COMPLIANCE REPORT

9A000248
August 9, 2011
Final

GOVERNMENT OF LAO PDR

Main Report

Xayaburi Hydroelectric Power Project
Run-of-River Plant

PÖYRY
Engineering balanced sustainability™

Preface

Contact

René Schmidiger / Knut Sierotzki
Hardturmstrasse 161, P.O. Box
CH-8037 Zurich/Switzerland
Tel. +41 44 355 5554
Fax +41 44 355 5556
http://www.poyry.com

Pöyry Energy AG

Table of Contents

Figures and Tables

EXECUTIVE SUMMARY

General

The Consulting Services Agreement for Compliance Review signed between the Government of Lao People's Democratic Republic and Pöyry Energy AG on 5 May 2011 asks for the following matters to be reported on:

- Whether the Owner (Xayaburi Power Company) has complied with and satisfied the Mekong River Commission (MRC) Design Guidelines
- Whether Government of Lao (GOL) and the Owner have taken into consideration the comments submitted by each of Mekong River Committee (MRC) member countries during the Prior Consultation (PC) process
- Whether the GOL and the Owner have complied with and satisfied the terms of the "Prior Consultation Project Review Report on the Xayaburi Project", dated 24 March 2011.
- Issues relating to the development, construction and implementation of the Xayaburi Hydro Power Plant (HPP) and any discrepancies, conflicts and the need for any changes thereto in connection with the comments by the Riparian countries.

The reviewed documents consist of:

The Feasibility Study, the Outline Design including drawings, part of the EPC contract, the Concession Agreement and Environmental documents like the Environmental Impact Assessment, Social Impact Assessment and the Resettlement Action Plan related to the Xayaburi project.

Concerning the Compliance with MRC Guidelines the following reports have been used as reference:

- Preliminary Design Guidance for Proposed Mainstream Dams in the Lower Mekong, August 2009, MRC
- Prior Consultation Project Review Report, including all annexes, MRC
- Strategic Environmental Assessment of Hydropower on the Mekong Mainstream Final Report October 2010, MRC
- Form for Reply to Prior Consultation Viet Nam
- Form for Reply to Prior Consultation Kingdom of Cambodia
- Form for Reply to Prior Consultation Thailand
- Comments by Lao PDR on the MRCs Technical Review Report of the proposed Xayaburi Dam Project

This document summarizes our findings and conclusions as follows.

Safety of Dams

Today a comprehensive dam safety concept is used for projects with a large damage potential such as dams with a large storage volume. It includes the following elements

a) Structural safety,

b) Dam safety monitoring,

c) Operational safety and maintenance, and

d) Emergency planning.

At the present stage of the project the structural safety is the key issue, while the other items will become of interest at a later project stage.

For the design of the Xayaburi dam project guidelines, design manuals and codes prepared by the

a) Technical committees of the International Commission on Large Dams (ICOLD),

b) US Army Corps of Engineers (USACE),

c) US Bureau of Reclamation (USBR),

d) American Concrete Institute (ACI),

e) ASTM, and others are used.

These guidelines, design manuals and codes are used for large dam projects in most parts of the world when no specific design documents are available such as in the case of Laos and the other ASEAN countries. In the Mekong basin only China is known to have special codes for hydropower plants, hydraulic structures and large dams.

In the design of large dam projects the possible hazards affecting the safety can be subdivided into natural hazards, man-made hazards, and hazards originating from the project and the local conditions, which are referred to as structural hazards.

However, in the design phase a review of the different hazards shows what measures should be taken, i.e. in some cases it is possible to eliminate hazards or the reduce them. This applies mainly to the structural and some of the man-made hazards. However, in the case of the natural hazards the structures have to be designed for these hazards. In the case of the Xayaburi project the main hazards from the natural environment are the flood and earthquake hazards, and the design has taken both such risks into account.

The standard structural design procedure (deformation, stress and stability analyses) used for dam projects includes the following load combinations:

1. Usual loads (dead load, water load from normal water level, silt load, uplift);
2. Unusual loads (dead load, flood water level, temperature effects, silt load, full uplift etc.); and
3. Extreme loads (static: probable maximum flood (PMF) water level, full uplift etc.; dynamic: usual loads plus safety evaluation ground motion).

For the flood design of the Xayaburi project, the following internationally accepted concept is used:

1. The PMF can be released safely without overtopping the concrete dam. In the case of embankment dam sections the PMF water level shall not exceed the top of the impervious core.
2. The power plant is out of operation when the PMF arrives.

3. The largest capacity gate is closed when the PMF arrives.

As the Xayaburi dam and reservoir are classified as a storage project with large damage potential, the dam and safety-relevant elements are designed for the worst earthquake ground motion to be expected at the dam site. Such projects are designed for the so-called Safety Evaluation Earthquake (SEE) ground motion. The SEE ground motion parameters are either determined probabilistically considering a return period of 10'000 years or they are determined deterministically using critical earthquake scenarios. In connection with the deterministic approach, at present investigation works are ongoing at site and at the wider site area to explore the presence of potentially active faults to be considered in the determination of the relevant design ground motions. The current investigations have not shown any evidence of an active fault at the site.

Navigation Lock System

The navigation lock system consists of a lock arrangement where ships are lifted or lowered in two steps. From downstream ships will reach the first lock gate through the approach channel. In the lower lock bay the water table can be lifted by max. 24 m from el. 236 m up to el. 260 m. Then the ships will pass the central gate and move into the upper lock bay, where they will be lifted by max. 19.5 m up to the prevailing upstream reservoir water level (el. 275 m) where they can leave the facility via the upstream approach channel.

The lock bays are 12 m wide and each of the bays has a useful length of 120 m, which allows passage of convoys of 10.8 m wide and up to 109 m long, as required of the MRC Design Guidelines. The planned time for a ship to pass the locks is about one hour, with a water rising respectively lowering speed in the locks of 1 m per minute.

The upstream and downstream approach channels are wide enough to allow large barges crossing with barges going in the opposite direction. Waiting areas are available both at the downstream and upstream entrance area, protected from strong spillway water currents. Some 800 m upstream of the lock the removal of an outcrop should be considered to improve the navigation access.

The design of the navigation lock system largely complies with the Preliminary Design Guidance (PDG) issued by the Mekong River Commission and is considered acceptable. But some design adaptations are required in the lock system including the emptying and filling system; these are however of limited extent and importance and these design adaptations can be done once the construction phase begins. In the original documents there was no provision for a second navigation lock system as required by the MRC guidelines. In the latest drawings received, the space and location of such a system is now being shown. It is located to the right of the planned current lock system, and the construction of that second system will go a long way toward solving any issues relating to navigation.

With the implementation of these adaptations the design will be in compliance with the MRC Guidelines for navigation.

Fish Passing Facilities

The present layout of the fish passing facilities comprise the following main structures: a facility for upstream migration, a fish passage recording system for upstream migration and a facility for downstream migration.

The layout of the upstream migration facilities is complex and so a short description is given of the main features. This system consists of the following main parts: several fish entrances, the collecting gallery, the spillway fish gallery, the junction pools (left and right), the water feeding galleries and the climbing canal including the fish pass exit.

See Figure below:

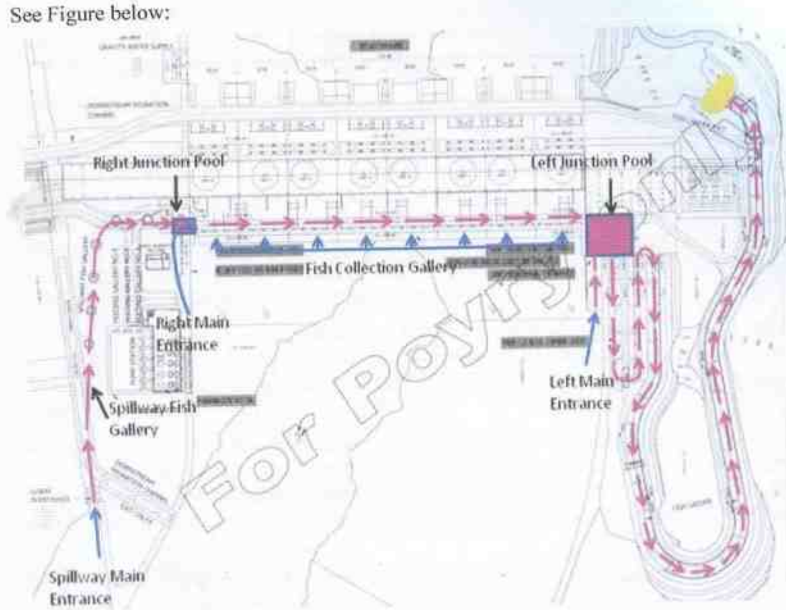


Figure 1: General layout of the upstream migration fish passage facility

The main system is designed to be operational for tailwater levels between el. 236 and 254 m. At el. 245 m the spillway starts spilling and the spillway main entrance starts operating and at a tailwater level of 245 m or more, only the upper part of the passage is operated. Hence the current design covers all operational stages of the power plant.

The system is based on the principle that the main drive of a migrating fish is to swim against the current. By using attraction currents, the fish can be guided into the various entrances of the fish passing facilities.

A fish counting and viewing facility has been included into the upper section of the fish passage consisting of an observation window, video cameras and a light panel.

In general, the planned system is quite comprehensive, employs a state-of-the-art technology and covers all operational conditions of the scheme. However any changes after construction might be quite difficult to implement and therefore adaptations are recommended to be done already during the early construction phase. For the downstream migration a combination of Surface Bypass Collectors (SBC) avoiding turbine passage, the use of fish-friendly turbines and improved spill operations are recommended in the feasibility study.

The SBC is arranged in the upstream part of the powerhouse intake. The channel is 6 m wide, with gated orifices installed at the upstream face of the channel wall providing multiple en-trances for fish along the intake wall. A constant flow will be maintained inside the channel to conduct the fish passively into the SBC system and through the bypass channel, until they glide over an exit chute into the tailrace bay.

While the structure for the current project stage is satisfactory and in principle in compliance with the MRC Guidelines, it is necessary to develop additional baseline data on biology, ecology and livelihood restoration (fishery including related business, aquatic fauna and flora consumed, river bank gardens) and there is a need to improve the knowledge concerning the specific requirements of the aquatic fauna on the fish passage facilities. With additional investigations (trans-boundary issues in regard to hydrology, baseline investigations on fauna, flora, habitat and socio-economy), which the developer plans to start as soon as possible, it should be possible to fully meet the MRC Design Guidelines requirements relating to the Xayaburi HPP.

A Cumulative Impact Assessment of the mainstream dams also needs to be done; however, this is not the responsibility of the developer, it needs to be carried out by the Government of Laos and the other riparian countries after the necessary input data has become available.

All of the recommended works can be carried out during detailed design and construction of the spillway, since the main fish passage facility is on the left bank and the construction of this part will start 3 years after the right bank part. The developed data can then be used to adapt the fish passage facilities, concerning biomass capacity and design details.

For the continuous passage of fish during the construction stage it will be necessary either to include a fish lock next to the navigation lock or to adapt the navigation lock so that it is more suitable for fish migration; the decision on which alternative to choose will depend on the additional data from baseline investigations which will become available during the early stages of construction works. The adaptation of the design of the navigation lock is an urgent issue, since the navigation lock is one of the first parts which will be constructed.

In order not to depend on one single fish climbing canal on the left bank it is recommended to complement the system by providing a fish lift in this area.

Fish friendly turbines are suggested to be installed and it needs to be explored with the envisaged suppliers how to achieve an optimum solution based on current practice and state of the art.

A fish breeding station should be also considered to re-stock any potential decline of key fish species and also reintroduce species which already are very rare or even have disappeared from the river stretch.

A detailed biological/ecological monitoring plan (fauna, flora and habitat) will have to be developed during the construction and operation phase.

These adaptations are recommended in order to ensure that the Xayaburi HPP will be fully in compliance with the various existing and future (if any) requirements of the MRC Guidelines. These adaptations are recommended to be carried out during early construction phase.

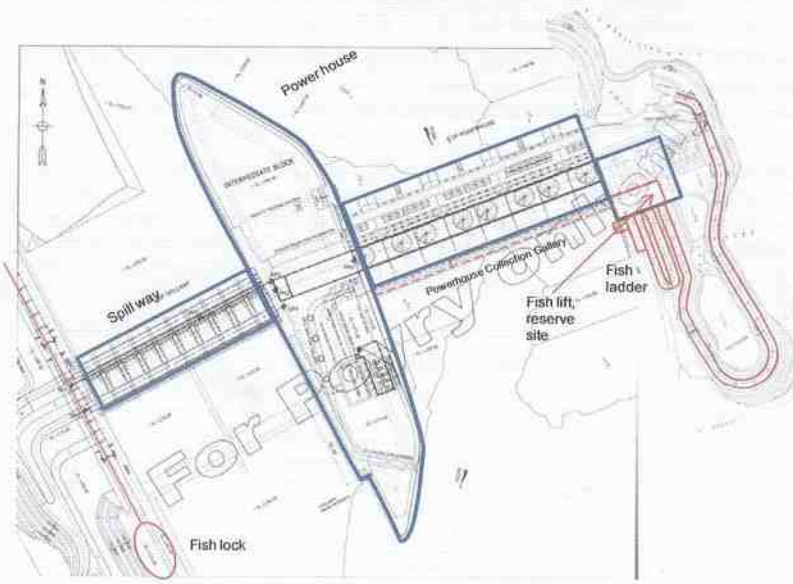


Figure 2: Location of additional fish pass facilities

Water quality and aquatic ecology

The water quality sampling carried out by the developer's technical advisor indicates that the water quality is mainly within the relevant standards both during the rainy and the dry season . It is noteworthy that during the dry season the total and the fecal coliform bacteria increase from the dam site upstream to Luang Prabang. At the sampling site near Luang Prabang the total and the fecal coliform bacteria are above the standards. The report on the 2008 bio-monitoring survey of the lower Mekong river and selected tributaries MRC Technical Paper No.27 assessed inter alia one sampling point at Ban Done Chor in Luang Prabang, which classified the sampling site as good, since 7 of 12 indicators have met the guidelines.

During the construction and later operation period measures are designed to maintain the good water quality and the environmental health downstream and upstream of the Xayaburi Hydropower plant.

However the Feasibility study, EIA SIA, and EMP RAP though acceptably in compliance with the MRC design guidance, need to be expanded and refined further in order to describe all of the environmental issues in a more comprehensive manner. The monitoring described in the EIA and EMP mainly covers the chemical and physical parameters but the biological parameters need to be added.

This means that some complementary work and mainly a detailed design of monitoring programs will have to be carried out to reach full compliance with the MRC guidelines. Mainly, it is advisable to adapt the proposed water quality monitoring, including biological quality parameters and a water flow monitoring during the construction phase.

The development of a project like Xayaburi HPP takes place in stages and several issues like the optimisation of operation and the integrated approach of all water releases within the scheme will be carried out in the next stage after the development of the data from the baseline investigations is available.

Although we have identified a few matters that require being addressed regarding water quality, there is still adequate time in the project time schedule to carry out all necessary investigations and to develop more detailed and effective monitoring plans to be in full compliance with the MRC Guidelines. Such investigation may be carried out during the first phase of the construction.

