are: • Provide upstream and downstream	The monitoring facilities will be constructed along with project construction, and the specific operation and management measures will be refined in the subsequent design.	We recommend to clarify how this monitoring will work in the final report.	The detail schedule and budget will be conducted after got approval from GoL. The plan will be endorse by GoL and Committee	NOT FULLY COMPLIANT	The developer will provide a protocol for evaluation and monitoring of the fishway and fishing (who, how, when and where they will be carried out).	

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<tr><td></td><td>safely from the fishways as well as monitor fish movements and water quality.</td><td></td><td rowspan="3">passage past barriers
§ Maximize passage efficiency
§ Minimize delay
§ Minimize mortality, injury, and predation
• Exclude exotic/invasive species
• Restore/sustain natural populations and genetic diversity
There are no considerations on monitoring and evaluation of fish passages in the EIA, TBESIA and FSR - 5 Project Layout and Main Structures. We strongly recommend including all issues recommended by MRC (2009) detailed in the FSR - 5 Project Layout and Main Structures, and a proposal for evaluation and monitoring of the fishways regarding hydrological and biological aspects (attractiveness and efficiency of fishway; fish swimming behavior). Furthermore, it is essential to consider studies on spawning and early development areas of the target species to better understand the passage efficiency, i.e Da Silva et al. (2015).
It is very important to clarify how the fish passage assessment will be done. When, Who and How will be held and the Universities in the region could help these studies. There are advanced technologies in order to assess and monitor the fishways with high precision (radio and pit telemetry, acoustic tags, videos, etc). In South America region, studies were conducted for tropical fish species, i.e in the largest fish pass system in the world – Canal da Piracema at Itaipu Dam (Makrakis et al., 2007a, 2011), and Porto Primavera fish ladder (Makrakis et al., 2007b; Wagner et al., 2012), both in the Paraná River. Also, we recommend to consider a</td><td rowspan="3"></td><td rowspan="3"></td><td rowspan="3"></td><td></td><td rowspan="3"></td><td></td></tr>
<tr><td>86</td><td>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.</td><td>NOT COMPLIANT</td><td>NOT FULLY COMPLIANT</td><td></td></tr>
<tr><td>87</td><td>The monitoring programme should be funded by the developer for the duration of the concession period.</td><td>NOT COMPLIANT</td><td>NOT FULLY COMPLIANT</td><td></td></tr>
</table>

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.	NOT COMPLIANT	monitoring program during the concession period, and consider the use of international experts to assist in the design and implementation of the monitoring program.				NOT FULLY COMPLIANT		
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.	NOT COMPLIANT					NOT FULLY COMPLIANT		

5.7 Annex - Supplementary Explanation on Fishway Design Scheme

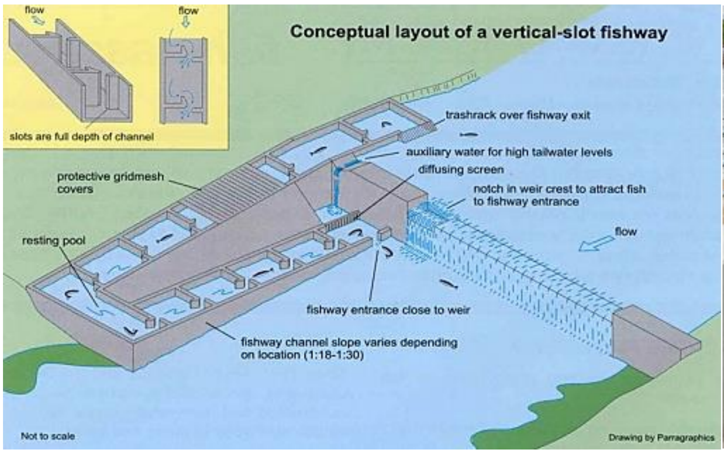
This document was originally prepared by the developer and discussed with the consultant from the workshop of the Interim Report to the workshop of the Final Report. The Comments exchanged are after the text under discussion (in bold), in chronological order.

In accordance with the study results of the integral model test of the Pak Lay HPP and the expert's suggestion, the fishway layout scheme has been adjusted **as below: (1) a water supplement system is added to improve the fish luring effect; (2) a large resting pool is arranged in the middle of the fishway.**

Consultant Augusto 02, 2016

We recommend to increase the water flow into the fishway instead of use water supplement system. If the water flow will be of 3.8m³/s, the depth into the fish ladder will be only about 0.50m. The trigger for the tropical fish movement will be the flood pulse, and not necessarily an attraction flow as water supplement system proposed. Also, the giant fish as *Pangasius* needs more depth. Thus, it will be better if increase the depth and the water flow into the fishway.

So, a suggestion will be to build the fish ladder with one vertical lateral slot (see Figure below) instead of two lateral slots. For instance, one vertical slot with 0.70m width, 2.5m depth and 2.2% slope will result around water flow of 9.80m³/s. And, this discharge must be used in the migratory season.



Developer: August 08, 2016

We have estimated the flow in the fishway in several ways (see the attachment Notes on Calculation of Flow in the Fishway), and the flow in the fishway will range from 3m3/s to 6m3/s. As the upstream entrance of the fishway will have sufficient inflow, no gate will be used to control the flow, and the vertical-slot fishway will have good performance in energy dissipation, the water depth in the fishway will reach 2.5m.

If the flow in the fishway is 9.80m³/s, the flow rate in the vertical slot will reach 5.6m/s. In this case, most of the fish species can not overcome such flow rate to pass the fishway.

Consultant: August 29, 2016

Yes, I agree, the average depth will be 2.43m (2.5 – 0.5 water drop (ΔH);

ΔH=slope·lenght=0.028*5=0.14 m)

I liked more of the idea of two slots (I think that a hydraulic diversity it is better).

The discharge will be:

Q=B·H·Cd·(2gΔH)^0.5=(2·0.7)·2.5·0.85·(2g0.14)^0.5=·4.93 m3/s

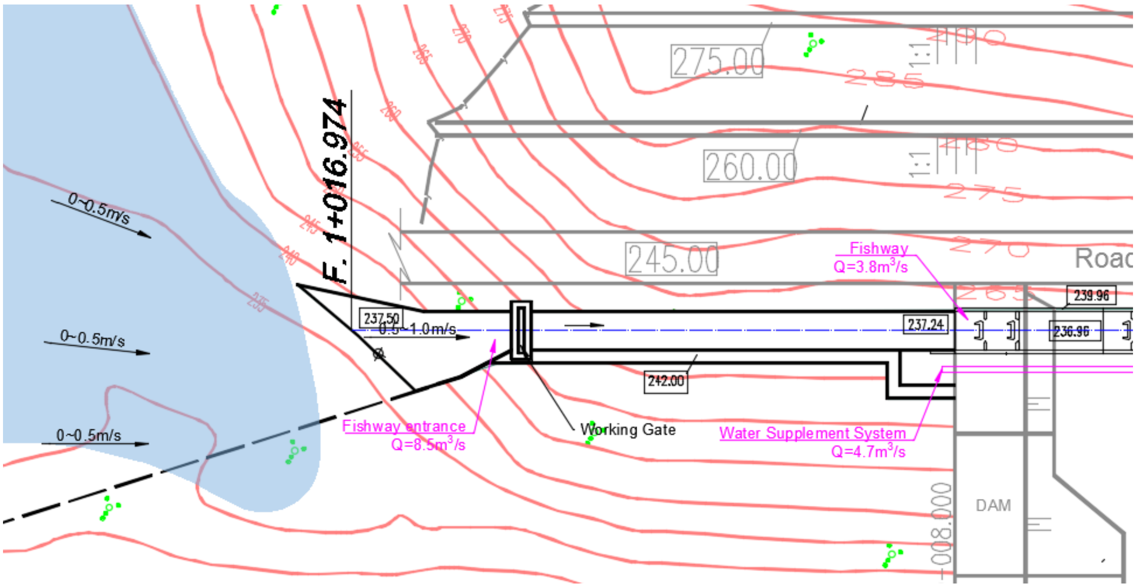


Fig.1. Upstream entrance and water supplement system of the fishway

The downstream outlet of the water supplement system is arranged downstream of the downstream entrance of fishway (see Fig.2), with an elevation of 226.00m. The flow will drop from the outlet to the river channel, forming an artificial waterfall (see Fig.3). **The flow and sound luring fish is formed downstream of the fishway entrance so as to achieve the fish luring effect.**

Consultant: August 01, 2016

The downstream entrance will stop in the quota 217.50m. We recommend to extend the fishway to quota 215.00m, because the water level will change during the day/night for energy production, and decrease in the dry season.

Developer: August 08, 2016

The minimum operating level of the Sanakham HPP reservoir downstream is 219.00m. Therefore, it is proper to take the invert elevation at the downstream entrance of the fishway as 217.50m.

Consultant: August 29, 2016

Well in downstream, but what happened upstream? What is the bigger and smaller quota? How to adapt to water the entrance to have the design flow? It flood gates?

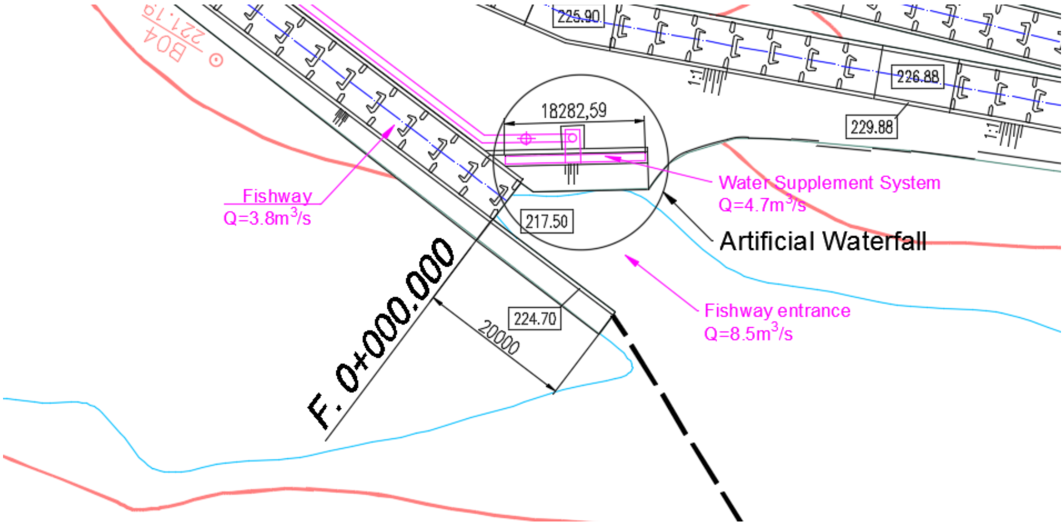


Fig.2. Downstream entrance and water supplement system of the fishway

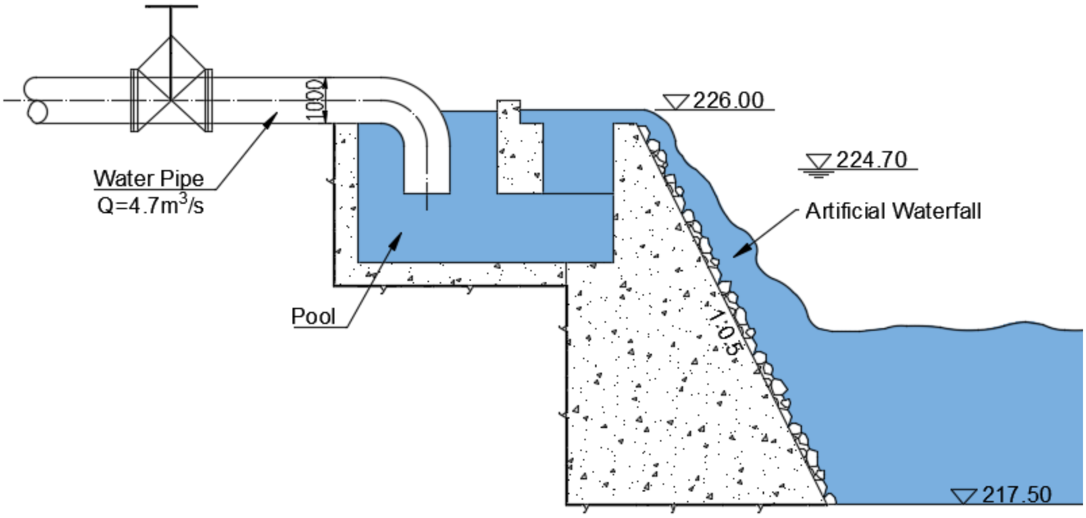


Fig.3. Downstream outlet profile of the water supplement system

2) Large resting pool

The large resting pool is arranged in the middle of the fishway, ranging from stake no. F. 0+613.834 to F. 0+670.567. The resting pool is about 56m long, 23m wide and 3 to 4.5m deep. The bank slope of the resting pool is of ecological state simulating the nature. **The fish may rest and prey in the resting pool, supplementing energy for the migration.**

Consultant: 29 August, 2016

If the bottom of the river has stones the fish ladder can have roughness too.

It is important in two vertical slot fish ladder a join between the central block and side deflectors:

In addition to the large resting pool, a 10-m long horizontal section is provided on the fishway for every 50m, and the flow rate in the horizontal section is about 0.25m/s. **The fish may reduce the swimming speed in the horizontal section to have a temporary rest.**

Consultant: 08 August, 2016

This big resting pool will be very usefully, but for each small resting pools, we suggest that the width will be of 10.00m instead of 6.00m.

Developer: 08 August, 2016

As the fishway will have a flow ranging from $3m^3/s$ to $6m^3/s$, the average flow rate in the resting pool will be only 0.2m/s to 0.4 m/s, meeting the resting requirements of the fish.

Consultant: 29 August, 2016

Yes, better. I agree, the speed of the pool resting is not an important parameter. It is more important to the volume of water, natural conditions, ... 10 m better.

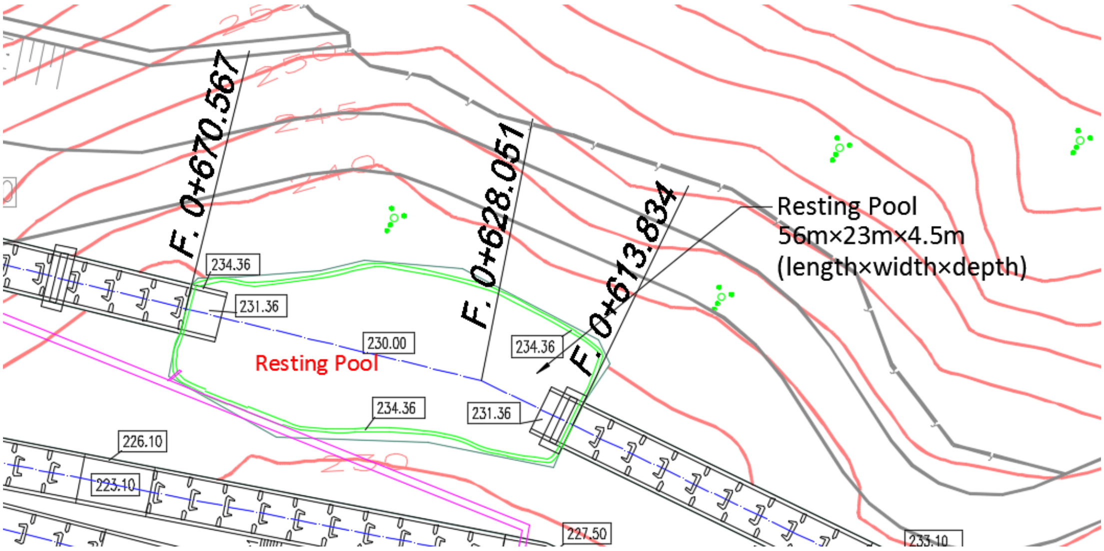


Fig.4. Resting pool on the fishway

Attached drawings:

Drawing 1：Structural Arrangement of Pak Lay HPP Fishway (1)

Drawing 2：Structural Arrangement of Pak Lay HPP Fishway (2)

Consultant: 01 August, 2016

Over again, we don´t recommend the use of electric barriers.

Developer: 08 August, 2016

The electric barriers will be cancelled in this stage.

6 WATER QUALITY AND AQUATIC ECOLOGY

For the component water quality and aquatic ecology there are 34 items in the 2009 MRC Preliminary Design Guidance for Proposed Mainstream Dams in the Lower Mekong Basin (PDG) that were analyzed according the status concerning compliance. For compliance analysis were considered the following documents in addition to those produced by the developer mentioned in section 2.3:

- ✓ **Strategic Environmental Assessment (SEA) of Hydropower on the Mekong Mainstream – Final Report. Prepared for the Mekong River Commission by ICEM – International Centre for Environmental Management (October 2010).**

- ✓ **Procedures for Notification, Prior Consultation and Agreement (PNPCA) Proposed Xayaburi Dam Project – Mekong River. PRIOR CONSULTATION PROJECT REVIEW REPORT. Mekong River Commission Secretariat (March 2011).**

Other guidance material has been considered for aspects not fully covered in the PDG and for which references to international good practice will be made.

The status concerning compliance of each item and comments is presented in the Table of Compliance in the final of this report (topic 6.4).

However, although Developer has not updated the Environmental and Social Impact Assessment (ESIA) with regard to the aspects related to water quality and aquatic ecosystem on the basis of the information shared during the interim stage of the review, we are presenting this final report taking into account the answers and comments presented in the compliance table and the discussions held during the final workshop in Sep.2016.

6.1 Overview of ecological status on Mekong basin

The Mekong is a large river whose course crosses several geologic and climatic zones. The MRC continuous water quality monitoring indicated water of the Mekong River has been in a normal range except some areas near urban center or with intensive agriculture or aquaculture. However, the trends indicated that the areas of high human habitation or intensive agriculture, that causing the decline of water quality of the Mekong (MRC, 2010).

In addition, chemicals used in livestock farming and aquaculture, such as antibiotics for catfish (Pangasius) and shrimp farming may pose a threat to aquatic organisms. However, little is known about the effects of these chemicals in the environment but caution is needed as they can result in antibiotic resistant bacteria and may accumulate in species used for human consumption (MRC, 2010).

Whilst the river is relatively clean and in good ecosystem health at present, there are increasing point sources of pollution, e.g. urban areas, and dispersed sources, e.g. agricultural run-off, which are currently mitigated by the large dilution effect of the river flow.[1] The result of this is that poor water quality is often rather localized, and quickly diluted, with rapid improvement in water quality e.g. after high polluting loads from urban areas (SEA Report, 2010).

- Acidification of surface waters is the most significant water quality issue, with a noticeable trend throughout Zone 3 (Vientiane – Pakse)
- Organic loads are increasingly becoming a problem at Vientiane, Nakhom Phanom and Khong Chiam, reflective of the large population centers at these sites.
- Nitrogen and phosphorous loads are not problematic at any reach between Chiang Saen and Pakse.
- Mineralisation is affecting water quality downstream of Chiang Saen and Vientiane.

1 Good refers to the MRC IBFM score card rating and corresponds to “largely natural” conditions.

According to the SEA report, there are signs of decreasing water quality – a trend which is expected to increase in the future with growth of population. These trends are strongest for downstream areas of the LMB and also near growing population centers.

In general, zones 2 and 3 continue to maintain its key ecological features better than the lower zones (Table 1).

However, a significant increase in the total-P concentrations at the mainstream stations of the Water Quality Monitoring Network is reported in the MRC Technical Paper no. 19 as a concern that can lead to eutrophication (MRC, 2008). So this parameter must be taken into consideration in the water quality monitoring program of the hydropower projects.

More recent results available showed that water quality of the Mekong River is still good, with only a small number of samples of pH, dissolved oxygen and chemical oxygen demand exceeding the MRC Water Quality Guidelines for the Protection of Human Health and Aquatic Life (MRC, 2015).

Table 1: Results of the IBFM specialist assessments of ecological status of different river zones: A = Excellent/Unmodified; B = Good/largely natural; C = satisfactory/moderately modified; D = room for improvement; E = improvement necessary/largely modified.

Discipline	**Zone 2**	**Zone 3**	**Zone 4**	**Zone 5**	**Zone 6**
Geomorphology (channel form)	B+	B+	A	B+	C
Water Quality (chemical only)	B	B	B	B	B-E
Vegetation - In Channel/River bank	C	C*	B*	D*	C-D
		D#	C#	B-E#	
Invertebrates	B	B	B+	B-	C
Fish	C	C	C	C	D
Water Birds	C	C	D+	D+	D+
Frogs/Reptiles	C	C	D+	D+	D+
	B-	B-	C+	C+	C+

Source: SEA report, 2010.

The water quality in the Delta tends to be more impacted by human activities than in other sections of the Lower Mekong Basin, partly because of more intensive agriculture and higher population densities and cumulative effects of pollutants flowing from upstream to downstream (MRC, 2013).

However, we should be borne in mind that with the construction of hydropower plants on the Mekong mainstream, concerns about water quality will no longer be restricted to problems related to human activities. The cascading reservoirs will produce cumulative effects with additional impacts on the water quality and aquatic ecosystem along the river basin affecting the delta region even more significantly.

Currently the major environmental problems in the Mekong River Basin are already in the delta region such as characterized in the Pak Lay EIA final report, based on information below extracted from the MRC's 2010 report (State of Lower Mekong Basin):

For the aquatic environment, the use of agrochemicals, especially pesticides, poses a threat to organisms. Agrochemicals are most intensively used in the Mekong Delta, where farmers may have as many as three crops of rice per year. Also, the use of pesticides in orchards and on vegetables is high, where large quantities are suspected to end up in the aquatic environment. Many pesticides with high toxicity to aquatic organisms and humans, are still being used. The loss of wetlands in the LMB has been widespread. In the Mekong Delta for example, less than two per cent of the area's original inland wetlands remain. Many of the pressures on wetlands in the delta – population growth, poverty and agriculture and upstream infrastructure development are common *threats to wetlands throughout the Mekong Basin. In the delta vast areas of natural wetlands have been converted to other uses. In recent decades, land development in Thailand for example has accelerated with the construction of many reservoirs for irrigation, flood control and hydropower. The area of wetlands reclaimed for cultivation has increased greatly, combined with intensive, often unsustainable, human use of those small wetlands which remain.*

Other concerns including deforestation, agriculture, mining, and road construction all increase the amount of silt and sediment in rivers and wetlands. Too much silt can clog up the gills of fish, suffocate freshly laid eggs, affect nursery grounds of juvenile fish and reduce the amount of light penetrating the water – reducing plant survival. Degradation of seasonally inundated forests along the banks, channels and islands of the Mekong mainstream and its tributaries has significant impacts– not least because forest fruits, flowers, leaves, bark and roots are important food items for various species of fish of economic importance that feed in the flooded areas in the rainy season.

The EIA mentions that the MRC indicated no strong evidence for trans-boundary pollution within the Mekong Basin between Lao PDR and Thailand, Lao PDR and Cambodia, and Cambodia and Viet Nam, although elevated nitrogen levels in the upper part of the river indicate some trans-boundary transmission of pollutants from the Upper Mekong Basin into the LMB.

Regarding the sediment production, there are two major sources responsible for 90 per cent of the total. The first is the upper basin in China with an estimated production of 60 x 106 tons per year (based on the post 1993 data sampled at Chiang Saen), which is about half of the regional total and sourced from less than 20 per cent of the overall basin area. The second major source terrain is the Central Highlands, with the Se Kong, Se San and Sre Prok tributaries delivering considerable loads to the Mekong mainstream. Elsewhere, tributary sediment contributions are relatively low with erosion rates just 5–10 per cent of those in the two principal source areas.

The Mekong River transports large amounts of sediment, much of which originates in the upper part of the basin. This process helps to redistribute nutrients within the basin and is very important for areas of high productivity, such as the Tonle Sap Great Lake. In this sense, trans-boundary transportation of nutrients along the river has, so far, been regarded as a benefit rather than a cause of pollution. Concerns on sediment issues have received considerable attention in recent years, reflecting a growing realization of the potential consequences of reduced sediment transport due to trapping behind dams (MRC, 2010).

Information about environmental conditions in Laos are also presented by developer in the Pak Lay EIA Final Report (2014).

Statistics in 2010 indicated Lao PDR has an area of 236,800 km2 with the population of 6.8 million. The population density is low (approximately 25 persons/km2) but the growth of population is moderately high (2.5%). The Lao environmental resources including forest, water and wetland are considered one of a high bio-diversity in Southeast Asia; however, the environmental resources are at risk to be degraded rapidly from uncontrolled illegal exploitation and encroachment to these resources.

As part of its efforts to conserve its biodiversity, Lao PDR currently has 24 National Protected Areas (NPAs) and two Corridors, covering almost 3.5 million ha, or 15 % of the country. If the area under provincial and district protection is added, the area increases to 5.3 million ha, or 22.6 % of the land area. The protected areas in Lao PDR are among the most remote areas in the country. However, human use of these areas is rising as a result of increased population growth in traditional communities, migration, and settlement. In addition, both protected areas and the land around them face increasing degradation as a result of expanding agricultural frontiers, illegal hunting, illegal logging, and uncontrolled burning.

Development emphasis on expanding land cultivation and increasing exploitation of hydropower potential is putting additional pressure on the resource base.

In Lao PDR, surface water is the major water source for urban supply as most towns are located along the rivers, while groundwater is the main source for the rural population. Whilst still within acceptable limits both surface and groundwater quality is declining. With rising populations in urban and upland areas, water pollution issues will become increasingly important in the near future. Only 64% of Lao people have access to safe drinking water.

6.1.1 Hydropower in the Mekong

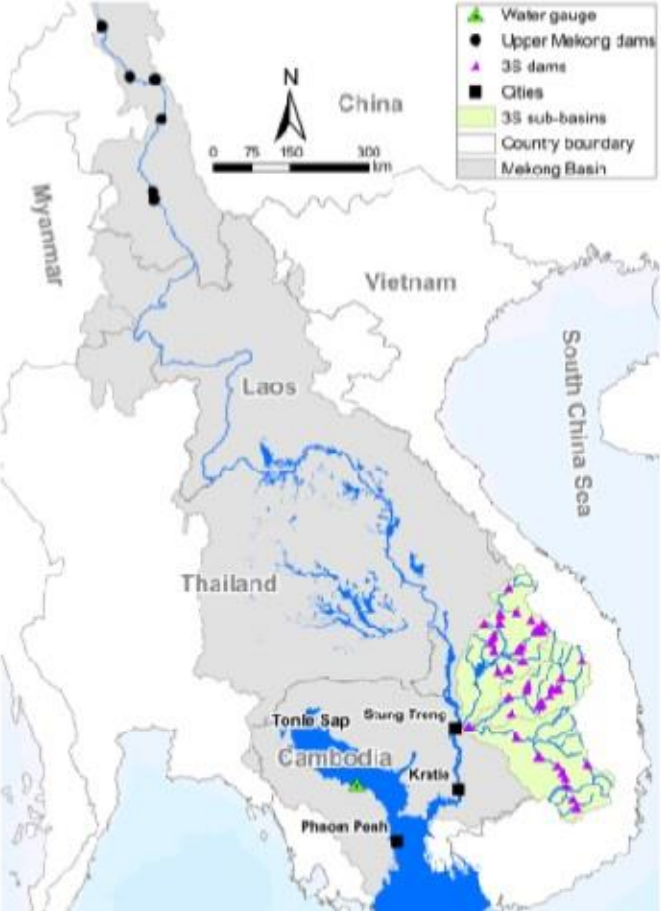


Figure 9 : Map of the Mekong Basin highlighting its floodplains and dams in the definite future (black dots) and 3S development scenarios (violet triangles). The green triangle shows the Kampong Luong water level gauge location on the Tonle Sap.

Hydropower development in the Mekong is occurring in three distinct regions (Arias et al., 2014a). The first is the Lancang Jiang cascade in the Upper Mekong River in China (Fig. 9), a series of 6 dams (5 already built) with downstream hydrological alterations expected as far down as Kratie (Räsänen et al., 2012). The second focus of development is a series of 11 dams along the mainstream channel in the Lower Mekong, only one of which is under construction, the Xayaburi Dam in Laos. Of greater concern in terms of hydrological alterations is the third region of development occurring in the Mekong tributaries, in particular the Sesan, Srepok, and Sekong (3S) rivers, where at least 42 dams are at some stage of development without much regional coordination or stakeholder consultation. Because of its proximity to the Tonle Sap and the rest of the Lower Mekong floodplains, flow regulation in the 3S will most likely affect the floodplain's hydrological seasonality. Should the Tonle Sap hydrology be altered, there could be serious consequences for the ecological productivity supported by its floodplain (Arias et al., 2014b).

Studies using numerical models representing the basin's surface hydrology, water resources development, and floodplain hydrodynamics demonstrated that the cumulative effect of development in the Upper Mekong and the 3S will cause significant disruption to the inundation patterns of the Lower Mekong floodplains, in particular through an increase in dry season water levels as well as a reduction in water level rise and fall rates (Arias et al., 2014a).

6.1.2 The MPLHPP area

Two site visits were afforded by developer to the consultant. The first visit was held on 19 and 20 of September 2015, during the wet season, including a visit by land to Ban Phaliap village and a ride by boat from Pak Lay city to the dam site. The second site visit occurred in the dry season, on 10 of January 2016, covering the navigation from dam site to Ban Phaliap. Both visits were very useful to assess the environmental conditions and the possible effects of the project to the aquatic ecosystem.

Waste on the river banks were observed in the small villages along the basin, and we think that this is a problem that must be managed in the area of reservoir to avoid compromising water quality. Bulks of aquatic weeds which have potential to impact the aquatic ecosystem and the HPP operation or causing effects downstream have not been observed in the visited areas. This may be an indirect evidence of the absence of significant sources of diffuse pollution, which are usually associated with the proliferation of aquatic plants due to supply of nutrients, especially phosphorus and nitrogen.

Aquaculture can also be a source of nitrogen, phosphorus and organic matter, which contribute to the eutrophication of water bodies. However, according to the Pak Lay EIA Final Report (2014) there were no inland aquaculture activities found to be operating in the project area based on both observation and discussions with local government officials and residents.

Nevertheless, we have observed that creation of buffalo is frequent in the region and this kind of extensive livestock has the potential to cause erosion on the banks of the watercourse and destruction of riparian vegetation, if not properly conducted.

Apparently, there is still abundant forest cover along both banks of the river in the Paklay project area. We think this is an opportunity to include in planning the preservation of a belt of native vegetation around the future reservoir.