Sediments

In general, the design of the hydropower plant is based on the assumption that after a number of years of operation (around 10 years) a new equilibrium will be reached in the reservoir with respect to sedimentation. This would mean that during this period a considerable amount of the sediments would be retained and deposited in the reservoir. Such a process would not detrimentally affect the power production, but it could retain sediment loads which would not be passed downstream and consequently would be missing there and which could also have an impact on the reservoir, e.g. filling of pools. Such a development would start when the Mekong River will be closed by the powerhouse cofferdams and the water be diverted through the spillway.

However, in the case of Xayaburi project, by creating the possibility to route or flush flows during the high flow season when most of the sediment load is transported at a lower sill level than the present spillway sill level (el. 254.00), the effect of retaining excessive sediment loads can be mitigated and the requirements of the MRC Guidelines can be met.

It is considered that the most suitable location to provide such flushing gates is in some of the spillway openings. It is recommended to use in maximum 5 spillway bays and this will allow the pass-through of sediment loaded inflows and the venting of possible turbidity currents (flows along the reservoir bottom containing higher concentrations of sediments).

There would be two flush gates per spillway bay, equipped with radial gates and with a base level of up to 24 m lower than the current spillway sill level and gate sizes of 8.0 m width. A simple flap gate would be sufficient to close the top part of the spillway opening.

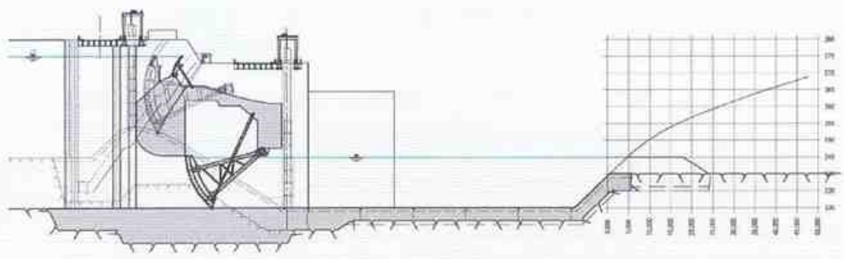


Figure 3: Spillway section with flushing gate and flap gate;
Normal operation: flushing gate closed and no spillage through spillway

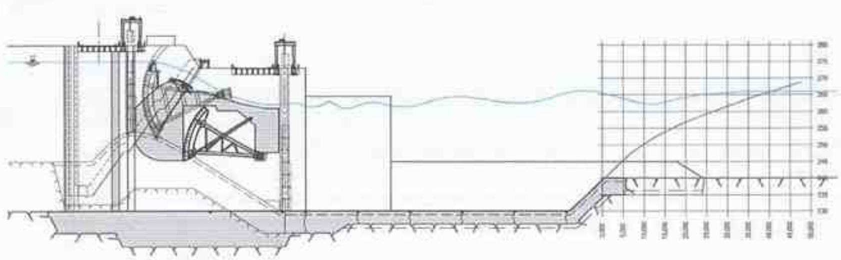


Figure 4: Spillway section with flushing gate and flap gate;
Operation during floods: flushing gates & flap gate fully open

The method of pass through routing is preferable to drawdown flushing since it is expected to provide the best mimic of the natural sediment flow as recommended in the MRC Guidelines. It will also allow to transport through the sediments during the construction time by means of free flow flushing.

The technical solution will need to be refined further during the early construction stage and complemented by numerical simulations and hydraulic model tests. Also duration and extent of a possible drawdown needs to be established.

The provision of such additional flushing facilities will allow the reduction to a great extent of the amount of sediment retained in the reservoir, hence also filling of deep pools under the respective operational rules. With this design recommended, as one of the optimal possible mitigation measures, it is expected that after the flushing facilities become operational, after diverting of the river, detrimental long-term effects in the Mekong delta located in Cambodia and Vietnam will be avoided.

It is also highly recommended to start a continuous sediment monitoring program immediately to allow the monitoring of the current status and continue it during the entire construction and operation time of the power plant.

With these measures in place, the Xayaburi HPP will be in full compliance with the relevant MRC Guidelines.

Comments of MRC member countries

The main concern of the riparian countries are *"the trans-boundary issues and that certain impacts (sediment trapping, nutrients, fishery, biodiversity, socio-economic) have not been addressed in as great detail as one would like and that a detailed monitoring should be initiated"*. With respect to sediment trapping and nutrient flow, ways to alleviate the situation are presented above. More precise baseline data to be established now will allow to evaluate in more detail the magnitude of impacts and the effectiveness of the designed mitigation measures.

The above mentioned concerns can be remedied with the additional investigations recommended to be carried out during construction phase as explained in the previous sections of this executive summary. It is also advisable to cooperate in these investigations with representatives of the riparian countries.

Conclusions

The Xayaburi HPP has principally been designed in accordance with the applicable MRC Design Guidelines. A number of technical adaptations and improvements are recommended, which can easily be done during construction phase. Such topics will require particular detailed attention during the construction phase. The first topic concerns sediment transport through the reservoir and the second topic relates to fish passing facilities.

In connection with sediment transport, flushing outlets are recommended to best mimic the current sediment transport conditions. A suitable location for such outlets will be at the spillway. This will require some design adaptations and additional investigation work, but this can be done in the framework of the present implementation schedule. The suggested adaptation will greatly alleviate the problem of a possible lack of sediment transport towards downstream, an issue which was brought up by a MRC member country.

For a proper handling of fish passes, there is a need to improve the base line data. Such data must be obtained and developed and there is sufficient time to complete such work during the early part of the construction phase, which will allow any necessary technical adaptations to be made. The planned system is based on an adaptive approach, allowing for operational changes of this system to be implemented for optimal effectiveness. It is also recommended to add two more fish pass systems, namely, the use of the navigation lock for this purpose or a fish lock situated parallel to the navigation lock and the preparation of an additional corridor for a third system which all can be accommodated within the current design layout.

1 INTRODUCTION AND CURRENT STATUS

Pöyry Energy AG has been nominated as Government of Laos Engineer for the Xayaburi run-of-river Hydropower Scheme in Lao PDR and has been requested to prepare an Initial Technical Review with regard of compliance of the Feasibility and Outline design of the Project with the Mekong River Commission Guidelines and the design criteria stipulated in there.

In order to accomplish this, Pöyry has reviewed the technical sections of the Feasibility Study prepared by TEAM and AF-Colenco, parts of the Outline Design prepared by the same companies for the purpose of EPC tendering and the technical sections of the main EPC Contract.

This report summarizes our findings and conclusions.

1.1 The Xayaburi Run-of-River Power Scheme

Main features of the Xayaburi Project are as follows:

- Owner/Developer: Xayaburi Power Company which was incorporated on 22nd June 2010 ("XCPL"), and includes the following shareholders: Ch. Karnchang Public Company Limited ("CK"), Electricite du Laos ("EdL"), Natee Synergy Company Limited ("NSC") a subsidiary of PTT, Electricity Generating Company Limited ("EGCO"), Bangkok Expressway Public Company Limited ("BECL"), and P.T. Construction & Irrigation Company Limited ("PT")
- EPC Contractor: Ch. Karnchang (LAO) Company Limited ("CHK")
- Installed capacity 1,285 MW, 7 + 1 Kaplan turbines
- Expected Construction cost 2.2 Billion USD
- Energy Tariff MoU signed in July 2010
- Concession Agreement signed, PPA & Financing Agreements finalized
- Environmental Impact Assessment approved by GoL in September 2010

1.2 Overview of Reports and Guidelines relevant to the Project

The following main documents relevant to the Xayaburi Hydropower Project have been issued in the time sequence below:

1. Agreement of the Cooperation for the Sustainable Development of Mekong River Basin (95 Mekong Agreement) between the countries Cambodia, Lao PDR, Thailand and Vietnam, April 1995.
2. Procedures for Notification, Prior Consultation and Agreement, 1995 (Mekong River Commission, MRC)
3. Rules for Maintenance of Flows on the Mainstream, 2005 (MRC)
4. Rules for Water Quality, 2005 (Mekong River Commission (MRC)
5. Feasibility Study Xayaburi Hydroelectric Power Project, 2007 to 2008 (CHK)

6. Preliminary Design Guidance for Proposed Mainstream Dams in the Lower Mekong Basin, August 2009 (MRC)
7. EIA, EMP, SIA and RAP for the Xayaburi Hydroelectric Power Project, 2007 to August 2010 (CHK)
8. Strategic Environmental Assessment of Hydropower on the Mekong Mainstream, October 2010 (MRC)
9. Prior Consultation Project Review Report - Proposed Xayaburi Dam Project - Mekong River, March 2011 (MRC)

It can be seen that some of the guidelines and detailed independent assessments were still under preparation at the time when the Feasibility Study and Environmental Assessments were done for the project.

1.3 Scope of Pöyry for this Review Report

The Consulting Services Agreement for Compliance Review signed between the Government of Lao People's Democratic Republic and Pöyry Energy AG on 5 May 2011 asks for the following matters to be reported on:

- Whether Owner has complied with and satisfied the MRC Guidelines and its design criteria.
- Whether the GOL and the Owner have taken into consideration the comments submitted by each of the MRC member countries during the Prior Consultation (PC) Process
- Whether the GOL and the Owner have complied with and satisfied the terms of the "Prior Consultation Project Review Report on the Xayaburi Project", dated 24 March 2011.
- Issues relating to the development, construction and implementation of the HPP and any discrepancies, conflicts and the need for any changes thereto in connection with the comments.

Pöyry's scope of work does not include any update of studies and reports which have been prepared by others.

1.4 Structure of the Main Report

The Project's compliance with the MRC guidelines is summarised in Chapter 2. This includes dam safety, navigation, fish passing facilities, water quality and sedimentation. Recommendations how the design and the project implementation can be improved are given

The prior consultation process conducted for the project and the key comments of MRC member countries are reviewed in Chapter 3.

The Project's compliance with the technical report of the MRC is reviewed in Chapter 4 with detailed comments on the fish passage facility presented in Annex 5-1.

2 COMPLIANCE WITH THE MRC GUIDELINES

2.1 Navigation Lock System

2.1.1 Introduction

The following comments are based on information presented in the Navigation Assessment Report (Annex 6 of the Prior Consultation Project Review Report) compiled by MRC and issued in March 2011.

2.1.2 Water levels, range of operation of the locks

The maximum navigation flow was assumed to be 25'000 m3/s (30 years return period flow) which seems to be too large. A two years return period flood (14'580 m3/s) seems more appropriate. Therefore the high operating level for the downstream lock now set at 260.0 m could be considerably lower.

For daily peaking operation the upstream water level can vary up to 2.5 m to a minimum normal reservoir water level of 272.5 m. This can be the case for river flow rates below 5'140 m3/s. Filling up the reservoir by 2.5 m can lead to fluctuating reductions of the downstream level reducing the available water depth in the navigable channel close to the dam and the entrance of the lock downstream. The magnitude of these fluctuating reductions should be evaluated in the different operating scenarios considered.

During operation of the power plant accidental stops of one or several turbines may occur. Such stops create surges upstream and downstream of the plant and the consequences on navigation should be assessed.

For managing of flood levels in Luang Prabang the headwater level will be lowered during flood conditions. With a 15'000 m3/s flood the reservoir level at the dam will be lowered to 265.9 m and the spillway gates would be opened fully. This suggests that the lowering of the headwater level would begin with a flow lower than the maximum navigation flow, proposed by MRC to be 12'000 to 14'580 m3/s. This would lead to decreasing hydraulic sections and increasing velocity values at the entrance of the spillway and the lock, in the range of navigation operations. These adverse conditions need to be evaluated.

2.1.3 Design vessels and navigation standards

The report "Standard specifications for ship locks on Mekong mainstream dams" recommends to choose the following design vessels:

- 2 x 500 DWT 109 m x 10.8 m x 2 m

adapted from PR of China class IV standards.

This recommendation is consistent with the Preliminary Design Guidance for the lock dimensions (120 m x 12 m x 4 m).

So the design of Xayaburi dam project must take into account that ships or convoys up to 109 m long could transit through the locks.

The navigation channel and the approaches characteristics of the lock must be adapted to Chinese class IV convoys 109 m long. Chinese standards recommend minimum bend radius of 330 m for the navigation channel and French standards recommend for comparable cases normal bend radius of 700 m and minimum bend radius of 450 m.

It is recommended to adopt straight alignments of at least two times the maximum vessel length for entrance and exit, and at least one time the maximum vessel length between two bends.

2.1.4 Nautical accessibility and approaches of the locks

In the future situation after commissioning of the dam, the navigation accessibility needs to be improved, because of some adverse characteristics of the site, as said below.

During the construction stage

During the first phase, navigation will continue in the low water channel of the river, on the left bank of the bend.

Up to a water level of 245 m (i.e. up to a discharge of 5'000 m3/s, exceeded statistically for 70% of the year) the flow velocity will be the same as in the present situation (about 2.3 m/s at km 1930.7) and navigation is not disturbed.

For discharges higher than 5'000 m3/s, the entire discharge is concentrated in the low water channel, instead of partially overflowing onto the right bank. The increase of average velocity of the flow therefore makes passage by navigation more difficult. This increase of velocity throughout the whole range of discharges where navigation now operates needs to be precisely evaluated.

If necessary, this increase in average velocity could be reduced by dredging the bed of the low water channel during the first phase of construction.

During the second phase the lock will be commissioned while the hydropower plant is being built on the left bank, behind another set of cofferdams. During this phase, the level of the floor of the upstream lock must be compatible with the passage of navigation with damming at the spillway ogee crest (level 254 m). As stated in the design report the minimum water level when the river is diverted over the spillway is 255.5 m, which will allow the normal water depth of 5 m a the entrance upstream of the lock.

After commissioning of the dam

The downstream part of the lock is separated from the spillway by a dividing wall; it should be checked that it is sufficiently long to limit the effects of turbulence caused by the flow.

For the access downstream a plan and sections should specify the width and depth available during periods of very low water level (236 m), in the situation where de Pak Lay dam in not built.

Access upstream of the lock appears to be inadequate. Due to the hill projecting from the alignment of the right bank, 800 m upstream of the lock, the bend radii of the access channel are much too small for the gauges of the boats likely to use the river in the future (about 350 m whereas the normal bend radius should be 700 m).

For discharges lower than the maximum powerhouse flow, the current leads towards the powerplant and its mean velocity is rather low. By following a route on the right side of the river where the velocity is very low, boat should be able to turn quite easily towards the entrance of the lock.

For discharges higher than 5'000 m3/s (exceedance probability of 30%) the boats will be obliged to slow down and be positioned at an angle close to 45° crosswise to the current towards the spillway, which seems dangerous. The least problem, of motor for example, could cause them to be drawn towards the spillway.

In the upstream area the layout of the site leads to conclude that that the velocity field hardly favours navigation, at least for discharges higher than 5'000 m3/s. The flow conditions upstream of the lock are likely to provoke sedimentation and accumulation of floating debris in the lock entry.

The slope of the hill on the right bank, 800 m from the dam, will undoubtedly cause a shift of the flow detrimental to the efficient distribution of the discharge in the spillway and liable to generate reverse flows in the upstream outer port of the lock. The removal of the outcrop should be seriously considered.

It is necessary to perform a more in-depth investigation of the navigation access upstream and downstream of the lock, including the construction of a physical model. This investigation should take into account standard and non-standard operation configurations of the main works (spillway and power plant)

2.1.5 Lock design

Design aspects which need to be considered further can be summarized as follows:

- The useful dimensions of the lock chambers must be confirmed. According to the plans the dimensions are 120 m x 12 m as specified in the guidelines.
- The minimum air clearance of 12 m has to be compared to the other constraints along the navigable waterway
- The design of the second set of locks is not acceptable. It is recommended to design the second lock side by side with the first one. This has already be rectified in some drawings.
- The elevation of the upstream mitre gate has to be increased to level 280.0 m and the middle gate can be lowered down to level 276.0 m in order to protect all the lock chambers against extreme floods, in order to limit maintenance operations after the flood.
- The dimensioning of the arrester cables has to take into account the capacity of the largest ships or convoys (1'000 T).
- The mooring posts in approach channels must be equipped with mooring bits.
- One ladder on each side of the lock chambers have to allow access to the bottom for maintenance purpose.

2.1.6 Emptying and filling system of the locks

For the system the following changes and adaptations are recommended to be considered:

- Considering the high head of the locks and the necessity to limit the emptying and filling time, the proposed emptying and filling system is not the appropriate one. Feeding and emptying flows vary all along the longitudinal culvert and then on the different ports and each transverse culvert. The injection of flows is therefore asymmetric, longitudinally and transversally, leading the ships to move erratically in the chambers. There is also no redundancy of critical equipment (gates, culverts).
- A system with two longitudinal culverts and several transverse culverts in staggered rows are recommended.
- The geometry of the filling-emptying system, comprising lateral culvert diffuser and openings, gates in the lateral culvert, water intakes in the upstream spillway approach channel and outlets in the downstream spillway approach channels, needs to be modified.

2.2 Fish Passing Facilities

2.2.1 Present Layout of the Fish Passing Facilities

The fish passing facilities comprise of:

- Facilities for upstream migration
- Fish passage recording system for upstream migration
- Facilities for downstream migration

2.2.1.1 Upstream Migration Facility

The layout of the upstream migration facilities is rather complex; therefore below a short description is given of the lower half of the Xayaburi fish passing facilities, including the hydraulic system. This system consists of four integral parts, namely:

- Main Fish Entrances
- Collecting Gallery
- Spillway Fish Gallery
- Junction Pools (left and right)
- Water Feeding Galleries / Auxiliary Systems

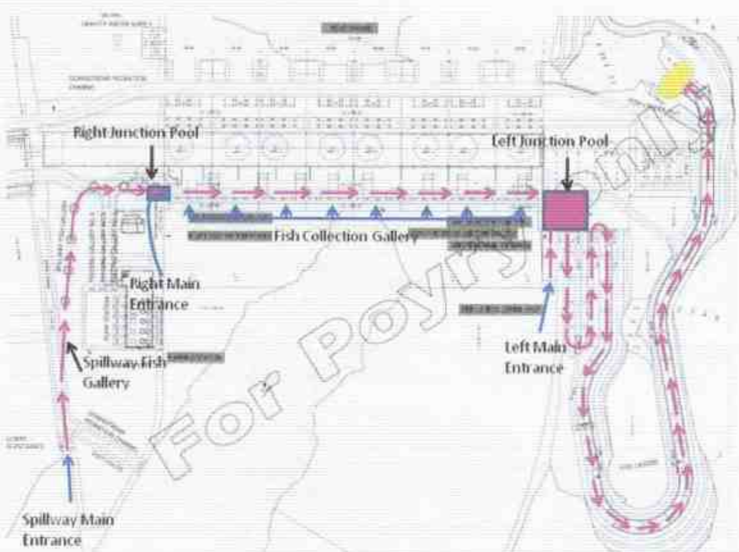


Figure 2.1: Plan view of the upstream migration facility

Figure 2.1 above shows the way the fishes are supposed to follow through the fish passing system. The galleries, junction pools and the fish ladder are marked in purple. The entrances are marked in blue and the exit out of the fish ladder in yellow. The arrows show the direction in which the fish are swimming at each place in the system. The water will be flowing in the opposite direction.

There are four ways for the fish to enter the system:

- Spillway main entrance, which is only in operation during spilling
- Right Powerhouse Entrance
- Left Powerhouse Entrance
- Fish Collecting Gallery

Modes of operation

The system is designed to be operational for tailwater levels between 236 and 254 MSL. At 245 MSL there is a transition in the operation:

- The Spillway starts spilling and the spillway main entrance starts operating
- At a tailwater level of 245 or more, only the upper part of the ladder is operated.

This covers the entire operation range of the plant.

Attraction and navigation current

The system is based on the principle that the main drive of a migrating fish is to swim against the current. By using attraction currents, the fish can be diverted into the entrances of the fish passing facilities. By maintaining a smaller current within the facilities, the fishes can be guided through them. The former shall be referred to as attraction current and the latter as navigation current.

These currents must have a particular minimum velocity in order to be perceived by the fishes. If they are, on the other hand, too strong, the fishes won't be able to swim against them. In the Feasibility Study the following values were set:

- Attraction Current: 1.2 - 2.4 m/s
- Navigation Current: 0.6 - 1.2 m/s

The range of the attraction current, as defined above, means that the difference in water level between two compartments must be between 7 and 30 cm.

Fish passage recording system for upstream migration

A counting and viewing fish facility has been included into the upper section of the fish ladders consisting of a viewing window, video cameras and a light panel.

Subsequent to the counting and viewing facility, provisions for sorting and trapping fish may be located in the fish ladder. Additionally to a holding box, the traps may be equipped with slide gates to either retain fish or return them to the ladder. This area may be used for brood stock collection, fish tagging or other research opportunities.

2.2.1.2 Downstream Migration Facility

To improve downstream survival a combination of Surface Bypass Collectors (SBC), completely avoiding turbine passage, the use of fish-friendly turbines, and improved spill operations are recommended in the feasibility study.

The SBC is arranged in the upstream part of the powerhouse intake, between the slot of the upstream stoplogs and the upstream face, connected to a descending bypass channel, located in the spillway - powerhouse separating block. The channel is 6 m wide, with gated orifices installed at the upstream face of the channel wall providing multiple entrances for fish along the intake wall. A constant flow will be maintained inside the channel from the left to right side, in order to conduct the fish passively into the SBC system and through the bypass channel, until they glide over an exit chute into the tailrace.

2.2.2 General Functionality of the Upstream and Downstream Fish Passage Facilities

2.2.2.1 Upstream Fish Passage Facility

The general layout of the upstream fish passage facility is state of the art and has a very complex design, but it needs to be taken into account that the basic knowledge concerning the fish species of the Mekong river, their swimming ability and behaviour needs to be greatly improved.

From the hydrological point of view the most critical issues is the big fluctuation in the tailwater level. As the tailwater level rises, the wetted cross sectional area in the fish collection gallery gets quite big and so do the discharge levels needed, in order to achieve the set navigation current. As the system is open to the tailwater for the majority of its length. The allowable head between the fish collecting system must stay between 7 and 30 cm. These 23 cm of head must then suffice to drive the water through almost 600 m of galleries. Although this head can be increased locally within the system with the help of the auxiliary water supply system care must be taken to maintain the navigation current over minimal levels throughout the system. The whole system needs a complex regulation, galleries and pools need to be inspected regularly and maintained.

Furthermore, the flow from the spillway itself might smother the attraction flow from the spillway main entrance.

The three main entrances of the fish passage facility are located on strategically good positions and in addition the Powerhouse Collecting Gallery will transfer the fish in the middle of the powerhouse to the left fish pass. The velocity of the water through slots and orifices and the slope of 4.5% (Drawing no. XB -1611) and 5% (Feasibility Report) for the substrate layer of fish ladder are in the range which is commonly used for fish passes in Europe and North America, but it is probably too much for Mekong species, the drop height between the pools should not exceed 15 cm to allow small fish and weak swimmers to migrate up stream.

The presented design of the pools is very schematic, size and location of the slots and orifices in partition walls between the pools are not described. Drawing no. XB -1611 depicts the length of the pool with 4 m and the Feasibility Report described it with 7.5 m. It is correctly stated in the Feasibility Report that the minimum length of the pool is a function of the size of the fish to be given passage, therefore the pool length should not be smaller than 6 m. The bottom layer is 50 cm high consisting of rocky blocks in the same range of size. It is essential that the surface of the pool bottom is roughened by using river boulders with a suitable size to give weaker swimmer or juvenile fish the chance to rest. It will be important to provide enough resting zones or even additional resting pools (half way up the left fish pass). In general fish collection gallery should be in daylight since diurnal fish avoid swimming into dark channels or it must be lit artificially in a such a way that lighting is as close as possible to natural light (Fish Passes, Design, Dimension and Monitoring; FAO, DVWK 2002), but this can be investigated in a later stage.

It is of importance that basic concepts are fixed early, but it is equally important that structural overall dimensions are in a correct range, since otherwise at a later design stage shortcomings can only be corrected at the expense of uneconomical reinforcement contents and substandard concrete quality (because of too much reinforcement) and longer construction time.

From the impression of the Feasibility Report several questions are still open and will have to be decided by developing the detailed design of the fish ladder. The available design is a good starting point, but offers room for improvements in various respects.

2.2.2.2 Downstream Fish Passage Facility

The general layout of the downstream fish passage facility is not described in detail. There are also the following other potential down stream migration possibilities.

1. Downstream migration channel, see comment below
2. Fish passage through the turbines; the suppliers were requested to show potential solutions for fish friendly turbines.
3. Downstream migration through the spillway and sediment flushing devices; this possibility is mentioned but not described in detail and should be subject to detailing in the design phase.
4. Downstream migration through navigation locks

The Drawing XB 1637 and XB 1638 are showing the downstream migration channels. There are several open questions which need to be solved during the detailed design phase:

- The velocity within the channel is not clear and should be adapted within the physiological limits of the fish species
- The entrance structure is not clear and currently it seems to be behind the trash rack of the power intake.
- The water depth sufficient for large-bodied fish species
- The slope should be smoothen since the fish will have rather high velocities sliding down

- The exit at a level of 240 m asl during minimum tailwater level of 236 m asl the fish will fall 4 meters.

2.2.3 Compliance with MRC Guidance

The main issues recognized concerning the compliance with the MRC Design Guidance on baseline data require still further investigations and improvement, leading to the current situation that the knowledge concerning the specific requirements of the aquatic fauna on the fish passage facilities is not sufficient.

The Preliminary Design Guidance for Proposed Mainstream Dams in the Lower Mekong Basin (MRC, 2009) for the fish passage facility is divided in seven main topics:

- General
- Planning and design phase
- Biological/ecological
- Hydrological
- Hydraulic environment
- Operation
- Monitoring and evaluation

The general guidance has partly been taken into account by the developer, up and downstream fishways have been included into the design. A multiple system has not been included in the original outline design. The knowledge on the actual amount of biomass, which has to pass the fish passage facilities in up and downstream direction, needs to be assessed during the first phase of construction (first two years) to form a sound basis for the design of the multiple fish passage system.

The guidance concerning the planning and design phase have been mainly taken into account and Hydraulic Model Test on the Fish Passing Facilities including Computational Fluid Dynamic (CFD) Model Tests, Numerical Model Tests and Hydraulic Laboratory Model Tests, have been recommended by Colenco for the next phase of the fish passage design, if those are carried out the planning will be fully in compliance with the MRC guidance.

The guidance on operation issues are in compliance and if additional fishways (paragraph 63 on general guidance) have to be included, paragraphs 81 and 82 concerning captivity period, interruption to the normal movements and oxygen levels will be taken into account.

The guidance on monitoring and evaluation has been taken into account from the technical side and are included into the fish passage design, but the Management Plan on biological/ecological monitoring has not been developed. Whether the budget included in the Concession Agreement is sufficient will depend on the investigations which have to be carried out and on the adequacy of the fishway and therefore on the compensation cost resulting from the project development.

Biological/ecological guidance have yet to be taken fully into consideration, since EIA, EMP, SIA and RAP are weak concerning aquatic fauna and all related issues. The literature survey and the field studies performed need to be extended and complemented during the next project phase.

Furthermore, one guidance of MRC is to develop a compensation program for lost fishery resources, if the fish passage rates are unlikely to be adequate. The livelihood and restoration program, in the zone influenced by the project, prepared by the developer needs to be improved to address this point. Baseline data, like how many people and to which extent are using the aquatic fauna and flora including any depending businesses, need to be developed and investigations on trans-boundary effects also need to be carried out in the forthcoming project phase.

2.2.4 Recommendations Concerning Fish Passage Facility

2.2.4.1 Baseline Data

The missing baseline data concerning fish species, migration pattern, behaviour, swimming ability, biomass, economic value, etc, should be carried out with the utmost urgency to allow the design changes within the existing time frame.

It is strongly recommended to carry out following investigations and studies:

- An aquatic baseline investigation concerning important habitats (deep pools, riverbank vegetation, river weed etc.), spawning areas, feeding areas (e.g. the giant catfish feeds on algae), etc. within the future reservoir area.
- A fish survey: which species occur (type, size, weight, life cycle, reproductive stage, upstream or downstream migrating, fish guild (resident, spawner, refuge seeker, generalist, semi-anadromous, catadromous, etc.), abundance, at what time of the year and day, and in which depth have they been caught (benthic, mean water or surface water). Total fish biomass and larval drift.
- Select target species which are representing whole groups and carry out fish swimming ability and behavioural studies. The target species have to cover a wide spectrum. At least one species for each sizes 5, 10, 20, 30, 40, 50, 75, 100, 150 cm and larger if possible but this could be difficult due to their low frequency. Furthermore they should be selected based on considerations of commercial and livelihood importance, broad coverage of ecological guilds, as well as conservation of threatened species.

The fish survey has to start as soon as possible to have an adequate set of data. The survey needs to cover at least one yearly up- and down-migration cycle with fish eggs, larvae, juvenile and adults including total biomass migrating upstream and downstream. After one migration cycle the target species should be selected due to size, commercial and livelihood importance, ecological guilds, conservation status, and the swimming ability and behavioural studies need to be started. The fish survey should go on for an additional year to receive an adequate set of data. Sampling should be carried out at least twice a month.

The baseline investigations on the aquatic habitats should be used to develop habitat maps indicating deep pools, spawning areas, feeding areas, occurrence of aquatic plants, etc.

With these baseline surveys an adequate set of data will be available to optimise the fish passage facilities.

2.2.4.2 Optimisation of Fish Passage Facilities

Currently one large comprehensive fish passage facility has been designed with a collecting gallery, and several entrances working at different tailwater levels. As recommended above this facility needs to be amended by two additional systems to form a multiple system. It is not clear whether the originally designed fish passage facility would be suitable to cope with the high amount of biomass, which will have to pass upstream and downstream, but with the recommended multiple system this will certainly be the case. Fish migration is triggered by several environmental factors (water level, current, discharge, rainfall, food occurrence, etc.) and is therefore not equally distributed over the year. The migration pattern and the amount of biomass need to be assessed and it needs to be verified whether the envisaged designs are capable for handling the biomass, especially during migration peaks.