According to the Pak Lay EIA Final Report (2014), topographically, the whole area is high in the north and west, and low in the south and east, with mountains extending smoothly. The highest elevation of the surveyed area reaches 1 ,000m. There are valleys among mountains, and the water systems are quite developed. The lowest elevation of the river valley is around 200m. The difference in elevation between mountain range and valley is around 150m-200m. The river valleys of the Mekong and its large tributaries are open and have gentle slopes. Flood plain or bela is distributed discontinuously near the river bank and in the river.

6.2 Review of feasibility study regarding water quality and aquatic ecology issues

6.2.1 Assessment of aquatic ecosystem

The Mekong River basin is a complex ecosystem encompassing rivers, flood plains, wetlands, lakes, islands and transitional zones. These systems differ according to their morphology, hydrodynamics, and degree of connection with the mainstream, conveying them peculiar characteristics that affect the distribution and structure of aquatic communities.

Artificial dams are used for many and varied purposes that affect the water quality, the operating mechanisms and the succession of aquatic communities in rivers and watershed. The dam management should be based on a constant process of monitoring and evaluation of the system operation, depth knowledge of limnology of these ecosystems and the adoption of innovative techniques based on eco-technologies and ecohydrology (Tundisi & Tundisi, 2008).

The main ecological effects on aquatic ecosystem caused by the construction of dams are:

- ✓ The interruption of connectivity for migratory species;
- ✓ The transformation from lotic to lentic environment;
- ✓ Sediment and nutrient retention.

These effects can be partially mitigated by the implementation of fish passage facilities and structures for sediment flushing. The change from running water to slower water environment tends to be attenuated in runoff river projects, but even so raising the water level in the reservoir area reduces the velocity of flows and bring about other deleterious effects on the aquatic ecosystem.

The cascade of reservoirs on the Mekong mainstream will result in the permanent submersion of seasonally floodable areas and the consequent elimination of the flood pulses upstream of each dam with detrimental consequences for the maintenance of biodiversity and of ecological services.

In addition to the problems normally related to the construction of the dam and auxiliary structures, there are three main factors that can permanently affect the water quality in a hydropower project:

- ✓ Operating of the power plant;
- ✓ Variation of the water level;
- ✓ Water residence time.

The runoff-river projects usually are good, but not always enough to maintain the water quality under ecologically acceptable conditions and to provide environmental flows. In this kind of project the water quality will depends fundamentally on the depth of reservoir.

Considering that the MPLHPP will raise in about 30 m the level of the river upstream of the dam and that the variation of the water level during the operation phase will be very small (between 239 and 240 masl), this will be the main factor affecting the water quality and the aquatic ecosystem in the Pak Lay reservoir.

6.2.1.1 The flood pulse concept

The main force governing ecological relationships in fluvial ecosystems subjected to high seasonal variations of water level is the flood pulse concept, originally described by Jung et al. (1989) and that has been adapted by various authors for different regions of the planet.

Floodplains can be defined as areas periodically flooded by lateral overflow of rivers or lakes, and / or by direct precipitation or groundwater. The variations of the hydrometric levels and the water flow provide a variety of habitats and interfere directly in the spatial and temporal dynamics of the aquatic communities so that the changes between terrestrial and aquatic phase is the main factor influencing the biota of these areas.

The vast floodplain of the Mekong River basin is located in the lower portions, especially in the Tonle Sap region, but a mosaic of many smaller flood plains extends across the Lower Mekong River from the southern Yunnan to the delta region.

The flood pulses are important for the lateral exchanges between the marginal areas and the river channel (Figure 10).

At the start of the flooding occurs nutrients input from the level where the flood begins. During flood periods the most important element is called the moving littoral. With increasing the water levels, nutrients that have been mineralized in the dry phase are suspended with sediments in the flood waters and main river. This pulse of water is the primary driver of high productivity and decomposition rates as it moves nutrients in and out of the system, and is good breeding ground for many organisms specially for larval stages of some fish species. In this phase the production rates exceed decomposition rates. When water levels stabilize, decomposition rates outpace production rates, frequently contributing to dissolved oxygen deficiency. When the water starts receding, the moving littoral reverses, concentrating nutrients and contributing to phytoplankton growth.

The flood pulse helps maintain genetic and species diversity in the flood plain ecosystem, as well as increases productivity due to the increased of water surface incorporating land in the river biota. Flood plain systems serve as migration routes, hibernation spots, and spawning locations for many species.

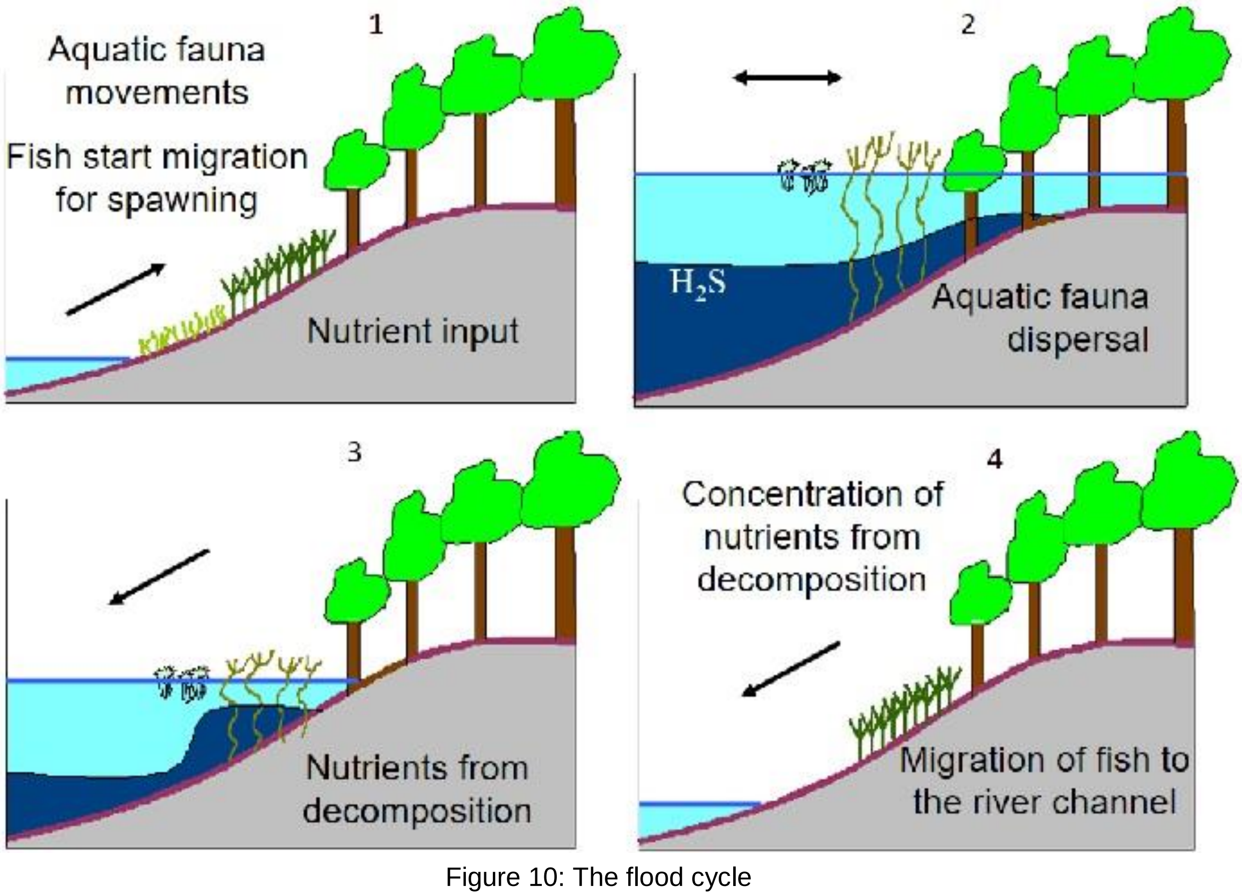


Figure 10: The flood cycle

In the dry phase, there again the growth of terrestrial vegetation in areas previously flooded with nutrients from flood and particularly the decomposition of aquatic vegetation and lands flooded in the full phase. Thus, the system can incorporate and take advantage of organic matter very efficiently, explaining the wealth and productivity of rivers with floodplains.

Flood pulses mainly favor the diversity and abundance of fish scavengers that feed on organic matter from terrestrial phase floating aquatic phase. It is expected that these nutrient incorporation conditions and organic matter, meet a diverse community with complex and rich trophic structure, composed of scavenging species, herbivorous, omnivorous, carnivorous and insectivorous.

The organisms have adjustment of its life cycles, fertility, growth and reproduction at the time where occur hydrologic events. The flood pulses usually have an important role in triggering biological phenomena of aquatic species, particularly with regard to reproduction.

6.2.1.2 Ecological effects of a runoff hydropower project

In the case of a runoff hydropower project, the level of reservoir is constant and the flood pulse upstream from the dam does not occur. This contributes to decrease productivity in the reservoir area over time in that the nutrient incorporated into the ecosystem by flooding of land areas are being consumed by the aquatic organisms. So permanently flooded areas can ecologically function as oligotrophic lakes poor in nutrient.

Another harmful effect of regulation the water level by dams is the increasing transparency of water. Maintaining a relatively constant level of water promotes the precipitation of suspended solids and the consequent increase of the transparency of the water, both upstream as downstream of the dam, contributing to decrease the productivity in aquatic ecosystem. Spatial and temporal variations in water transparency affect the abundance and distribution of fish groups according to their dependence on vision. Clear waters usually favor the species adapted to visual hunting, but increases the stress, exposing aquatic organisms to interference from external factors, favoring predation and cannibalism.

The changes in water level can be used as an effective management technique to increase the abundance of fish, specially, in run-of-river reservoirs, and minimize the negative effects of phases of long-term ageing (Baumgartner et al, 2016). Therefore, the flexibilization in the operation of the reservoir including the simulation of flood pulses with variations of water level of at least about 3 meters between the dry and wet seasons for the MPLHPP area, could benefit aquatic fauna and increase productivity of the ecosystem. So, we had recommended that Developer should consider the possibility of operating the reservoir by simulating the natural flood pulses, decreasing the water level in dry season and increasing it in wet season.

This operational protocol will be adopted by Pak Beng HPP, in order to avoid impact on Keng Pha Dai area nearby the Thai-Lao border and but this adjustment will end up benefiting the aquatic ecosystem. For Pak Beng project, the reservoir will be operated at 340m during the flood season and at 335m in dry season. If a similar management of water levels operation could be adopted by Pak Lay and the other runoff hydropower plants in the Mekong mainstream, this would greatly benefit the aquatic ecosystem.

However, during the workshop held in September it was clarified by the designer that Pak Lay reservoir will be operated between the elevations 239 and 240m, such that below the minimum operation water level of 239m the power generation stops. Therefore, unfortunately it becomes infeasible our recommendation to promote seasonal variation in the water levels to benefit the aquatic ecosystem in the Pak Lay reservoir.

6.2.2 Assessment and monitoring of water quality

The Pak Lay EIA Final Report (2014) presents the field survey, sampling and observation at 7 stations in Mekong River, at proposed dam site, downstream area and three upstream stations, that was conducted for surface water quality evaluation and aquatic ecology (Figure 5). Two samples were taken at each point, one in dry season and one in wet season.

Overall the result of water quality study in dry season revealed that the surface water quality in Mekong mainstream from the area of Ban Pha Liap from upstream to downstream area at PakLay town are good and there are no heavy metal contents over acceptable limits. The most important that must to concern are the value of BOD and COD which were very high at all stations. This need to have mitigation measure to prevent the problem of water deterioration in the future. The organic matters from any sources should be prohibiting not to dumping to the natural water body with any manners. Total phosphate and some nitrates concentration were *found at lower value than wet season and are in acceptable of surface water standard. The surface water quality of the Mekong River from the seven sampling sites in the project area shows a good quality of class three for fresh surface water; it's suitable for irrigation supply, aquatic biota (NEAP, 2000, STEA), and human consumption after a normal treatment process.*

The results of field surveys in wet season showed that water quality was in very good quality by the mean of dissolved oxygen even through the water is relative turbid. Total Solids are high concentration due to the influence of high water flow. Nitrate are in high ranged of 1.87-4.28 mg/l which ammonia are 0.07-0.52 mg/l. The water in this area showed the contamination of coliform bacteria. Total coliform bacteria are in range of higher than 230MPN/100 ml and fecal coliform bacteria are higher than 23 MPN/100 ml in all stations.

Regarding to these surveys the Developer should provide a map with the location of sampling stations in a figure in order to facilitate the understanding. In the section 5.5.1.1 (Existing Biotic Environment in the Project Area) it is mentioned that field surveys and collection of aquatic organisms were performed at 6 stations, but then 7 sampling stations are described (the same of water quality). This divergent information needs to be corrected.

Some concerns on water quality of the MRC Secretariat were described in the Procedures for Notification, Prior Consultation and Agreement (PNPCA) Proposed for the Xayaburi Dam Project. The main aspects also applicable to Pak Lay HPP include the following:

6.2.2.1 Construction period

The water quality of the impoundment would be affected during the construction period from the release of construction materials, oil from boats and machines and waste water including organic matter and coliform as well as other bacteria from living quarters. Degradation of organic matter being submerged during impoundment would also negatively affect the quality of the water. Good international practice exists to mitigate these impacts.

Recommendations towards mitigation should include provision of settling ponds and other measures to treat wastewater and capture construction material prior to release of water to the river.

According to the Pak Lay EIA Final Report (2014), as the project is on the Mekong mainstream there may be effects on surface water quality especially Down Stream. The impacts on water quality may be related to specific activities during construction and/or operation. During construction the activities that may cause changes in water quality include dredging, excavating, and surface runoff from construction and camp sites. The placement of the dam will result in some degree of impoundment and this will affect water quality and the aquatic environment both upstream and downstream. Direct physical changes upstream include increased water depth, increased water retention time, and possible thermal stratification. These direct changes will affect a broad spectrum of water quality parameters both upstream and downstream.

The EIA relates that construction will only take a few years and construction impacts are easily controlled providing an adequate Environmental Management Plan (EMP). The main impact that was identified was the need to carry out work within the river channel to prepare the dam foundations whereby the downstream water may be compromised by sudden release of sediment disturbed by the activities. The construction work will need to be stopped if the downstream turbidity increases above a critical level.

The EIA also recommends that during the construction and demolition of the cofferdam a water quality monitoring program shall be regularly performed and appropriate techniques and measures for the demolition of the cofferdam are implemented accordingly. Appropriate mitigation measures for the control of sediment shall be in place and strictly implemented.

The mitigation measures proposed by the Developer for construction phase includes:

- ✓ Installation of waste water treatment plant for worker camps.
- ✓ Safe disposal of vehicle maintenance oils.
- ✓ Safe storage of chemicals and disposal of used containers.
- ✓ Attention to concrete shuttering to prevent accidental spillage of wet cement into water courses, and prevention or washing cement mixing equipment in water courses.
- ✓ Prevention or washing cement mixing equipment in water courses.
- ✓ Attention to good earth moving practice when working near water courses.
- ✓ Removal of surplus vegetation in the reservoir area prior to impoundment.
- ✓ Monitoring of water according to Lao Environmental Standard: "Agreement on the National Environmental Standards, 2009 – No 2734 /PMO.WREA"

Under our understanding, monitoring of water quality, sediment and nutrient-related impacts upstream and downstream from the dam site should include inorganic fractions, total phosphorus, total nitrogen, suspended solids, organic content (COD or BOD), chlorophyll-a, oxygen, pH, temperature, light adsorption/penetration capacity (secchi disc depth), oil/grease components and bacterial levels. Sampling frequency should vary between monthly and weekly, depending on the intensity and type of construction activities at the time. During periods of intense construction activity, sampling frequency may need to be even higher. Sampling locations should be upstream and downstream from the construction area to ensure that the effectiveness of mitigation measures can be detected.