One very important issue is that no upstream migration facility is included in the original design for the second part of the construction period (year 3 – 7) and the migration pattern will also be stopped if the fishway has to be maintained, this could have a serious impact on the fish population depending on the season of the maintenance work. Furthermore, it should be noted that not a lot of experience is available concerning fishways on large tropical rivers hence the system should be adaptive. With a multiple system these issues can be resolved.

Therefore it is strongly recommended to include a multiple system, consisting of three complementary systems in total of different types and two additional mitigation measures:

1. A fish lock built into the navigation lock, which is necessary to guarantee continuous upstream migration during the construction period,
2. A fish lift on the left bank which can potentially be incorporated into the planned fish ladder.
3. A fish ladder (currently planned) which is also located on the left bank. But the drop height of the pools is too large to allow small species and weak swimmers to migrate upstream to accommodate the various behaviours of the large variety of species.
4. Fish friendly turbines have been recommended in the feasibility study. The degree of fish friendliness of the turbines should be verified with the envisaged supplier of such turbines.
5. It is also recommended to set-up and operate a fish breeding station for the augmentation of the existing fish population and re-instruction of possible disappeared species for release in a suitable river stretch.

The design optimisation should be implemented stepwise:

- The data received out of the above mentioned baseline surveys especially those concerning biomass, size, migration pattern and swimming abilities will help to dimension, develop and upgrade the fish passage facilities (head difference between pools, pool depth, width and length, different sizes of orifices, etc.)

- The hydraulic model test on the fish passing facilities including computational fluid dynamic (CFD) model tests, numerical model tests and hydraulic laboratory model tests will further optimise the facilities.
- Further requirements will be detected during operation monitoring. The flow of the feeding system of the left bank fish ladder can be varied on a wide range and all entrance are gated, it will be possible to adjust flow and water velocity through the entrance.

Counting and viewing facilities as well as trapping and sorting facilities are included into the fishway design. It is hard to envisage that a fish numbering system with video could work in the Mekong River due to the low visibility caused by the high sediment load. It is recommended to use other options like high definition sonar imaging which would be a good alternative (main disadvantage fish < 5 cm can not be detected).

2.2.4.3 Monitoring

A surface water quality monitoring is part of the EMP. It is recommended to include an additional sampling site within the fishways. The sampling frequency needs to be increased (at least on monthly basis if not even weekly basis). The existing EMP can be used as framework. Detailed Sub-Management plans which are taking international standards into account will have to be developed as soon as possible.

For the fish passage facility and for a biologically/ecologically healthy environment it is necessary to develop a thorough monitoring program on fish fauna using the fish passage facilities (monitoring of fish entering and fish leaving the upstream and downstream fish passage facilities). A biological/ecological monitoring needs to be included. This will have to be carried out during the construction period and for the concession period (at least 10 years). The biological/ecological monitoring needs to take place at least at one site below Xayaburi HPP (20 km d/s), one site within the reservoir area and one site above the reservoir area. An aquatic baseline investigation concerning important habitats within the reservoir area needs to be carried out to see to which extent the habitat is changing (deep pools, riverbank vegetation, river weed etc.). This will have to be carried out once a year during operation in the first years and when the habitat does not change anymore every second year.

An adequate fish protection management program for the near surrounding at least 500 m up and downstream of the fish passage facilities needs to be developed for the construction and operation period.

One of the MRC guidance, requires that: "*where fish passage rates are unlikely to be adequate to maintain viable populations mitigation options as one element of compensation program for lost fisheries resources must be proposed.*"

Therefore a detailed baseline investigation on socio-economic issues related to river bank gardens and fishery, and any other aquatic fauna or flora which are used as additional livelihood income, including any depending businesses will have to be carried out for an corridor of about 15 km to each side of the Mekong river from the dam site up to Luang Prabang.

An additional hydrological short study should be carried out, concerning the impact of discharge pattern from Xayaburi HPP on the downstream area especially on Tonle Sap, a lake in Cambodia, which depends entirely on the Mekong regime. During the high discharge period, water flows from the Mekong into this lake, its level then rises, during the low discharge season, the lake is drained, its level is lowered. Many fish (important for the local population) depend on this system for their reproduction, and the drawdown area is cultivated during low water level periods. Given the fact that this is a very sensitive issue at international level, it is recommended that the developer proves by means of an additional investigation (based on data which are available) that the effect of the HPP during filling and operation is minor or even negligible.

Furthermore a monitoring on the fish biomass should be included at the border between Laos and Thailand, about 200 km downstream of the construction side. The Monitoring should start as soon as possible to receive a suitable baseline, which can then be compared with the monitoring data during construction and during operation. Since several dams are planned the GOL should take the initiative in this respect, both on the investigation itself and on the sponsoring.

2.3 Sediments

2.3.1 Introduction

The knowledge of sedimentation rate and pattern in the reservoir types similar to the Xayaburi reservoir are an important input for the selection of feasible types of remedial strategies. Deposition patterns are governed by the transport processes in the reservoir and can provide information on sediment delivery and distribution processes that are not visible from available data and modeling results.

Nutrients are another major concern of the MRC and the member countries. Since this concern essentially relates to sediment bound nutrients, the assessment and mitigation measures of this issue are considered largely identical to sediments.

It should be noted that the approach as described hereafter is based on a semi-quantitative assessment of available information and does not include any results from own numerical or physical modeling.

2.3.1.1 Initial conditions

The entire reservoir reach of Mekong as well as the downstream area down to the Thai border is not alluvial, but a "supply-limited wash load in the geologically constrained bed rock channel" ([2], p.70). This means that the slope, as imposed by the geology, provides an excess in transport capacity as compared to what is required to discharge the available sediment load.

Wash loads (or suspended loads) consist of silt and fine sand. Bed loads are particularly sand and gravel size sediments. According to the Sediment Expert Group (SEG) Report bed load is expected to be around 2 Mt/year (million ton/year), suspended load around 70 Mt/year at Xayaburi HPP.

Future sediment flow conditions are mainly dependent on the hydro power development in the Chinese part of the Mekong River. The anticipated amount of sediment to be removed from the Mekong River by the Chinese dams ranges from roughly about one third to almost one half of the total amount of sediment flowing on average into the Mekong Delta. The total sediment load between the Manwan Dam at the Chinese border and Pak Chom is around 5% of the total sediment load arriving at the Mekong Delta. Therefore in the theoretical case if 100% of the incoming sediments at Xayaburi are trapped, the total sediment loads at the Mekong Delta would be reduced by a maximum of 5%.

2.3.1.2 Sedimentation processes

Sedimentation in reservoirs does not occur in a uniform manner:

1. Bed load and coarse fraction of the suspended load are deposited immediately at the head of the reservoir to form delta deposits.
2. Fine sediments with lower settling velocities are transported further into the reservoir in turbid density currents or by non-stratified flows.

Turbidity currents may appear if during flood occurrences highly concentrated flows plunge and flow along the reservoir thalweg. It is expected, though, that occurrences of turbidity currents are uncertain due to the rather low water depth in the reservoir and the very fine suspended sediments, but this still needs to be verified. Non-stratified flows during floods are expected with comparatively higher sediment concentrations at the bottom.

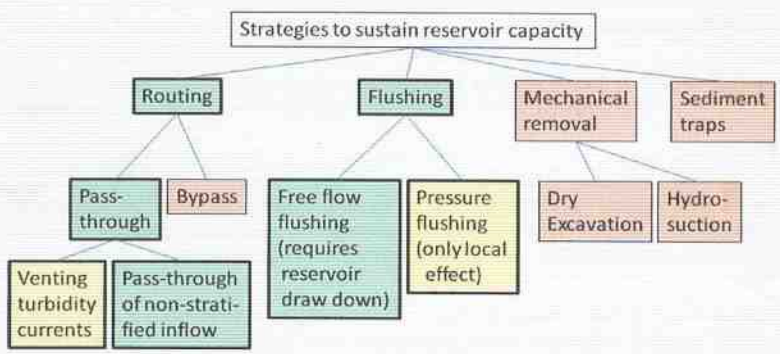
Based on the above processed a certain amount of sediments will be trapped in the Xayaburi reservoir depending on time and flow conditions

The released water contains a lower amount of sediments, at least during the first years, and is called "hungry" waters with reduced sediment loads. In the downstream river stretches such flows can typically cause adverse effects such as bed and river bank erosion, morphological changes within the river bed (erosion of sand/gravel bars, washing out of deep pools), and lowering of ground water tables.

Further downstream missing sediments and nutrients are suspected to affect the riparian users in relation of the amount potentially trapped in the reservoir which is in the case of Xayaburi less than 5% of the total load e.g. the area of Tonle Sap lake in Cambodia and the Mekong delta in Viet Nam. However, with appropriate mitigation measures (see next chapter) these affects can be further reduced to an insignificant level.

2.3.2 Mitigation of run-of-river reservoir sedimentation

The most effective of all strategies to mitigate adverse impacts of the above processes is to reduce sediment deposition in the reservoir. The MRC PDG [1] presents a variety of possible strategies, an overview of which is given in Figure 2.2 below.



Mitigation measures shown in red are explicitly or implicitly ruled out, measures shown in green represent promising suitable strategies for Xayaburi HPP, those shown in yellow are techniques with assumedly low impacts.

Figure 2.2: Strategies to mitigate reservoir sedimentation

Due to the large amount of (fine) sediments and due to the length of the reservoir, several of these measures are not considered feasible at Xayaburi dam such as: bypassing, sediment traps, and any kind of mechanical removal (see also [2], p.54). Furthermore, pressure flushing will be required to maintain the operability of the powerhouse intakes and of the spillway, but has only local effect and will not contribute to reservoir conservation.

The remaining methods are therefore:

- pass-through routing,
- free-flow flushing.

The SEG report does not distinguish explicitly between the two pass-through techniques, i.e. turbidity current or non-stratified pass-through. In particular no focus has been given on turbidity currents which is described in detail below.

2.3.2.1 Venting of turbidity currents

Turbidity or density currents are flows within the reservoir water body. They usually flow along the reservoir bottom due to their higher specific weight, caused by high sediment concentrations.

Venting of turbidity currents requires them to reach the dam. They may then be vented and flushed through corresponding low level outlet devices without lowering the reservoir. It would allow as well to preserve the mimics of natural sediment flows of the Mekong River. In the case of the Mekong river these turbidity currents may have typical velocities in the range of 1 m/s.

Only fines would be transported, coarser materials will be deposited in the lower reservoir reach. Evidently, a certain knowledge of the exact sediment grain distribution is essential to verify the appearance of such currents.

Such low level outlet devices would vent and flush through as well the higher sediment concentrations at the reservoir bottom in case of non-stratified flows.

2.3.2.2 Pass-through routing

It is estimated that routing would limit in the long run the sedimentation volume well below about 60% of the reservoir volume. SEG in their report ([2], p.8) estimated the 60% value for the case of the current spillway design, i.e. without the use of low level outlets.

For routing it is required to maintain a high transport capacity during flood events by opening the low level spillway gates completely, which implicates a partial reservoir drawdown. Thus, in the upper part of the reservoir almost river like conditions may prevail and lead to considerable erosion of deposits, part of which will sediment further downstream.

However any drawdown would impact the head available for energy production.

2.3.2.3 Free flow flushing

Free flow flushing requires the reservoir to be drawn down as far as possible for a certain time. In general this technique allows to keep open an erosion channel which in the long run will constitute the remaining reservoir. In the case of Xayaburi the effect can be expected to be relatively high, because the reservoir is narrow, so the erosion channel may be expected to occupy a large portion of the original cross-section. The MRC SEG estimates that flushing may keep a long-term reservoir volume of about 70%, i.e. the sedimentation volume would be about 30 % of the reservoir volume.

Small amounts of deposits in the delta area of the reservoir are expected to settle mainly during the dry season with low flow velocities, while during the wet season with higher flow velocities delta deposits will be moved further downstream.

In lower areas the siltation of natural deep pools is inevitable and difficult to prevent due to the backwater effects, especially on a long-term view. Occurrence of pools is generally related to high velocities and steep water gradients as may be found in river bends (secondary currents), in reaches constricted by geology or by tributaries, or alternating geology. Evidently, lowering the flow velocities in the pool reach creates a permanent filling. A temporary drawdown of the reservoir would create a partial washing out of such deposits depending on the sill level, drawdown level and flushing duration. However such free flow flushing would generate extreme sediment concentrations in the downstream stretches which can be harmful to the aquatic life.

2.3.2.4 Effect of routing and flushing scenarios on sediment trapping

For their simulations on the ISIS software, the sediment expert group (SEG) investigated the following scenarios [4]:

- Simulation i: base condition (no dam),
- Simulation ii: operation of dam continuously at 275-m pond level,
- Simulation iii: operation of dam as proposed by Developer and 1 week opening of gates per year for flushing,
- Simulation iv: as iii. but with lowered spillway sill elevation from 254 m to circa 230 m (1 week flushing per year),
- Simulation v: as iv. but with spillway gates fully opened for a full month (August),
- Simulation vi: dam as proposed by Developer during construction with spillway gates all fully open, but no flow through power house side of the channel.

As for the results, only trapping rates (sediments trapped per year) are presented for ISIS simulation. The effect on the reservoir conservation is not shown for this type of calculation. The results of the scenarios ii to v are summarized in Table 3.1 (scenario vi is for the construction period).

Scenario		Routing / flushing conditions				Trapping	
		Sill el. mSL	Drawdown mSL	Period Month	Days	Sand / Gravel %/Yr	Silt %/Yr
Dam as feasibility	ii	254.00	275.00			96%	67%
Routing	iii	254.00	**260.00**		7	94%	56%
Free flow flushing	iv	**224.00**	**~TWL**	July	7	73%	39%
Free flow flushing	v	**224.00**	**~TWL**	Aug.	**31**	31%	11%

Table 2.1: Trapping of sediments according to [4].

Scenario iv flushing (1 week) was simulated in July, whereas scenario v takes place in August. Since the Mekong discharges are generally higher in August than in July, the higher trapping values may also be due to this, not just due to the longer flushing period. Hence a shorter period might also show good routing or flushing results when timed at higher Mekong discharges. The limiting factor would then probably be a sufficient dilution of the flushed sediments. However, this problem is considered more severe for the full drawdown scenarios iv and v than for scenario iii.

2.3.2.5 Mitigation against erosion processes downstream ("hungry water")

The most importance measures will again be to allow as much of the incoming sediments to pass through the reservoir. Besides that there are only two more types of measures:

- augmentation of the sediment load downstream,
- protection measures for river banks.

Augmentation is not considered feasible and has been excluded ([2], p.54). Protection of river banks is foreseen by the Developer (EIA, p.6-7).

2.3.3 Design requirements

It is not recommended to wait until an equilibrium between the inflow and outflow of sediment concentration happens. Such equilibrium is expected to happen after an initial operation period of about 10 to 20 years when most suspended sediment load will pass through Xayaburi reservoir, not considering the influence of Chinese dams (SEG [2]). In the case of the simultaneous development of several hydro power projects at the Mekong River, one may see that suspended sediments accumulation in the individual reservoirs will be a multiple of 10 years, aggravating natural sediment flows in downstream areas by the cumulative effects of several dams.

The sediment deposition should be mitigated as far as possible to achieve the recommended "transparent" dam for sediment. This can be achieved by creating a "quasi"-equilibrium with regular routing and flushing procedures as outlined above. Such procedures are expected to be effective at Xayaburi due to the rather narrow valley geometry and the non-alluvial reach.