We therefore recommend that the company takes over and start monitoring the above parameters upstream and downstream of the dam site as soon as be signed the concession agreement, extending it throughout the construction phase. The monitoring protocol should be provided in the EMMP.

The monitoring of water is planned for the construction phase as a short term impact, but this action must be extended to the operation phase (long term impact), including phosphorus among the parameters to be monitored. In the National Standard, the concentration of phosphorus is prescribed for General Industrial Wastewater Discharge Standards, but we recommend including this parameter also for monitoring of surface water quality in order to fully attend the issues of the MRC Preliminary Design Guidance for Proposed Mainstream Dams in the Lower Mekong Basin (PDG).

Stormwater drainage systems and sewage systems must be completely independent. Oils and greases should be collected in boxes of separating and accumulation for subsequent proper disposal.

Among the erosion control measures proposed in the Pak Lay EMMP Final Report (2014) it is planned to monitor suspended solids in stormwater drainage from concerned area with bi-monthly frequency, but we think that it should be made more frequent in the wet season, at least monthly.

For the area of reservoir, the proposed measures of cut, cleared and burnt the bulk of the vegetation should mitigate the potential depletion of oxygen and eutrophication during and immediately after impoundment. The maintenance of a 100 m wide buffer zone of vegetation around the perimeter of the reservoir and 20 m along the tributaries may be suitable for the protection of the water resources and other relevant ecological functions.

There is great controversy regarding the effects of the removal of vegetation for the water quality of reservoirs, however there is a certain unanimity to be said that there must be a balance between the non removal or full removal of vegetation. Besides contributing to the depletion of oxygen levels in the water, underwater decomposition of organic matter turns into carbon dioxide and methane responsible for increasing the greenhouse effect. In some areas, however, there is no need to remove the vegetation. This procedure is important, among other things, to ensure the escape and rescue of animals; maintenance and stabilization of slopes and ravines surrounding the lake; besides serving as a nursery for fish in the reservoir (Some areas with vegetation can be maintained in the future reservoir to assist the processes of feeding and reproduction of aquatic fauna). A previous forest inventory and assessment of plant biomass can subsidize deforestation work and modeling of water quality.

According to the proposed plan, the most extensive cleanup of residual burnt vegetation in the upper reaches of the reservoir where the water depths are shallowest and could cause the greatest hindrance to navigation and fishery operations. However, we suggest to consider sufficient cleaning possibility just to maintain a navigation channel. The residual vegetation maintenance might be interesting to prevent overfishing, especially in shallow areas. In addition, various species use the submerged terrestrial vegetation as spawning substrate and protection of their eggs and larvae from predation. For some species, the presence of these habitats is essential for reproductive success (Ploskey, G. R. 1985).

6.2.2.2 Operation period

The decreased water velocity in the reservoir would lead to increased settling of suspended matter and lower water turbidity resulting in higher transparency of the water and, following from this, potentially increased primary productivity, i.e. algae blooms and proliferation of aquatic weed. With the current nutrient concentrations in the water it can be expected that algae blooms will occur in the dry season when the retention time is higher than 15 days.

This impact can be mitigated and therefore minimized through reservoir operation. As an integrated part of this mitigation measure, frequent monitoring is required in the dry season to detect the onset of a bloom of algae or aquatic weed. Monitoring every second week during the dry season would fulfil this need for information.

The chemical, thermal and physical changes, which flowing water undergoes when it is stilled can seriously contaminate a reservoir and the river downstream. The extent of deterioration in water quality is in general related to the retention time of the reservoir. Water in a small headpond behind a run-of-river dam will undergo very little or no deterioration. However, water released from deep in a reservoir can affect the temperature and the amount of dissolved oxygen and suspended solids in the river downstream with harmful consequences for aquatic life.

Recommendations regarding the monitoring protocol of water quality for the operation phase should be proposed by the developer.

In tropical regions, the wind and precipitation are the main natural factors regulating stratification. The wind on the water surface can displace the hottest surface layer that will be replaced by the lower layer of cooler water, which shifts to the surface. In tropical regions it is more common occur stratification and destratification daily, culminating respectively in the late afternoon and overnight. In the hot, wet season may occur lasting stratification, which sometimes remain throughout the season. In deep lakes, destratification usually occurs in the cool dry season due to the cooling of the surface layer (epilimnion).

In the case of a hydroelectric plant the water can flow from different depths through the turbines, by the spillway and by bottom discharger, and this produces a thermal and density stratification similar to the natural process (hydraulic stratification). However, it is very difficult to predict what will be the behavior of this limnological variable to the Pak Lay project, but usually dams operation has some flexibility that can be used to mitigate impacts on the aquatic ecosystem, mainly downstream.

According to the Pak Lay EIA Final Report (2014), the reservoir will not act as a storage reservoir and will have a very short residence time which will be only slightly longer than the pre-impoundment condition. The overall impact on water quality as expected from a reservoir that may develop thermal stratification will not occur.

In fact, the lower the residence time the greater the tendency of the reservoir to behave as a river. However, as previously mentioned, we must consider that the depth of the river in the dammed area will be increased by approximately 30 meters, and this may lead to the occurrence of vertical stratification processes, especially during the dry season when water flows are lower. Therefore, this can only be assessed by means of a properly monitoring program.

In the tropical region, the seasonality of the abiotic and biotic components in reservoirs is determined by the climate forces. The water temperature, pH, conductivity, dissolved oxygen, turbidity and suspended solids are the variables that change the most between the seasons.

For ITAIPU reservoir, that has some similarities with the projects on LMB mainstream as the location in tropical zone, long, deep and relatively narrow reservoir, high flow rates and low residence time of water, it has been adopted with good results a protocol for monitoring of water quality recommended by reputed limnologists that could also be proposed for the MPLHPP.

Thereby sampling should be done monthly for temperature, pH, dissolved oxygen and electric conductivity, each one meter in the water column in order to check the possible occurrence of thermal or chemical stratification. This kind of sampling can easily done with a multiparameter sounder.

The other physical, chemical and biological parameters, as nitrogen, phosphorus, biochemical oxygen demand (BOD), total solids, transparency, turbidity, chlorophyll-a, coliforms, phytoplankton and zooplankton the sampling can be done quarterly in the photic and aphotic zones.

Reservoirs usually exhibit vertical stratification also in light penetration. Light is rapidly absorbed by the water and aquatic micro-organisms resulting in a rapid decrease in light intensity in that the depth increases. This divides the lake into two layers: the limnetic zone or photic zone in the upper layer where light is enough for photosynthesis; and the profundal aphotic zone that receives little light and no photosynthesis occurs (Figure 11).

Water transparency, which determines the depth of the photic zone is measured with a Secchi disk. The aphotic zone is an area of decomposition, where detritus (dead organic matter that drifts from above) is broken down. Oxygen is usually low due to cellular respiration of decomposers; mineral nutrients are usually plentiful due to decomposition of detritus. In thermally stratified reservoirs, waters of the profundal zone usually do not mix with surface waters due to density differences. So the behavior of the monitored parameters can be quite different between photic and aphotic zones. When mixing of the layers occurs, this results in oxygen entering the profundal zone and nutrients being cycled in the water body.

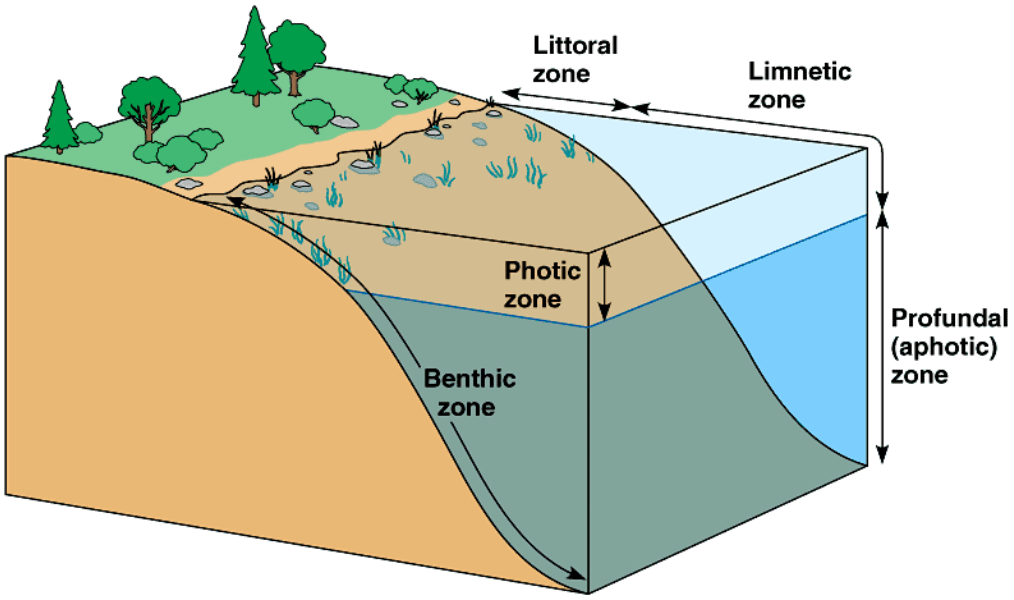


Figure 11. Zonation of lakes and reservoirs.

6.2.3 Effects on aquatic ecology

In the Pak Lay EIA Final Report (2014) it is admitted that, during the construction period, the water quality in the river will be affected by the construction work in the project area. Increased turbidity is expected to be generated which will affect the living conditions of plankton and benthic organisms. At the downstream site, there are confluences with tributaries; the fisheries here need to be managed properly to prevent incorrect exploitation and promote sustained fishing practices.

During the site visit it was observed that fish exploitation in tributaries downstream is practiced in a predatory manner with fishing gear installed in the entire section of river (Figure 12). This is a predatory practice that tends to worsen with the construction of the dam due the imposition of physical barrier to fish in upward movements, which will tend to accumulate in the river downstream and nearby tributaries. Therefore, this aspect should be managed since early with a view to promoting sustainable fishing practices.

Figure 12: Fishing gears installed in the entire section of a tributary downstream the dam site.

We also recommend that in the construction period the blocking of migration routes and fragmentation of habitats between downstream and upstream the dam should be avoided. Developer should provide evidences that this will not occur, or propose mitigation measures if the dam structures do not allow the passage of fish while the fish pass facilities are not up and running.

This is a serious problem that we have observed in the present stage of works in the Xayaburi HPP where the only possibility of fish passage to upstream is through the navigation lock. However, this route of dispersal is extremely limited, which has led to the accumulation of fish immediately downstream of the dam, harming the upward migration and encouraging overfishing (Figure 13).

Figure 13: Fishermen take advantage of shoals that accumulate downstream from the Xayaburi dam.

To mitigate this deleterious effect during the construction of the MPLHPP, we recommend that the works should be planned aiming to reduce as much as possible the river blockage and that fishing downstream and in nearby tributaries is banned until the free movement of fish through the dam is restored.

The Pak Lay EIA Final Report (2014) considers that *different species should be affected at different degrees and different trophic levels, with those directly feeding on plankton among the most affected. According to the fish species survey, the majority of fish found abundantly in the Mekong Hydroelectric Power Project area of the rheophilic type which feed mainly on plankton and bottom sediment. The reduction of plankton and benthic fauna during construction period is believed to be insignificant since the level of plankton density is already low and the effect of siltation and water turbidity will only occur during the construction period; the aquatic organisms will recover in the short time*.

In our view this statement should be considered with reservations and possible effects should be checked by means of adequate monitoring, and mitigated when necessary.

The developer's report mentions that *some issues like deforestation, agriculture, mining, and road construction all increase the amount of silt and sediment in rivers and wetlands. Too much silt can clog up the gills of fish, suffocate freshly laid eggs, affect nursery grounds of juvenile fish and reduce the amount of light penetrating the water – reducing plant survival. Degradation of seasonally inundated forests along the banks, channels and islands of the Mekong mainstream and its tributaries has significant impacts – not least because forest fruits, flowers, leaves, bark and roots are important food items for various species of fish of economic importance that feed in the flooded areas in the rainy season.*

In sum, the biodiversity, water quality, flood protection, fisheries, and a range of livelihoods in the basin are at risk from endangered wetlands and increasing deforestation.

However, the document emphasizes that *the principal impacts on water quality occur mainly during the construction phase. All the activities can affect the water quality, increasing the total solids and sediment in the Mekong River. Significant increases of oils and chemical spills may also create negative impacts on fish and water quality at the areas around the construction site and at downstream area. The report assuages the potential impact of the reservoir because it will not act as a storage reservoir and will have a very short residence time which will be only slightly longer than the pre-impoundment condition. The overall impact on water quality as expected from a reservoir that may develop thermal stratification will not occur*.

The control, monitoring and possible mitigation measures to avoid these potential impacts on aquatic environment during the construction phase are addressed in the Pak Lay EMMP Final Report (2014). However, although the dam works will produce many significant impacts it should be considered that environmental effects during this phase are usually localized and temporary, but the impacts arising from the impoundment and the operation phase of the project tend to become permanents and deserve a careful and comprehensive planning. So, the careful assessment of the potential effects resulting from the formation and operation of reservoir should be taken into account on project stage. As explained theretofore, despite the project is a run-of-river HPP with a short water residence time, these only features may not be enough to avoid environmental effects related to the possible occurrence of stratification and sedimentation problems.

The proposed low-dam run-of-river hydropower station based on upstream inflow is theoretically better than a regulation dam for the ecosystem health downstream. However, the area upstream will be permanently flooded to operate at a constant level and no longer suffer variations characteristics of flood pulses. This will definitely affect the riverine ecosystem in the reservoir area and only the constant monitoring may indicate whether there will be loss of biodiversity or significant changes in aquatic communities. Thus, we suggest the inclusion of biological sampling in EMMP to evaluate these potential impacts and allow the design of mitigation measures for operation phase.

The most relevant way to assess aquatic ecological health is to monitor the health of key functional groups of organisms (biological quality elements) in the Mekong River – biomonitoring. Relevant indicator organisms for ecosystem health include fish, macroinvertebrates, primary producers such as phytoplankton and macrophytes and "consumers" such as zooplankton. An indication of negative health impacts can be changes in the numbers of individuals or species, changes in the species composition or abundance when compared with undisturbed reference sites (MRCS, 2011).

As well addressed in the Pak Lay EIA Final Report (2014), the upstream pond will be created with different flow condition and the following impacts may occur to aquatic biodiversity.

1) Loss of habitats with rapids / riffles and deep pools throughout the entire river stretch from the dam to the upper reservoir tail water. Considerable reduction in spawning / production areas and dry season habitat for rheophilic Mekong species (require flowing water) and certain more sedentary type fish species. Fish production of some real riverine species over the impounded area will be less than under pre-impoundment conditions over one calendar cycle.

2) The fish species composition of the upstream pond will be different to that of the pre-impoundment riverine species population. Some species that are able to adapt to the reservoir conditions may develop to the point where they dominate the fish population including the possibility of the proliferation of predatory species which may impact on non-predatory fish populations.

3) Impact on spawning and recruitment to reservoir fish populations. Certain riverine species will adapt to reservoir conditions.

4) Proliferation of exotic species such as Tilapia (Oreochromis spp.) that are farmed in net-cages or in earth ponds have much less consumer appeal. If the MPLHPP is to proceed, then landings of introduced species will need to be monitored and assessed. Common Carp (Cyprinus carpio) that produce adhesive eggs laid on various substrate material may become a very important part of the fishery.

Some recommendations and mitigation measures are proposed in the EIA as follows.

During the operation period, with the increasing amount of water for the living of aquatic organisms, the dynamic of trophic level in the aquatic ecosystem will be relatively stable to existing plasticity of food preference by each group. An increase in biomass of fisheries resources according to the increasing of water body may cause the positive impacts to the aquatic ecosystem.

It is expected that even there will be significant change on the aquatic ecology but there will be no significant change on spawning activities of fish. The flow of water pass barrage site in every season will be not changed. During wet season, the water flow should be proper evaluated to determine the effective tool for sustaining fish biodiversity.

It is possible to have a project fishpass facility to mitigate the migratory of fish. Any fishpass design is not considered to be a viable answer to the issues regarding fish migration as there is no known type of fishpass that could possibly cope with the large number of Mekong fish species that would need to use it during the critical time periods when fish need to move. The maintaining downstream flows and upstream migration is crucial to the sustainability of fish populations.

Fishery research station at project area should be set up near project area. Many activities will be related to breed the indigenous fish species for release to the Mekong River in the project upstream pond. The fish transport mobile unit with large container with aeration system will set up for collected the fish from downstream or pond of fishpass way cross to upstream. Adoption of aquaculture within the headpond area would be a partial solution to the loss of migratory species.

Again here, we must take into account that, although the Pak Lay HPP is a run-off-river project, the ecosystem upstream the dam will be permanently flooded. The biological fauna will respond by changing fish, plankton and invertebrate species favoring those that are best adapted to lake-like waters. How this could potentially happen and how it would affect other aquatic species, and the ecosystem including the food chain, this needs to be further assessed.

According to the Pak Lay EMMP Final Report (2014), *under the basic design of operations, run-off during the early part of the wet season will be used to fill the dam which will then be drawn down during the dry season. The flood events that occur naturally during the early wet season would be largely eliminated and discharge of the excess waters over the spillway would occur at least one month later than occurs naturally e.g. in September compared to July/August.*

The migratory fishery in particular is dependent upon the early flood events which act as triggers for the migrations. Late flood events would either not trigger the migrations in the same way or if the fish do migrate to spawn upstream the eggs laid may hatch too late in the season to be able to take advantage of food availability. The result would be a much reduced recruitment of new fish stock and populations would decrease.

It is recommended that the first short natural flood event (around 3 to 5 day duration) should be released early in the wet season, coinciding with rainfalls in the catchment, i.e. mimicking natural flows, in order to maintain the ecological integrity of the river and the fish migration triggers. It is important that such flood events are made during dry years as well as normal and wet years.

Floods occurring later in the wet season when the reservoir is full and the water is discharged over the spillway will be transmitted downstream as before (as if the dam were not there). However, because the water has been held back during the refilling of the reservoir in the early wet season, recharge of the floodplain will not have occurred to the same extent. It is therefore likely that in some years the recharge of the floodplain groundwater will be less than before and that there will be some shrinkage of the floodplain itself over the years. This effect *cannot be mitigated and the shrinkage of the floodplain and loss of its productivity is accepted as an unavoidable loss. The extent of this could be a part of the environmental flow assessment.*

The Mekong basin contains a number of other important tributaries. There may be other tributaries that can be identified for conservation that can continue to provide for migratory fish and other aquatic biodiversity. These should be dedicated as "Conservation Rivers" and further development on them limited.

This mitigation measure is especially urgent in the light of the number of the other Projects being considered before all the options for Conservation Rivers are closed. The government should consider establishing an Integrated River Basin Management Plan for the Pak Lay area to coordinate hydropower, fisheries and conservation objectives for the basin. This could be done under the auspices of a Mekong River Basin Organization.

In line to this proposal, we strongly recommended the management for conservation of tributaries upstream the reservoir and its flooding areas, as well as downstream. Measures to that effect meets the requirements of the 2010 MRCS Strategic Environment Assessment report guidelines:

''*Review, survey and classify aquatic habitats in whole Lower Mekong (biodiversity and ecological importance)*

- *Identify key biodiversity hotspots on Mekong mainstream*
- *Prioritise key tributaries for ecosystem integrity and health of the Mekong, highlighting those affected by proposed mainstream dams*
- *Leading to identification of a system for protection of key stretches of the river and its tributaries.*''

The developer has informed this refers to Standards Environmental and Social Obligation (SESO) as will be annex of CA. The project developer will need to do the ESMMP-CP and ESMMP -OP as to be tool for monitoring of Environment and Social at each stage. The aquatics system will be monitor as longterm of the project and stresses that should have consistency in process and data collection system of all cascades.

We recommend the above information should be included in the ESIA.

Some concerns and mitigation measures proposed by MRCS in the PNPCA for Xayaburi dam regarding aquatic ecosystem also can be applied to the PB HPP, among them:

- ✓ *The impacts on endangered species and possible risks of threatening other species should be assessed. It is necessary to establish such information to design any potential mitigation measures.*
- ✓ *Monitoring programs should be set up to fill existing knowledge gaps for all biological quality elements, particularly impacts on ecosystem health and water quality if the project goes ahead. Tailormade monitoring programs will support the assessment of the effectiveness regarding the mitigation measures.*

We believe that the fish passage proposed for Pak Lay HPP has potential to partially mitigate the effects on migratory fish. In addition, the fishery research center proposed in the EMMP should carry out further studies of the fish fauna monitoring and conservation in order to support measures for preventing biodiversity loss and the risk of establishment of invasive species. Developer also should clarify whether will be used fish friendly turbines.

6.2.4 Assessment of environmental flows

6.2.4.1 Hydrological aspects

An environmental flow assessment (EFA) for a river may be defined simply as an assessment of how much of the original flow regime of a river should continue to flow down it and onto its floodplains in order to maintain specified, valued features of the ecosystem. An EFA produces one or more descriptions of possible modified hydrological regimes for the river, the environmental flow requirements (EFRs), each linked to a predetermined objective in terms of the ecosystem’s future condition. For instance, these objectives may be directed at the maintenance or enhancement of the entire riverine ecosystem, including its various aquatic and riparian biota and components from source to sea, at maximizing the production of commercial fish species, at conserving particular endangered species, or protecting features of scientific, cultural or recreational value (Tharme, 2003).

A global review mentioned in Tharme (2003) of the status of environmental flow methodologies revealed the existence of some 207 individual methodologies, recorded for 44 countries within six world regions. These could be differentiated into hydrological, hydraulic rating, habitat simulation and holistic methodologies, with a further two categories representing combination-type and other approaches.

The EFR may be specified at several levels of resolution, from a single annual flow volume through to, more commonly nowadays, a comprehensive, modified flow regime where the overall volume of water allocated for environmental purposes is a combination of different monthly and event-based (e.g. low flows and flood pulses) allocations. The scale at which the EFA is undertaken may also vary widely, from a whole catchment for a large river basin that includes regulated and unregulated tributaries, to a flow restoration project for a single river reach (Tharme, 2003).

Thus, most often it is not sufficient maintaining a minimum flow downstream of a dam. In some cases, even if the downstream flow is always greater than the flow rate set as "ecological" there may be significant environmental damage.

Every river has a unique flow signature that is determined by the climatic, geology, topography, vegetation, and other natural features of its watershed. That signature can be depicted by a hydrograph—a line drawing of the river's flow over time (Figure 14). In monsoonal climates, for example, river flows peak during the rainy season and then drop to very low levels during the dry season (Postel & Richter, 2003).

Among the several methods for environmental flow assessment, the hydrological methods are the simplest and have the advantage of using small amount of information needed for its implementation, in general only the historical series of flows. These methods do not analyze the environmental aspect, just assume that maintaining a reference flow, based on historical flows, can result in benefit to the ecosystem.

The EFA of a complex river system as the Mekong River Basin should take into account the combined effects of all the possible anthropogenic interference in the basin and especially the cascade of reservoirs. In a very simplified way we could assume that the ecological hydrograph prescribed should be as much as possible like the nature hydrograph. Thus, the flow upstream and downstream of a hydroelectric project should reflect the natural conditions of the river, without the possible flow-regulating effects potentially exercised by the dam.

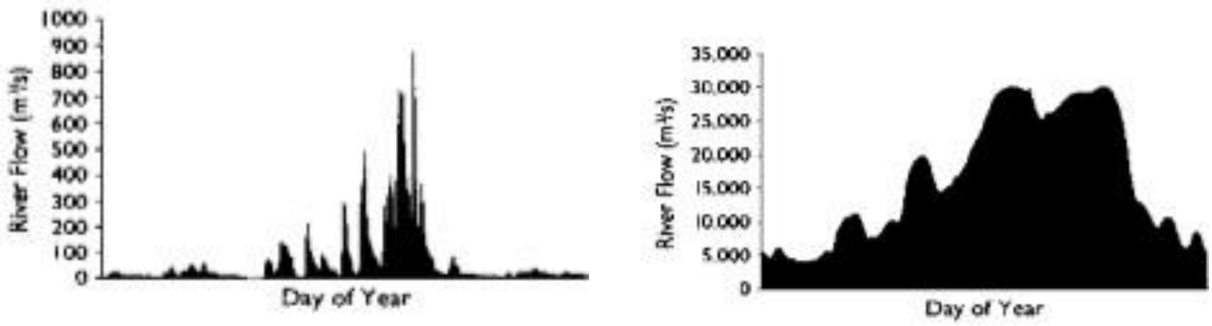


Figure 14: Examples of hydrograph of Nam-gang River, Korea (on left) and Mississippi River, USA (on right) showing the river's flow variations over the course of a simgle year (in: Postel & Richter, 2003).

For the Mekong Basin the unifying hydrological feature of the system is the river’s flood pulse, which sees the individual rainfall runoff events throughout the catchments coalesce into a stable and predictable hydrograph with distinct hydrological seasons (Figure 15l). For the LMB, it is the Mekong flood pulse which drives the river’s high levels of aquatic and terrestrial biodiversity and system productivity (Pak Lay TBESIA & CIA Final Report, 2014).

As the Mekong River enters Cambodia over 95% of the flows have already joined the river. From here on downstream the terrain is flat (Figure 15) and water levels rather than flow volumes determine the movement of water across the landscape. The seasonal cycle of changing water levels at Phnom Penh results in the unique “flow reversal” of water into and out of the Great Lake via the Tonal Sap River.

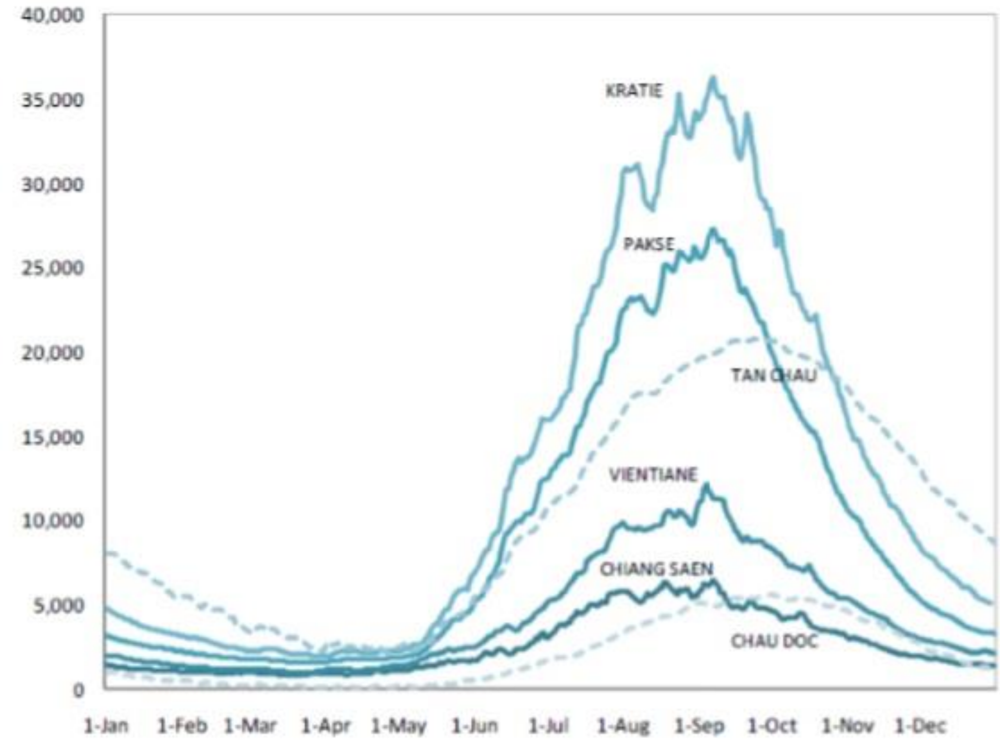


Figure 15: Average daily flow hydrographs for the Mekong River ffor the MRC Baseline (1986-2000). In: Pak Lay TBESIA & CIA Final report, 2014.

The simulated flow with Pak Lay HPP using the SWAT model was compared with the baseline flow in 2010 at 6 stations and it showed clearly that the Pak Lay HPP will have a substantial impact on the natural flow regime of the mainstream river. This new dam will store and release water in the wet season reducing flood peaks and, significantly, will cause increased flows during the dry season. These changes will result in an increase in dry season flows at Kratie of 20% on average. In contrast, wet season discharges will reduce by about 4% on average (Pak Lay TBESIA & CIA Final Report, 2014).

In the same document, it is also reported that *operation of the mainstream dams can cause significant downstream fluctuations during any one day if they are operated as peaking projects. In this case, water level fluctuations locally may amount to typically 2-4 m or more in extreme cases. The mainstream dams are generally sized and sited at intervals where the backwater effects of one reaches close to the next. Thus, although they may have a small effect at basin-scale on flow volumes, water levels will be significantly affected both up and downstream of their sites. The attenuation of flood season flows due to increasing amounts of storage envisaged within the basin under the different storages would have a consequential effect on year-to-year average flooding. The total area inundated by the mainstream flooding in an average hydrological year reduces from 4.76 Mha to 4.45 Mha (-7%) going from the Baseline to the LMB 20-Year Plan Scenario. In percentage terms, changes are biggest in Thailand (-21.8%) and Lao PDR (-18.6%), are moderate in Cambodia (-6.5%) and small in Vietnam (-0.9%). In a dry year changes in Lao PDR and Thailand are smaller, only about 3%, in Cambodia bigger (-9%).*

The Peaking operation with maximizing turbine discharge may increase the rate of fluctuation of water levels. The 3-6 m fluctuation may reach to the downstream communities located 40-50 km away from the dam. Case of unplanned and emergency releases these peaking events, the impacts may be larger like 100 km (Pak Lay EIA Final Report, 2014). A diversion of water in different stages will be applied to minimize downstream water supply impacts.