Therefore an adaptive approach is recommended, which foresees the technical solution adjustable during operation based on latest findings, to provide the best possible mimic of the natural sediment flow as well as mitigating other environmental impacts, e.g. nutrient transport etc.

Xayaburi HPP is a mainstream dam with the purpose of energy production thus creating a different situation from present and therefore any operation adjustments will not prevent environmental impacts completely. Within the framework of the MRC guidelines, however, such impacts are considered acceptable.

The main impacts are as follows:

- Sedimentation during low flow season are distributed over the total width of the river. Flushing most likely at the beginning of the flood season may then create a channel similar to its old river cross section taking along deposit material in its vicinity. Lateral deposits may not be affected and remain, however in comparison to other reservoir the remaining proportion is expected to be small,
- Temporarily reservoir drawdown procedures create instable situation at the river banks leading to local slides and erosion along the banks, however such effects can be also observed under the natural conditions at the start of the flood season and during high flood events.
- Some of the pools upstream of Xayaburi HPP will be partially filled as the sill level of any release facility is significantly higher than the observed pool depths.

The required operation strategies can be summarized as follows:

- drawdown flushing,
- pass-through routing (preferable to drawdown flushing since it is expected to provide the best mimic of the natural sediment flow),
- adaptable flushing (to deal with uncertainties, e.g. due to future developments, and also to be able to react on high sediment concentrations),
- also during construction phase, not only during operational phase.

2.3.4 Recommended Design Changes

2.3.4.1 Alternatives

There are basically two technical alternatives to provide flushing capacities:

- modification of the powerhouse flushing sluices,
- modification of a part of the spillway.

The modifications of the powerhouse flushing sluices such that they could serve for reservoir flushing would require a much larger total cross-sectional area, which is not available in the present powerhouse design. A major re-design would be required, heading towards a solution as has been realized by Russian engineers in a number of power plants (e.g. Tishrin, Syria). However a number of technical issues such as energy dissipation, sedimentation in the tailbay etc. would then need to be solved.

Another disadvantage of the powerhouse solution is the construction phase. If this period was to be handled by the powerhouse section alone, it could only be covered by a very complicated and risky construction schedule.

It is therefore recommended that the main flushing devices will be built by modifying some of the spillway gate arrangements. In the spillway section more space is available, thus the total capacity for flushing will be significantly higher than at the powerhouse. The risk of erosion / sediment deposition due to uncontrolled energy dissipation downstream of the spillway is reduced considerably as compared to the tailbay of the powerhouse.

The developer has already performed model tests for two or three spillway sections without the ogees not yet inserted to allow additional diversion capacity during construction. It could also be a option for flushing during construction time.

It can be summarised that the modification of the spillway is far more beneficial and has less risks then the use and extension of the existing flushing devices in the powerhouse.

2.3.4.2 Boundary Conditions

The following boundary conditions must be considered in the design:

1. For Free Flow Flushing:

   The sluices must be low enough to simulate river like conditions. The difference between the upstream and the downstream water level must be within a defined range.

   The main parameter will be head loss and flow velocity in the sluices and therefore the sill elevation is one of the parameters to be considered for the head loss through the sluices, in particular in the free flow mode. It is required to optimise the hydraulic parameters important during flushing such as cross-section, sill elevation, intake forms etc. Nevertheless any layout of low level flushing outlets will limit the capacity at the barrage and hence limited head losses will appear.

2. For Pass-through Routing

   The cross-section and the to a certain extend also the sill elevation are the main parameters to be considered.

3. For Venting of Turbidly Currents

   The sill elevation would have more influence, if turbidity currents could be expected to occur.

The sluicing system must be *adaptable*, i.e. it must be possible to regulate the gates for various flows. The structural and hydraulic solution should be studied during the detailed design of these structures and the following principles should be followed:

- Splitting up the cross-sectional area into two or more gates
- Non-uniform gate operation should be limited for hydraulic reasons
- The gates should be also used as spillway outlets
- The outlets will have to be specially designed to flush sediments safely (as compared to conventional low level outlets).

- Regular operation is ensured due to the flushing requirements.
- The large range of heads and discharges to be covered by the flushing gates requires safe hydraulic operation.

2.3.4.3 Proposed Solution

The following technical solutions are recommended by the Consultant for the project.

The flushing gates shall be foreseen pair wise at five bays, each 8 m wide (total 10 flushing gates). A middle pier (width of 3 m) is placed to reduce the dimensions of the stop logs and the radial gates to a reasonable range. The flap gates will be divided in two sections.

The required capacity to discharge floating material will have to be provided by the remaining original spillway gates.

The use of up to 5 spillway openings for this purpose is likely to be sufficient and will allow the pass-through of sediment loaded inflows and the venting of possible turbidity currents. With 10 flushing gates the loss of head at the barrage can be limited to an acceptable range. During the detailed design the final decisions on number of openings, size of gates etc. should be made based on the hydraulic and numerical model tests.

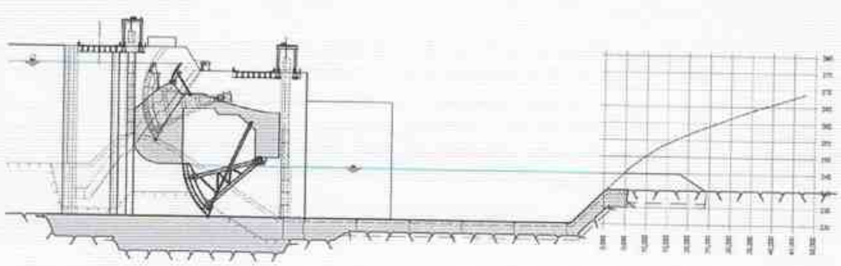


Figure 2.3: Spillway section with flushing gate and flap gate;
Normal operation: flushing gate closed and no spillage through spillway

The overall capacity at each spillway bay shall remain the same one covered by two modified low level outlets. The flap gates are placed above the flushing gate chamber will only be used to pass safely floating debris during flood occurrences and for extreme floods.

The final hydraulic design should minimize unfavourable hydraulic conditions as far as possible such as:

- During the beginning of flushing operation, when the water level in the reservoir is considerably high, energy dissipation will move downstream creating a hydraulic jump in the river bed, which is prone to erosion. Such events shall be reduced with operational restrictions.

- During flood events the hydraulic jump will travel further upstream leading to a situation that flow conditions at the weirs will be submerged creating ondular waves and unfavourable rollers

A systematic modelling for different flow conditions is recommended.

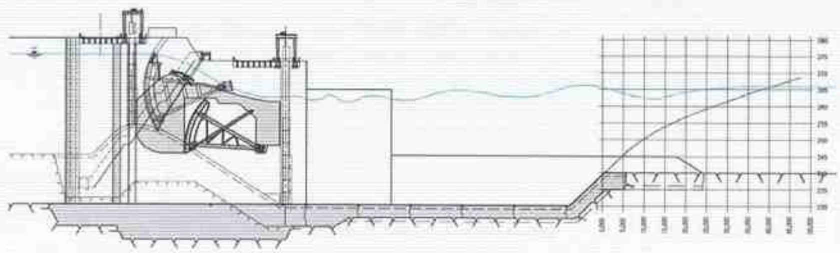


Figure 2.4: Spillway section with flushing gate and flap gate;
Operation during floods: flushing gates & flap gate fully open

Negative impacts on the stability of the spillway structure are expected to be negligible. Stability safety margins remain similar comparing the design of spillway bays with radial gates with the proposed design of spillway bays with flushing gates. However, the concrete volume will increase by 26'000 m^3 and excavation volume by 23'000 m^3 per spillway bay with flushing gates. Additionally, costs of such flushing gates including flap gates will increase by approximately 20% compared to the radial spillway gates.

Intermediate opening positions of such flushing gates are not easy to achieve due to submerged hydraulic conditions. Either open or closed positions are preferable.

Special attention shall be paid on floating debris. Flap gates with a width of 8 m are not wide enough for safely bypassing such material, therefore a reasonable arrangement should be chosen (see Figure 2.5) allowing to release floating debris on both sides of the spillway with flap gates on top of the spillway radial gates.

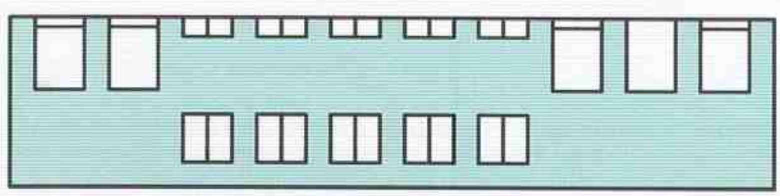


Figure 2.5: Possible arrangement with five flushing gates located in the middle of the spillways.

2.3.4.4 Flushing procedures

Generally, flushing shall be done annually using flood peaks to closely mimic the natural timing of the sediment concentration.

The example flushing procedure which is described below is based on a 2 years return period flood with a estimated peak of 15'000 m^3/s.

The resulting backwater curves with or without any drawdown are shown in Figure 2.6.

During a 2 years flood the water level will be constant at el. 275.00 from Xayaburi (RS 1905) up to RS 1930. Further upstream backwater effects are expected up to RS 2000, i.e. 70 km u/s of Xayaburi. Due to technical limitations the reservoir can only be lowered during such a flood event down to el. 258, which is about 4 m above the natural water level at the dam site. Hence, the length of the backwater effects is reduced to 25 km (Figure 2.6, RS: 1930 – 1955).

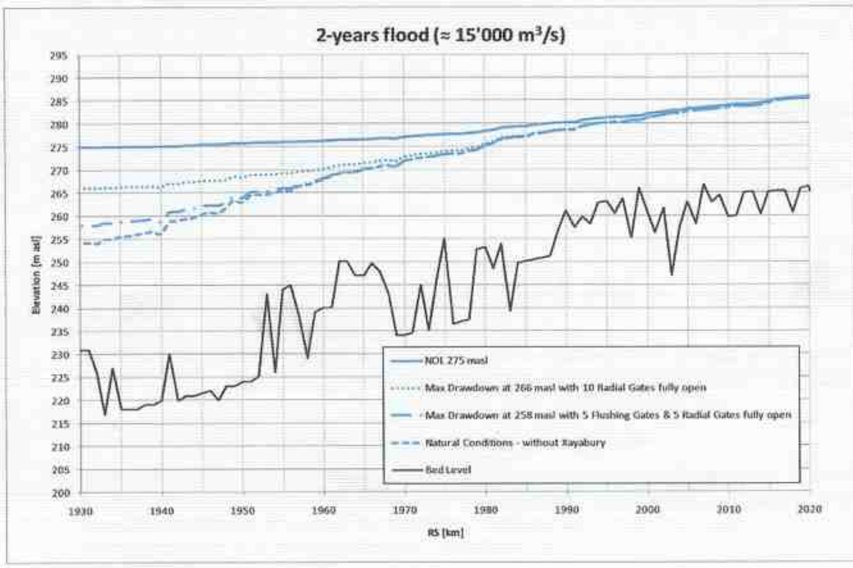


Figure 2.6: Drawdown water levels in reservoir

The resulting backwater curve (up to km 1970) has to be compared to the natural conditions. Generally it is assumed that sediments in the backwater reach will not or only partially be mobilized and will not pass the barrage completely. Suspended sediments may even deposit in the lower reach additionally and fill natural pools.

A pass-through routing with all flushing gates fully open and a partial drawdown of the reservoir to e.g. el. 258 during approximately every 2 years will restore the natural conditions in the upper part of the reservoir. If the lower reach of the reservoir is supposed to be restored completely and the remaining deposits mobilized, free flow flushing will be needed during lower river flows.

The duration of pass-through routing with a partial drawdown can be adapted according to the natural flood duration allowing to mimic closely the natural timing of sediment transport dynamics in the river. The required duration of free flow flushing is expected to be rather short, as most sediments will be mobilized at the beginning of a flood event. As incipient sediment concentrations during free flow flushing will be considerably higher than at natural conditions (see Figure C.9. SEG report), careful attention is required. It should be then discussed if free flow flushing to maintain the relatively short river stretch in the lower part of the reservoir is necessary as the amount of deposits to be mobilized is expected to be relatively small. Measures to reduce these initial sediment concentrations are limited.

However, a detailed assessment will be done during the construction phase. Additionally, during operation a permanent adaption of flushing procedures based on made experiences is foreseen.

2.3.4.5 Adaptation during construction phase

During the first construction phase, i.e. construction of the spillway block, no sediments are expected to be trapped upstream. During the second construction phase, after the powerhouse construction pit is closed, the current spillway sill at el. 254.00 would govern the upstream flow conditions. Sedimentation may then be expected to occur in the lower parts of the future reservoir.

However, already the option is foreseen to keep two or three ogee blocks at the stilling basin elevation (230.00). This was to improve the river diversion capacity, but it would at the same time mitigate potential sediment trapping during the second construction phase.

Based on the design changes the sills of the new flushing outlet would far below el. 254.00. In this case sedimentation trapping will not occur during the construction phase.

2.3.4.6 Impact of flushing or routing drawdown on power production

One of the major issues concerning flushing or routing is the fact, that not only the total amount of produced energy is important, but also or even more to have as little interruptions as possible. A drawdown for routing or flushing may come into some conflict with this requirement of a power production as constant as possible.

Some information on this can be obtained when relating the boundary conditions for energy production to the tailwater levels (Figure 2.7):

- Full supply level FSL is at 275.00 m asl.
- The minimum head required to operate the turbines is between 17 and 19 m. Relating to the tailwater levels, this leads to a curve for the minimum required reservoir level (plain red line in Figure 2.7).
- Above Mekong discharges of 18,000 m^3/s, the reservoir has to be drawn down to protect Luang Prabang. This corresponds to a 5-years flood. As can be seen from Figure 2.1 (right part), operation of the turbines is then no longer possible, since the

minimum head required is not available. For the present spillway design, the minimum reservoir level is then essentially determined by the spillway capacity.

As a result, a shaded area is given in Figure 2.7 which shows the range for possible drawdown without stopping the energy production completely. For discharges above 18'000 m^3/s the shaded area can be extended below the spillway capacity curve. Suitable low level flushing outlets are to be provided then.

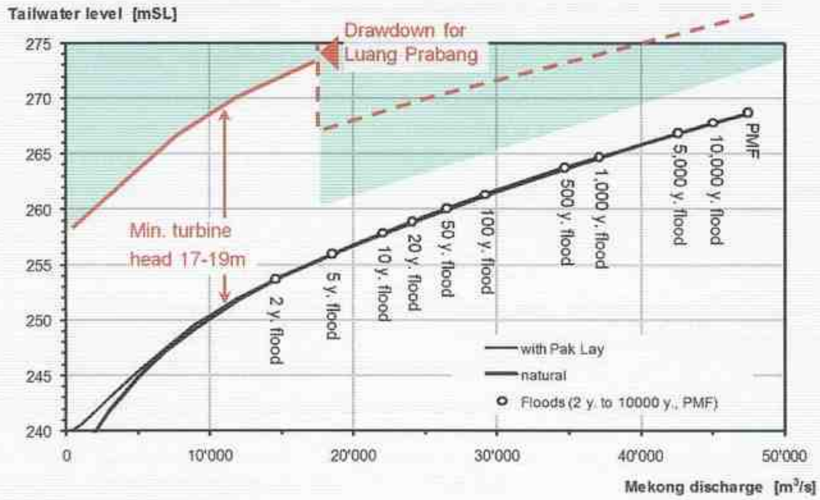


Figure 2.7: Boundary conditions for energy production.