In a broader context, the TBESIA & CIA report argues that *the large storage dams on the Lancang, the existing LMB tributary dams, and Pak Lay dam, operated primarily for power generation in response to fluctuating demand, will alter mainstream river flows substantially along its length by reducing wet season flows and increasing dry ones. However, the inevitable and irreversible flow changes will have substantial impacts compared with the Baseline Situation. These include a reduction of wetlands, reduced flow reversal into Tonle Sap and reductions in sediment flows causing long-term irreversible riverbed incision and bank erosion, with consequent impacts on the Deltashaping processes. Reduced sedimentation will occur within a decade, with consequences for reduction* *of valuable wetland and agricultural productivity as well as for the discharge of sediments and associated nutrients to coastal waters which may affect marine fishery production.*

The mitigation measures proposed aim to minimize impact due to construction such as planting of vegetation after soil excavation and construction of sedimentation pond at the construction site. Some measures are also proposed for the operation phase, but it is weighted that mitigation on damage is a complex issue and all options including changing the operation of reservoir projects must be compared with each other to identify the most efficient solutions.

In the Pak Lay EIA Final Report (2014) there is an only reference to the environmental flow assessment as a pre-construction activity to provide the data for developing a hydrological model for filling the reservoir that maintains environmental integrity.

Thus, we emphasize that developer must fully inform the methodology to be used for the environmental flow assessment for the phases of implantation and operation of the project. This would be a major initiative to boost the treatment of this issue more broadly, as proposed below by the Pak Lay EMMP Final Report (2014):

With the development of schemes similar to the Mekong Pak Lay Hydroelectric Power Project either on tributaries of the Mekong mainstream, there exists an opportunity for coordination and management of the waters and of the watershed in the basin as a whole. Without such planning there is a real possibility that any individual facility on the Mekong could result in shortages of flow at certain times followed by excessive flows at other times. Coordination can add greater value to the environmental flood flows of each individual Mekong River dam site and be used to maintain ecosystem services such as recharging groundwater in the flood plain and triggering fish migrations.

Coordination in watershed management can develop a more consistent application of management techniques, provide a shared learning experience and spread the economic benefits over the whole basin rather than on isolated sections of the watershed. Also, co-operation in addressing the issues of an even greater loss of the river fishery should exist between all of Mekong River development projects as this will be more productive than individual initiatives.

6.2.4.2 Sediments

Sediments strongly characterize the morphological structure (morphology) of rivers. Further, they influence water quality regarding physico-chemical aspects (including nutrients) and also the ecological status. Rivers carry important nutrients (nitrogen and phosphorous) of which about one to two thirds are attached to fine sediments. A functioning nutrient balance – that is linked to the sediment balance – is crucial to sustaining riverine ecosystem health and services as well as biodiversity (MRCS, 2011).

Changing hydrology and sediment flows resulting from the dams in China and the tributaries will alter the river morphology and the productivity of different parts of the river channel in the mainstream. Raised dry season water levels and decreasing sediment coming down the river will tend to reduce the diversity and productivity of the Mekong mainstream (SEA Final Report, 2010).

The sediment of the Lower Mekong River Basin (LMRB) has critical implications for aquatic ecology; fisheries, agriculture, water supply and river navigation. However, in comparison with other large rivers (such as the Yangtze River and the Yellow River), studies on the sediment generation, transportation and deposition in the LMRB are sparse (Pak Lay EIA Final Report, 2014).

According to the developer, *the sediment accumulation within the reservoir is not expected to be a major issue since the dam gates will be opened during floods, allowing the river flow to recover a quasi-pre-impoundment state. It is consequently assumed that the major part of the bed-load will be able to move throughout the reservoir and pass the dam. However, the movement of sediments may be somewhat affected and while the majority will pass the structure it is expected that some may accumulate in front of the dam. The dam has been provided with a series of low opening gates that are intended to flush sediments away from the turbine intakes. When these are operated it is likely that there will be a flush of sediment through to the downstream aquatic environment. The consequences of this have been recognized in the MRC publication on Preliminary Design Guidance and a section is devoted to management of sediments released from run-of-river dam sites.*

In the PDG there are some possible sediment management measures that may be employed to avoid or mitigate these potential impacts depending on the specific situation, among them:

- ✓ Operating the dam to transport as much of the sediment load as possible downstream by maintaining a high sediment transport capacity during the period when the sediment concentration and discharge are highest.
- ✓ Sediment bypass channel to convey sediment around the reservoir and discharge it downstream. This means releasing sediment laden water and impounding sediment free water.
- ✓ Re-mobilizing previously deposited sediment and flushing it downstream of the dam. This is only feasible if river-like flow conditions can be recreated in the reservoir by drawing down the water surface elevation using a low-level spillway that has the ability to pass free surface flows at very low elevations at the dam.
- ✓ Sediment increase introducing sediment into the river to replace that trapped in a reservoir upstream and so reduce the extent and intensity of adverse impacts caused by 'sediment hungry' water.

According to the SEA report (2010), the LMB mainstream dams fundamentally affect the integrity and productivity of the Mekong aquatic system by: (I) permanently inundating the majority of the river's aquatic habitats, (II) serving at the local level the seasonal distinctions of the river hydrology, and (III) cutting the transport of sediment and nutrients between the upland areas and the floodplain.

The strategy of sediment management is not properly addressed for the Pak Lay project in relation to the MRC requirements. However, in the TBESIA & CIA Final Report (2014) there are some recommendations very well described and justified that could fully complete the PDG. The recommendations include:

- ✓ Modification to Dam Design;
- ✓ Modifications to operations;
- ✓ Modifications to the Monitoring Program

Thus, we strongly recommend the implementation of these measures, as described in the mentioned document, as a way to tailor the MPLHPP to the best practices in order to reduce local and transboundary effects of the project regarding maintenance of sediment flows.

We would like to emphasise that basic information about the design and functionality of the plant structures related to discharge of sediments and spillway releases shall be provided in the EMMP to facilitate analysis of this issue. The goal is to demonstrate that the water flows and sediment flush (which carry associated nutrients) will be maintained to meet the downstream ecosystem needs.

In the SEA report (2010) there are some recommendations relating to this topic:

- Monitor passage of fine sediment and associated nutrients down the system, including in the Mekong Plume.
- Monitor fish catches and aquatic ecosystem health upstream and downstream of dams and in reservoirs.
- Assess discharge of effluents that may affect reservoir water quality and develop treatment.

Monitoring the sediment and nutrient loads to downstream should be done in the construction and operation phases. In the interim stage of this review, Developer has informed that in the ESMMP-CP and ESMMP OP at later stage will be mentioned that Monitoring the sediment and nutrient loads to downstream should be included in the monitoring plan. In this way, we recommend that the monitoring protocol should be provided in next step.

6.3 Conclusions

The Pak Lay Environmental and Social Impact Assessment – ESIA is in general well prepared regarding to description of physical and biotic conditions in the Project area, environmental regulatory framework, baseline data and field surveys for the environmental aspects. The assessment took into account international standards as well the national and regional standards as much as possible.

The EMMP presents 17 sub-plans comprising a wide range of activities and mitigation measures in several areas, primarily focused on the construction phase.

However, for the operation phase the issues related to water quality and aquatic ecosystem are poorly addressed in the developer's documents in relation to the requirements of MRC's Preliminary Design Guidance and to the wide range of measures proposed by the SEA Final report (2010). The documents have some basic studies, but fail by lack of insufficient detail of the measures that can be taken to prevent or mitigate the environmental, transboundary and cumulative impacts. So a minimum scope of activities should be addressed for the operation phase in order to comply the PDG.

6.3.1 Recommendations regarding water quality and aquatic ecology issues

In a runoff hydropower project, if the reservoir level is constant, the flood pulse upstream from the dam is harmed and impact the aquatic ecosystem. At the same time, the regulation of the water level by dams affects the downstream ecosystem. As result:

- ✓ The flood pulse does not occur or undergo drastic changes.
- ✓ Sedimentation increases the transparency of water and affects the biological communities.
- ✓ Clear waters also favor the proliferation of submerged weeds, which in excess can impair the operation of the power plant.

The cumulative effects from the Mekong Pak Lay Hydroelectric Power Project, as well of other HPP along the Mekong River, will be felt downstream in Cambodia down to the Tonle Sap and even down to the delta in Vietnam. Migratory fish have been shown to come from both of these parts of the river in to the upper Mekong system.

The cumulative impact is addressed as a long term impact in the Pak Lay EIA Final Report (2014) and the mitigation measures include:

- ✓ *Cooperation between hydro projects and governments.*
- ✓ *Maintenance of river's flow regime through proper dam design and operation.*

The proposed mitigation measures for the impact on fishing include:

- ✓ *Implement a Fishery research center that will monitor fish species and quantities.*
- ✓ *Implement a fish hatchery program that will raise and release important fish into the project area.*
- ✓ *Design and install a fish pass that meets or excedes MRC's guidelines.*
- ✓ *Institute conservation measures and management*.

Developer says that *transformation of the habitat from a river with rapids into to standing ecosystem due to impoundment will not occur for MPLHPP due to the run-of-river design. Fish species which live in running water habitat will not be negatively impacted to the new conditions. There are number of species which appear in schools such as Henicorhynchus spp. Cirrhinus spp. with a short life span and a fast rate of reproduction; normally their abundance in the catch appears to follow the level of floods from the upstream.*

The creation of a barrage without any reservoir stagnant effects will improve the overall natural fish production capacity of the Mekong River in the project area, especially in the dry season; based on the information of the water quality and the existing aquatic organisms, species diversity and their quantities, a positive impact on fish biomass will occur for species that do not have long distance migration patterns. The increasing volume and regulation of the water level would be a benefit for many aquatic living organisms.

But the same document argues that *operation of project will cause changes to freshwater ecosystem, altering flows, interrupting ecological connectivity, and fragmenting habitats. This will adversely affect fisheries, aquatic biota and aquatic biodiversity.*

There are, therefore, contradictory and mistaken information that not objectively contribute to meet the MRC requirements. This should be reviewed and corrected in the EIA report

Another important factor influencing the aquatic ecosystem is the occupation and land use pattern in the river basin. The land use pattern in the coverage area of Pak Lay HPP is well characterized in the Pak Lay EIA Final Report (2014).

The latest satellite image map (forest cover map) indicates that most of the area along both sides of Mekong river were covered by the unstocked and bamboo forests; only a small portion was covered by mixed deciduous forest (MD) and dry dipterocarp forest (DD). Apart from these there are some small portions of swidden (Ray), rice paddy field and also grassland especially where the area is quite flat and easy to access not only along the rivers but in the upper area as well.

Rivers are dominated by geomorphology and hydrological factors of the watershed, and the riparian vegetation contributes significantly to the maintenance of adequate physical-biotic conditions of river ecosystems.

The preservation of existing vegetation and planting of native species in areas already devoid of vegetation around the reservoir can effectively protect the water body against erosion and anthropogenic pollution from surrounding areas. Moreover, the riparian vegetation helps maintain productivity in the aquatic ecosystem and provides biodiversity conservation. We suggest to establish a belt of 100m wide of protected riparian vegetation in the not flooding area around the whole reservoir.

Preserving the tributaries in the area of influence of the HPP is also very important to keep at least part of the integrity of aquatic ecosystems. The tributaries generally have important wetlands for fish reproduction and own environmental characteristics or species that can do not occur in the mainstream. So its preservation could have a significant effect for conservation of biodiversity.

Changes suffered by an aquatic ecosystem due to nutrient loads can be monitored through trophic status indicators. Trophic status is an important property of the aquatic ecosystems as it reflects the anthropogenic influence on water quality and the ecological functioning of rivers, lakes and reservoirs. Trophic status indexes provide an insight on how nutrient and light availability controls phytoplankton development. One of the most used is the Carlson index (1977), which relates total phosphorus, chlorophyll *a* and transparency of Secchi disk. However, these indexes were developed for temperate environments and their results should be interpreted with caution in the tropics. Some authors have developed modifications to better adapt the Carlson index to tropical region.

The monitoring of water according to Lao Environmental Standard: "Agreement on the National Environmental Standards, 2009 – No 2734 /PMO.WREA" is planned for the construction phase as a short term impact, but this action must be extended to the operation phase (long term impact), including phosphorus among the parameters to be monitored. In the National Standard, the concentration of phosphorus is prescribed for General Industrial Wastewater Discharge Standards, but we recommend including this parameter also for monitoring of surface water quality.

The main parameters of Water quality that should be permanently monitored are:

- ✓ Temperature
- ✓ pH
- ✓ Dissolved oxygen
- ✓ Biochemical oxygen demand
- ✓ Total nitrogen
- ✓ Total phosphorus
- ✓ Total solids
- ✓ Transparency (Secchi disc depth)
- ✓ Chlorophyll-a
- ✓ Coliforms
- ✓ Harmful substances

We also recommend that monitoring should cover not only the physical and chemical parameters, but also some biological parameters such as macroinvertebrates, phytoplankton, zooplankton and macrophytes, and fish, in order to fully attend the issues of the MRC Preliminary Design Guidance for Proposed Mainstream Dams in the Lower Mekong Basin (PDG).

6.3.2 Proposed basic scope for water quality monitoring program

A comprehensive plan for monitoring physical, chemical and biological parameters in the water should be proposed for all stages of the project. The monitoring protocol must be comprehensive in time and space, including samplings upstream, downstream and at dam site, starting before works and extending through the construction and operation phases.

6.3.2.1 Temporal span

Long-term study starting as early as set the start of work. During construction phase, the sampling should be monthly or weekly according the MRCS (2011). For the operation phase should be recommend monthly in the first three years of conception and quarterly after that depending on the previously observed behavior.

6.3.2.2 Spatial span

Sampling upstream and downstream from the dam site before and during the construction phase. For the operation phase, it should be recommended sampling at least three sites arranged along the main body of reservoir (near the dam, middle and beginning of reservoir), in attempt to cover the possible longitudinal gradient usualy observed in large reservoirs (Thornton et al., 1990). One site in the backwater and one downstream of the dam should also be included in the monitoring protocol.

Take at least temperature, pH and dissolved oxygen each one meter in the water column to check the possible occurrence of seasonal thermal or chemical stratification. This can easily done with a multiparameter sounder.

For the other parameters, sampling can be done each station in two points in the water column: photic zone and aphotic zone.

In the interim stage of this review, Developer has informed that all water quality monitoring parameters will be identified in SESO and in ESMMP-CP and ESMMP-OP when the detail programme shall be written and implement at those stages. Now the develop is committed to do and allocate the sufficient budget.

We agree, but this information should be included in the ESIA emphasizing that monitoring protocol will be provided in next step.

6.3.3 Environmental flows

The main concern of MRC guidance on the aquatic ecosystem refers to the maintenance and monitoring of environmental flows to ensure the flow of nutrients and ecosystem's health. Thus, this issue should be managed and evaluated permanently.

The effects of projects in cascade are cumulative and sometimes the efforts of each one alone are not enough to obtain the expected benefits of the environmental flow. However, it is very important that every hydropower project do your part independently of the others, because the sum of individual efforts can contribute effectively to the achievement of better results in the context of the cascade.

The creation of a national office to coordinate the discharges of each HPP focusing not only on the issue related to electricity supply, but also for maintaining the environmental flows can be a solution to properly manage this issue. Accordingly, it is necessary to maintain a dialogue with the HPPs of the Lancang and take into account the needs of the stretch downstream, especially for the Tonle Sap region.

Due to the morphometric characteristics of the Pak Lay reservoir the processes of material accumulation and sediment transport should occur predominantly in the longitudinal axis.

The maintenance of flow pattern during the filling period is addressed in the Pak Lay EMMP Final Report (2010) as follows:

To prevent degradation of aquatic habitats and loss of ecosystem integrity during the filling period, it is essential that a seasonal flow pattern that resembles the normal flow regime in the river downstream of the dam site is maintained. Environmental flow studies should be carried out during the first two years of the construction period to develop knowledge about appropriate flow regimes necessary to maintain the health of the river, its ecosystems and its productivity. This should be agreed between the developer and provincial authorities in consultation with local communities dependent upon the river. The release of the agreed seasonal flow regimes during the filling period should be facilitated through variation of the flows through the bottom release outlet and through the diversion tunnels.

However, the levels in the reservoir will vary depending upon the season and usage of the water for power generation and this could result in variation in height of the river levels downstream of about 0.5 - 1 m during the day. The ESIA assumes that there can be no mitigation of this effect on the environment, but only for river users. So, to fully complete this issue it is necessary to provide additional mitigation measures or change the operation routine of the HPP so as to maintain flows the closest possible of the natural river hydrograph.

Regarding the Pak Lay HPP, the developer must provide a study using consistent methods of environmental flow assessment for the operation phase.

Developer has informed that EFA will be done further study after CA and before impoundment.

The updated flow assessment the technical team should be provided and add in the ESIA report, but the implementation plan should be done at each stage. The ESMMP-CP and ESMMP-OP will need to identify the detail work to be implemented and approved by MONRE.

Accordingly, we recommend that the measures and recommendations are provided in the updated version of the ESIA regardless of the stage where it will be implemented. The EFA must take special account of the provisions of topic number 164 of the PDG:

“Because the proposed mainstream dams are run-of-river with peaking or daily operation cycles for hydropower generation, the focus of the EFA would be on systematically looking at the localized impacts on river morphological processes, erosion and bank stability and aquatic ecosystem functions, as well as impacts on natural habitat such as riverine wetlands, fish habitat and related social and livelihood aspects.”

There is an excessive focus on Pak Lay EMMP regarding the control of downstream sediment flow. This is really important in the construction phase. However, the PDG recommends that the project should allow the free flow of sediments transported by the river course. So it is important to clarify in the EMMP how will be the management of sediment discharges to maintain the health of ecosystems downstream, which need of nutrients associated to sediments. It is important to take into consideration that the dam must pass sediment as much as possible.

6.3.4 Management

In the case of Pak Lay HPP, more than the implementation of the hydropower project, the conservation of water resources and its environmental, social and economic benefits demand an integrated planning for the development of several actions to protect the catchment basin in order to avoid deforestation along watercourses, order the urban occupation, promoting sustainable agricultural practices, prevent soil erosion and contamination of water by waste from various sources.

The Pak Lay EMMP Final Report (2014) proposes the formation of the Mekong River Basin Organization to manage these resources and to coordinate the Mekong schemes, recommending to the Government of Lao PDR to demonstrate the best practice and efforts to maintain ecosystem services. The sharing of information about flows and developments on the Mekong should be one of the functions of the Mekong River Basin Organization with counterparts in Cambodia, Thailand and Vietnam through the Mekong River Commission.

This could be a very good and important measure for implementing actions to control potential environmental damages on the Mekong basin as a whole regarding the hydropower projects and mitigating impacts of cascading reservoirs.

The institutional arrangement of environmental management proposed in the EMMP and creation of the Environmental Management Office (EMO) by the Company should provide an appropriate framework for implementation the necessary mitigation measures.

As set forth in topic number 165 of the MRC Preliminary Design Guidance for Proposed Mainstream Dams in the Lower Mekong Basin (2009), developers should utilize a core group of independent international experts to assist with the design and implementation of water quality compliance monitoring programmes and environmental flow assessment and provision, with all expenses covered by the developer.

Finally, under our understanding, the run-of-river dams on the mainstream should be prioritized in relation to projects in tributaries. The plants in the main river can usually generate more energy with less environmental impact, considering that the impoundment in tributaries often produce larger flooding involving important ecosystems most often with unique features for the maintenance of biodiversity and aquatic life in the Mekong River Basin.

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6.5 Appendix - Table of compliance

No.	Issues of the 2009 MRC Preliminary Design Guidance for Proposed Mainstream Dams in the Lower Mekong Basin (PDG) regarding Water Quality and Aquatic Ecology	Status concerning compliance (Compliant, Possibly compliant, Not fully compliant, Not compliant)	Consultant's Comments	Answer / Adress of the issue by the developper	Consultant comments	Update of compliance status
Background						
141	Hydropower operations influence temporal flow patterns of rivers, which in turn, can influence instream water quality and the health, functioning and productivity of riverine ecosystems and flood plain ecosystems.	Not fully compliant	Actions for maintenance of flow pattern during the filling period are planned in the EMMP. However, the levels in the reservoir will vary depending upon the season and usage of the water for power generation and this could result in variation in height of the river levels downstream of about 0.5 - 1 m during the day. The ESIA assumes that there can be no mitigation of this effect on the environment, but only for river users. So to fully complete this issue it is necessary to provide additional mitigation measures or change the operation routine of the HPP so as to maintain flows the closest possible of the natural river hydrograph.	The fluctuation of water level at downstream is depending on the operation routine of the project. We agreed that the maintain flows the closest possible of the natural river hydrograph is important. The project will need to monitor regularly. The developer will need to keep monitor the flow in the Mekong River as mentioned in the FS.		Compliant

142	Healthy riverine ecosystems support the livelihoods of many people living along the banks of Mekong River (e.g. nutrition and income). At the same time they provide a variety of “ecosystem services” that contribute to water resource and water quality protection. River floodplains, wetlands and riparian vegetation trap silt and nutrients, provide fertile soils, and protect the upland areas from flooding and erosion. The regulation of river flow affects the complex food-web and aquatic ecosystem dynamics that support fish productivity, especially changes in flow pulses.	Not fully compliant	Worth the same comment above. Also follow the guidelines of SEA (MRCS, 2010). Review, survey and classify aquatic habitats in whole Lower Mekong (biodiversity and ecological importance): • Identify key biodiversity hotspots on Mekong mainstream • Prioritise key tributaries for ecosystem integrity and health of the Mekong, highlighting those affected by proposed mainstream dams • Leading to identification of a system for protection of key stretches of the river and its tributaries. Assessment of the ecological importance and productivity of the seasonally in-channel wetlands.	Refers to Stanards Environmental and Social Obligation (SESO) as will be annex of CA the project developer will need to do the ESMMP-CP and ESMMP -OP as to be tool for monitoring of Envoronmental and Social at each stages. The aquatics system will be monitor as longterm of the project, but we recommend that we should have consitency in process and data collection system of all cascades.	This recommendation should be included in the FS or ESIA	Compliant
143	Impacts on dams on riverine water quality and aquatic ecology are interrelated. The degree and significance of the impacts depends on many factors, especially the volume	Possibly compliant	These impacts tend to be small in runoff river dam. The land use on the areas that are covered by the proposed reservoir is well characterized in the ESIA. The Watershed Management Plan (WMP) addressed this issue satisfactorily in the EMMP.	Since the project is run off river dam the land use will not major and no need to do much biomass clerance.		Compliant

	of the reservoir impoundment in relation to river flows, water retention times and the depth of the impoundment and the patterns of land use in catchments.					
144	The focus of this guidance is the current proposals for a series of low-head dams that would span part of, or the entire mainstream channel in the Lower Mekong Basin. The changes to water quality in the long reservoirs that will be formed behind these dams (mainly in the existing river channel) may be less than changes that might occur in large, deeper storage dams, such as those in the Lancang-Mekong portion of the basin in China. This is due to the short retention time of the water in the proposed impoundments of the mainstream dams in the lower basin (expected to be in the range of about four	Not fully compliant	According to developer the reservoir will not act as a storage reservoir and will have a very short residence time which will be only slightly longer than the pre-impoundment condition. However, we must consider that the reservoir will be relatively deep (about 40 meters) and therefore only the short residence time does not rule out the possibility of stratification. The operation in order to simulate the natural flood pulses with seasonal variations around 4 to 5 meters in the reservoir water level, if possible, would contribute to promote mixing in the water column and prevent thermal or chemical stratification.	Throughout the water quality monitoring in the operation phase the project will be able to find exact mitigation but for the recommendation from expert the project will need to considered accordingly. The update ESIA will be identified the possible stations to monitor.	During the workshop held in September the developer reported that the reservoir will operate between the elevations 239 and 240 m, such that the generation stops below the level 239. Therefore, it becomes unfeasible our recommendation to promote seasonal variation in the water levels. The monitoring program to be presented must be able to properly assess the water quality and propose possible	Compliant

	days). But it also depends on the amount of mixing that occurs between water column above and below the dead water levels and the number of dams.				mitigation measures	
145	Potentially, the more significant impacts of these dams will be related to physical and chemical water quality parameters (such as in relation to sediment concentrations in water released from the dam), which will impact on downstream aquatic ecology and the associated river morphology that results in aquatic ecosystem habitat changes.	Possibly compliant	Worth the same comment of previous item. According to the EIA, run-of-river systems will have little overall impact on altering the sediment discharge with some expected build up of rapidly settling sediments at the top of the reservoir. Fine suspended sediments will probably continue as before with little settlement in the reservoir due to the short residence times. However, as the dam will operate as a cascade the overall impact on sediment being retained within the cascade system will be enhanced and this may result in larger amounts of sediment being stored within all reservoirs which may only be mobilised when the river returns to its pre-existing situation during floods when all the dam gates are open. Monitoring the sediment and nutrient loads to downstream should be done in the construction and operation phases.	In the ESMMP-CP and ESMMP OP at later stage will be mentioned that Monitoring the sediment and nutrient loads to downstream should be included in the monitoring plan.	The monitoring protocol should be provided in next step.	Compliant

146	Water related diseases should be foreseen and prevented at all potential dam sites in the mainstream. A particular concern is the known presence of the parasitic and eye disease schistosomiasis, at the proposed locations of the Ban Koum, Lat Sua, Don Sahong and Stung Treng projects.	Not fully compliant	Data of possible occurrence of schistosomiasis in the project area should be provided.	We have done the HIA and we have collected the samplings in the sites (we have some data in the report) , in the construction phase and operation phase the Department of Decease Control from Ministry of Health will work with project to monitoring the health and safety within hte project area.	To be monitored including biological parameters.	Compliant
Water Quality						
147	Water quality is one of the environmental factors to be considered as part of the project-specific EIAs. Water quality parameters to be considered are generally cited in national regulations and include temperature, concentration of dissolved oxygen, PH, phosphorus, nitrogen, biological oxygen demand and faecal coliform bacteria concentrations.	Not fully compliant	Monitoring of water according to Lao Environmental Standard: "Agreement on the National Environmental Standards, 2009 – No 2734 /PMO.WREA" is planned for the construction phase as a short term impact, but this action must be extended to the operation phase (long term impact), including phosphorus among the parameters to be monitored. In the National Standard, the concentration of phosphorus is prescribed for General Industrial Wastewater Discharge Standards, but we recommend including this parameter also for monitoring of surface water quality in order to fully attend this issue of PDG.	Base on Lao's and regulation the project must monitoring regularly the water quality throughout the concession period which in clude construction and operation. The project has allocated the budget for this work. The monitoring will be conducted by Environmental Office of the project and report to the GoL and it may random check by GoL.	Monitoring of phosphorus concentration should be included even it is not demanded by Lao standard.	Compliant

148	Overall the water quality and the ecological heath of the Lower Mekong River Basin in its present unregulated state ranges from high to good quality (See MRC Technical Paper no. 19 and MRC Technical Paper no. 20). The MRC Procedures on Water Quality and the associated Technical Guidelines that are currently under development express the wish of Member Countries to maintain acceptable/good water quality of the Mekong River. The Technical Guidelines will provide criteria and thresholds to determine acceptable/good water quality considering the protection of human health as well as aquatic life. These standards would provide valuable guidance to assess river flows including run-of-river impoundments.	Not fully compliant	Provide a water quality ongoing monitoring plan not for only the construction but also for operation phase that should monitor the parameters mentioned in the previous item (147) and others required by Lao's regulations and MRC guidelines, including biological samplings.	We are agreed and we have allocated budget to do this work, the detail water qualty parameter will be identifie in SESO as part of Concession Agreement.	To be monitored by developer including biological parameters.	Compliant

Water Quality in Reservoirs						
149	Stagnant water in impoundments behind dams can lead to a stratification of the water in the reservoir during parts of the year, with cold water at the bottom and warmer water at the top. In deeper impoundments the temperature difference can be as much as 5-10 degrees Celsius. This stratification phenomenon generally occurs during the dry season and lasts until the onset of the wet season. [1] The measured average dissolved oxygen concentration in the running water of the Mekong mainstream is in the range from 5.5-8.5 mg/l (1985-2005 data). Generally, lower oxygen concentrations can be observed in stagnant water during the dry season with high temperatures, but very low and anoxic conditions rarely occur unless the water is	Not compliant	According to the Pak Lay EIA report the reservoir will not act as a storage reservoir and will have a very short residence time which will be only slightly longer than the pre-impoundment condition. The overall impact on water quality as expected from a reservoir that may develop thermal stratification will not occur. Our concern is that the reservoir will be about 40 m deep and it is not possible to say that stratification will not occur in the dry season. For that reason, it is strongly recommended developing an ongoing water quality monitoring program that should include the monthly taking of at least temperature, pH and dissolved oxygen each one meter in the water column for check the possible occurrence of thermal or chemical stratification along the reservoir. This can easily done with a multiparameter sounder.	All water qulaity monitoring parameter will be identified in SESO and in ESMMP-CP and ESMMP-OP the papramenter necessary will be take into the account. The ESIA has samplings as baseline data 2 season for future reference. We also recommended that the project should be do sampling before the construction starts. Since we have to do ESMMP-CP and ESMMP -OP the detail programme shall be written and implement at those stages. Now we have to make sure that the develop is committed to do and allocate the suffcient budget	This information should be included in the ESIA emphasizing that monitoring protocol will be provided in next step.	Compliant

	stratified such as in a deep impoundment.					
150	Another aspect of reservoir water quality is temperature alteration and variation which may affect fish species. Cold water released from the impoundment may affect organisms (e.g. affect fish species negatively and also pose the potential for thermal shock of irrigated crops if very cold water is withdrawn for irrigated agriculture with no provision for warming during conveyance).	Not compliant	Provide a monitoring plan to monthly measure temperature each one meter in the water column for check the possible occurrence of thermal stratification.	We are agreed that the water quality monitoring plan at each station should be put in detail to ensure that we have data. We will use National Standards for reference. Since we have to do ESMMP-CP and ESMMP -OP the detail programme shall be written and implement at those stages. Now we have to make sure that the develop is committed to do and allocate the suffcient budget.	This information should be included in the ESIA emphasizing that monitoring protocol will be provided in next step.	Compliant