The following conclusions may be drawn:

- Below discharges of 18'000 m^3/s low drawdown levels and high flushing discharges can hardly be combined without affecting constant energy production.
- Above discharges of 18'000 m^3/s in fact any drawdown level which is technically feasible can be reached without any production interrupts or losses, provided the refill can be started in time.

2.3.5 Additional investigations and modelling

2.3.5.1 Collection of sediment data

There are only a limited amount of sediment measurements (e.g. sieve analysis) available and especially bed load data are rarely available. Additionally, little information is available of an average annual distribution of recent suspended sediment concentrations.

Due to this uncertainty the results of any sedimentation modeling will vary in its results as already shown in the preliminary numerical model results of the SEG report. Effects due to different grain size distribution, alternative transport function, deposition in the delta areas and river banks during drawdown and the possibility of turbidity currents are not yet completely understood.

Some additional sediment data is required to verify operational sequences already in advance.

Information shall be therefore collected concerning the following topics:

- Annual hydrographs of sediment concentration at barrage site (Xayaburi HPP),
- Regular sieve analysis of suspended & bed load material during different discharges ranging from low flow to peak floods.

Such baseline information would allow to understand possible deposition development in more detail leading to a more profound estimation of possible operation sequences.

Furthermore it would be important to understand the influence of the upstream developments in China and have data covering the start of the operation period of these schemes.

2.3.5.2 Physical & numerical modelling

Physical & numerical modelling is recommended in terms of verifying and refining the foreseen measurements.

Modelling of the following issues are recommended:

- Numerical modeling of sediment deposition effects in the reservoir including a verification of the foreseen technical adaptations and possible operational sequences
- Numerical & physical modeling of the proper functioning of the spillway flushing gates including the behavior of the stilling basin

The modeling should be performed without undue delay to have the required basis for the detailed design. It is estimated that it should be completed within the next 4 to 6 months.

2.3.6 Monitoring system

In accordance with the MRC guidelines a monitoring system should be implemented. Such system should include the following issues allowing to verify the success of the operational adaptations:

- Periodical bathymetric surveys of the complete reservoir,
- Regular collection of sediment samples (grain size distribution etc.) for different flow discharges and during flushing procedures in the delta area and downstream of the main barrage,
- Regular measurements of sediment concentration upstream and downstream of the barrage,
- Visual observation of river bank development concerning instabilities (e.g. landslides, lateral erosion)

Generally, the detailed monitoring shall be elaborated by the developer in collaboration with the relevant governmental authority and should cover success control of fish passages & water quality issues as well.

2.3.7 Summary on the recommended solution concerning sediment issues

With pass-through routing using the present spillway design it is estimated that in the long run about 60% of the reservoir volume would finally be filled with sediments [4]. This amount of sediment retained in the reservoir can be reduced considerably to acceptable levels by providing low level outlets which allow pass-through routing at a lower outlet level and also partial free flow flushing. This would reduce the long-term amount of reservoir silting to minimal of the total reservoir volume which can be achieved by reducing substantially the sediment retention process in the reservoir during the high flow season, when the sediment load in Mekong water is highest.

Therefore, it is recommended to provide up to the maximum of 10 new low level flushing outlets (number to be defined) as shown in Figure 2.5. During operation a combined application of routing and flushing should be based on constant monitoring of the sedimentation development, but also on measurements during routing/flushing procedures, e.g. of the sediment concentration.

This will allow to release the sediments in a controlled way to a sufficient extent, minimising much the amount of sediment finally retained in the reservoir.

2.4 Water quality and aquatic ecology

2.4.1 Present Situation

The water quality sampling carried out by TEAM indicates that the water quality is both in the rainy and in the dry season mainly within the relevant standards. It is noteworthy that during the dry season the total and the faecal coliform bacteria increase from the dam site upstream to Luang Prabang. At the sampling site near Luang Prabang the total and the faecal coliform bacteria are above the standards. The report on the 2008 biomonitoring survey of the lower Mekong river and selected tributaries MRC Technical Paper No.27 assessed inter alia one sampling point at Ban Done Chor in Luang Prabang, which classified the sampling site as good, since 7 of 12 indicators have met the guidelines.

It should be the target to maintain the good water quality and the environmental health downstream and upstream of the Xayaburi Hydropower plant.

2.4.2 Compliance with MRC Guidance

The MRC Agreement states the following:

"T*o cooperate in the maintenance of the flows on the mainstream from diversions, storage releases, or other actions of a permanent nature; except in the cases of historically severe droughts and/or floods:*

A. Of not less than the acceptable minimum monthly natural flow during each month of the dry season;

B. *To enable the acceptable natural reverse flow. of the Tonle Sap to take place during the wet season; and,*

C. *To prevent average daily peak flows greater than what naturally occur on the average during the flood season.*

Furthermore MRC design guidance specifies general requirements and requirements on water quality monitoring, on environmental flow assessment and provision, and on monitoring of environmental flow provision.

The reviewed reports (Feasibility study, EIA SIA, EMP RAP) are principally in compliance with the MRC design guidance. The main issue is that the work which has been carried out is often described not in the required detail (especially the environmental issues) and the impacts have not been assessed in sufficient detail. Even if an impact is expected to be small e.g. Xayaburi will be a run-of-river scheme and the retention time of the water within the reservoir is short, it needs to be assessed and proven by the developer that the impact is negligible. To be in compliance with the MRC guidance additional investigations will have to be carried out, data will have to be sourced and evaluated. An environmental flow assessment as required in the guidance has not yet been carried out and a monitoring on the environmental flow remains to be performed in the next project step. The monitoring described in the EIA and EMP needs to be in more detail, it mainly covers the chemical and physical parameters but any biological parameters need to be added.

It should be mentioned that the development of a project like Xayaburi HPP takes place in stages and several issues like the optimisation of operation and the integrated approach of all water releases within the scheme will be carried out in the next stage.

There is still enough time to carry out all the investigations and studies and to develop more detailed and effective monitoring plans to be in compliance with the MRC Guidance.

2.4.3 Recommendations

To be incompliance with the MRC guidelines it will be necessary to carry out following investigations and studies:

- An additional hydrological study should be carried out, concerning the impact of discharge pattern from Xayaburi HPP on the downstream area especially on Tonle Sap. (See Chapter fish passage facilities)
- A baseline survey on the aquatic fauna should be carried out. This includes the migration pattern of eggs, larvae, juvenile and adult fish (See Chapter fish passage facilities). The hydrological flow and the sediment load should be measured to assess, if migration is triggered by the flow and to identify if special adaptations have to be included into the discharge pattern.
- Additional investigations concerning biological, ecological and socio-economic (livelihood) baseline data needs to be carried out by the developer to be in compliance with the guidance. (See Chapter fish passage facilities)
- Amend the simulation of flow patterns during different seasons (excluding and including Chinese HPPs). The current simulation was done without the EdL turbine. Furthermore, after having established the ecological boundary conditions, these

should be included and a yearly operation plan needs to be developed. Alternative discharge regimes with priority setting of fish passages, navigation, flushing sluices, energy production (time distribution of Laos and Thailand should be separated) and spillway discharge have to be assessed. Show the extent of the fluctuations and assess the impacts on the ecosystem downstream and upstream of the dam site. The boundary conditions should be clearly set up. This activity should include the optimisation study on operation considering all ecological (egg and larvae peaking, sedimentation flushing, etc.) boundary conditions previously defined and an operation plan should be developed.

- Water quality monitoring during construction: additional chemical and biological quality parameter needs to be included and sampling frequency needs to be increased during construction period to once a month. It is not necessary to have six sampling points during construction period this can be reduced to two or three measurement points one upstream and one to two downstream of the construction site (on each side of the river if necessary). In addition it is recommended for the construction period to implement an online monitoring on water quality for a reduced set of parameters (temperature, pH, conductivity, turbidity, dissolved oxygen, oil).
- Water quality monitoring during operation: The six measurement points can be kept, additional measurement points need to be included into the fish passage facilities. The measurement frequency will be in the first years of operation once a month until a new equilibrium (5 years) has developed, then a frequency of every three month is acceptable.
- A thorough biological/ecological monitoring needs to be developed (fauna, flora and habitats). This will have to be carried out during the construction period and for the concession period. Measurement should take place at least on one site below Xayaburi HPP (20 km d/s), on one site within the reservoir area and on one site above the reservoir area. The monitoring concerning important habitats within the reservoir area needs to be carried out to see to which extent the habitat is changing (deep pools, riverbank vegetation, river weed etc.). This will have to be carried out once a year during operation in the first years until a new equilibrium has developed and then every second year. (See Chapter fish passage facilities)
- A monitoring of the flow conditions needs to be carried out to prove that the water, which is coming into the reservoir will leave the reservoir within a defined time period (e.g. 24h). A hydrological station is located at Luang Prabang and another one is as far as known located below Xayaburi HPP
- The up-dated/ graded EMP including all Sub-Management Plans will need to be prepared by the developer as soon as possible and then be reviewed and approved by the relevant national authorities.
- It is recommended to use key experts for the design and implementation of the several studies and investigations recommended and for the water quality compliance monitoring programmes. Furthermore a close cooperation with specialists from the Government of Lao PDR and relevant experts is recommended.

In general it should be clear that monitoring should control the implementation of mitigation measures defined in the EMP in order to make sure that these measures are implemented as planned, and that they produce the expected results. Corrective measures need to be formulated in case implementation is not in compliance with the EMP (e.g. relevant environmental standards are not reached), identification of responsibilities for implementing these corrective measures, and checking on their effectiveness.

2.5 Safety of Dams

2.5.1 Introduction

Today a comprehensive dam safety concept is used for projects with a large damage potential such as dams with a large storage volume. It includes the following elements:

a) Structural safety,

b) Dam safety monitoring,

c) Operational safety and maintenance, and

d) Emergency planning.

At the present stage the structural safety is the key issue, while the other elements will become of interest at a later project stage.

For the design of the Xayaburi dam project guidelines, design manuals and codes prepared by the

a) Technical committees of the International Commission on Large Dams (ICOLD),

b) US Army Corps of Engineers (USACE),

c) US Bureau of Reclamation (USBR),

d) American Concrete Institute (ACI),

e) ASTM, and others are used.

These guidelines, design manuals and codes are used for large dam projects in most parts of the world when no specific design documents are available such as in the case of Lao PDR and the other ASEAN countries. In the Mekong basin only China is known to have special codes for hydropower plants, hydraulic structures and large dams.

To focus on the ICOLD Bulletins 59 and 130 (see MRC guidelines, Section 6) is not appropriate as they cover only some limited dam safety aspects but not any design guidelines.

It must be pointed out that dam safety includes only the dam body, which in the current case comprise the powerhouse structure, and the safety-relevant elements such as the spillway and other outlets used for the control of the reservoir stored behind the dam and the related electro-mechanical and control equipment and power supplies.

Appurtenant structures such as office buildings, switchyard, fish ladders, access roads, bridges, storage facilities etc. are not directly related to dam safety as their failure will not lead to the uncontrolled release of water from the reservoir.

Accordingly, the dam safety monitoring and operation and maintenance manuals are related to the dam and the safety-relevant elements and components of the dam.

Therefore, the dam safety review is focusing on these important aspects. Appurtenant structures are not considered in the subsequent discussion.

2.5.2 Hazards considered in dam design and load combinations

In the design of large dam projects the possible hazards affecting the safety of the dam are listed in an hazard matrix. In the example shown below the hazards are listed as well as the protective measures to be taken in case of abnormal behaviour of emergencies are given. Such a matrix also forms the basis for the preparation of emergency action plans. The hazards are subdivided into natural hazards, man-made hazards, and hazards originating from the project and the lo-cal conditions, which are referred to as structural hazards.

However, in the design phase a review of the different hazards shows what measures shall be taken, i.e. in some cases it is possible to eliminate hazards or the reduce them. This applies mainly to the structural and some of the man-made hazards. However, in the case of the natural hazards the structures have to be designed for these hazards. In the case of the Xayaburi project the main hazards from the natural environment are the flood and earthquake hazards and the de-sign has to take both such risks into account.

	PROTECTIVE MEASURES				
HAZARDS	Rehabili-tation	Partial reservoir drawdown	Full reser-voir draw-down	Evacuation	Post-event evacuation
Natural hazards					
Floods	x	x		x	
Earthquake					x
Mass movements	x	x			
Structural hazards					
Spillway gates, equipment failure			x	x	
Differential movement of structure	x	x	x	x	
Embankment piping or seepage		x	x		
Electrical/mechanical failure	x				
Man-made hazards					
Sabotage, terrorism, acts of war		x			x

Table 2.2: Example of hazard matrix for hydropower plant showing hazards and required protective measures

The standard structural design procedure (deformation, stress and stability analyses) used for dam projects includes the following load combinations:

1. usual loads (dead load, water load from normal water level, silt load, uplift);
2. unusual loads (dead load, flood water level, temperature effects, silt load, full uplift etc.); and
3. extreme loads (static: PMF water level, full uplift etc.; dynamic: usual loads plus safety evaluation ground motion).

2.5.3 Flood safety of dam project

For the flood design of the Xayaburi project, the following internationally accepted concept is used:

1. The PMF (probable maximum flood) can be released safely without over-topping the concrete dam. In the case of embankment dam sections the PMF water level shall not exceed the top of the impervious core.
2. The power plant is out of operation when the PMF arrives.
3. The largest capacity gate is closed when the PMF arrives.

The dam is not designed for the flood wave generated by the failure of a major dam upstream of the Xayaburi project, i.e. the recently completed Xiaowan arch dam in China, which at the moment stores the largest reservoir at the Mekong in China (10 km3). However, in the design of the dam it will be taken into account that the dam and the safety-relevant elements will not be vulnerable to overtop-ping.

Overtopping of concrete dams is not a lethal hazard as after the May 12, 2008 Wenchuan earthquake in Sichuan Province, China, several run-of-river power plants at the Minjiang river were overtopped and suffered only minor damage due to overtopping. The overtopping was due to blocked gates (loss of power and emergency power supply) when a moderate flood wave arrived after the earthquake, and failure of a large gate due to rockfall which released the whole reservoir. Overtopping caused mainly damage due to sediments (mud) deposited on the dam.

It is also expected that a flood wave due to the failure of an upstream dam will carry a lot of floating debris as experienced for example during the tsunami caused by the March 11, 2011 Tohoku earthquake in Japan.

2.5.4 Earthquake safety of dam project

As the Xayaburi dam and reservoir are classified as a storage project with large damage potential, the dam and safety-relevant elements are designed for the worst earthquake ground motion to be expected at the dam site. Such projects are designed for the so-called Safety Evaluation Earthquake (SEE) ground motion. The SEE ground motion parameters are either determined probabilistically considering a return period of 10'000 years or they are determined deterministically using critical earthquake scenarios. However, such earthquake scenarios are only feasible when the relevant faults and their seismic activity are known. This is not the case for the Xayaburi project. Therefore a probabilistic seismic hazard analysis was carried out considering all available earthquake catalogues and seismotectonic data (faults in greater project region).