151	Subject to designs, the mainstream reservoirs proposed in the Lower Mekong Basin may have weak, large-scale turbulence associated with the flow of water through the reservoirs (rapid transit time for all reservoirs, speed of movement in the range 0.1 to 1 m/s). This would enhance the likelihood of mixing from surface to bottom and impacts on dissolved oxygen concentrations. Developers would need to verify the expected conditions in the EIAs that are prepared for each project.	Not compliant	By the features of project it is unlikely to occur chemical stratification with anoxia on the bottom, but this can only be verified by monitoring the parameters in water column as mentioned above.	The best to adress this is issue we have to do monitoring water quality after impoundment. Since we have to do ESMMP-CP and ESMMP -OP the detail programme shall be written and implement at those stages. Now we have to make sure that the develop is committed to do and allocate the suffcient budget.	This information should be included in the ESIA emphasizing that monitoring protocol will be provided in next step.	Compliant

Aquatic Ecology						
152	Aquatic biodiversity and biodiversity in the riparian zones can be affected by impoundments for a range of reasons. The impoundment may block migration routes and lead to fragmentation of habitats (as discussed in Section 3). The hydrological changes and water quality changes may change habitats and the basis for ecosystems. The changes in hydrology, water quality and ecological conditions can change the ecological balance and pave the way for invasive and pest species affecting the biodiversity negatively.	Not fully compliant	Some mitigation measures for this issue are presented in the Pak Lay ESIA including the implementation of fish pass facilities. However, during the construction period, the blocking of migration routes and fragmentation of habitats between downstream and upstream the dam should be avoided. Developer should provide evidences that this will not occur, or propose mitigation measures if the dam structures do not allow the passage of fish while the fishpass facilities are not up and running. The implementation of an effective fish passage, as well the adjustment of reservoir operation according our comments in the items 142 and 144 can contribute to the conservation of biodiversity and thus reduce the risk of establishment of invasive and pest species.	During construction, the river will not totally block, the project will construct the Navigation Lock first then will allow the fish to pass on Navigation Lock. At the implementation stage all stakeholders will be monitored those mitigation and adjust plan from time to time to ensure the mtigations meet the real situation. Since we are aware of fish pass and the period of construction quite take sometimes and the expert should work and the EMO of the project should be setup and work.	The navigation lock is not only sufficient to maintain the fish passage during construction. We strongly recommend that additional measures are planned to prevent overfishing in that period and other possible negative effects on fish.	Not fully compliant
153	Changes in the hydrological variability caused by impoundments may affect ecosystems and natural resources depending on the seasonal variability. Requirements to	Not fully compliant	Even considering that the flow of water pass through barrage site in every season will be not changed, the implementation of complementary measures as recommended to the items 141 and 144 could fully meet this issue.	CNR was satisfied with Hydrological, Sediment from technical component.		Compliant

	provide a flow regime or the environmental flows downstream of the impoundment may help to mitigate these adverse impacts and risks.					
Environmental flows – downstream releases						
154	A family of techniques called Environment Flow Assessments (EFA) are rapidly becoming a legal requirement in many countries. EFAs are an emerging practice in the Mekong and Asia more generally. [1] An environment flow assessment enables the government, developers and all stakeholders to consider how much water needs to be provided within rivers to maintain freshwater ecosystems and wetlands and their benefits, as well as impacts on riverine livelihoods. A comprehensive EFA also considers the river flows required for all water uses, expressed	Not compliant	A study using an appropriate methodology for environmental flow assessment for the MPLHPP should be presented.	The EFA will be do further study after CA and beofre impoundment.	Explain in the ESIA report that EFA will be provided after CA and before impoundment	Compliant

	in terms of sufficient quality, quantity, timing and duration of river flows.					
155	It widely recognized that the allocation of water for hydropower operations must take into account other beneficial uses of water. Today there is increasing recognition that modifications to river flows also need to be systematically balanced with the maintenance of essential water-dependent ecosystems. These ecosystems include not just river fauna and flora, but also the floodplains and wetlands watered by floods, groundwater-dependent ecosystems replenished through	Not fully compliant	Except flow assessment, that should be provided by developer, the other economic, social and environmental issues are well addressed in the Pak Lay ESIA. However, the implementation of other recommendations aforementioned can improve the compliance to this issue.	The updated flow assessment the technical team should be provided and add in the ESIA report, but the implementation plan should be done at each stage. The ESMMP-CP and ESMMP-OP wiil need to identify the detail work to be implemented and approved by MONRE	The important thing is that the measures and recommendations are provided in the updated version of the ESIA regardless of the stage where it will be implemented.	Compliant

	river seepage, and where applicable, estuaries. Flow assessments are becoming integrated with other tools such as EIA and water allocation planning for guiding decisions on sustainable water resource developments (balancing economic, social and environmental considerations) in hydropower development.					
156	Compensation and mitigation programs can also be developed on the basis of specific consideration of downstream issues, which are often different to upstream issues. Downstream impacts relate not only to the reduction in water flows, but also the associated transformation to the aquatic environment induced by the dam operation, including any daily and seasonal fluctuations in water	Not fully compliant	Measures to maintain the hydrograph as close to the natural conditions of the river during the various stages of implementation and operation of the project would meet fully these issues. The performance of the Environmental Management Office (EMO) should remain focused on this question	The project EMO will use EFA as tool to maintain the hydrograph as close to the natural conditions of the river during the various stages of implementation and operation of the project and the hydrological data will be kept record for monitoring. The ESMMP-CP and ESMMP-OP wiil need to identify the detail work to be implemented and approved by MONRE	This should be mentioned in the updated ESIA report	Compliant

	levels. [1] Downstream issues that may form part of the compensation and mitigation programs for riverine resource losses may include reduction in fish, vegetables, vegetation, animal forage, firewood, timber for other uses and water supply for people, livestock and other uses from direct and indirect changes in the amount, quality, and timing of flows.					
157	It is important to incorporate instream flow (environmental flow) considerations appropriately at all project stages (design, implementation, operation and monitoring). Good practice is to introduce the EFA concepts and methodologies at the EIA stage, either as a parallel study to inform the EIA, or as a sub-component of the EIA.	Not compliant	To be addressed by the Developer as suggested in previous items	The EFA will be done further study after CA and before impoundment.	This should be mentioned in the updated ESIA report	Compliant

Monitoring						
158	The monitoring program for water quality and aquatic ecology (identified in environmental flow assessment or as part of the EIA) must be designed in compliance with national standards and maintain appropriate communication with concerned local governments, municipalities and agencies and downstream communities. This is important to enable stakeholders to provide essential feedback on whether: • that targets specified in the monitoring programme (e.g. for water quality, wetlands protection, river morphology, impacts on fish habitat, etc.) are being achieved; • the agreed-upon flow regime is being provided, in this case recognizing the run-of-river nature of the mainstream projects,	Not fully compliant	Develop an ongoing program of monitoring water quality and aquatic ecology according the National Standards and MRC Guidelines. The water quality monitoring program must be implemented before the start of work and should be kept on the construction and operation phases.	We are agreed with recommendation, since we have baseline for water quality and aquatic ecology we will conduct the sampling before start of work, We also request the project developer to set up Environmental and Social Office to do and follow up this work.	This should be mentioned in the updated ESIA report.	Compliant

	the fact there may be peaking operation and taking into account the position of the dam in the potential cascade; and • the operation of the reservoir and water releases downstream needs to be modified in the light of the observed responses.					
159	Governments may also give consideration to requiring the dam owner to set aside contingency funds for additional water quality management measures, which may be identified as necessary based on the results of the water monitoring programme.	Compliant	No comment			Compliant

Guidance on water quality and aquatic Ecology						
160	General requiriments					
161	Optimization of operation of the reservoir to meet water quality objectives should aim to maintain sufficiently high levels of dissolved oxygen and sufficiently low levels of phosphorus, nitrogen, biological and oxygen demand. Criteria for optimization can be derived from the MRC Technical Guidelines for Procedures on Water Quality.	Not fully compliant	The proposed measures of cut, cleared and burnt the bulk of the vegetation in the reservoir area should mitigate the potential depletion of oxygen and eutrophication during and immediately after impoundment. However, we do not recommend the complete removal of vegetation. The submerged vegetation provides an opportunity for the development of organisms important to maintain biological diversity. A previous forest inventory and assessment of plant biomass can subsidize deforestation work and modeling of water quality.	The peoject as run off river dam, we are agreed with expert's recommenrdation. The next step we will work closely with Ministry of Agriculture and Forestry to addressed this issues before impoundment since we need to create another plan before impoundment which need to be agreed and approve by MONRE.		Compliant
162	Developers should consider the impact of the dam and operating policies of any cascade on the 1995 Mekong Agreement as regard to water levels. Developers should demonstrate the projects meet the Mekong Agreement requirements (in the EIA).	Compliant	No comment			Compliant

163	Minimum flow releases as well as restrictions on changes to natural variability need to be assessed using appropriate environmental flows assessment (EFA) techniques and approaches).	Not compliant	A study using appropriate methodology for environmental flow assessment for the MPLHPP should be presented.	The EFA will be done further study after CA and before impoundment.	This should be mentioned in the updated ESIA report	Compliant
164	Because the proposed mainstream dams are run-of-river with peaking or daily operation cycles for hydropower generation, the focus of the EFA would be on systematically looking at the localized impacts on river morphological processes, erosion and bank stability and aquatic ecosystem functions, as well as impacts on natural habitat such as riverine wetlands, fish habitat and related social and livelihood aspects.	Not fully compliant	For the full compliance of this issue, more data should be provided by complementary studies.	The EFA will be done further study after CA and before impoundment.	This should be mentioned in the updated ESIA report	Compliant

165	Developers should utilize a core group of independent international experts to assist with the design and implementation of water quality compliance monitoring programmes and environmental flow assessment and provision, with all expenses covered by the developer.	Not fully compliant	The amounts for environmental monitoring shown in Table 3 (EMMP) seem very modest considering the importance and needs of an adequate monitoring program, for both the construction and operation phases.	The EMMP in the FS will be baseline for further implementation at ESMMP-CP and ESMMP-OP , these reports will beed to be approved from MONRE months before the project phases commence.	This should be mentioned in the updated ESIA report	Compliant
Water quality monitoring						
166	The monitoring systems need to be designed to facilitate the optimization of hydropower operation with respect to water quality and ecological health. The MRC Water Quality Monitoring Network and Ecological Health Monitoring Network can provide the general trends and status of the water quality and ecological health, whereas monitoring of impacts of hydropower operations need to have targeted and	Not fully compliant	Implement the localized monitoring system according the MRC guidelines. We recommend that monitoring should cover not only the physical and chemical parameters, but also some biological parameters such as macroinvertebrates, phytoplankton, zooplankton and macrophytes, and fish	We are agreed, in our sampling we have collectd Species composition and abundances of benthic invertebrate animals in Mekong River for Sanakham and Pak Beng as well and we did into 2 seasons. We will write the recommendations for the independent review of flow release regime that should be detailed in the next steps. The project developer should be aware of the budget to cope with this issues therefore the specifc TOR must be identify in ESMMP-CP and ESMMP-OP.	Details to be provided. Monitoring should include also some biological parameters.	Possible compliant

	localized monitoring systems.					
167	The monitoring and monitoring programme normally required as part of the Environment Management Plan (or environment mitigation and monitoring plan) should be funded by the developer for the construction phase, and the owner full duration of the concession period.	Compliant	Extend the monitoring plan for the concession period.	Agreed		Compliant

Environmental Flow assessment and provision						
168	Developers should systematically assess the effect of combination of flow releases from the dam to address downstream impacts at different times of the year, also taking into account the position of the dam in the possible cascade series of dams. This should be done by introducing appropriate environmental flow assessment methodologies at the EIA and feasibility study stage, appropriate to the scale and significance of the flow changes, and referring to good practice techniques and methodologies.	Not compliant	The developer must fully inform the methodology to be used for the environmental flow assessment for the phases of implantation and operation of the project	The EFA will be done further study after CA and before impoundment.	This should be mentioned in the updated ESIA report	Compliant

169	At the detailed design stage, the environmental flow regime would be established for average and low hydrology years (flow regime of quantity, quality, duration, and seasonality). An integrated approach should be used that takes into account the combined effect and coordination of water releases for electricity generation (i.e., turbine releases) sediment management (i.e., flushing, density current venting, etc. through low level outlets or partly open spillway gates), navigation and fish passage, as well as the relative dominance or influence of spillway releases on downstream conditions.	Not compliant	Basic information about the flow regime related to all plant structures shall be provided in the EMMP to facilitate analysis of this issue. The goal is to demonstrate that the water flows and sediment flush (which carry adsorbed nutrients) will be maintained to meet the downstream ecosystem needs.	The updated hydrologigal data and sediment from technical component will be added in the report before get approval from MONRE.	Explain this in the ESIA report.	Possibly compliant

170	Developers should pay special attention to the possible the impact of rapid fluctuations in water levels downstream of the dam due to any daily releases for peak power generation and the ramping rates (hourly rate of change in releases, which in peaking operations, depends on how many generation units are brought on line at once, and how quickly).	Compliant	No comment			Compliant
171	Releases via the turbines and the spillway gates need to be ramped so change in water surface downstream (and upstream) is sufficiently slow to minimize adverse effects on downstream river bank stability and does not pose a public safety hazard. In particular, if the mainstream dams are proposed as peaking projects, with anticipated hourly fluctuations in water flows, it will be important to find	Compliant	No comment			Compliant

	agreement on satisfactory rates of ramping.					
172	The environmental flow provisions and the monitoring arrangements should be incorporated in the Environmental Management Plan (EMP), or its equivalent, for both the construction and operation phases, which is to be reviewed and approved by the relevant national authorities.	Not compliant	More detailed assessment of the environmental flow provision should be provided by developer	The EFA will be done further study after CA and before impoundment.	This should be mentioned in the updated ESIA report	Compliant

Monitoring of environmental flow provision						
173	The developer and operator should ensure the environmental flow considerations are adequately reflected in the operating policies for the reservoir and sediment management strategy. Good practice is to adaptively manage the downstream releases from the dam based on continuous review of the monitored results in accordance with the environment management and monitoring plan (EMMP) for the operation phase, or its equivalent.	Not compliant	Follow the recommendations on section 6 of the TBESIA & CIA report, especially regarding sedimentation	The impoundment plan will be connducted and get approval from MONRE, therefore the environmental flow will be monitor and the project will be allocated budget for this task in the future. This need to be consistency monitoring with all dams in the mainstream.	This should be mentioned in the updated ESIA report	Compliant
174	The monitoring arrangements for environmental flows should be integrated with the overall environment monitoring system for the operations stage of the project that comprehensively incorporates impact monitoring of all parameters (e.g. sediment monitoring,	Not fully compliant	Adjustments in the monitoring programs are required.	The impoundment plan will be connducted and get approval from MONRE, therefore the environmental flow will be monitor and the project will be allocated budget for this task in the future.	This should be mentioned in the updated ESIA report	Compliant

	impact on wetlands, impact on fisheries habitat, impact on river morphology and water quality, and socio-economic aspects related to these effects, etc.).					
175	For the well-being of the natural aquatic downstream environment, the monitoring should provide an independent review of the flow release regime, including releases down the fish ladder and releases during daily cycling of the turbines for peak or daily generation and the daily water level changes. This should be reported, and submitted to government to check annually to ensure compliance with approved operating ranges.	Not compliant	The independent review of flow release regime must be provided in the monitoring plan	We will write the recommendations for the independent review of flow release regime that should be detailed in the next steps. The project developer should be aware of the budget to cope with this issues therefore the specific TOR must be identify in ESMMP-CP and ESMMP-OP		Compliant