For the comprehensive seismic hazard analysis carried out by P. Warnitchai from the Asian Institute of Technology in Thailand state-of-the-art seismic hazard analysis concepts were used. The seismic hazard analysis report and seismic ground motion parameters determined for the Xayaburi dam site (peak ground acceleration, acceleration response spectra for horizontal and vertical earthquake components on the rock surface) have been reviewed and have been found as adequate for this projects. But the seismic hazard is higher than that used in other recent dam projects in Laos where Pöyry Energy was involved since the project is located in north western Laos where the earthquake activity is higher than at the other project locations.

As the dam will be designed for these ground motion parameters, and in view of the fact that such structures are not vulnerable to seismic actions, it is very un-likely that the dam will fail during strong earthquakes.

However, additional seismotectonic investigations are under way to locate the Dien Bien Phu fault, which is capable of producing large earthquakes, as based on certain publications it passes close to the Xayaburi dam site. The ground motions caused by an earthquake at the Dien Bien Phu fault are considered in the probabilistic seismic hazard analysis; however, if the fault should pass through the footprint of the dam then any fault movements would cause a new hazard, which has not yet been accounted for. The result of the seismotectonic study will provide this lacking information.

The recent earthquake in the Xayaburi region of February 23, 2011 was relatively small although it was also felt in Thailand. The maximum ground motion caused by this magnitude 4.6 earthquake with a focal depth of 16 km was much smaller than the SEE ground motion used for the design of the dam and safety-relevant elements.

2.5.5 Run-of-River Reservoir triggered seismicity

With a maximum water depth of about 50 m and a reservoir volume of ca. 1.3 x 109 m3 it is rather unlikely that reservoir-triggered seismicity (RTS) will occur as most cases of RTS have occurred in large reservoirs with the maximum water depth exceeding 100 m. Moreover, it would be necessary that the reservoir is located in a tectonically stressed area with faults close to failure.

However, it is proposed to install some seismic stations in the dam and reservoir region to monitor any RTS. It is important that these seismic stations are in-stalled before filling of the reservoir in order to get any information on the seismicity prior to the filling and operation of the reservoir.

The largest RTS events will produce ground motions, which are less than those caused by the SEE, which is used for the design of the dam. Therefore, any RTS events will not cause a safety problem for the dam and the safety-relevant elements of the dam.

However, RTS may be a problem for the people living in the reservoir area if it should occur.

2.5.6 Dam break flood wave analysis

For the emergency planning a dam break flood wave analysis has to be carried out first. Several dams are existing, under construction or planned upstream of Xayaburi. In order to estimate the worst effect of a flood wave on the Xayaburi project it is feasible to consider the worst case scenario, as done for all large dam projects in Switzerland. In this scenario it is assumed that the dam (existing or under construction) with the most relevant effect on Xayaburi would be destroyed instantaneously. The flood wave analysis would then be carried out for the case without and with the Xayaburi project in order to see the incremental effect of the Xayaburi project. The other failure scenarios would be less serious and would not have to be considered.

From this analysis it could be seen by how many meters the Xayaburi dam would be overtopped in the worst case.

2.5.7 Dam safety management

Current international practice in dam safety management will be used, similar to, e.g., the Nam Ngum 2 project.

Dam safety management includes the following:

- Periodic visual inspections of the dam and reservoir area;
- Preparation of an annual dam safety inspection report, which includes the assessment of the dam monitoring data (inspection is done by independent dam expert together with the dam safety engineers of the dam owner);
- Detailed inspection by independent experts every 5 years. For this inspection a dam engineer, an engineering geologist and hydro-mechanical engineer would be needed as a minimum. In this detailed inspection the main design criteria would be reviewed as well.

Furthermore, inspections and increased frequency of readings will be required after unusual events such as an earthquake or major flood etc.

This is standard international practice, which will be followed.

2.5.8 Operational safety

The operational safety includes qualified staff, a maintenance program and budget for the dam and safety-relevant components and operational guidelines for usual and unusual conditions, which could lead to the failure of the dam.

2.5.9 Emergency planning

An internal emergency action plan (IEAP) is standard practice today and shall be prepared for the Xayaburi project. The basis for such a plan is a dam breach flood wave analysis.

An external emergency action plan and water alarm system may have to be coordinated with the Laotian government.

An important aspect is that the dam owner has access to dam experts, who can support him in the solution of unusual or emergency situations.

2.5.10 Dam safety assessment

From the technical point of view the design of the Xayaburi project should be rather straightforward and no critical hazards have been identified for which no solution exists.

River diversion and overtopping of the coffer dams are the main construction risks.

3 COMMENTS OF MRC MEMBER COUNTRIES

3.1 Introduction

The Environmental Impact Assessment for the project received approval from the Government of Lao PDR in September 2010. As part of the Social Impact Assessment (SIA) and the Resettlement Action Plan (RAP) the developer together with the Lao Government carried out public consultation activities between 2007 and 2010, at both the district and province level with government officials and community leaders (in 2007 and 2008). Further, consultation meetings with the identified Project Affected Persons (PAPs) were held in April 2009 and August 2010.

The project has also been submitted on 20 September 2010 to the Mekong River Commission for the prior consultation process under Procedures for Notification, Prior Consultation and Agreement (PNPCA) as required in the 1995 Mekong Agreement for countries to jointly review any development of projects proposed for the mainstream, with an aim to allow other riparian countries (Thailand, Vietnam and Cambodia) to be consulted and to give comments on the project back to the Government of Lao PDR. It was agreed between the countries to ensure a mechanism to raise awareness and to involve affected people directly as well as indirectly, the regional community, the public from local and national government agencies, civil society and non-governmental organisations.

According to the definition in the 1995 Mekong Agreement, the Prior Consultation is neither a right to veto the use nor unilateral right to use water by any riparian without taking into account other riparians' rights. This means that the prior consultation process does not give right to any member countries to suspend the project. As its name suggests, the prior consultation process gives right to member countries to comment on the project. In case of the Xayaburi HPP, the decision whether or not to proceed with the project rests solely with the Government of Lao as stated by its representative during the 3rd PNPCA Working Group Meeting held on 14th February 2011 in Vientiane under a condition that the Government of Lao PDR must take comments from other member countries into consideration if it decides to proceed with the project.

Based on the documents provided to Pöyry the following actions have been taken during the Prior Consultation process:

- Xayaburi Power Company Limited ("XPCL") submitted its Prior Consultation documentation to the Lao National Mekong Committee (LNMC) in September 2010.
- The LNMC then informed the MRC Secretariat (MRCS) about the submission and sent to it the Prior Consultation documents of the proposed Xayaburi Project.
- The MRCS circulated such Prior Consultation materials to the MRC Joint Committee (MRC JC) and other National Mekong Committees (NMCs) for evaluation. A working group established by the MRC JC (PNPCA Working Group) held several meetings to consider the Prior Consultation. A site visit took place, and all four Member countries, namely, Cambodia, Lao PDR, Thailand, and Viet Nam, organized and held Public Participation events.
- The PNPCA stipulates that the time frame of the Prior Consultation process is six months from the date of receiving the relevant documents The PNPCA pro-

vides room for the MRC JC to extend the period of the Prior Consultation process when it deems necessary after all four members of the NMCs and the MRC JC agree to do so.

- Each NMC provided its comments and opinion on the Xayaburi Project (in April 2011 – before end date of the Prior Consultation). Each Member country has taken the opportunity to review, discuss and comment on the Prior Consultation of Xayaburi Project in accordance with the criteria of the Prior Consultation process under the PNPCA.
- The PNPCA Working Group collected all comments and opinions from Public Participation and from the other NMCs and took note of it at its meetings.
- In April 2011, the NMCs of the three Member countries submitted their replies on the Prior Consultation of Xayaburi Project to the MRCS.
- The MRCS determined that the end date for the Prior Consultation process of Xayaburi Project occurred on April 22, 2011, being the last date of the six-month period under the 1995 Mekong Agreement. By this date, all comments from other Member countries had been rendered to the MRCS.
- In the Joint Committee Meeting on 19. April 2011 it was concluded that the Prior Consultation Process had been ended as no extension was agreed between the member countries and that any further topics related to the Xayaburi Project would be tabled for consideration at the ministerial level.

3.2 Main Concerns of the Riparian Countries

The main concerns of the riparian (Thailand, Vietnam and Cambodia) countries expressed during the Prior Consultation Process can be summarized as follows:

- The impact assessment of Xayaburi HPP is not detailed enough to evaluate the magnitude of impacts and risks and to design effective mitigation measures and monitoring plans. There is a lack of knowledge and/or baseline data concerning biodiversity and overall ecology (habitats, aquatic fauna, larvae drift, biomass etc.), sediment trapping (deep pool in the reservoir, nutrients in relation to sediments, loss of nutrients for agriculture), changes in water quality and flow regime, hydrology and human environment (livelihood, health, food security, river bank land-use etc.). There is a high uncertainty concerning effectiveness of the fish passage facility.
- Trans-boundary issues and impacts have not been assessed adequately. The impacts (social, economical and environmental) on specific locations and on each downstream country should be assessed. Viet Nam expressed their great concerns about possible impacts of the project on the productivity of the Mekong Delta and the livelihood of millions of people living in the Delta with particular concerns on impacts on sediments, fisheries, wetland ecosystems and loss of agriculture cultivated land due to salt intrusion. Furthermore, Viet Nam propose to Lao Government to jointly undertake researches on the project impacts, especially on trans-boundary issues to overcome the lack of data.
- Cumulative Impact Assessment should be carried out with all planned mainstream hydropower projects and other planned water developments on the mainstream.
- Further points of concern have been freedom of navigation and dam safety.

- A regular monitoring program is needed before, during and after construction period. Mitigation measures, compensation and benefit sharing mechanisms should be included.
- Assistance from international organisations, who are capable in assessing hydropower impacts would be needed.
- Stakeholder participation needs to be widened to involve community people who can possibly be affected by proposed projects. The developer should participate any stakeholder meeting in order to clarify and respond to questions raised in relation to the project, especially the project design and the possible impacts is considered as very important.
- The stakeholder consultation process needs to be transparent, open and accountable. All documents related to the projects, especially the EIA need to be released to the public timely before the stakeholder consultations take place in order to allow effective involvement. The Lao Government and the developer should continue to provide more information on the project, especially the information on the environmental impact for consideration.
- Request to extend the Prior Consultation timeframe because of insufficient information and to ensure sufficient public participation of other member countries and time to the developer to adapt and use the recommendations in the Prior Consultation Review Report.
- Xayaburi dam project will trigger the remaining Mekong dams.
- The riparian countries requested to defer Xayaburi HPP, as well as all other mainstream hydropower projects to be deferred by 10 years until uncertainties and risks could be clearly understood.

With the studies and investigations recommended in Chapter 2 of this report some of the above mentioned concerns can be addressed and the impacts can be assessed in further detail so that the design of the mitigation measures will be more effective.

This will include mainly:

- To use key experts for the design and implementation of the several studies and investigations recommended and for the monitoring programmes and to reinforce a close cooperation with the Government of Laos.
- Baseline data concerning biodiversity and overall ecology (habitats, aquatic fauna, larvae drift, biomass etc.).
- Hydrological study concerning the impact of discharge pattern from Xayaburi HPP on the downstream area especially on Tonle Sap, a lake in Cambodia, which depends entirely on the Mekong regime.
- Baseline data on socio-economic issues related to river bank gardens and fishery, and any other aquatic fauna or flora which are used as additional livelihood income, including any depending businesses
- Optimisation study on operation (flow regime), considering all ecological (egg and larvae peaking, sedimentation flushing, etc.) boundary conditions previously defined.
- Adaptation and optimisation of fish passage facility.
- Adaptation of sediment sluices
- An updated/upgraded Environmental Management and Monitoring Plan including water quality monitoring during construction and operation, a monitoring of

the flow conditions and a biological/ecological monitoring (fauna, flora and habitats).

But it needs to be mentioned that additional studies and investigations on trans-boundary issues and the cumulative impacts assessment of all mainstream hydropower plants is not within the responsibility of the developer and needs to be carried out by the Government of Laos and the riparian countries when ever sufficient data become available.

The sediment trapping is the main concern expressed by the riparian countries. The specific concerns of each country are presented below, together with the related comments of the Consultant.

No.	MRC Member Countries	Status concerning consideration	Comment of Consultant
Viet Nam			
1	Viet Nam expressed their concerns that insufficient evidence is given that mitigation measures (e.g. sand flushing outlets) would help reduce the negative impacts of the project in reality.	**Partly considered**	Not all mitigation measures can be checked with either a numerical or physical model. Several issues shall be solved based on an engineering judgement, others can be adapted in due case as an adaptive technical solution is foreseen.
Thailand			
2	Thailand proposed to support rehabilitation of deep pool in the Mekong River affected by sediment allusion.	**Partly considered**	Deep pools shall be rehabilitated during flushing and drawdown operation. However pools in the vicinity of Xayaburi HPP, which are deeper then the flushing devices are difficult to effectively rehabilitate during flushing operation.
Cambodia			
3	Cambodia basically refers to the findings and recommendations of MRC. It is recommending a comprehensive study and assessment of trans-boundary environmental impacts including the cumulative impact assessment.	**Considered**	The detailed comments on the recommended improvements are are given in Chapter 2.3 "Sediments"
Lao			
4	Based on the MRC's report recommendation for having a comprehensive baseline assessment for the future monitoring, Lao proposes that MRC shall be appointed to be the responsible for the sediment monitoring agency as inter-governmental body.	**Considered**	The detailed comments on the recommended improvements are given in Chapter 2.3 "Sediments"

Table 3.1 Concerns of riparian countries related to sediments

4 COMPLIANCE WITH THE TECHNICAL REPORT OF MRC

4.1 Findings of MRC Expert Group on Safety of Dams

The most relevant findings and recommendations of the MRC Expert Group on Safety of Dams can be summarized as follows:

- Putting in place of an Overall Dam Safety Management System
- Clarification on the process for consultation and engagement of local stakeholders, especially for the Emergency Preparedness Plan (EPP)
- Review of adequacy of design for earthquake loading
- Formation of an Independent Dam Safety Review Panel
- Assessments of how upstream developments and sensitivities of design floods to different climate change scenarios can affect the project
- Performance of dam break analysis with a full range of scenarios, including dams in China

Section 2.5 presents the concept and the intentions on how the issue of "Safety of Dams" should be handled and what the activities should comprise. The GOL-Engineer will play an important role in this process and will have to handle and initiate the process.

In addition to what was said in Section 2.5 and referring to the recommendations of the Expert Group the topics "Clarification of the process for the EPP plan" and the "Assessment of potential effects on the project caused by upstream developments and climate change" need to be given the proper attention.

4.2 Findings of MRC Expert Group on the Navigation Lock System

The MRC Expert Group on the Navigation Lock System made a number of comments concerning this structure. They concern mainly issues which have an influence of the forthcoming construction design and the most relevant ones can be summarized as follows:

- A maximum navigation flow of 14'580 m3/s, corresponding to a two years return period flood, is considered appropriate
- The standard design vessel which shall be able to pass the lock is adapted from PR of China class IV Standard (2 x 500 DWT 109 m x 10.8 m x 2 m). This is consistent with the Preliminary Design Guidance lock dimensions of 120 m x 12 m x 4 m
- A rock outcrop in the approach area 800 m upstream of the dam should be cut back in order to improve the approach flow conditions
- There must be provision for a future second navigation lock
- Adjustment of elevation of upstream mitre gate (higher) and the middle gate (lower)
- Adjustments in the concept of the filling and emptying system of the lock

The suggested changes should be considered and where appropriate the relevant design changes should be initiated. There is no particular problem to introduce this type of changes at this project stage.

On the latest drawings the location of a future second lock has already been indicated. It is located immediately to the right of the currently planned lock.

4.3 Findings of MRC Fishery Expert Group on fish ecology and fishery

Main gaps identified by the MRC Fishery Expert Group (FEG) concerning fish ecology and fishery are as shown in the Table 4.1 below.

The Consultant agrees with the gaps identified by the MRC Fishery Experts and the recommendations are considered reasonable.

It is recommended that the monitoring program on endangered species is part of the overall biological/ecological monitoring (fauna, flora and habitats). This will have to be carried out during the construction period and for the concession period (at least 10 years). The biological/ecological monitoring needs to take place at least at one site below Xayaburi HPP (20 km downstream), one site within the reservoir area and one site above the reservoir area. Furthermore, the species within the fish passage facilities will be monitored.

The developer of Xayaburi HPP has the responsibility to assess the impacts related to Xayaburi project, but a cumulative impact assessment of multiple dams on the Mekong Mainstream on the basin wide fishery goes beyond his responsibility and will have to be carried out by the Government of Laos and the riparian countries when necessary information are available.

The gaps identified by the MRC Expert Group on fish ecology and fishery and the related recommendations are shown in Table 4.1 below.

All other gaps which have been identified can be covered by the recommended investigations and studies described in Chapter 2.

Gaps identified	Recommendations by MRC
Species diversity, ecology of downstream movements, the scale of fisheries in the affected region, livelihoods analyses and fishing activities	Revise species inventory in the area, using surveys and Local Ecological Knowledge methodologies to provide comprehensive baseline information of ecology
Basic ecology of species or species groups not well developed, especially in relation to rhithronic species, and the impacts of impounding the river on community structure and functioning.	Comprehensive review of the basic ecological needs of main commercial fish species that migrate in this reach of the mainstream Mekong
IUCN Red-listed species not mentioned in the study	Set up the monitoring programme for endangered species
Little consideration given to trans-boundary issues, especially impact on fisheries reliant on long distance migratory.	Comprehensive review of river basin wide fisheries impacts of single and multiple dam proposals
Limited recognition that each species has its own pattern of upstream and downstream migration	Revise understanding in fish ecology of, at least, common catch-species in the area
Fish-morphology also key factor that governs migratory behaviour and also influences fish passage design	Monitoring programme on the performance of fish passage(s)
Limited studies on fish recruitment process and larval drift, which is also an important component of downstream migration	Continue targeted larval drift studies initiated by MRC and interrogate data more fully to design mitigation measures. Due consideration must be given to non-fish drifting organisms

Little consideration of impacts both during construction and operation periods on major habitats such as deep pools and littoral areas along impounded reach	Make a clear understanding on the likely impacts to the major habitats and reassess the impact to fish community
No definitive picture on the likely changes in water quality	Reassess the consequent changes of water quality both after construction and operational phases and also reassess the impact to the fish community Sedimentation and siltation should be minimized
The EIA is not concerned on the impacts to fish community and ecosystem but just individual species	Fish stocking programs may be an option but the candidate species have to be investigated
No clear mitigation measures are proposed in the EIA (see Text)	Compensation in loss to fisheries should be a high priority option.

Table 4.1: Gaps on fish ecology and fishery identified by the MRC Expert Group

4.4 Findings of MRC Fishery Expert Group on the fish passage facilities

The MRC Fish Expert Report contains a table with 51 key issues, gaps in knowledge and recommendations to fish ecological inputs of the project design and impact assessment.

The recommendations are mostly reasonable and it should be checked how far the developer is able to take them into account.

A nature-like bypass channel will probably not be possible due to space problems. Furthermore, the 300 m long collecting gallery cannot be connected in a functional way with a nature-like bypass channel.

It is not realistic to have a distance of 1 cm between the bars of a screen in a river of the size of the Mekong. A reasonable option (screen width) concerning hydrology, fish survival and energy needs to be investigated. As stated in the MRC Fishery Expert Report the mortality of juvenile fish trough high-head Kaplan turbines is between 10 – 40 % and up to 100 % for adult fish. Therefore it is necessary that most of the larger adult fishes > 30 cm will be lead to the downstream migration facility. The mortality of fish passing the turbines increases with the size of the fish. With respect to the received data from the fish survey concerning species, body widths and heights distribution and the frequency in the Mekong it will be possible to select a suitable screen.

Furthermore fish friendly turbines should be included, even if there are no investigations concerning the survival of cyprinids it will probably be higher than if conventional Kaplan turbines are used. It is questionable whether it is possible to carry out an investigation concerning the fish friendliness in respect on Mekong fish species. It will have to be checked with the supplier of such turbines.

With the results of the recommended investigations and studies (see Chapter 3) it will be seen, which of the recommendations of the MRC Expert Group are economically, technically, and environmentally feasible to be taken into account.

The recommendation to use a multiple system on both sides of the river can be supported by the Consultant. Since a continuous possibility of upstream migration should be given, which is not possible with just one system due to maintenance activities. In addition the upstream migration needs also be guaranteed during the whole construction period and therefore either an additional fish lock should be included into the right abutment or the navigation lock needs to be adapted to be suitable for upstream fish migration.

The comments concerning the 51 key issues have been included into the Table of the MRC Fish Expert Report.

4.5 Findings of MRC Fishery Expert Group on Socioeconomics and rural livelihoods aspects

The main finding of the FE Group is that the baseline and impact information and data on socioeconomic conditions and livelihoods of people living within the corridor 15 km in the downstream area of Xayaburi is not sufficient (trans-boundary between Lao PDR and Thailand, Cambodia and Vietnam) to develop effective mitigation measures and a detailed Environmental and Social Management and Monitoring Plan.

The main recommendations have been that the missing baseline data will have to be developed and that based on the baseline data a monitoring program needs to be implemented.

4.5.1 Baseline Investigation

The Fishery Expert Group states that (p. 65) "*The following detailed baseline and impact knowledge, information and data on socioeconomics and water resources related livelihoods of people living within a corridor of 15 km either side of the Mekong River and its dependent tributaries and floodplains in Xayaburi mainstream project areas, Lao PDR (particularly the southern Lao Champasak province), Thailand (particularly the northern Thai Chiang Rai areas), Cambodia (particularly the Cambodian Tonle Sap Great Lake areas) and Vietnam (particularly the Vietnamese Mekong delta areas) should be included in the EIA report.*"

This would obviously be an enormous task, just given the population involved and the fact that that several countries would have to be included. In our opinion, such a task, especially in view of the fact that a number of other projects of similar nature are planned, cannot be the responsibility of the developer of one project. If such an investigation should be carried out, it would have to be done by the countries involved and under a different financing. However, the investigation as it is proposed, including the topics to be investigated, makes perfect sense. In our opinion, the developer of Xayaburi should do the following:

1. Carry out an investigation as proposed in the Fishery Expert Group Report for the population affected by the project. This needs to cover the population in the reservoir area and in the directly affected downstream area (whereby this needs to be defined very carefully; the final decision would have to be made based on hydrological data and analyses, but cannot be more than a few km d/s of the dam site, where the probably rather minor effect of peaking production in Xayaburi, if any, still might have an influence). Such a detailed investigation is required as a basis for a Resettlement Action Plan which will be acceptable according to international standards.
2. Carry out a careful analysis on river discharge conditions (including the aspects of water quality end especially sediments) in order to show what are actually the effects of the project on the downstream area. This investigation of study will

have to include a analysis of any effects the project might have (or will not have) on Tonle Sap.

3. Carry out a detailed investigation of fish migrations in the project area, as proposed above, and, if required, modify the fish pass in a way as to optimise its performance, and/or propose additional mitigation measures which might be required.

As mentioned, the investigation under point 1 above is required as a basis for a RAP.

The study mentioned under point 2 should investigate and describe in detail the discharge situation. The main point is to see if (as might be expected given the operation of the project as a ROR plant) it will not have any negative impacts on the situation in the downstream area (and mainly also on Tonle Sap). Such a cumulative impact assessment was made, a few years back, for Nam Theun 2, since during its development it was feared that it might have a detrimental impact on Tonle Sap. This study showed that the influence by Nam Theun 2 on the Tonle Sap is minimal. The analysis for Xayaburi could be made based on this existing study, by updating it with the data from Xayaburi. It should be emphasized from the start that other projects which are planned on the Mekong, would only be taken into account in such an assessment if suitable and sufficiently detailed data on them will be readily available.

The Consultant recommends that the developer of Xayaburi HPP should carry out a detailed baseline investigation on Socio-economic issues, mainly related to riverbank gardens, fishery, and any other aquatic fauna (this means all animals (snails, frogs, turtles, etc.) living and spawning in the river, at the river banks, on sand banks) and flora which are used as additional livelihood income, including any depending businesses will have to be carried out for an corridor of about 15 km to each side of the Mekong river from the dam site up to Luang Prabang. This is more or less in line with the request of the Expert Group (for the project area) and with what was said above. However, this investigation should be modified in the following way:

- The directly affected population would have to be investigated in detail, since for this a RAP needs to be made.
- For the population outside of the direct influence of the project, i.e. the reservoir and its immediate surroundings, the investigation should clearly be limited to aspects related to fish and other aquatic resources.
- On the other hand, the investigation needs to be extended to the downstream area as mentioned above and cannot stop at the dam site.

The aim of the investigation mentioned under point 3 should if possible allow to create a situation where fish migrations would not be hindered substantially, so that fish populations (at least those of the economically important species) can be maintained for more details see sections on fish pass above.

If these investigations can show in a convincing way that the effects of Xayaburi are manageable and not really detrimental for the entire region, then the project (and the developer) will be in a good position for not having to carry out the large socio-economic study as mentioned above. In the short run, a good and convincing program for invstigations to be carried out should be prepared and presented to the relevant authorities.

It is not clear if the statement that Xayaburi "cannot be expected to fund the wider trans-boundary studies that have basin wide value" refers only to studies that might result from the monitoring (as e.g. the definition of compensation measures required in the future), or if this includes the proposed baseline investigation mentioned above. This point should be clarified. However, as stated above, one single project and its developer cannot be expected to carry out and finance such a study, which is clearly a task for the involved countries. Since six more dams are planned on the stretch of the Mekong river between the borders with China and Thailand, it cannot be the responsibility of Xayaburi HPP to develop the baseline data for all projects planned. A feasible approach might be if the Government of Lao could carry out a sample survey (covering about 20 % of the population living in the corridor of 15 km to each side of the Mekong river) also mainly on fishery, and any other aquatic fauna and flora which are used as additional livelihood income, including any depending businesses. This could be done in parallel to work which is planned to be performed by the Xayaburi developer. However, ultimately this would be useful in the sense of the Fisheries Expert Group that only the other riparian countries would carry out similar studies on their respective territory. In order to make these studies directly comparable, they should be done under a common approach and following a common methodology.

4.5.2 Monitoring

The monitoring for Xayaburi will obviously have to be carried out by the developer (and later on by the operator, if this should be a different entity), as proposed in the Experts report. However, the criteria to be monitored will have to be reconsidered and clearly defined. So e.g. it is not clear why "dependency on fish" should be monitored, but not "availability of fish".

Furthermore, a monitoring on fish biomass should be implemented at the border to Thailand about 200 km downstream of Xayaburi HPP to see if the biomass changes and to compensate for the decline in fish catches. Obviously, this monitoring program should be started as soon as possible, in order to have reference data from the period before any direct effect of Xayaburi might have occurred.

4.5.3 Compensation Measures

The proposal for reasonable compensation scheme, taking into consideration additional mitigation measures to be implemented such as a fish breeding station, to be made to persons affected by Xayaburi is acceptable. However, in order to really know what type and to whom this has to be made, it is required to have a good baseline, i.e. a RAP based on sound data on the present situation. Such a data basis and a detailed RAP is needed to provide fair and reasonable compensation to the affected population, but also to protect the developer from unjustified claims at a later stage.

4.6 Findings of MRC Sediment Expert Group on Sediments

It should be noted that parts of the requirements stated in the Technical Report of the MRC SEG exceed the MRC PDG requirements. Such additional requirements were commented by the Consultant in the previous chapter and the resulting suggestions were included in the recommendations.

The following issues, however, are not covered by the MRC Guidelines:

- Sedimentation during construction:

  This issue will be of importance already during the construction phase (especially second phase), since the sedimentation process will start as soon as the water level in the river will be artificially raised. This will be case once in the second phase of construction when the cofferdams will close the original river course and the water will have to pass the higher spillway sill (el. 254.0 m).

- Adaptive Management of Flushing Devices:

  The flushing devices to be provided should be able to manage sediments under changing natural conditions. Reasons given for this requirement are:

  - Uncertainties considering the available data (e.g. sediment load and grain size distribution of sediment),
  - Uncertainties considering the future development (e.g. climate change and changes in land use),
  - Mitigation of sediment concentration peaks that are expected during the flushing process, in particular for drawdown case.

The SEG also emphasize cumulative effects of all hydropower developments in the Lower Mekong. Such development is mainly governed by the Government of Laos and the other riparian countries. Therefore the effects of further developments cannot be estimated by the Xayaburi Power Company and such planning should be done by a multinational body.

5 REFERENCES

[1] MRC PDG (2009). "Preliminary Design Guidance for Proposed Mainstream Dams in the Lower Mekong Basin" (MRC PDG), Final Version, 31st August 2009.

[2] MRC PNPCA (2011). "Prior Consultation Project Review Report - Proposed Xayaburi Dam Project – Mekong River", March 2011

[3] MRC PNPCA (2011). "Prior Consultation Project Review Report – Volume 2, Stakeholder Consultation related to the proposed Xayaburi dam project", March 2011

[4] MRC Sediment Expert Group (2011). "Review of Sediment Transport, Morphology, and Nutrient Balance", Report to MRCS, March 2011.

[5] MRC Fishery Expert Group (2011). Annex 4 to the "Proposed Xayaburi Dam Project – Mekong River, Prior Consultation Project Review Report", Report to MRCS, March 2011.

[6] MRC SEA (2010). "Hydrology & Sediment Baseline, Assessment Working Paper", Vol.II, March 2010.

[7] MRC SEA (2010). "Aquatic Systems Baseline, Assessment Working Paper", Vol.II, March 2010.

[8] MRC SEA (2010). "Fisheries Baseline Assessment, Working Paper", Vol.II, April 2010.

[9] MRC SEA (2010). "Social Systems Baseline, Assessment Working Paper", Vol.II, April 2010.

[10] TEAM, Colenco (2010). "Feasibility Study Xayaburi Hydroelectric Power Project Lao, PDR – Final Report"

[11] MUNLV (2005). "Handbuch Querbauwerke"

[12] FAO, DVWK (2002). "Fish passes – Design, dimension and monitoring"